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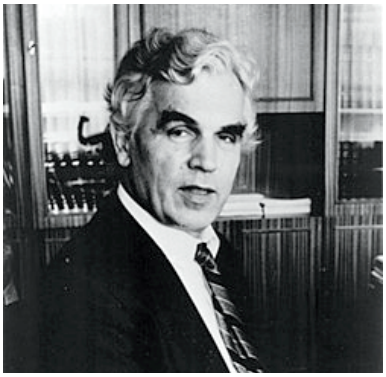

The philosophy behind the approach

Industrial manufacturing systems form the basis for obtaining products necessary to meet the needs of the population, work organizations, and society as a whole. In the structure of overall engineering work, industrial systems engineering has the role of researching, designing, building, organizing, and managing integrated flows of materials, information, and energy in real work processes, with the ultimate goal of obtaining new scientific information and professional foundations for designing high-quality products of modern technological, manufacturing, and management structures, providing conditions for manufacturing products of necessary and sufficient quality, managing the work process in a rational way, achieving output values—effects of the system at the designed level—and achieving the overall economic and social benefits.

Long-term studies of the operation of real industrial systems are becoming increasingly vital as demands for participation, overall effectiveness, and quality rise, and as system structures grow more complex due to the constraints placed on them, so does the need for these studies. In this sense, the basic philosophy in the field of industrial systems consists of finding a complex harmony between the different influences in work processes, in terms of their direction, course, and strength, that results in the maximum overall effect (Dragutin Zelenović, Industrial systems engineering, FTS - ITS, Novi Sad, 1979).

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FOREWORD

Dear readers,

I am pleased to introduce you to the research papers of the 19th International Scientific Conference on Industrial Systems. With this proceeding we continue the works of the previous conferences which have been held since year 1981.

We're delighted that this international Conference has once again gathered many participants from many countries as it became a tradition over the past 42 years.

The papers include the achievements of researchers in the field of technology and scientific areas relevant to industrial engineering, industrial management, industrial logistics, smart technology, and etc. Through the work of the Conference on Industrial systems, we continued significant scientific cooperation with educational institutions all over the world. With them, we are continuing good cooperation which is the driving force for the creation and display of new developments, both individual and common. I want to thank everyone who participated with their paper and presentation in the Conference. Your contribution is significant for the improvement of the Conference on Industrial Systems IS `23. The research achievements presented here are also highly appreciated and valuable to the scientific and professional community.

Editors

KN

KEYNOTE LECTURES

KN1.1

Franz, Haas, Austria

SMART AND SUSTAINABLE PRODUCTION - A BOTTOM-UP APPROACH TO FULFIL THE TARGETS OF CIRCULAR ECONOMY

Abstract - The key note gives an overview on the activities and research topics of the 18 institutes of the Faculty of Mechanical Engineering and Economics. The terms of sustainable production and circular economy will be covered fundamentally and a path towards CO2-neutral production will be presented. A bottom-up approach is proposed, which, starting from the processes, suggests a way to improve the CO2 footprint for discussion. This will drive forward the optimisation of processes and the improvement of quality in addition to climate targets. After the process stage, the plant stage is considered. The higher-level data management and networking of production plants bring another significant contribution. The smart value creation networks also offer opportunities to bring circular reasoning to reality and generate new success stories.

FRANZ HAAS

Univ.-Prof. Dipl.-Ing. Dr.techn., born 1966, studied mechanical engineering and economics at TU Graz, Austria

After completing his studies, Franz Haas worked as a university assistant at Graz University of Technology, where he received his doctorate in 1996. Then he starts his profession as managing director and as owner of Franz Haas GmbH, based in Stainz in Styria. This is a family business specialising in custom-made products and precision engineering, which was founded 1919. He continued his academic activities in 2007 as professor and scientist at the University of Applied Sciences “Campus 02” in Graz. In 2013 he was appointed as a university professor and head of the Institute of Production Engineering at TU Graz. From 2018 to 2020 he took over the chairmanship of the Austrian Scientific Society for Production Engineering. He is acting as a member of scientific boards of different organisations and as the Austrian delegate of the ISO working group for machine tool precision tests. Since 2020 Franz Haas is working as the dean of the faculty of Mechanical Engineering and Economic Sciences.

KN1.2
John K. Duchowski, Germany

IOT - ADVANCED METHODS ONLINE OIL CONDITION MONITORING

Abstract – Various on-line oil conditioning methods are presented and discussed in the context of the available on-line sensor array monitoring devices. Both the advantages and disadvantages are discussed. The former mostly refer to the timeliness of the response, while the latter refer to the existing discrepancies between the on-line sensor and the laboratory data obtained with the usual standard ASTM and/or ISO analytical techniques. It is shown that when the on-line instrument method is simplified to deal with well defined situations a very good agreement with the standard analytical methods can be obtained. However that may not always be the case when the actual industrial systems and applications are involved. In this regard several examples of these are presented with one or two surprise examples thrown in. Overall, the context of the presentation focuses on bringing the ideal and the reality together recognizing the limitations of the current sensor technology but paving the path towards a reasonably brighter future.

DR. JOHN K. DUCHOWSI
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Dr. John Duchowski

John K. Duchovski is the director of the filter and filtration media development sector for industry with vast experience in the field of mechanical engineering and the industrial sector. During his work experience, he has gained extensive experience and skills in Root Cause Analysis, Continuous Improvement, Research and Development (R&D), Filtration, Fluid Analysis and Treatment, and Product Research and Development.

Strong engineering professional with a Doctor of Philosophy (Ph.D.) degree in Physical Chemistry (Molecular Spectroscopy) from Carnegie Mellon University.
Dr. Duchowski received his BA in Chemistry from Simon Fraser University in Vancouver and his PhD from Carnegie Mellon University in Pittsburgh. From 1992 to 2004, he held the position of Chief Scientist in the Scientific and Laboratory Services Division and Vice President of Technology in the Machinery and Equipment Division at Pall Corporation. In 2005, he moved to HIDAC Technology Corporation, where he held the position of Corporate Director for Research and Development of Filtration. His projects focus on the effects of physical and chemical contaminants on the performance of hydraulic and lubrication systems and on the fluids used in those systems.
Dr. Duchowski is a Fellow of the Society of Tribologists and Lubrication Engineers (STLE) and an STLE Certified Lubrication Specialist and Oil Monitoring Analyst I and II.
He published 6 patents and authored more than 34 scientific publications.

KN1.3
Dušan Šormaz, United States

KNOWLEDGE ENGINEERING METHODS AND TOOLS FOR RESILIENT PRODUCTION AND SUSTAINABLE SOCIETY

Abstract – This talk will cover a broad subject of Knowledge engineering and its impact on modern production and its resilience in order to establish sustainable society. Recent advent of Large Language Models (LLM) and corresponding tools for AI (such as ChatGPT) requires that we examine the role of knowledge in modern engineering and production. We will first explore the topic of knowledge and intelligence from high-level perspective, and postulate some statements for the rest of talk, most important being, can machines think, or can they replace humans.
After this brief introduction, we will enumerate some traditional and modern AI methods, such as expert systems, rule-based systems, symbolic AI, machine learning, semantic web, ontologies. Emphasis will be on utilizing engineering knowledge to enable resilient production. We will illustrate knowledge engineering methods using examples from our research. We will cover integrative manufacturing planning procedures, with illustration of several design and planning tasks: process planning, setup planning, cell formation, dynamic planning and scheduling. The recent work of the presenter in semantic smart manufacturing, data interoperability, ontologies, and representation of digital artifacts and digital twin follows after those methods. The talk will conclude with the presenter's outlook on needs for knowledge engineering, semantic, and ontologies in order to design and manage resilient production systems, and develop sustainable circular economy.

DUŠAN ŠORMAZ, IFPR
Professor Emeritus at Department of Industrial and Systems Engineering, Ohio University, Athens, Ohio, USA

Dušan Šormaz received the Ph.D. in Industrial and Systems Engineering from University of Southern California (USA) in 1994; M.S. in Computer Science from University of Southern California (USA) in 1995; M.S. in Industrial Engineering from University of Novi Sad, 1985; and B.S. in Mechanical Engineering from University of Novi Sad in 1979.

Dr. Dušan N. Šormaz is the Professor Emeritus of Industrial and Systems Engineering at Ohio University, Athens, USA. Dr. Dušan N. Šormaz's principal research interests are in the application of knowledge-based systems in manufacturing including Ontologies, Simulation, Additive Manufacturing, Process Planning, and Semantic Data Integration. He has been working on applying AI techniques in engineering problem areas such as cost estimation and oil corrosion prediction.

Dr. Šormaz has published over 40 refereed papers in scholarly journals and more than 150 conference papers. He also delivered 12 keynotes, workshops and tutorials and around 50 contributed presentations at international research events. Šormaz has organized several international conferences (GT/CM Symposium 2003, ASME APSP Symposium 2006, IISE Manufacturing and Design Track 2016 and 2017, IISE Modeling and Simulation Track 2019). He was the General Chair of the 28th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2018 in Columbus and Plenary speaker chair of International Conference on Production Research, ICPR25 in Chicago 2019. He is a member of the editorial board of International Journal of Industrial Engineering and Management (IJIEM), he edited a special issue of International Journal of Production Research, and a special issue of Robotics and Computer Integrated Manufacturing (RCIM) Journal. He serves as regular

reviewer for several research journals in his area of expertise. He also regularly advises student teams who participate in Simio Student Simulation Competition. He is faculty advisor for Alpha Pi Mu - National Industrial Engineering Honor Society, OHIO Chapter. He is senior member of IIE, senior member of SME, and senior member of IEEE. He is a member of The International Foundation for Production Research (IFPR) Board from 2019. He is a member of the Industrial Ontology Foundry (IOF) and the Chair of its Production Planning and Scheduling working group.

Dr. Sormaz has received the Lean Techign Award from IISE Lean Deivision in 2018, he was finalist of the NIST organized RAMP Competition at NAMRC 45 in Los angeles in 2017. He was also finalist for the Ohio University presidential Teacher Award in 2016/17. He was adviser of the student team that won the 1st Place in Simio Global Student Competition in May 2017 and advisor of multiple team that achieved the finalist status in Simio cometitions. He was winner of Marvin E. and Ann D. White Teaching or Research Awards at Ohio University in the ISE Department on 11 ocassions. He was also recipient of the Fulbright Program Grant for Ph.D. studies in the USA, and Graduate Assistantship at University of Southern California, 1990-1994.

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PARAMETRIC DESIGN OF A PRODUCT FAMILY

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Abstract: *Parametric design (PD) is an approach in which the parameters are set, and they are responsible for the outcome. The approach is known and familiar, but the new technologies and advancements in production are making it more applicable now.*
Parametric design is an emerging research issue in the design domain. The development of a product family requires product architectures in three domains, defining the required function, technological realization, and the physical realization. A product architecture separates the stable and the variable aspects of the design. By the proposed modeling approach, the focus of product configuration can be shifted to identification and definition of attributes instead of modules and components. It is also shown that classification is a means for identification of multiple abstraction levels.
With this paper we want to explore the possibilities to use parametric design as a tool for the design of a product family. Parametric design is an approach that can be used for design of a family of products. At the same time this approach enables fast changes and modifications in the initial design. This is a fast and efficient way for serial production products but also for creation of unique and personalized products fast.

Key words: parametric design, product design, product family

1. INTRODUCTION

Industrial design has a long history that started in the early 1900s, as an effect of the industrial revolution. Industries have expanded quickly because of innovation in the field of industrial design. Over the time the meaning of the term industrial design has broaden its meaning. According to the IDSA, industrial design is the professional practice of designing products, devices, objects, and services used by millions of people around the world every day…. During this process, myriad decisions are made by an industrial designer (and their team) that are aimed at improving your life through well-executed design (IDSA, 2020). Form this definition it is consequent that design of a contemporary product or service is a complex task. In the last years designers work in interdisciplinary teams in order to respond better and faster to the market demands. The advantages of the interdisciplinary teams are countless, such as: increased level of innovation (Rosenberg & Kumar, 2011), team creativity (Repko, 2012; Sanders & Strappers, 201), customer satisfaction and company profit (Norman, 2002; Akinnawonu, 2017). But main problem in this type of teams is the lack of communication. This is why methodologies and approaches that facilitate that are always welcomed.
With this paper we go with the premise that a parametric design can be used as an approach to the design of a product family. This approach can be used as an effective tool for communication in the team especially in the early design phases of form-findings.
Product family design and development essentially entails a conceptual structure and overall logical organization of generating a family of products by providing a generic umbrella to capture and utilize commonality, within which each new product is instantiated and extended so as to anchor future designs to a common product line structure (Jiao et al., 2007).
The interpretation of product families depends on different perspectives. The engineering view of product families embodies different product technologies and the associated manufacturability and thereby is characterized by various design parameters, components, and assembly structures (De Lit & Delchambre, 2003; Simpson, 2004).

1.1. Parametric design

As early as the 1970s, parameterization has been used to automate control the production process and results in large-scale industrial production. With the continuous development of computer and numerical control technology, parameterization has become a major trend in the information age and has been widely used in various design fields, changing the way of designing and manufacturing (Sun, 2019).

The goal of parametric design, therefore, is to add the dimensions and any other specific information needed for functionality and manufacturability. If the exact material has not already been designated, it is also chosen. To put it another way, parametric design provides all the dimensions, tolerances, and specific material information required for a design that complies with both the marketing concept and the engineering design specification.
Parametric design can be used as approach for product personalization, since one algorithm can provide multiple variations (Djokikj et al. 2022). Abdullah and Kamara (2013) propose the procedures for parametric design in order to increase the idea generation in the conceptual phase. Dean (2009) uses parametric and generative modelling to fully exploit the AM's possibilities and to offer personalized products to users.
Parametric design has few advantages that are important to the designers: design of complex geometries – organic designs inspired by the nature in various dimensions can be easily created from jewelry to bridges and automobiles (Fu, 2018); accuracy – advanced software's for parametric modeling can accurately and effectively modify any design in addition to complex shapes; time efficiency – use of algorithms improves the workflow efficiency by automating repetitive operations; hand-in-hand with manufacturing – new technologies like the additive manufacturing provide easy fabrication of the parametric designs (Djokikj, 2020).

1.2. Grasshopper

Grasshopper has increasingly gained popularity in recent years as a parametric design tool. Grasshopper is a visual editor within Rhinoceros that is a modeler for complex freeform shapes, while Grasshopper is utilized for additional mathematical modelling, or even programming (Khabazi, 2009). However, Grasshopper on its own can be used for the modelling of the whole part. Rhino uses non-uniform rational B-splines (NURBS) to precisely model geometry (Zhang & Yin 2015). With visual programming, you can algorithmically generate geometry by composing diagrams that link data to functions. Through its intuitive visual programming, architects and designers can swiftly create complex forms and make changes to multiple elements by adjusting a single value—a testament to the power of parametric design (Dai, 2016).

2. METHODOLOGY

The design process in utilizing parametric design requires different approach. In the initial design phases with the functional aspects of the product and all the design criteria, the parameters need to be determined. This means that very fast in the conceptual phase the work is converted from paper to computer. We propose the use of Grasshopper as it is relatively easy to use and still has all the advantages of the parametric design. Also it is a visual editor, so it is user friendly the designer. Once the algorithm has definite shape, the variations in the outcome can be conducted by all team members. This can increase the time for final design decision, but it is valuable step in the co-designing process.

3. DESIGN OF A PRODUCT FAMILY WITH GRASSHOPPER

As mentioned before, when designing a product family it is necessary to define the similarities and differences between the products. The similarities are the design elements that will visually connect the products and the differences has to give unique take on each product. This is why we proposed the use of parametric design and Grasshopper as a tool in the design process. Because with Grasshopper with the creation of an algorithm, the basis of the product family is determined, and the differences can be explored with the use of sliders. The result is immediately visible in the Rhinoceros, so the manipulation is easy and straightforward.

3.1. Planning parameters

Based on the research findings and design positioning, we should choose our design concepts, examine the project's requirements and constraints, digitize several critical elements, and choose the quantitation and variables that will serve as the foundation for our parametric design algorithm.

3.2. Creating an algorithm

After analyzing the logical relationships and transfer relationships among the parameters, a collection of logical algorithms for managing parameter relationships and generating models is put together, as presented in Figure 1.

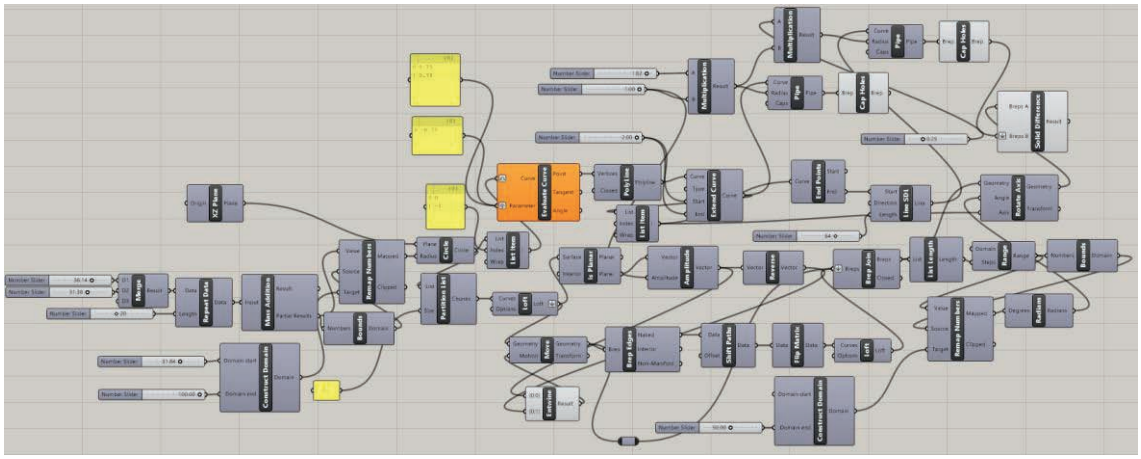

Figure 1: Grashopper alorithm for the lamp family

3.3. Design of the model

Design of the product is consisted of series of concentrically circular elements. Each element is a separate one, which means that move independently. In order to constrict the movement, the circular elements are fixated in two places along the Z axis. In Figure 2, some of the variation for a celling lamp are presented. Furthermore, these designs can be scaled, colored, elements can be added or omitted in order to create the whole product family.

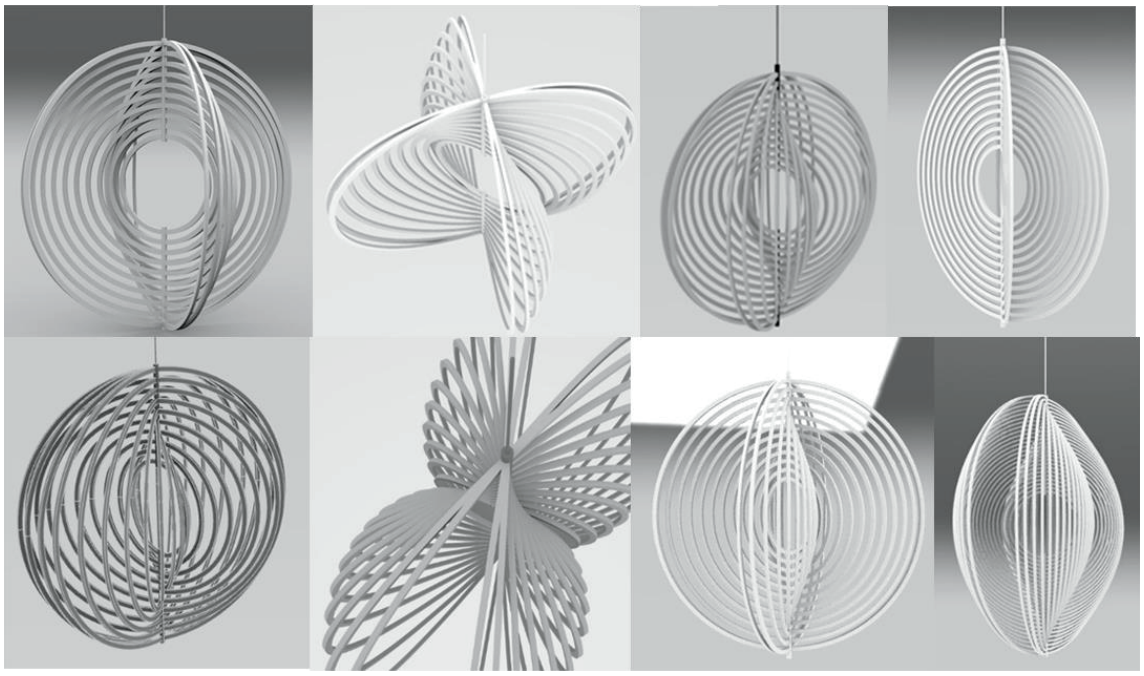

Figure 2: Different variations of one design

In Figure 3 design of one product family is presented. These designs can be explored and result in many different solutions. In the example only celling lamps are presented, but again this method can be applied for bigger product family.

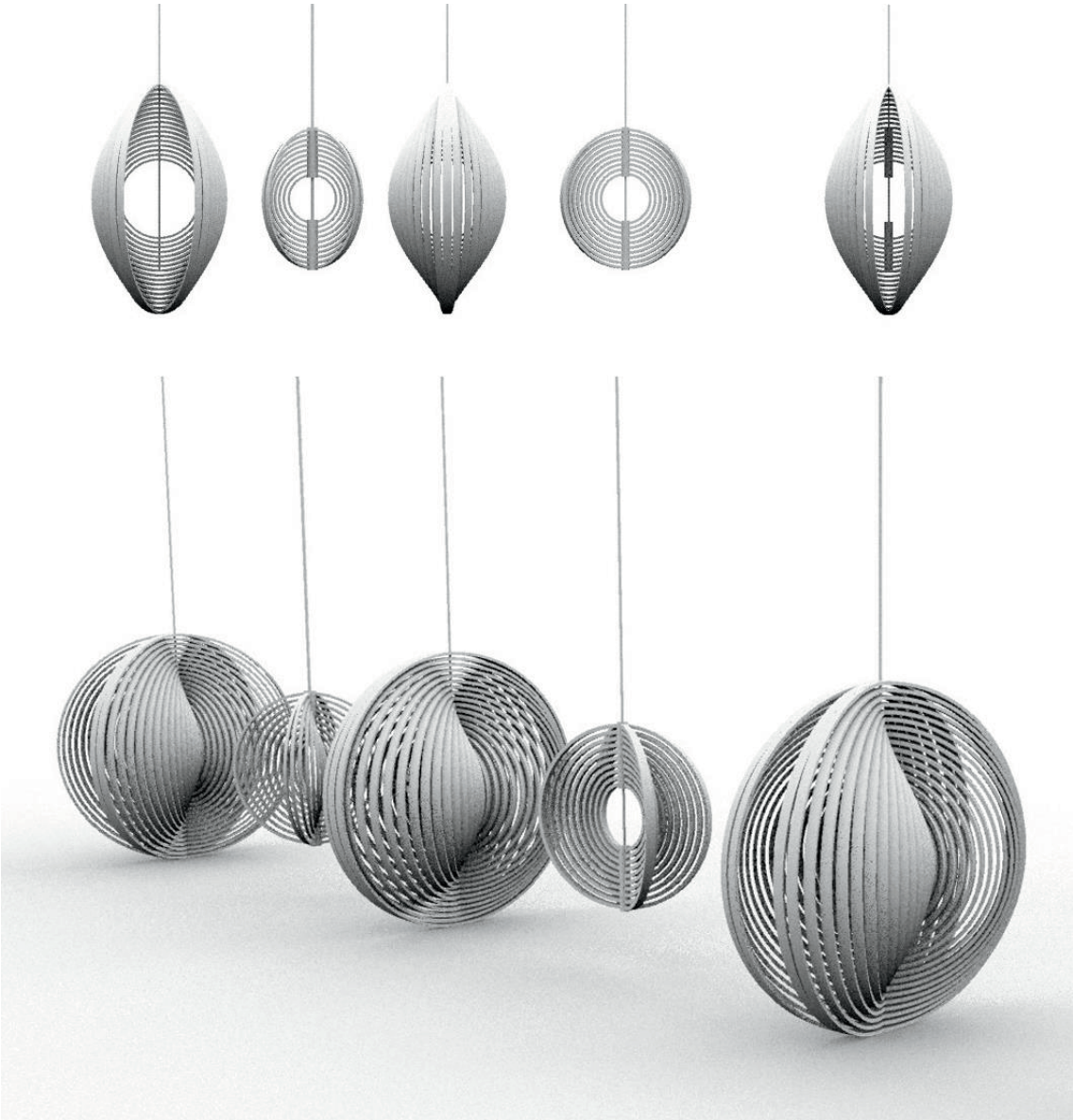

Figure 3. Design of one product family

4. DISCUSSION

The process of designing a product using parameters is challenging, it is completely opposite of the classical design process. The parametric design requires precision and detail planning of the parameters. Positioning and setting of the parameters need to be precise, especially in the case of product family.
The use of Grasshopper can be also challenging for some designers, since it requires basic knowledge of mathematics, three-dimensional visualization, basic CAD modeling logic.
Then again, once the parameters are set and the algorithm is working properly it is pretty easy to change the design and create variations. The application of this design approach is extremely helpful for designers in the initial phases of the form-finding process or research through design. Also, it can be useful for bigger co-designing project, when many people, most of the non-designers need to intervene on the design and give their input.

5. CONCLUSION

The paper explores the use of parametric design for a product family. As a software for the design exploration Grasshopper, part of Rhinoceros, was used. The proposed methodology was applied on a one example product family of lamps.

From previously stated, it can be concluded that this approach is valuable as a tool for the new ways of designing, like co-design. Having large group of participants working on a design, without previous knowledge in 3D modeling or CAD software, can be difficult to communicate. This is where tools like the one proposed in this paper can be useful. Also, designers can exploit it in the initial design phases as a form-finding tool.
Therefore, it can be concluded that parameterization can be a useful tool and a source of creativity for a serial production of a product design. Offering the possibility for a renewal iteration, revision serialization design, multi-scheme comparison and evaluation, rapid parametric model creation, dynamic adjustment, and convenient modification all have clear benefits.
For further research, the methodology needs to be tested by applying it to a various design tasks.

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UNVEILING THE INHERENT PARADOXES IN LEAN MANUFACTURING

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Abstract: *Lean manufacturing stems from the Toyota Production System renowned for its emphasis on waste reduction, continuous improvement, and customer value, it has been widely adopted by organizations seeking operational excellence. However, the methodology possesses some inherent paradoxes which contradict the guiding principles of the methodology and can represent obstacles during implementation or even the comprehension of the methodology. This paper aims to identify and discuss the paradoxes which lie in the methodologies, tools, and principles of Lean manufacturing such as Jidoka, Just-in-Time etc. through a comprehensive analysis of existing literature, case studies, and empirical evidence, this paper aims to deepen the understanding of these paradoxes and Lean thinking.*

Key words: Lean, Manufacturing, Paradox

1. INTRODUCTION

Optimizing processes has been at the heart of industry since the beginning, eliminating unnecessary steps, lowering costs of production, enhancing quality, and shortening lead times all for the goal of maximizing value and increasing profitability, no methodology has exemplified this better than Lean manufacturing. With its goal of maximizing value-added activities by eliminating waste or optimizing and shortening value added activities it achieves the shortening of Lead times and thus expediting cash flow it achieves more with less than other methodologies applied across industry. Lean, a manufacturing philosophy derived from the Toyota Production System has been widely adopted across all types of industries (Liu & Yang, 2017; Maciąg, 2019; Sarhan et al., 2017; J. P. Womack et al., 1990). At its core it sees two type of activities value-added and non-value added.

1. Value-Added Activities: Value-added activities are those tasks or steps that directly contribute to the creation of value as perceived by the customer. These activities transform raw materials, components, or information into the final product or service that the customer is willing to pay for. Value-added activities enhance the form, function, or quality of the product, meeting the customer's needs or desires. Examples of value-added activities include assembly, customization, design, and testing. The goal in Lean is to identify, prioritize, and optimize value-added activities while minimizing or eliminating non-value-added activities.
2. Non-Value-Added Activities (Waste): Non-value-added activities are tasks or steps that do not directly contribute to the creation of value and can be eliminated without affecting the end product's quality or customer satisfaction. Identifying and eliminating non-value-added activities is a core focus of Lean principles.

Lean recognizes that each system and each process contain both types of activities, it also recognizes that there are other types of wastes in the system(Krafcik, 1988; Taiichi Ohno, 1978; J. Womack & Jones, 2003), the three types of wastes in the system according to Lean are:

1. Muda - The Waste of Non-Value-Adding Activities: Muda refers to any activity or process step that doesn't add value to the product or service from the customer's perspective. These are tasks that can be eliminated without affecting the outcome. There are various subtypes of muda, including:
    - Transportation: Unnecessary movement of goods or materials.
    - Inventory: Excess inventory that ties up capital and increases the risk of obsolescence.
    - Motion: Unnecessary movement of people or equipment.
    - Waiting: Idle time when resources are not actively engaged in value-adding tasks.
    - Overprocessing: Performing more work than required, adding features that the customer doesn't value.
    - Overproduction: Producing more than what the customer demands, leading to excess inventory.

- **Defects:** Quality issues that lead to rework, scrap, or customer dissatisfaction.
- **Skills:** Not utilizing the talent and skills of workers wastes their potential.

2. **Mura - The Waste of Irregularity or Inconsistency:** Mura refers to the unevenness or inconsistency in workloads, processes, or outputs. This irregularity can lead to inefficiencies, overburdening some parts of the process while leaving others underutilized. It can also lead to increased lead times, lower quality, and increased stress on employees. Mura can manifest in different ways, such as fluctuating demand, uneven work distribution, or inconsistent process flows.
3. **Muri - The Waste of Overburden:** Muri refers to overburdening or straining resources beyond their capacity, which can lead to fatigue, errors, and reduced overall efficiency. This waste occurs when unrealistic demands are placed on people, equipment, or processes. Overburdening can negatively impact the well-being of employees and the reliability of processes, resulting in increased errors, accidents, and burnout.

2. PARADOXES

To eliminate waste from processes, Lean philosophy employs a rich array of methods, tools, and techniques, all meticulously designed to identify waste and excise it from organizational processes. However, it is through the practical application of these methods, tools, and techniques that organizations often encounter the very paradoxes that are subtly nested within the fabric of Lean philosophy.

A paradox, by definition, is a construct—an assertion, proposition, situation, or concept—that initially exhibits traits of self-contradiction, logical absurdity, or apparent impracticality. Yet, paradoxes are far from mere puzzles to be solved; when subjected to thorough examination, these surface contradictions possess the remarkable capacity to unveil concealed truths, intricate intricacies, or profound insights (W. V. Quine, 1962). Paradoxes hold a pivotal role in challenging conventional thought patterns, compelling us to reevaluate our assumptions and beliefs. Found not only in philosophy but also in literature, mathematics, and numerous other disciplines, paradoxes serve as catalysts for contemplation, sparking discussions, and pushing the boundaries of our cognitive grasp.

The manifestations of paradoxes are as diverse as they are intellectually stimulating, encompassing logical paradoxes, semantic paradoxes, self-reference paradoxes, and beyond. Their central function lies in expanding our intellectual horizons, revealing the subtleties and complexities hidden within seemingly straightforward concepts (Michael, 2012). Some paradoxes illuminate fresh perspectives and catalyze groundbreaking innovations, while others persist as enduring philosophical enigmas, captivating the minds of thinkers across generations (Nicholas, 1985).

In the context of this paper, Lean paradoxes (as outlined by Emi et al., 2008) represent the self-contradictory tools, principles, methods, and techniques intricately woven into Lean philosophy. While the overarching goal of Lean is to reduce waste, these paradoxes highlight a nuanced reality: in the process of waste reduction, waste is often shifted from one form to another. This subtle but profound paradox underscores the complexity and depth of Lean philosophy, prompting organizations to not only identify waste but also to grapple with the intricate dance of waste transformation within their processes. Through the exploration of these Lean paradoxes, this paper seeks to shed light on these multifaceted challenges and offer insights into how organizations can navigate and harness them to drive continuous improvement and operational excellence.

2.1 Lean paradoxes

In the world of Lean philosophy, numerous paradoxes lurk beneath its seemingly straightforward principles. However, in the following section of this paper, we will shine a spotlight on two pivotal paradoxes that often take center stage in Lean discussions: Just-in-Time (JIT) and Jidoka. These concepts are not just integral but are often regarded as the main pillars of the Toyota Production System (TPS), which has set the gold standard for Lean manufacturing.

JIT, or Just-in-Time, is a Lean principle that places a premium on minimizing waste and optimizing the flow of production. Its core tenet revolves around producing and delivering items precisely when they are needed, with an aim to eliminate inventory waste and reduce lead times. On the other hand, Jidoka, another cornerstone of the TPS, centers on infusing quality into the production process and empowering workers to detect and address issues immediately. The synergy between these two principles, JIT and Jidoka, is what gives the TPS its remarkable efficiency and effectiveness.

However, it's important to recognize that despite their undeniable effectiveness in Lean philosophy, both JIT and Jidoka can present paradoxes or challenges when translated into real-world manufacturing scenarios. In this paper, we will embark on a journey to explore these paradoxes within the broader context of Lean principles and how they influence the overall efficiency and effectiveness of the TPS.
Within each of these pillars, a plethora of tools, methods, and techniques are nested. For JIT, these include well-known approaches like Kanban, Pull systems, Heijunka, and more. These tools serve as practical implementations of JIT principles, aimed at achieving the elusive goal of producing and delivering goods precisely when needed. Likewise, for Jidoka, tools such as Poka-Yoke and Andon play crucial roles in building quality into the process and empowering workers to address issues promptly.
These nested tools and techniques are not just practical manifestations of JIT and Jidoka but are also valid representatives of the Lean paradoxes. As we delve deeper into the paradoxes associated with JIT and Jidoka, we will explore how these tools, seemingly designed to enhance efficiency, can sometimes introduce complexities and trade-offs that challenge the very essence of Lean philosophy. Through this exploration, we aim to shed light on the intricate nature of Lean paradoxes and provide valuable insights for organizations striving to embrace Lean principles while navigating the nuances and challenges they present.

2.2 Just-in-Time (JIT)

Just-In-Time (JIT), a renowned manufacturing and inventory management approach, stands as a beacon of efficiency in the world of production. JIT's core objective is to produce and deliver goods precisely when they are needed, orchestrating a synchronized dance between supply and demand. This approach holds the promise of minimizing waste and significantly reducing excess inventory (Ohno & Mito, 1992).
One of JIT's fundamental principles is to eliminate inventory, which aligns with Lean's overarching goal of waste reduction. By ensuring that goods are produced only when they are needed, JIT combats the waste associated with overproduction and excess stockpiles of inventory (a form of muda). However, the pursuit of this Lean ideal through JIT can give rise to another type of muda, namely, transport.
In JIT systems, to maintain the delicate balance between supply and demand, more frequent deliveries are required compared to traditional push systems (SÁEZ-CARRAMOLINO et al., 2019; Storhagen & Hellberg, 1987). While this approach effectively eliminates excess inventory, it introduces the need for increased transportation. The heightened frequency of deliveries necessitates additional transport activities to move the same quantity of goods, which can be seen as another form of waste, or muda.
This concept becomes evident when examining a simple example (Table 1). Imagine a manufacturing facility implementing JIT principles. As orders for goods are received, production is initiated immediately, and goods are delivered as soon as they are ready. This process eliminates the need for large inventory stockpiles. However, it also means that transport activities must occur more frequently to ensure timely deliveries. This increased transportation, although necessary for JIT's success, can be seen as a potential source of waste in the form of excess transport.

Table 1: JIT Paradox

Type of delivery	Goods per delivery	Size of good (m^2)	Distance per delivery (km)	Number of trips	Inventory stored	Space used (m^2)	Total transport distance (km)
JIT	5000	1	500	3	5000	5000	1500
Traditional	15000	1	500	1	15000	1500	500

There are a couple of assumptions for the example, the first one being that the JIT system works in 3 shifts therefore it requires a delivery for every shift, and that both systems are supplied from the same supplier.

2.3 Jidoka

Jidoka, a foundational concept in Lean manufacturing, refers to the practice of building quality into the production process and empowering workers to stop or address issues immediately when abnormalities or defects are detected (Tri et al., 2018). Jidoka emphasizes installing value and quality into products; therefore, it places a significant focus on reducing defects, a type of muda (Abed & Ibrahim, 2018).

The application of Jidoka is a crucial aspect of Lean manufacturing, as it not only enhances product quality but also prevents the accumulation of defects and waste. However, it's important to note that the implementation of Jidoka may require stopping the production line in some situations to address issues promptly and avoid the propagation of defects, which aligns with the Lean principle of "stop the line." This action, while essential for quality control, can create another type of muda, which is waiting.
The concept of waiting as a form of waste becomes evident when we consider a simple example (Table 2). Suppose a defect is detected at a particular workstation during the production process. In line with Jidoka principles, the worker stops the production line to address the issue and prevent further defects from being produced. While this immediate action aligns with Lean's focus on quality, it can lead to a temporary halt in production, resulting in workers downstream waiting for materials or components to resume their work. This waiting time can be considered a form of waste, as it adds no value to the product and can impact overall production efficiency.

Table 2: Jidoka Paradox

Type of production	Goods to produce	Size of good (m^2)	Stopping the line (min)	Number of stoppages	Defective products	Rework time per defective (min)	Storage space for rework (m^2)	Total waiting time	Total rework time
Jidoka	10000	1	10	20	200	1	200	200	200
No stoppage	10000	1	10	0	800	1	800	0	800

The example in Table 2 shows an example of a production system which would stop the line in case of a quality issue, against a production system which would not stop the line and simply continue production and store the products with quality issues for rework. A couple of assumptions were made in the example, the first being that stopping the line and solving the problem would reduce the chance of the reoccurrence of the problem, and that the only stoppages for both systems could be only due to quality issues.

3. RESULTS

In the previous section two examples of Lean paradoxes were shown JIT and Jidoka, from the JIT example it can be derived that JIT shifts the muda from inventory to transport which can be seen in *Table 1* where it is shown that for the same amount of goods given the assumptions, a production system will use more storage space for inventory and have higher inventory, but have less transport in a traditional production system, against a JIT system which will shift this so that a system will have more total transport and have less inventory and use less storage space. This example shows that JIT is a Lean paradox that shifts muda from one type to another.
The Jidoka example shows in *Table 2* that a production system with no stoppages under the assumptions produces more defective products, uses more storage space for defective products, and spends more time on rework but has less stoppage time (waiting time) as opposed to a system which utilizes Jidoka which will have less defects and use less space for storage of defective products, less rework time but will have more stoppage (waiting) time. This example again shows another Lean paradox which shifts the muda from defects to waiting.

4. DISCUSSION

While Lean principles have repeatedly demonstrated their prowess in enhancing operational efficiency and productivity, the paradox emerges when we contemplate the fate of waste within this framework. Does Lean's systematic approach truly eradicate waste, or does it merely metamorphose it into different shapes and sizes, lurking in the shadows of improved processes?
This paradox beckons us to shift our focus from the binary perspective of "eliminating waste" to a more nuanced understanding of "transforming waste." In essence, waste is not entirely eradicated but rather repurposed, sometimes unintentionally, within the system. This shift in perspective compels us to reevaluate which forms of waste wield the most significant impact on organizational success.
The essence of Lean paradoxes lies in the recognition that the Lean journey is not a straightforward path to waste eradication; it's a journey of continuous transformation and optimization. While Lean

methodologies indeed lead to improved efficiency, reduced costs, and enhanced product quality, they do so by redirecting waste into more manageable forms. This raises questions about the true efficacy of this approach and whether the benefits outweigh the complexities it introduces.

Therefore, the core inquiry emerges: does Lean's ability to reconfigure waste genuinely benefit organizations, or does it inadvertently introduce new layers of complexity, giving rise to these perplexing paradoxes? To unravel this conundrum, organizations must embark on an introspective journey that delves into the subtle intricacies of Lean implementation.

In summary, Lean paradoxes compel us to reconsider our fundamental understanding of waste and its role within Lean methodologies. By acknowledging that waste is not eliminated but rather transformed, we open the door to a more holistic perspective on Lean's impact on organizational efficiency and sustainability. This exploration encourages organizations to embrace the complexities and contradictions inherent in Lean principles, ultimately leading to a more profound and comprehensive understanding of Lean's true implications.

5. CONCLUSIONS

This paper delves into paradoxes inherent within Lean philosophy, using foundational examples from the TPS pillars. While focusing on two paradoxes, it acknowledges the presence of others like Jidoka and the interplay between improvement and standardization. The central inquiry emerges: does Lean genuinely eradicate waste or orchestrate its transformation into new forms? This prompts a reevaluation of how waste is understood within the Lean framework, compelling organizations to dissect its impact on operational efficiency and sustainability.

In essence, this paper serves as a gateway to understanding the intricate nature of Lean paradoxes. By exploring these paradoxes, it encourages organizations to contemplate waste not as an absolute entity to be eliminated, but as a dynamic force that undergoes shifts and conversions within the Lean context. This exploration fosters a deeper appreciation of Lean principles, urging a comprehensive assessment of their implications in the pursuit of operational excellence.

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PRODUCTIVITY IMPROVEMENT THROUGH IMPLEMENTATION OF LEAN TOOLS

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Abstract: *In the competitive manufacturing industry, cost-effective production is crucial for success. A key element in achieving operational efficiency and minimizing costs is an effective facility layout. This paper examines the packaging process for PU foam rolls, employing LEAN tools such as activity analysis, 5W2H, spaghetti diagram, and standardized work sheet among others. By identifying non-value adding steps and areas for improvement, insights were gained. Additionally, optimized machine layout was developed using From/To charts and CRAFT tool. The objective was to enhance process efficiency by analyzing distances, tools, and time for material handling and redesigning the layout accordingly. The results showed significant improvements, including reduced transportation distance (76.2%), time spent (63.3%), operational costs (50%), and increased operational efficiency (164.2%). This study highlights the effectiveness of LEAN tools and emphasizes the importance of production layout in enhancing efficiency and reducing costs for manufacturing companies to stay competitive.*

Key words: process improvement, efficiency, LEAN management, facility layout

1. INTRODUCTION

In production organizations, the efficient utilization of limited resources is paramount. The implementation of improvement methodologies, such as LEAN manufacturing, empowers organizations to streamline their production processes, identify inefficiencies, and eliminate wasteful practices [1]. A well-designed facility creates an environment that promotes efficient operations and facilitates seamless material flow [2]. By strategically organizing workstations, industrial engineers can create a framework that supports and enhances overall competitiveness. By adopting Lean methodologies in facility design, industrial engineers can identify and eliminate various types of waste, such as transportation of materials, excessive movement, waiting time, overproduction, and inventory buildup. This paper aims to outline a proposal for enhancing the efficiency of the PU foam rolls packaging process through a layout redesign. By using activity worksheet, spaghetti diagram, standard work sheet, from/to charts and the 5W2H method, distances, equipment requirements, material transfer times and opportunities for improvement were analyzed. By implementing the CRAFT tool an improved layout was obtained.

The paper was structured in the following way. Section 2 gives an overview of the methodology and methods used for the project. Section 3 describes the case, uses data to present the current layout and explains the proposed improved layout. Section 4 gives an overview and discussion of results.

2. METHODOLOGY AND METHODS

The methodology employed in the preparation of this study incorporates both theoretical research and empirical analysis. Building upon the theoretical framework established through the literature review regarding productivity of production organization, the methodology further involved a detailed analysis of the product packaging process with several methods. The activity worksheet as a widely adopted tool for structured representation of the process flow [3] was used for determining the event sequence capturing key information for each operation such as task duration, dependencies, distances and number of workers needed. The spaghetti diagram is an incredibly valuable and effective technique for visual mapping and analyzing the movement of workers and transportation of products [5]. By meticulously tracing and charting the actual paths taken with a spaghetti diagram, a clearer representation of the flow of activities was provided and an identification of losses was more easily identified. When planning activities, defining and supplementing the production schedules, production standards are needed for enabling the fulfillment of quality requirements and delivering safe working conditions with effective use of resources [4]. For this

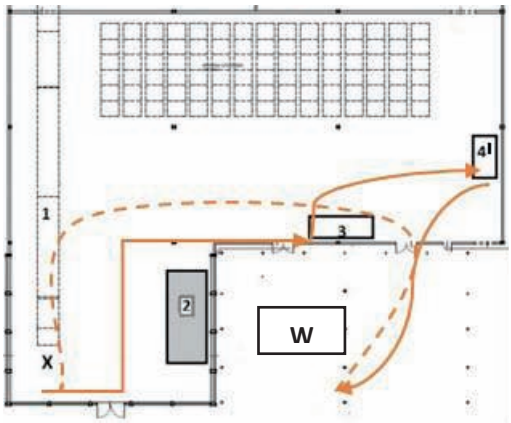
paper a standardized work graph was used for analyzing the ratio of automated and manual work. When in need of a tool for generating ideas and identifying opportunities for change, the 5W2H method is an effective method to apply by asking targeted questions related to a predefined problem or situation. The 5W2H method is built upon five questions that begin with the letter W (What, Why, Where, Who, and When) and two questions that begin with H (How and How often/much). By exploring the answers to these questions, deeper insight into the underlying causes of the problem or the opportunities can be examined with the aim of generating improvement ideas an uncovering overlooked issues [4]. CRAFT (computerized relative allocation of facilities technique) is one of the first tools for computerized layout enhancement and requires the user to specify an initial layout in detail [5]. Flow matrix with the number of units transferred between all departments in a given time, matrix of costs per unit distance when moving between departments, space required for each department should be provided with the goal to design a layout for the process with the greatest reduction of the total cost of transporting the product.

3. ANALYSIS OF THE PU FOAM ROLLS PACKAGING PROCESS

This paper focuses on the packaging process of polyurethane foam (PU foam, sponge) cut and wrapped in a roll which finds application in different segments of the textile industry. The PU foam is originally produced in a rectangular block which is cooled and cut horizontally to obtain PU foam sheets which are then wrapped up in a roll. The roll needs to be packaged in PE foil (for optimizing shipment and ensuring quality), weighed, marked and transported to the warehouse on a hand cart.
The activities included in the packaging process, their duration and number of workers needed for each one are given in the activity worksheet in figure 1. The visualization of the process is represented with a spaghetti diagram in figure 2. After the foam-sheets are cut and rolled up (position X on figure 2) it is placed on a trolley which is operated manually. Each placing of the roll on the cart or on a machine takes on average 3 sec. Transport to the packaging machine (position 3 on fig.2) 57 seconds, covering 55 m. The packing process is automated and takes 30 seconds. The distance between the packing machine and the scale (position 4' on fig.2) is 31 m covered in 30 s. The weighed and marked roll is placed back on the trolley with a forklift and transported to the warehouse (marked W on fig.2) in 30 s which is 25m away. From the warehouse, the worker returns to the starting position (marked X) with an empty cart, covering 95 m in 90 seconds. When performing the activities in this order, one worker travels 206 m and it takes 261 seconds, while two workers are needed for the measurement process in 7 seconds. Also shown in figure 1 is the information derived from the standardized work graph which shows that 13.2% of the overall time for processing one unit is required for automated work, 80.8% for manual work, and 6% for worker movement of the total time to perform an activity.

Starting obsevation point: finished foam-roll										Stand.worksheet information		
End point of observation: warehouse												
Present state												
Activity	Operation	Control	Transport	Waiting	Movement of worker	Storage	Time (sec)	Distance (m)	No.of workers	Manual	Automated	Movement
Placing roll on a trolley	○	◈	•	▪	◉	▽	3		1			⬬
Transport to packing	○	◈	•	▪	◉	▽	57	55	1	⬬		
Placing the roll on the packing machine	○	◈	•	▪	◉	▽	3		1			⬬
Packing	○	◈	•	▪	◉	▽	30		1		⬬	
Visual control	○	◈	•	▪	◉	▽	5		1	⬬		
Placing the roll on a trolley	○	◈	•	▪	◉	▽	3		1			⬬
Transport to scale	○	◈	•	▪	◉	▽	30	31	1	⬬		
Placing on scale	○	◈	•	▪	◉	▽	3		2			⬬
Weighing and marking	○	◈	•	▪	◉	▽	4		1		⬬	
Placing on trolley	○	◈	•	▪	◉	▽	3		1			⬬
Transport to warehouse	○	◈	•	▪	◉	▽	30	25	1	⬬		
Pushing trolley to stating point	○	◈	•	▪	◉	▽	90	95	1	⬬		
Total:							261	206	2	206	34	15

Figure 1: Activity worksheet



Legend;
X–Unpackaged foam roll;
1-Production of sponge-roll;
2-Block-foam packing (not used);
3- Foam roll packing;
4'- Scale and printer
W- warehouse ;
Solid line – transport of roll;
Dashed line – transport of empty cart

Figure 2: Spagetti diagram

In order to review this process, to discuss the problems and opportunities for improvement, the 5W2H method presented in Table 1 was applied.

Table 1: 5W2H Method

5W2H Method	Question	Answer
What?	What is the problem/opportunity?	- The problem is an inefficient arrangement of machines that imposes unnecessary transporting the product and exposes workers to risky situations while performing work tasks. - There is an opportunity to improve the efficiency of the packaging process by changing the layout of the machines.
Why?	Why does this problem occur?	- Due to the arrangement of machines necessary to perform the tasks
Where?	Where does the problem arise?	- - The problem arises during the transportation of the product for packaging, measuring and marking.
Who?	Who is affected by this problem?	- The employees involved in the process, who collectively spend a lot of time and distance, are affected. - Another process and employees using part of the same equipment. - The organization due to unused potential.
When?	When does this problem occur?	- When transporting the product from one working position to another.
How?	How do we define this problem? (with which parameters)	By analyzing the process by applying: - Chart for standard operations - From/To Matrices - CRAFT tool to improve layout - Time, distance and costs for performing the activities
How (much, long)?	How common is this problem?	- With each delivery of the product, a sponge in a roll

In order to improve the flow of activities by improving the layout in the production enviroment, the CRAFT tool was applied. As explained in section 2, CRAFT is a layout improvement algorithm by which the initial layout is improved by swapping adjacent departments in order to reduce transportation costs.
The production environment is divided into 8 departments, the surface of each department with the number of cells, where one cell has an area of 1 m2. The layout has been corrected manually, to better reflect the real position of departments and machines. In this case, the traditional algorithm with rectilinear movement was used. From/To chart for the initial layout is shown in figure 3 which describes the flow of a roll from the starting point of the cutting machine to the warehouse.
From/To chart for transportation costs between departments shown in figure 4. The cost of transferring one unit between each department is calculated by using the distance data from the activity data sheet presented in Figure 1 and assumptions that gross monthly compensation for the employee is 25,000 den, monthly demand for the product is 500 units, compensation for the worker for one unit is 50 den, distance traveled for one unit is 206m, therefore gross compensation for the worker for one meter is C = 0.24 den/m
According to the formula (1) F=the number of units transported and D=transportation distance, the transportation cost between the departments given in figure 4 is calculated.
Total transportation cost:

$$\sum_{i=1}^{n} * \sum_{j=1}^{n} * F_{ij} * D_{ij} * C_{ij} \quad (1)$$

Flow Matrix

FROM \ TO	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8
D 1				1				
D 2								
D 3								
D 4					1			
D 5								1
D 6								
D 7								
D 8								

Figure 3: Material flow

Cost Matrix

FROM \ TO	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8
D 1	1	1	1	13.2	1	1	1	1
D 2	1	1	1	1	1	1	1	1
D 3	1	1	1	1	1	1	1	1
D 4	1	1	1	1	7,44	1	1	1
D 5	1	1	1	1	1	1	1	28.8
D 6	1	1	1	1	1	1	1	1
D 7	1	1	1	1	1	1	1	1
D 8	1	1	1	1	1	1	1	1

Figure 4: Transportation cost for a single unit

The tool automatically determines the centroids of the departments and, according to the entered data for the flow of one unit and the costs of transportation, calculates the value of the initial layout shown in figure 5 which in this case is 37.57. By replacing the position of the adjacent departments with the same areas,

the proposed layout shown in figure 6, with the largest reduction in the costs of transportation and of one unit and the lowest possible value 28.21.

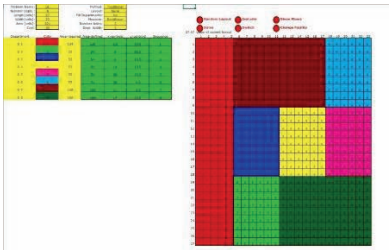


Figure 5: Initial layout visualized by CRAFT tool

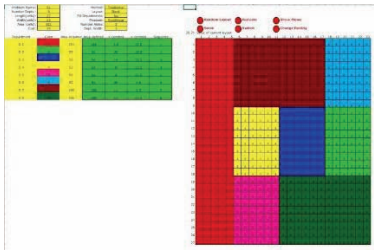


Figure 6: Improved layout

Production of foam roll/ Empty space/Not needed for process/Empty space/Foam roll packing/Not needed for process

/Scale and printer/Warehouse

4. DISCUSSION

By analyzing the process of packing the foam-rolls (which includes packaging, measuring, labeling) through activity worksheet, spaghetti diagram, standard operations graph and 5W2H method an opportunity to reduce the waste of transportation of the product through rearrangement of the layout of the machines was observed. CRAFT tool was used for obtaining an improved layout by reducing the transportation distance between the machines thus reducing the transportation cost.

For the implementation of the proposed layout obtained by applying the CRAFT tool, it is necessary to replace the positions of machines 2 (for another process that is not used) and 3 (machine for packing the rolls) shown in Figure 2. It is also necessary to relocate the scale (in Figure 2 marked with 4'), which is part of a transport conveyor system and is needed for weighing another product (block-sponge) and therefore cannot be moved. For that reason, to achieve the proposed layout, it is necessary to provide an additional scale which should be appropriate for the process, position, dimensions and shape of the foam-rolls.

By replacing the layout of the machines and assuming the new distances according to the centroids value obtained from the CRAFT tool shown in Figure 6, the activity sequence remains the same, but the time for performing the tasks and the distance traveled by the worker are shortened.

The total time to complete the activities is 98 seconds and the distance traveled by one worker for one roll is 49 m. The weighing and marking process with the revised layout requires only one worker, unlike the current layout where an additional forklift driver and electric forklift are required.

The change in layout requires changes to the standardized operations graph and a new ration between manual and automated work is established.

Table 2 gives comparison of the times and distances which are traveled by the worker as well as the means used to transfer the roll if the in the actual and the revised layout. It can be noted that in the revised layout there is no need for an electric forklift to position the roll on the scale thus reducing the number of workers involved in the process to one, for manipulating the trolley.

If we take into account the fact that the demand for the foam-roll product is 25 rolls/day, with the data on the time needed to pack one unit given in Figure 1, we can calculate the efficiency of the packaging process for the current and the proposed layout as well as the efficiency improvement by changing the layout with the following formula:

Efficiency Improvement = (New Output-Old Output)/(Old Output)*100

Old output= 261*25 = 6 525 s = 1.8 h - for 25 rolls → 13.88 ~ 14 r/h

New output = 98*25 = 2450 s = 0.68 h – for 25 rolls → 36.7 ~ 37p/h

Efficiency Improvement = (New Output-Old Output)/(Old Output)*100= (37-14)/14*100=164.2%

Table 2: Overview of improvements obtained from the new layout

Type of layout	From/To	Distance(m)	Time (s)	Equipment	Manual (%)	Automated (%)	Number of workers	CRAFT evaluation	Efficiency (units/h)
Actual layout					80.8	13.2		37,57	14
	Machine for rolls-Packing	55	55	Cart			1		
	Packing-Scale and marking	31	30	Cart			1		
	Weighing	1 (in height)	7	E.forklift			1		
	Scale-Warehouse	25	30	Cart			1		
	Warehouse-Machine for rolls	95	100	Cart					
Total		206	261	2			2		
Improved layout					45	38.2		28,21	37
	Machine for rolls-Packing	15	17	Cart			1		
	Packing-Scale and marking	3	3	Cart			1		
	Weighing	/	4	/			/		
	Scale-Warehouse	16	18	Cart			1		
	Warehouse-Machine for rolls	15	10						
Total		49	98	1			1		
Improvement		76,2%	63.6%	50%	Improved balance manual/automated work		50%	9,36	164,2%

5. CONCLUSIONS

The constant changes in the business environment and the demands of the market, impose a need for constant revision and improvement of the productivity of the processes that take place in production organizations. For small and medium-sized enterprises, it is especially important that the existing resources (space, equipment, human resources) are used to the maximum and aimed at greater efficiency during operation.

This paper highlights some of the claims found in the literature regarding the contribution of the optimal layout in the production environment to greater productivity and reduction of operating costs. Similar benefits are noticed when implementing LEAN methodology as a management approach. When using specific methods for analyzing processes and gradual reduction of activities which do not add value to the final product, a reduction of costs and improvement of efficiency can be obtained.

In order to analyze the packing process of the foam-rolls, activity worksheet was first applied, which defined and then explained all the activities in the process along with a spaghetti diagram which helped to visualize the flow of the material and the workers. Standardized work graph was analyzed in order to derive information regarding the ratio between manual and automated work. 5W2H method was applied for analyzing the process and brainstorming an opportunity for improvement. The CRAFT tool was implemented in order to obtain an improved layout based on the data for the initial layout and process.

By using the CRAFT algorithm a more efficient layout was obtained resulting in 76,2% transport distance reduction, 63.3% time reduction, 50% manpower reduction and 164,2% efficiency improvement.

Further research on this topic should include implementation of simulation models such as DES, ABM and SD for additional experiments with the proposed layout. Also a feasibility study should be conducted in order to ensure that undertaking this change will be profitable.

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APPLICATION OF MODERN TECHNOLOGIES IN THE SUPPLY CHAIN

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Abstract: *Modern technologies have resulted in improvements in many parts of the production process. Supply chains are complex networks involving a large number of people. In real processes, supply chains and logistics intertwine and complement each other. Classic logistics and lean logistics, lean production as well as information technologies in the production process were analyzed. By researching the production system for the production of wines and their location in Serbia, the problems that occur in the process of supplying catering facilities with quality wines produced in Serbia were observed. The application of new technologies provided solutions that gave results to the examined production process. A sketch of the improved process and a solution to eliminate the observed problems were presented.*

Keywords: Supply chain, logistics, QR code, wine.

1. INTRODUCTION

Among the vast types of fraud, the counterfeiting and relabeling of cheaper wines as expensive, rare, and collectible wines are the most prevalent (Biswas *et al.*, 2017). The actors involved in the wine supply chain are thus paying more attention to preventing every kind of counterfeiting. By adopting new technologies that enable traceability, anyone can check and verify each phase of the whole wine supply chain, from vineyard cultivation to wine consumption and packaging disposal, including reverse logistics processes (Danese *et al.*, 2021). In the supply chain from wineries to hospitality establishments in Serbia, there is a problem that affects both sides. Wineries produce a certain amount of wine each year, and the information they have is only initial information on how many bottles they managed to produce that year. In the wine cellars, wines are stored in appropriate conditions, but the state of the stocks in the wine cellar is not kept. When they want to know the actual state of stocks in the warehouse of each variety and from each year, physicists must count the bottles of wine and that information would be recorded on paper. On the other hand, hospitality establishments do not have quick information about how many bottles of wine they have in their warehouse and from which supplier.

When a guest orders a certain wine, the employees have to put it in the warehouse and check if they have that wine in their warehouse or if they have run out of stock. Commercialists are in charge of the field that they have to visit to check the state of stock in each hospitality establishment and in this way, the order of new quantities is made. Another way to order products is by phone, in which communication errors occur. More than 450 wineries are registered in Serbia and this problem occurs in a large number of wineries. With the advent of the Internet of Things (IoT) technologies, several traceability tools have been developed to track supply chain activities: barcodes, Quick Response (QR) codes, and Radio-Frequency IDentification (RFID) tags(Haroon *et al.*, 2016).

Barcodes are a one-dimensional pattern of parallel spaces and bars arranged to represent 10 digits. The encoded information can be read by an optical scanner that sends the data to a system where they are stored and processed. The QR code is a typical two-dimensional barcode and is commonly used in traceable labels because it can store more information than one-dimensional barcodes (Liang *et al.*, 2013). Quick Response (QR) code is a two-dimensional barcode using the ISO/IEC 18004:2006 (it is revised in 18004:2015) standard (Tarjan *et al.*, 2014). A QR code is generated by following certain protocols, the same of which are utilized for its decoding. While the generation of a QR code is a straightforward process, the main challenge lies in recognizing it with greater accuracy and speed. Getting information from a QR code in real-world environments comprises three vital steps: localization, image preprocessing, and decoding. Localization refers to the detection of a QR code and its exact coordinates or location in an image. Image pre-processing is an intermediate step where the detected QR code's image is improved to reduce blur, noise, distortion, angular perspective, etc to enable accurate decoding. Decoding is the final step where the information/data is retrieved and relies on the main standard architecture of the QR code. RFID is similar to barcoding because data from a tag or label are captured by a device and stored in a database,

but it is more advantageous than systems that use barcode asset tracking software (Fan *et al.*, 2019). The most notable advantage is that RFID tag data can be read outside the line of sight, whereas barcodes must be aligned with an optical scanner. Moreover, it has a larger storage capacity (around 32-128 Bit) and can be continuously updated, ensuring the highest level of security compared to previous solutions (Bosona and Gebresenbet, 2013). Within this context, traceability is becoming an essential management tool also for improving production efficiency. Traceability enables effective process control and allows for the elaboration of reliable risk assessment models to identify factors that cause quality and safety problems(Wang and Li, 2007). Each product is given a unique digital identity via the use of a unique tag (a barcode, RFID, or QR Code). This tag is a one-of-a-kind digital cryptographic identification that links the physical product to its network-based virtual identity, allowing any actor to access all or any related information (González-Reséndiz *et al.*, 2018).

Automated Identification: Concepts and Systems – The core of the approach is decoupling the physical item from the information representing it (as is the case with bar codes). In particular, digital identity is the only piece of product data that must be directly located on the product itself. All the other information can be stored elsewhere, with the identity providing a unique code to access it (Research, n.d.). Automated identification (Auto ID) involves the automated extraction of the identity of an object The Auto ID system described in this paper draws heavily on past and current developments in the area of Radio Frequency Identification (RFID).

2. METHODS

To succeed in proposing a method for solving problems in the supply chain of catering establishments with wines from wineries in Serbia, it was necessary to examine the market. The survey was sent to a total of one hundred addresses of both wineries and hospitality establishments. We received feedback and data from only ten respondents. Logistics can cause several problems for which winery owners have no solutions. The lack of expertise of employees in high positions in hospitality establishments results in the fact that they are not even aware of the problems they have. Communication with the wineries is done only through the salesperson. Neither the wineries nor the hospitality establishments are aware of how much stock each customer currently has in their inventory of each type of wine. When we talk about wineries, a large percentage of their wine is sold to hospitality establishments, which is up to 10,000 bottles per year. Wineries have an employee who performs commercial tasks and communicates with customers. Most of the wineries answered that the wines are transported by small van or car. Delivery of products is mostly delivered on a weekly or monthly basis. Not a single winery has information on how many of their wines are in each hospitality establishment and whether there is a sufficient amount of stock. Also, none of the surveyed wineries noticed problems in the supply chain. On the other hand, more than 60% of surveyed hospitality establishments said that they purchase wines directly from wineries. Most hospitality establishments purchase over a hundred bottles per month. they deliver wines by order, most often by phone or text. The wine lists are usually changed twice a year, guided by the wishes of the guests and current events in the market. A large percentage of hospitality establishments buy wines in wine shops, and often in liquor stores because quality wines cannot be found there. They sometimes order the products they need a day before and most often communicate with commercialists. There are also problems in that sometimes the winery cannot fulfill the customer's order and deliver it to a certain facility in one day. Also, hospitality establishments do not find any significant problems or improvements in this kind of supply chain. Modern technologies can greatly improve the supply chain and each party benefits from the use of new technologies. There are many benefits to implementing product traceability, and some of the most important are:

- Supply signals,
- The quality of the wine is monitored,
- Monitoring of wine stocks in the warehouse for each year and each type of wine,
- Stock status feedback,
- Transport is easy to follow,
- Wine guarantee,
- Food and wine combination recommendation,
- Guests in the hospitality facility can be informed about the wine they are drinking, the method and year of production, grape variety, percentage of alcohol, taste, style, and price,

- Quick and easy product ordering,
- Avoiding communication errors.

Salespeople communicate with customers (hospitality establishments) by phone or text. Orders are packed in a box and customers are supplied with products by a small van or car. The current situation in the supply chain is shown in *Figure 1.*

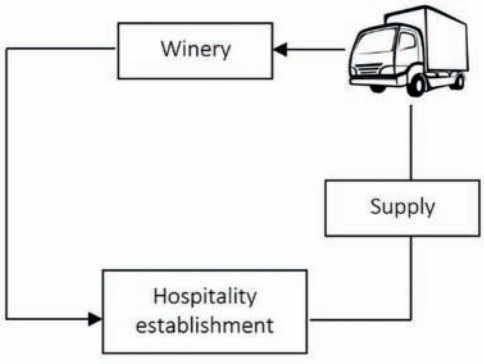

Figure 1: Current situation in the supply chain

Due to the problems observed in the supply chain, improvements need to be made to make the entire supply chain system work better. By using new technologies and QR codes, all steps in the supply chain can be tracked and every part of the chain benefits from the implementation of this improvement. *Figure 2* shows a block diagram showing the winery, catering facility, projected value stream, information system, and connection. Scanning the QR code opens an app that everyone can access, but they have different options, depending on their needs. The winery has the largest amount of data that it can enter, check and control. Hospitality establishments can easily check stock levels and order products. If there is any problem with the product they can report it through the application. Guests can read all the information about the product itself. The supply chain improvement model is shown in *Figure 3..*

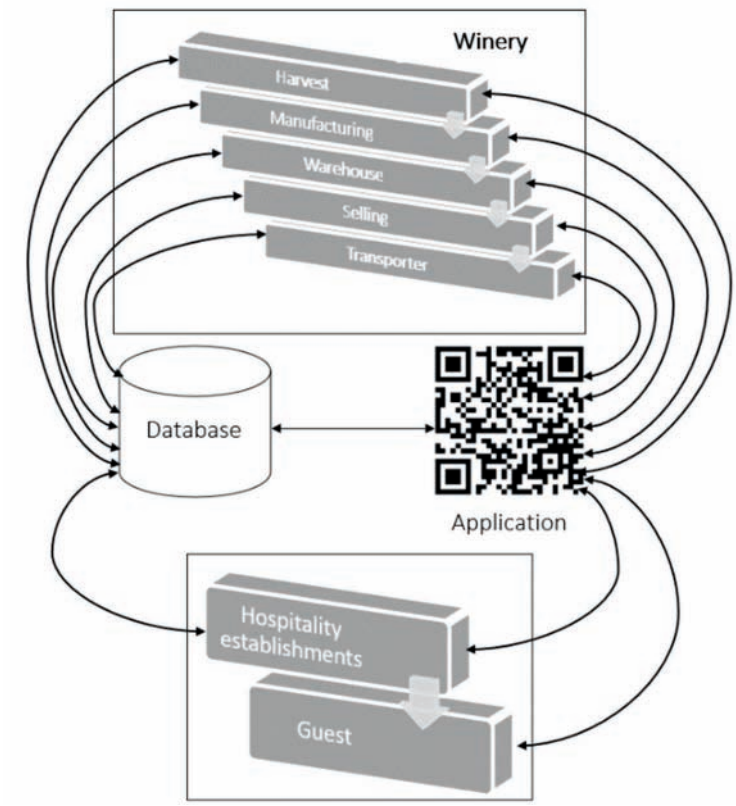

Figure 2: Block diagram of connection

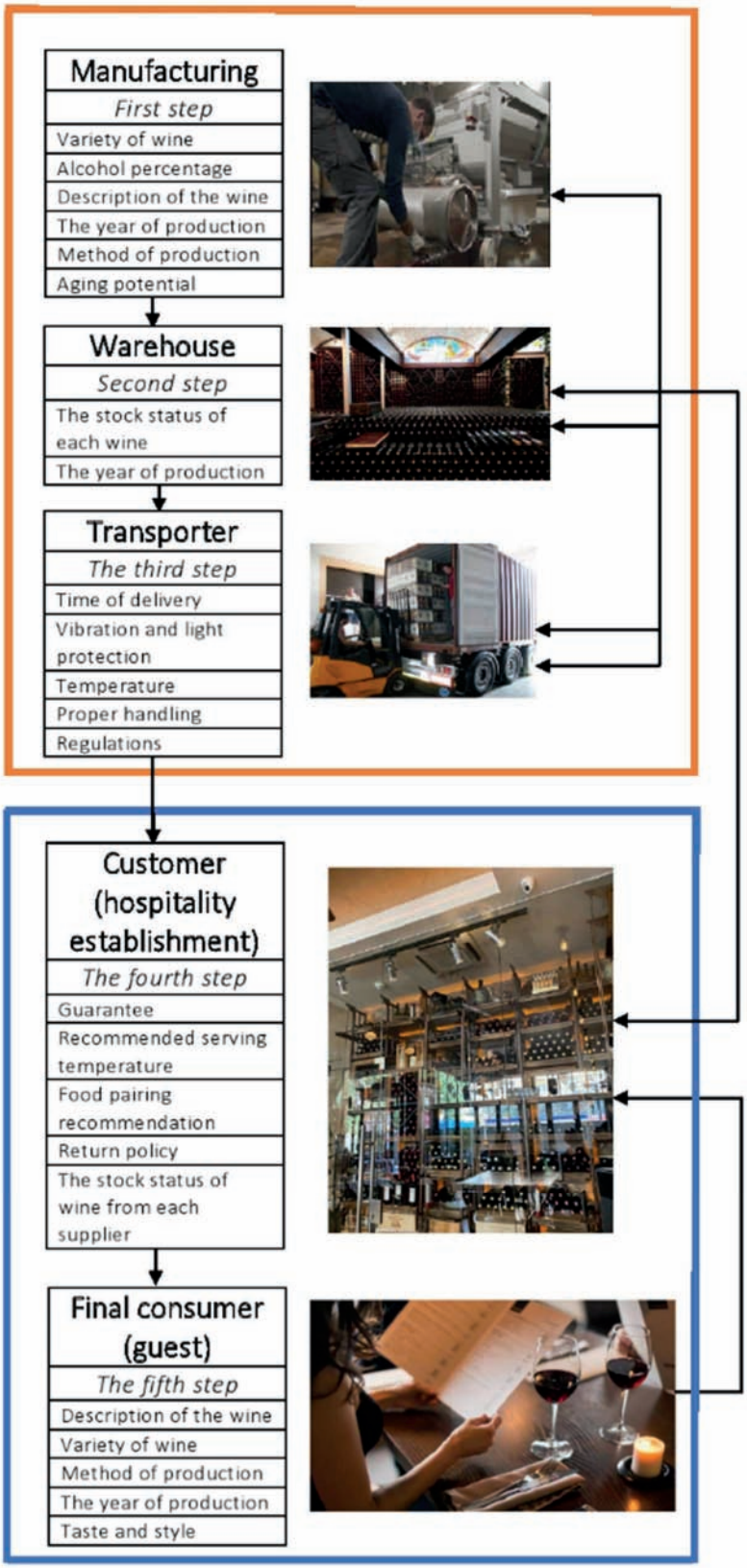

Figure 3: The supply chain improvement model

3. RESULTS

The first time you scan the QR code, you enter the application. There is a possibility of choosing an employee of a winery, or a restaurant. After the selection, you can register (if you don't have an account yet) or login to an existing account. Winery employees have various options, such as monitoring the status of restaurants, some kind of statistics, whether there are orders, complaints, or wines that are in transit and the possibility of monitoring the status of stocks... Hospitality establishments can monitor their stock status in the warehouse through the application, receiving notifications about signals for ordering new stocks, fulfilling requirements, tracking their shipment, and the possibility of complaining or leaving comments. Guests would have a special QR code that would be on the wine list and by scanning the code they would receive all the information about the wines.

4. DISCUSSION

As shown, the results of this research showed that the wineries did not perceive the problems occurring in the supply chain. The incompetence of employees causes problems to occur, but the root of the problem is not sought and not solved. The supply chain has brought benefits for all users when using the application. For the winery, the time to deliver and collect orders from customers has been drastically reduced. Many data and information that the winery has started to be used. They have reduced the possibility of making mistakes that occur with traditional work methods, they get information faster, communicate better with customers, and have the ability to plan production and sales forecasts. Also, they have information about changes in quantities in the warehouse, how much is in stock from all years, and from each type of wine. Logistics work is much easier. Hospitality establishments receive their orders much easier, faster, and more efficiently. All problems that occur during communication are avoided and they can track their product inventory. Guests who are wine lovers can get all the information about the wines they are drinking in just one step.

5. CONCLUSIONS

By using QR codes, employees in wineries and catering establishments will be able to access the application in a very simple way, which will bring new opportunities for every member of the supply chain. This represents only one step in the improvement of the supply chain of catering facilities with wines. In this paper, the basis of the information system, which can be upgraded, changed, and improved, is designed and presented. The winery application is very practical, useful, and new on our market. The application is very easy to use for any user. The steps are very simple and in just a few clicks, your action is complete.

The possibility of adapting the application to any winery located in Serbia. Further directions of research are aimed at introducing RFID tags so that each bottle of wine can be tracked individually. Also, with the progress of each winery, the problems of wine counterfeiting arise. To solve such problems, the application will be connected to the blockchain so that the data can be stored without the possibility of abuse.

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APPLYING THE EXPERIENCE OF THE TECHNICAL PASSPORT TOWARDS THE EU DIGITAL PRODUCT PASSPORT

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Abstract: *The EU wants to set a global standard for the development of a circular economy by reducing the carbon footprint and promoting the sustainable production and consumption of products and their parts. Therefore, the Digital Product Passport (DPP) is expected to be introduced in 2026. The DPP aims to provide information on the environmental sustainability of products. The starting point for creating a DPP must be the basic product data document. The experience of the Eurasian Economic Union (EAEU) in the field of Technical Passports can serve as a good basis. A Technical Passport is an operational document that indicates basic data about a product, service or equipment. It is issued by the manufacturer regardless of the country of manufacture. The Technical Passport is available during the entire life cycle of the equipment or device and must be taken out of service together with the product and accompanying equipment. This paper attempts to clarify the necessary product data that should be contained within a DPP and the road map to be followed to establish a DPP.*

Key words: Digital Product Passport, Technical Passport, Sustainability, Life cycle

1. INTRODUCTION

In an era marked by technological progress and increased consumer awareness, the concept of a "Digital Product Passport" (DPP) has risen to the forefront of discussions around sustainability, transparency and accountability. As concerns about the environmental and ethical implications of products continue to grow. This innovative approach has the potential to reshape industries and drive positive change globally.

At its core, a DPP is a comprehensive and digital record of a product's life cycle, from its creation to its final disposal. It offers a dynamic and interconnected way to communicate key information about a product's origin, materials, production processes and impact on the environment. Using digital technologies such as blockchain, QR codes and online databases, companies can create an accessible and verifiable platform for sharing vital data with consumers, regulatory bodies and other stakeholders.

One of the most profound impacts of Digital Product Passports lies in the empowerment of consumers. In an age where conscientious shopping is on the rise, individuals are increasingly seeking out products that align with their values and expectations. A Digital Product Passport equips consumers with the knowledge they need to make informed choices. Imagine scanning a QR code on a pair of jeans and instantly gaining insight into the cotton's origin, the factory's labor practices, and the carbon footprint of the production process. This newfound transparency fosters trust between businesses and consumers, encouraging a more sustainable marketplace.

The concept of a circular economy, where resources are used, reused, and recycled in a continuous loop, has gained traction as a solution to the challenges posed by traditional linear consumption patterns. Digital Product Passports can play an essential role in advancing this vision. By offering a digital record that documents a product's journey, companies can ensure that materials are sourced responsibly, products are designed with durability in mind, and the end-of-life phase is managed in an environmentally friendly manner. This not only minimizes waste but also encourages the development of innovative recycling processes.

2. EU'S PUSH FOR DIGITAL PRODUCT PASSPORTS

The European Union (EU) has been a pioneering force in pushing for the adoption of a Digital Product Passport as part of its broader sustainability and circular economy initiatives. The concept of a Digital Product Passport aligns closely with the EU's vision for a more sustainable and resource-efficient economy. The EU Circular Economy Action Plan, unveiled in March 2020, places a strong emphasis on promoting the

circular economy model, wherein products and materials are designed for longevity, repairability, and recycling. Digital Product Passports are seen as a crucial tool to help achieve the goals of this plan.

The EU's push for Digital Product Passports is driven by several factors:

- Transparency and Consumer Empowerment: By providing consumers with accessible and reliable information about the products they purchase, Digital Product Passports empower individuals to make more informed choices aligned with their values and sustainability preferences.
- Circular Economy Promotion: Digital Product Passports encourage manufacturers to consider the entire lifecycle of their products.
- Market Transformation: The widespread adoption of Digital Product Passports can incentivize businesses to adopt more sustainable practices to meet consumer demands and regulatory requirements. This can lead to a broader transformation of industries toward more responsible and environmentally conscious operations.
- Efficient Regulation: Regulatory bodies can use the data provided by Digital Product Passports to monitor compliance with environmental regulations, ensuring that products meet required standards and contributing to the achievement of sustainability goals.
- Data-Driven Decision-Making: The availability of real-time data through Digital Product Passports enables policymakers and businesses to make informed decisions about resource allocation, waste management, and product innovation.

The European Union expects the DPP for the first group of products to enter into force in 2026/7. years. This includes electronics and ICT, batteries and vehicles, textiles, plastics, construction and buildings. The battery passport will first come into effect for industrial and electric vehicle batteries in late 2026 or early 2027. In June 2023, the European Parliament adopted a new regulation for batteries and used batteries, repealing Directive 2006/66/EC. With this regulation, a new era of battery production and use with stricter sustainability rules begins (EC, 2023a). Final DPP format and content remain unclear at this point (WBCSD, 2023). For now, it is certain that the battery passport creates a digital twin of the battery, which stores all information about the battery in the cloud.

For now, there are only battery passport proof-of-concept results that Audi and Tesla have agreed to publish to demonstrate the feasibility of collecting data on sustainability performance, integrated with data on material origins and technical data (GBA, 2023).

3. TECHNICAL PASSPORT IN EAEU

One of the main conditions for the smooth movement of products and services in the Eurasian Economic Union (EAEU) is the possession of a technical passport. The EAEU is a regional organization that includes Armenia, Belarus, Kazakhstan, Kyrgyzstan and Russia, and aims to create a single economic market within these countries. A technical passport is an operational document that indicates basic data about a product, service or equipment. It is issued by the manufacturer regardless of the country of manufacture. It is written in Russian or bilingual, in which case one of the languages must be Russian. A technical passport must be issued for each product. The serial number of the product must be entered in the passport. It must be available during the life cycle of the product, equipment or device and at the end of the working life of the product and equipment. This puts the technical passport out of use together with the product and/or accompanying equipment. The document is structured, consists of several parts and has legally established conditions for execution.

In addition, in order for a certain product to acquire the prerequisite for placing on the market in the EAEU, it must have the EAC (Eurasian Conformity Mark). EAC is a certification mark that indicates that products comply with all technical regulations of the Eurasian Customs Union. The goal is to protect the life and health of people and the environment, as well as to prevent the transmission of false information to consumers. When applying for the award of the EAC mark, it is necessary to attach the product's technical passport.

The passport is a working document necessary for the circulation of equipment or devices on the EAEU market. It contains information on the manufacturer's warranty, technical parameters, information on product certification and disposal, as well as any additional information on installation, commissioning or maintenance. All changes to the machine, such as upgrades, conversions, installation of spare parts, repairs and welding, are recorded in the passport. It is a set of technical documentation written in a

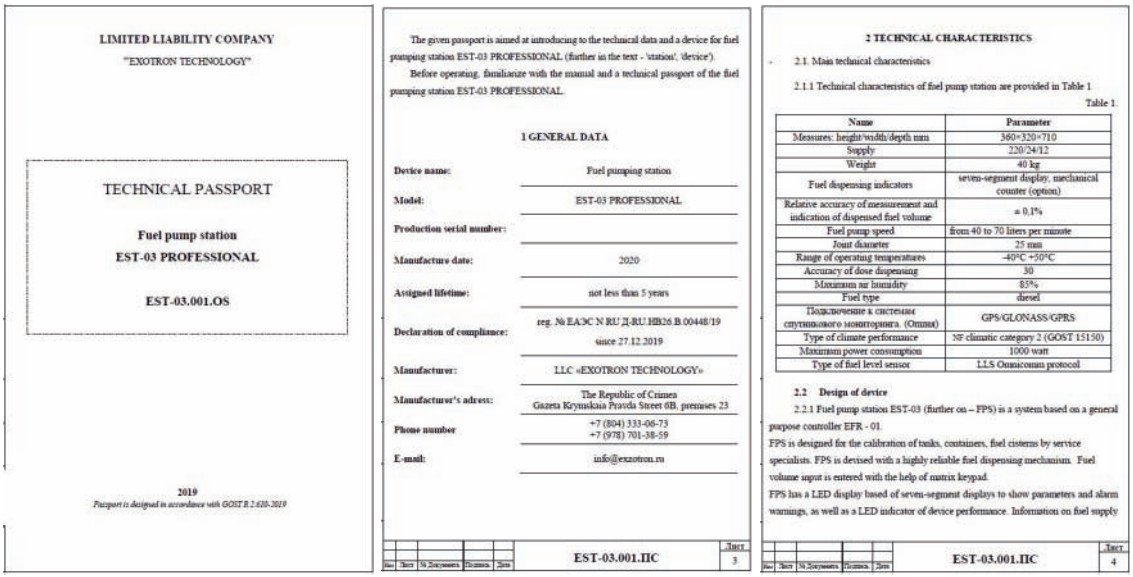
standardized format. That document must be submitted to the certification body for certification and licensing and must be delivered together with the machine to the end user.

Products without a technical passport cannot be placed on the market. Among them are various equipment, machines and mechanisms. The requirement for having a product passport is specified in the technical regulations of the EAEU. Each unit of the product is completed with such a document, which accompanies it throughout its working life.

The passport is issued in the design phase, i.e. the start of production. A technical passport must be issued for each piece of equipment or device and each serial number. It is a document intended for the customer. Depending on the equipment, the passport may consist of different chapters. In general, the passport has information about technical parameters and characteristics, recycling and certification. It is issued by the manufacturer most often according to the standards GOST R 2.610-2019 rules for the implementation of operational documents and general requirements, types, completeness, rules for designing and completing operational documents).

Each technical passport is unique and must therefore be issued individually for each item. The items in the passport depend solely on the type and name of the product itself. Figure 1 presents a few pages (out of 20) of the Technical passport for the Fuel pump station. In general, we can say that the technical passport should contain at least the following information:

- Basic product information (intended use, data sheet number, certificates, registrations, manufacturer, etc.);
- Product specifications and technical data (accuracy specifications for measuring instruments, IP ingress protection, weight, dimensions, transport conditions, etc.);
- Scope of delivery;
- Serial number, TAG number;
- Notes on quality control and production standards, as well as the signature of the quality representative;
- Warranty duration and conditions;
- For measuring instruments: Recalibration interval.



LIMITED LIABILITY COMPANY
"EXOTRON TECHNOLOGY"

TECHNICAL PASSPORT

Fuel pump station
EST-03 PROFESSIONAL

EST-03.001.OS

2019
Passport is designed in accordance with GOST R 2.610-2019

The given passport is aimed at introducing to the technical data and a device for fuel pumping station EST-03 PROFESSIONAL (further in the text - 'station', 'device').

Before operating, familiarize with the manual and a technical passport of the fuel pumping station EST-03 PROFESSIONAL.

1 GENERAL DATA

Device name:	Fuel pumping station
Model:	EST-03 PROFESSIONAL
Production serial number:	
Manufacture date:	2020
Assigned lifetime:	not less than 5 years
Declaration of compliance:	reg. № ЕАЭС N RU Д-RU.НВ26.В.00448/19 since 27.12.2019
Manufacturer:	LLC «EXOTRON TECHNOLOGY»
Manufacturer's adress:	The Republic of Crimea Gazeta Kryuskaia Pravda Street 6B, premises 23
Phone number	+7 (804) 333-06-73 +7 (978) 701-38-59
E-mail:	info@exotron.ru

EST-03.001.ПС Лист 3

2 TECHNICAL CHARACTERISTICS

2.1. Main technical characteristics

2.1.1 Technical characteristics of fuel pump station are provided in Table 1.

Table 1.

Name	Parameter
Measures: height/width/depth mm	360×320×710
Supply	220/24/12
Weight	40 kg
Fuel dispensing indicators	seven-segment display, mechanical counter (option)
Relative accuracy of measurement and indication of dispensed fuel volume	± 0,1%
Fuel pump speed	from 40 to 70 liters per minute
Jout diameter	25 mm
Range of operating temperatures	-40°C +50°C
Accuracy of dose dispensing	30
Maximum air humidity	85%
Fuel type	diesel
Подключение к системе спутникового мониторинга. (Опция)	GPS/GLONASS/GPRS
Type of climate performance	NF climatic category 2 (GOST 15150)
Maximum power consumption	1000 watt
Type of fuel level sensor	LLS Omnicomm protocol

2.2 Design of device

2.2.1 Fuel pump station EST-03 (further on – FPS) is a system based on a general purpose controller EFR - 01.

FPS is designed for the calibration of tanks, containers, fuel cisterns by service specialists. FPS is devised with a highly reliable fuel dispensing mechanism. Fuel volume input is entered with the help of matrix keypad.

FPS has a LED display based of seven-segment displays to show parameters and alarm warnings, as well as a LED indicator of device performance. Information on fuel supply

EST-03.001.ПС Лист 4

Figure 1: An example of the Technical passport for the Fuel pump station

4. DISCUSSION

As we saw, the DPP aim to collect data about a product and its supply chain and share it across value chains so that all actors, including consumers, better understand the materials and products they use and their impact on the environment:

1. **Product data.** First, it is necessary to define the framework for the information that will be included in the DPP. In the case of DPP, it can be all types of data contained in the EAEU

Technical Passport. These data can be supplemented with the elements listed by the European Commission in Annex 1 of the Proposal for an Ecodesign Regulation for Sustainable Products (ESPR).

2. **Data carrier.** Product information should be stored on a data carrier and associated with a unique product identifier. The required unique product identifiers can use existing technologies such as barcodes, QR codes, RFID tags or the like, to submit product digital passport data. The data carrier must be physically present on the product, its packaging or on the documentation accompanying the product.
3. **Digital technologies and infrastructure.** It should be taken into account that all information included in the DPP should be based on open standards, developed in an interoperable format and machine-readable, structured and searchable. In addition, there are privacy concerns related to data sharing, and the technological infrastructure needs to be robust and secure to prevent manipulation or fraud.

From an operational perspective, it's not as difficult as it might seem. In the end, this process can be almost completely automated.

Figure 2: Road map for establishing DPP

5. CONCLUSION

The Digital Product Passport is not merely a technological innovation; it is a catalyst for systemic change. By harnessing the power of digitalization and data transparency, businesses can transition towards more ethical, sustainable, and responsible practices. Consumers armed with information can drive demand for eco-friendly products. As the concept gains traction and overcomes its initial challenges, the DPP has the potential to reshape economies, mitigate environmental damage, and promote a more equitable global marketplace.

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THE RESILIENCE LEVEL OF MANUFACTURING FIRMS IN THE REPUBLIC OF SERBIA

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Abstract: *During the Covid-19 epidemic, resilience as a concept gained prominence. Firms that failed to handle the problems and changes they faced and were unable to survive had to be closed down. Only the companies who resolved them correctly were able to continue doing business. Today, resilience is frequently addressed in emerging global movements such as Industry 5.0. To thrive in today's fast-paced environment, it is essential to understand how to respond to challenges and changes. As a result, the purpose of this research is to demonstrate the level of resilience development in manufacturing enterprises in the Republic of Serbia. The data for this study came from 380 firms in the European Manufacturing Survey, which was conducted in 2018 and 2022. The findings demonstrate the amount of resilience in manufacturing firms in the Republic of Serbia prior to and during the Covid-19 epidemic. The key findings reveal a growing trend in the usage of data security measures, which increased by 30% from 2018 to 2022 in manufacturing firms.*

Key words: resilience, European Manufacturing Survey, manufacturing, data security;

1. INTRODUCTION

Today's world is characterized by fast-paced changes on a global level, not only predicted but unexpected ones as well (Gössling et al., 2020). One of the unexpected global changes certainly was the Covid-19 pandemic which forced the whole world to deal with challenges which were faced – borders were closed, travelling was not possible, and social isolation became the new normal (Raza et al., 2021). Some industries, such as tourism faced tougher challenges in comparison with other industries (Gössling et al., 2020). Many firms had to be shut down, because they were not capable enough to face new challenges in the right way and adapt their way of doing business to the new situation (Slavic, 2023). At this time, resilience as a concept started to attract more attention than before (Xu et al., 2021). Firstly introduced within ecology, this concept became relevant to different fields (Gallopín, 2006). In the manufacturing industry, resilience is referred to as a system's capability to return to the previous state after successfully standing up to affects coming from the system's environment (Sofic et al., 2022).
After surviving business challenges and circumstances brought by Covid-19, the whole manufacturing industry has realized the importance of developing the resilience level of individual firms and strengthening its capability of withstanding future unexpected changes (Javaid & Haleem, 2020). Accordingly, the authors are comparing data of 5 resilience parameters measured in 2018, and in 2022 which show the main focus areas that helped firms become strong and flexible enough to adapt to new conditions dictated by the environment. With an aim to discover which directions of development manufacturing firms have taken in order to survive unstable and unpredictable changes, authors propose these research questions:

RQ1: *What was the resilience level of Serbian manufacturing before Covid-19?*
RQ2: *What is the resilience level of Serbian manufacturing after Covid-19?*

The structure of this paper is: Section 2 provides a literature review of resilience as a concept, Section 3 explains the research methodology, while Section 4 shows the results and discussion. Last, but not least, Section 5 concludes the paper and gives future research implications.

2. LITERATURE REVIEW

The delivery of products or services that make life better for society is the focus of Industry 5.0. However, the aspects that lead to it, such as AI systems, mass personalization, bioeconomy, coworking robots and sustainable practices, are not sufficiently observed or achieved even in Industry 4.0 (Nagy et al., 2019). Nowadays, when there is appropriate knowledge and appropriate technology, it is necessary to change established practices and adopt sustainable, more resistant alternatives, in order to at least reduce the

already excessive impact of industry on nature (Đaković et al., 2020). Increasing resilience in the industry can be increased by implementing systems such as IoT-enabled ones, then AI-based management systems, renewable energy and advanced simulation (Sindhwani et al., 2022). In such a way, the focus shifts to human social aspects and leads to the creation of social value, adapting the industry to new conditions, thus achieving a bio-oriented and sustainable society. This preserves the values of humanity and the environment at the same time, which is the ultimate idea of Industry 5.0 (Lehmann et al., 2023), (Salunkhe & Berglund, 2022).

The current approach to globalized production has proven to be very easily disrupted by various geopolitical changes and natural crises such as the situation with the Covid-19 pandemic. Such conditions indicated the necessity of efficient supply chains in order to achieve flexibility and resilience in production (Jankovic-Zugic et al., 2023). Ensuring precisely this resilience becomes the main need and refers to the development of stable industrial production, which could be maintained even in disturbed conditions, providing support to critical infrastructure while certain disturbances are in effect (Ivanov, 2022). By achieving resilience in strategic value chains, business processes and agile production capacities, production becomes sustainable. In this context, the adjective "resilient" is used more and more, especially if we are talking about the concept of Industry 5.0 and taking into account the consequences that the Covid-19 pandemic has left on industry and society (Rakic et al., 2022), (Sá et al., 2022).

One of the growing challenges of the developing economy concerns achieving a balance between economic growth and environmental protection. The aforementioned further imposes the optimization of production technology and continuous improvement of the product (Rakic et al., 2021), (Ćirić et al., 2016). It is considered that the digitalization of the economy, and the development of network cooperation of local small and medium-sized enterprises with the use of local and regional potentials, could be a factor of the greatest importance for industrial resilience (Saniuk et al., 2022). This also means the confirmation of the trend of orientation towards digitalization of economic processes that proved to be vulnerable during the pandemic (Ghobakhloo et al., 2022). For example, the authors pointed out how workers in Industry 5.0 themselves manage to make their work environment and supply chains more resilient based on their cognition and movement using digital technologies such as artificial intelligence (Cortés-Leal et al., 2022), (Ahmed et al., 2023), (Miloradov et al., 2022), (Bastos et al., 2022).

All of the above led to the general agreement that Industry 5.0 differs from all previous revolutions that have occurred in the industry, due to the fact that it represents a socio-technological phenomenon that involves all interested parties in order to replace the classical economic models based on consumption and profit, turned into resilient, regenerative, sustainable and circular economic models that further create value (Ghobakhloo et al., 2022), (Nayeri et al., 2023), (Al-Zubaidi et al., 2022).

3. METHODOLOGY

Data for this empirical study were gathered using the European Manufacturing Survey (EMS) and a dataset from the Serbian manufacturing sector (NACE Rev. 2 codes 10 to 33) from two rounds in 2018 and 2022. The EMS is coordinated by the Fraunhofer Institute for System and Innovation Research in Germany. The analysis dataset contains 387 observations of manufacturing firms in the Republic of Serbia. Table 1 depicts the industry sector's share of the total sample in 2018 and 2022.

Table 1: Classification of manufacturing sectors according to share on the total sample in 2018 and 2022

2018 (240 observations)		2022 (147 observations)	
Manufacturing industry	*(%)*	*Manufacturing industry*	*(%)*
Manufacture of food products	17	Manufacture of fabricated metal products, except machinery and equipment	20
Manufacture of fabricated metal products, except machinery and equipment	15	Manufacture of food products	16
Manufacture of rubber and plastic products	8	Manufacture of rubber and plastic products	8
Manufacture of electrical equipment	7	Manufacture of wearing apparel	7
Manufacture of machinery and equipment n.e.c.	6	Manufacture of machinery and equipment n.e.c.	5
Manufacture of wearing apparel	6	Manufacture of furniture	5
Others	41	Others	39

Furthermore, the sample from 2018 includes 46% of small firms (fewer than 50 employees), 43% of medium firms (between 50 and 250 employees), and 11% of big firms (more than 250 employees). Furthermore, the sample from 2022 has 52% of small firms (fewer than 50 employees), 36% of medium firms (between 50 and 250 employees), and 10% of big firms (more than 250 employees). The authors

employ comparative descriptive statistics on the resilience parameters from 2018 and 2022 for data analysis. The authors use this methodology to compare the conditions before and after the Covid-19 pandemic. According to the literature, scholars examine the five resilience parameters. R1 - Standardized and thorough work instructions, R2 - Mobile industrial robots, R3 - Collaborating industrial robots, R4 - Data Backup: Activities to raise employee data security awareness, and R5 - Product development.

4. RESULTS AND DISCUSSION

According to proposed research question RQ1 and RQ2, this section shows results of aforementioned resilience parameters' data which were gathered both in 2018, and 2022, in Pre-Covid and Post-Covid periods. Figure 1 shows resilience parameters for different firm sizes in 2018, while Figure 2 shows the same parameters measured 4 years later, in 2022.

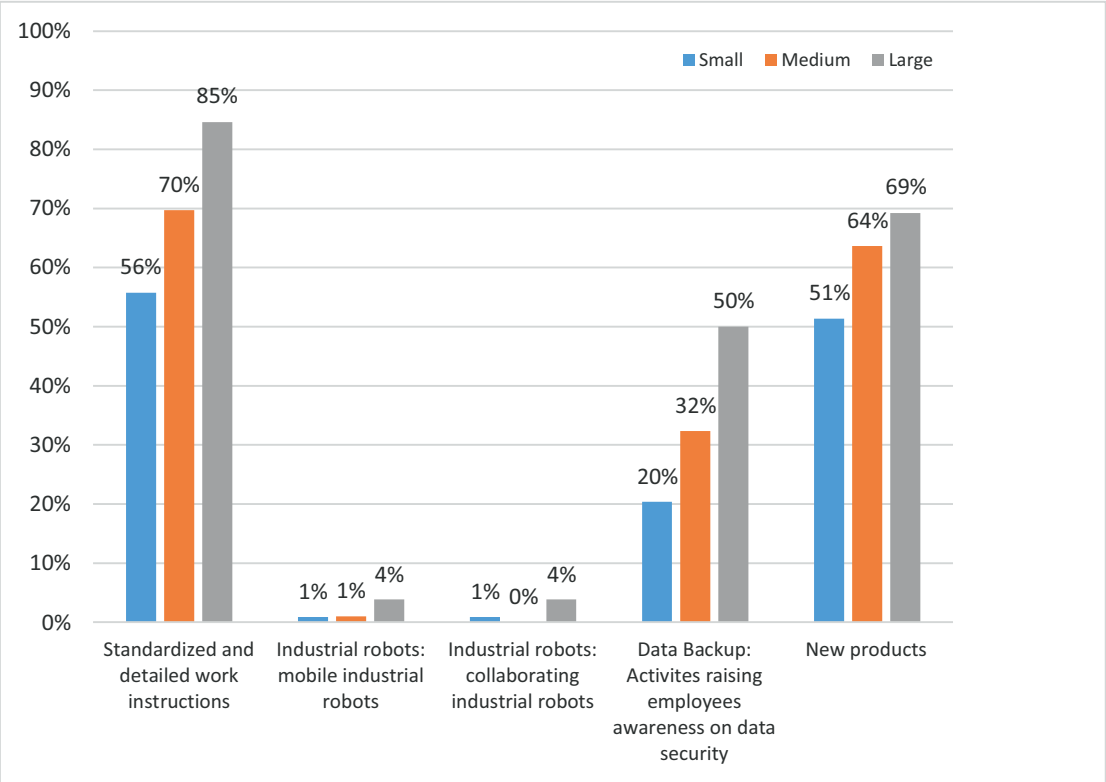

Figure 1: Resilience parameters in 2018: Before Covid-19 state

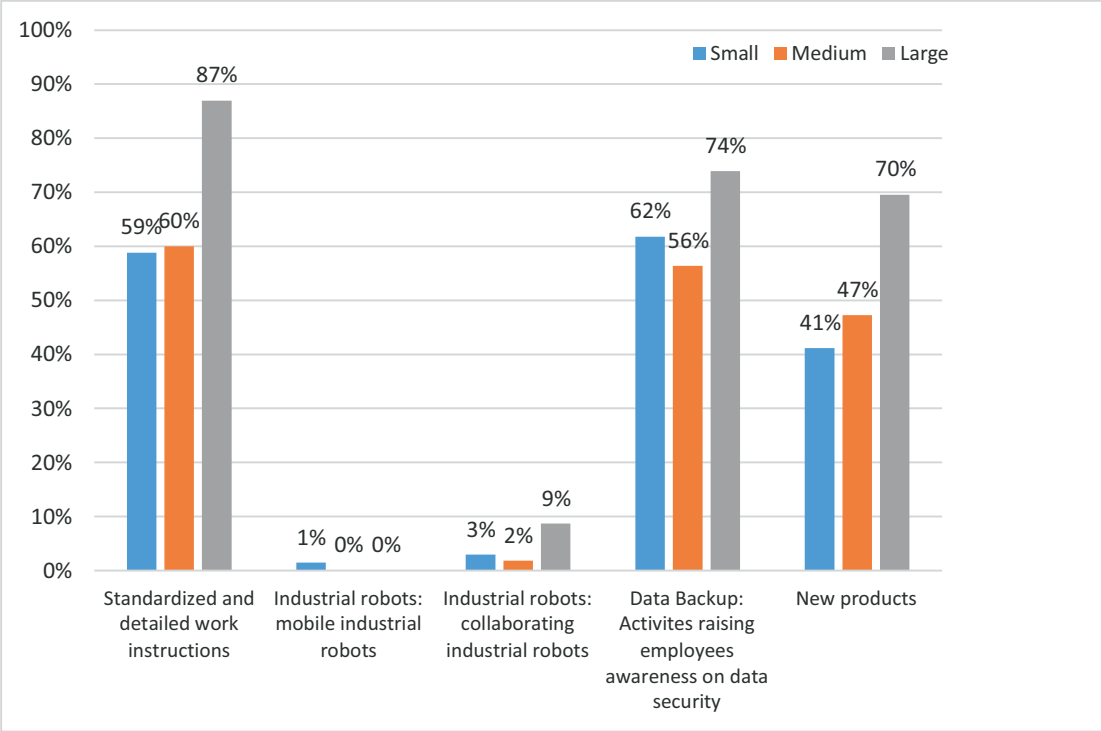

Figure 2: Resilience parameters in 2022: After Covid-19 state

When comparing data from Figure 1 and Figure 2, significant changes are identified. When it comes to parameter R1 – Standardized and detailed work instructions, an implementation decrease is recognized – 3% of overall small firms, and 10% of overall medium firms have stopped implementing standardized and detailed work instructions, while 2% of big firms have started to implement them. Parameter R2 – Industrial robots: mobile industrial robots shows a small progress in application. Their application in small firms stayed the same, however 1% of medium firms started using them, as well as 4% of big firms. Parameter R3 – Industrial robots: collaborating industrial robots has also attracted attention in firms in 2022 – 2% of small firms, 2% of medium firms, and 5% of big firms started to apply collaborating industrial robots. The most significant changes when comparing results from the Pre-Covid and Post-Covid periods are identified in parameter R4 – Data Backup: Activities raising employees' awareness on data security. All firms, despite their size, recorded an increase in these activities – 42% of small firms, 24% of medium firms, and 24% of big firms. The last resilience parameter R5 – New products has also shown an increase of implementation in small, medium, and big firms. When talking about new products, additional 10% of small firms, 17% of medium firms, and 1% of big firms have introduced them.

5. CONCLUSION

Within the paper, two groups of data are shown, the first group consists of data collected in 2018, and the second collected in 2022, that is, we can say that the situation in small, medium and large companies before and after the situation with the Covid-19 pandemic is shown. Data concerning five parameters of resilience were observed.

Resilience was observed precisely because of its importance for the survival of manufacturing companies in modern conditions, which become increasingly demanding and unpredictable over time, as we had the situation with the pandemic. Such situations require companies to be adaptable, flexible and agile in their processes and supply chains. In addition to the infrastructure itself, the influence of the human factor on resilience has also been highlighted in the literature, as well as the need for the industry to take more account of society and its survival in the ecosystem.

By observing the data, we can see that there is a difference in the results of research questions 1 and 2, i.e., that there was an increase in the degree of resilience in Serbian manufacturing in 2022 compared to 2018. This testifies to how much Covid-19 has influenced companies to change the previous practice and thereby lead to the observed difference in the measured parameters in favor of resistance. The biggest jump in application (30%) occurred with parameter R4 - Data Backup: Activities to raise employee data security awareness, where application by small companies increased by as much as 42%, by medium and

large companies by 24%. From this we can conclude that data, that is, knowledge, is even more recognized as a valuable asset that needs to be protected in times of crisis. By 2022, companies have begun to attach more importance to data security measures and to train their employees in this direction, in order to jointly build and preserve the data essential for the survival and prosperity of the company. The application of industrial robots (R2 and R3) is also experiencing its growth. We can point out that it is interesting that the number of small and medium-sized enterprises that introduce new products has decreased, 10% for small and 17% for medium-sized enterprises, while this parameter (R5) continues to grow for large ones for 1 %. This data could result from the fact that it was more difficult for smaller systems to cope with the effects of the pandemic. This study is limited to five parameters of resilience, where a larger number of parameters could potentially be taken for future research.
What is certain is that the Covid-19 virus pandemic has affected the operations of manufacturing companies of all sizes. Digital technology is recognized as needed to increase resilience, sustainability and move closer to Industry 5.0. Every company that strives for growth, development, and in situations like the pandemic, survival, must turn to greater application of sustainability parameters.

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AN OVERVIEW OF THE DIGITAL TRANSFORMATION AND INDUSTRY 4.0 TECHNOLOGIES IMPLEMENTATION FRAMEWORKS

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Abstract: *Digital transformation is vital for improving overall enterprise performance. Many companies are already engaging in such activities, but they often overlook the importance of a structured approach to these projects, considering their complexity and readiness. With technology advancing rapidly, manufacturing companies, which face unique challenges related to standardization, change management, and culture, must adopt a structured approach to digital transformation projects. This paper provides an overview of existing frameworks for implementing digital transformation and digital technologies, aiming to draw conclusions for future research in this area.*

Keywords: digital transformation, industry 4.0, governance, framework, lean management

1. INTRODUCTION

The impact of technology development disrupts organizations in different sectors, posing challenges in implementing new technology. Meanwhile, the popularity of the Digital Transformation (DT) and Industry 4.0 (I4.0) is still increasing in both scientific and business communities (Kraus, et al., 2021), but also with the general public (in a number of searches) as shown in Figure 1, generated with Google Trends tool in June 2023.

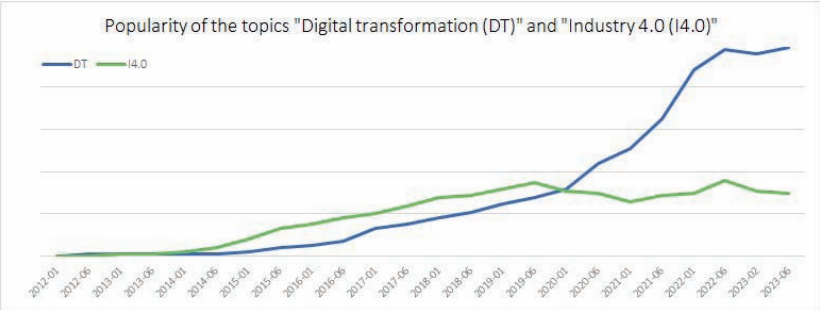

Figure 1: Popularity of the topics "Digital transformation" and "Industry 4.0" according to Google Trends

While the "buzz" around these words is getting louder, surveys reveal high failure rates (70-80%) in digital transformation and Industry 4.0 implementation projects (Carr, 2023; Uchihira & Eimura, 2021). As discussed further in the paper, many authors have emphasized the fact that the success of DT and implementation of I4.0 technologies is not purely based on the introduction of technology, but rather on structured organizational change and governance. Therefore, this paper aims to:

- explore the need for a comprehensive DT and I4.0 implementation framework, and
- review the current frameworks for implementation of DT and I4.0 technologies.

The next chapter provides a brief introduction to the relationship between DT and I4.0. The third chapter focuses on the need for a new comprehensive framework that will address the contemporary challenges, and finally the fourth chapter is presenting a literature review of the existing frameworks for DT and I4.0.

2. RELATION BETWEEN DIGITAL TRANSFORMATION AND INDUSTRY 4.0

DT and I4.0 are often used interchangeably. According to their high-level goal, they seem to be very similar – they both help companies become more efficient and productive through utilization of digital technologies; however, they are two different concepts (Koh, 2022). To understand the relationship between DT and I4.0, first, a distinction between digitization, digitalization, and digital transformation will be made. **Digitization** is the process of making information available and accessible in digital format.

Digitalization is the activity of making processes more automated by means of digital technologies (the ones that are part of the I4.0 concept). Finally, digitization and digitalization are the processes that precede **digital transformation** activities to create new business values. Based on (Connamix, 2021; Abdallah, Shehab, & Al-Ashaab, 2021; Bumann & Peter, 2019) the relationship between these three concepts is illustrated in Figure 2.

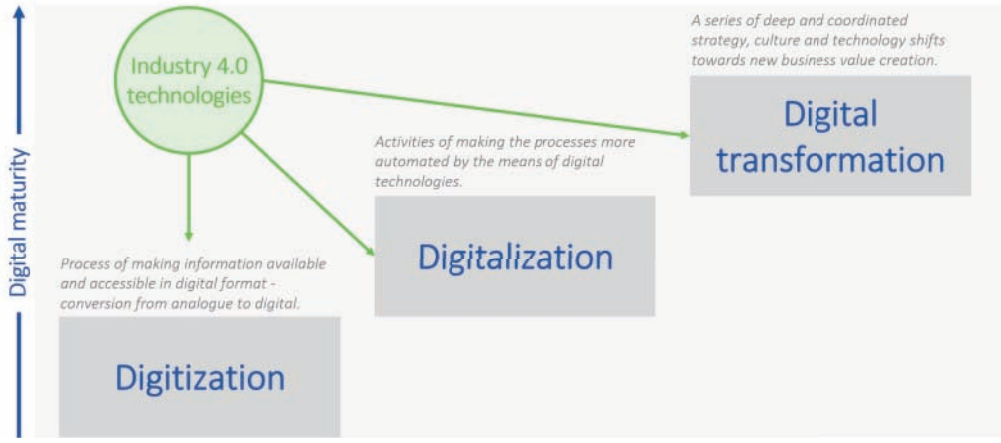

Figure 2: Relation between digital transformation and Industry 4.0 technologies

Industry 4.0 technologies, which is a set of digital technologies, come as an aid to the organizations to reach certain digitization and digitalization that will lead to the overall digital transformation of the organization. It is crucial to make a difference between these concepts considering that they are at entirely different levels in the maturity of the organizations when it comes to their digital goals (Katuu, 2022).

3. THE NEED FOR NEW COMPREHENSIVE FRAMEWORKS

There is not a definitive list of reasons why DT projects fail, but many authors have stated their perspectives or presented lessons learned regarding what can influence these failures. These insights serve as valuable guidance for future strategies, frameworks, and projects related to digital transformation and Industry 4.0.

According to (Carr, 2023), improving the existing processes towards digital transformation won't be successful unless the organization is focused on strategic objectives and includes measurable (where possible) demonstration of performance impact. This author emphasizes that digital transformation requires careful planning as many other projects. (Uchihira & Eimura, 2021) defined six impeding factors that could bring the digitalization projects in jeopardy. They accent the information and knowledge gap, but also the incomplete assessment of the current situation and the inconsistencies with the perspective of the future. In more general research, (Budagov, 2020), it is stated that there are three key groups of reasons for failure of these projects: strategic management, organizational management, and corporate culture development. These three factors along with people roles, responsibilities and organizational structure, top management engagement, current infrastructure and others are referred as identified issues and challenges when it comes to digitalization projects according to another comprehensive research by (Mahmood, Khan, & Khan, 2019). In more recent extensive research by (O'Brien, et al., 2023), the main reasons and risks to failure are stakeholders, culture, organization and strategy, processes, and technology. (George & Fernando, 2019) refer to the culture and management leadership as a main factor for success of the digital transformation and once again stress the fact that technology is not the first thing that companies should care about when it comes to digital transformation.

On a more practical level, the local SMEs also struggle when it comes to implementing DT and I4.0 technologies due to strategy and organization related factors. In previous research during the DigiTS-ME project (DigiTS-ME, 2022-2023) where the maturity of the local SMEs was assessed through three different maturity models, it can be observed that none of the included companies is at the top level of maturity when it comes to Industry 4.0 technologies implementation. If we take an example from the IMPULS maturity model (VDMA, 2016) that was applied in more than 20 Macedonian manufacturing companies, in the dimension “Strategy and organization”, we can observe that 31% of the surveyed companies are in Level 0 in this field; meaning they still haven’t integrated the digital technologies in their business strategies nor have any set rules for the governance of such activities. Half of the companies

(50%) are in Level 2, which means they have pilot initiatives in the departments, but strategic relevance is still lacking. No companies are in Level 4 (the highest level of maturity).

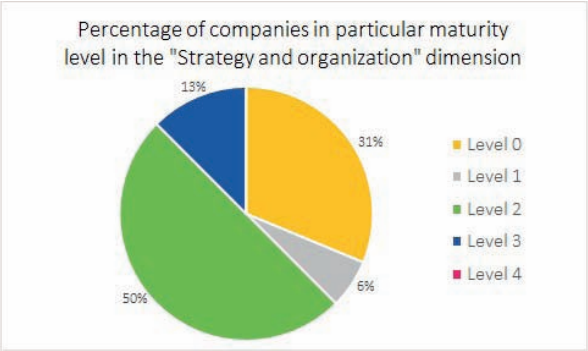

Figure 3: Maturity of the Macedonian SMEs in the dimension "Strategy and organization" according to IMPULS

To succeed, a well-defined and comprehensive framework that will not only focus on technology, is essential to guide the process. Butt (2020) highlights the need for such a framework and points out that organizations often lack a standardized implementation protocol, especially when introducing new technologies. A comprehensive framework is crucial to manage the digital transformation project effectively.

4. DT AND I4.0 FRAMEWORKS LITERATURE REVIEW

In the most general sense of the word, a framework is a structured set of guidelines, tools and deliverables that provide a foundation for developing or implementing projects, organizations, products, strategies or similar (Jabareen, 2008). It is very hard to narrow the final list of areas in which a framework can be applicable considering that they vary from project management frameworks to product development frameworks, testing frameworks, research frameworks etc. Frameworks can be **theoretical** (combining concepts and existing theory) or **conceptual** (unity of concepts for a particular study), (Ahrens et al., 2017). Frameworks can also be of **strategic type** – the ones that are related to designing or pursuing a certain organizational strategy, or **procedural type** – the ones that are related to the governance of certain activities. Some authors include the maturity models in the group of frameworks for the implementation of DT and I4.0 (Denning & Liyanage, 2022). This question was previously extensively researched in (Argilovski et al., 2022). In this paper, the accent is on the procedural type of frameworks, however some of them also include a strategic aspect.

In Table 1 the literature analysis regarding the existing procedural frameworks for implementation of DT and I4.0 is presented. They are analyzed according to the following criteria: phases/steps (which phases are part of the implementation procedure of a certain framework), topic (which concept is emphasized in the framework), type (strategic or procedural), SDLC (which System Development Lifecycle was used to design the framework), maturity models (are the maturity models considered within the framework), Lean aspects (are the Lean aspects considered within the framework). Authors often use different terminology and include varying aspects in describing the phases and procedures, but they generally share similar objectives. Some authors (Stojkovic & Butt, 2022; Mayer, Romina & Pessl, 2017; Gajdzik, Grabowska & Saniuk, 2021) refer to the frameworks as "Industry 4.0 implementation frameworks" but at the core of it, they consider strategy, people, processes and technology, meaning that these frameworks also fit the broader digital transformation definition rather than Industry 4.0 technologies. Only one of the reviewed frameworks, (Butt, 2020), is focused on transforming a process; all others refer to an organization-wide transformation.

One of the main similarities, in almost all shown examples in Table 1, is the inclusion of the maturity models or generally the awareness of assessing the current level of maturity for DT or I4.0 technologies implementation. Considering the importance of Lean management for the future research, the frameworks were reviewed from a Lean perspective too. Few frameworks mind the fact that the processes should be optimized prior to the transformation (Mayer, Romina, & Pessl, 2017; Sameer, et al., 2020) and one of the frameworks, (Butt, 2020), is entirely based on the DMAIC framework associated with Lean Six Sigma methodology. Regarding the System Development Lifecycle (SDLC) model used to design the frameworks, it can be noticed that the traditional waterfall model (typical for project management) is widely used. Many of them also use hybrid models (waterfall in combination with iterative or incremental model), and only one of the reviewed frameworks used the V-model, which is more often used for smaller projects in software testing.

Table 1: Reviewed digital transformation and Industry 4.0 frameworks

Article	Phases/Steps	Area	Type	SDLC	Maturity models	Lean aspects
(Stojkovic & Butt, 2022)	Business requirements, Operational requirements, Systems architecture integration and business case, Subsystems definition and subsystems design. Components design and test, Subsystems tests, Systems integration test, Concept of operations test, Technology transfer to Business as Usual (BAU).	Industry 4.0	Procedural	V-model	*Not included.*	*Not included.*
(Butt, 2020)	Process identification, discovery and process analysis, Process redesign and process reengineering, Streamlining business processes, Risk management & contingency planning, Skills gap analysis, Change management, Cost-benefit analysis, Process validation, process implementation, Process monitoring and controlling	Digital transformation	Procedural	Hybrid	*The paper emphasises that the frameworks could be based on maturity but this one is not based on it.*	*Lean Six Sigma as an approach in the Process Monitoring and Controlling phase*
(Korachi & Bounabat, 2019)	Business strategic planning, Organizational structure, Steering committee, Prioritization process, Investment decisions, Strategic planning, Budgeting, Reporting, Reaction capacity, Management strategy	Digital transformation	Procedural and strategic	Not specified.	*Includes recommendation for maturity assessment prior to the formation of the strategy.*	*Not included.*
(Majdalawieh & Khan, 2022)	Problem identification, Defining the objective of the solution, Design and development, Demonstration and evaluation, Communication	Digital transformation	Procedural	Hybrid (Waterfall and iterative)	*Mentioned in the theoretical background, not included in the following case study.*	*Not included.*
(Mayer, Romina , & Pessl, 2017)	Analysis, Industry 4.0 Maturity, Define target state, Define, and evaluate measures, Realisation, Define projects	Industry 4.0	Procedural	Waterfall	*Entire 2nd phase "Industry 4.0 maturity" is the assessment, and following phases are based on it.*	*Lean is set as a norm strategy for companies that have not yet defined their I4.0 targets*
(Gajdzik, Grabowska, & Saniuk, 2021)	Analysis of enterprise's capabilities, Strategy leading to Industry 4.0, Initial pilot projects, Project implementation evaluations, Transform to digital enterprise/ smart factory, Plan ecosystem approach	Industry 4.0	Procedural and strategic	Hybrid	*Considered in the first phase "Analysis of enterprise's capabilities"*	*In a context that Lean supports Industry 4.0 technologies.*
(Sameer , et al., 2020)	Identify manufacturing data present in the SME, Smart Manufacturing readiness assessment. Develop smart manufacturing-tailored vision for SME, Identify tools and practices to realize SM-tailored vision	Smart Manufacturing	Procedural and strategic	Waterfall	*Included as an entire second phase of the framework.*	*Mentioned several times as an enabler of smart manufacturing, not in the context of the framework.*
(Butt , 2020)	Define, Measure, Evaluate, Optimize, Develop, Validate, Implement	Industry 4.0	Procedural	Waterfall	*Not included explicitly in any phase, however by definition it should be done in the "Measure" phase where the current situation is evaluated.*	*Heavily based on Lean Six Sigma framework, includes LSS tools in the procedure.*

Additionally, Deloitte (Deloitte, 2020) have developed a roadmap framework that includes four steps to digital transformation including assessing the external and internal situation, developing strategy, and assessing business impacts, architect business solution and deploy solutions. Each phase has six sub-phases. This framework is different than the others due to the level of details in each of the main four steps as well as the assessment of the external situation, a step that was not observed in any other framework during this literature review. Another simpler framework is offered by (AIMultiple, 2023). This framework is a procedural waterfall framework and consists of six steps: Identify, Formulate, Tech Selection, Leadership and Digital Culture.

Project management (PM) frameworks are also a powerful tool for managing such activities, but the fact that the digital transformation by itself is more than a project, it challenges these frameworks. It all starts from the fact that DT is not a process nor a project. The traditional design methodology (waterfall model) is not entirely satisfactory for dynamic and uncertain organizational endeavors such as DT. Existing PM frameworks are considered insufficient to support transformational projects (Kimberling, 2021; Third Stage Consulting, 2021). For successfully managing and executing DT, it is needed to incorporate additional competencies like innovation management, organizational change, organizational learning, digital strategy implementation, Lean management, change management, process mapping and improvement etc. (Verhoef, et al. 2020), therefore besides PM skills, the organizations will need wider Industrial Engineering and Management set of skills to manage the transformation.

5. CONCLUSION

Many authors have researched the reasons for the failure of DT and I4.0 projects and according to the literature, success relies on more complex organizational change and governance, not just technology. Despite the negative trends when it comes to digital transformation projects' success, a comprehensive framework for implementation of DT and I4.0 can help organizations avoid failure by demonstrating a roadmap to success - a standardized approach can mitigate risks and enhance digital transformation's success. Several relevant frameworks for implementation of DT and I4.0 were reviewed according to several criteria including phases, area, type, maturity models inclusion and Lean manufacturing aspects. Future research should include the design of a comprehensive framework that addresses the failure reasons as well as a universal maturity model which seems to be missing in the literature even though many of the frameworks acknowledge the fact that maturity assessment is essential in the early phase of the transformation. Lean philosophy should also be a part of the development process of the framework from the very base. Future research should also identify which type of SDLC is most suitable for DT frameworks considering that the traditional project management methodology is challenged by the authors. In a more practical sense, future research should also include testing and verifying such comprehensive framework in a scaled-down environment, such as the Smart Learning Factory – Skopje.

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FACTORS THAT INFLUENCE ADOPTION OF AI IN ORGANIZATIONS

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Abstract: *In the last few years, the rapid development of Artificial Intelligence (AI) has created the conditions for its increasing use in various organizations, in order to achieve the well-known goals of increasing productivity, efficiency, effectiveness and more rational use of resources. However, most companies have difficulties in implementing artificial intelligence and realizing the benefits it brings. Most of the researchers in this field, in order to examine in more detail which factors influence the adoption of new technologies in the organization and what their mutual relationship is, uses previously well-developed models such as TAM (Technology acceptance Model), UTAUT (The Unified Theory of Acceptance and Use of Technology) and TOE (Technology-Organization-Environment). Through a more detailed review of the literature, this paper provides a framework overview of the factors. The article highlights the insufficient focus of previous studies on the factors related to the intention of employees to use artificial intelligence in everyday business tasks, that is, it proposes a framework for further research in this area with special attention to the intention of employees to use AI. Our results can help scholars and practitioners to include those factors in further theory development.*

Key words: Artificial Intelligence, Intention to use, Adoption of AI, Organizations

1. INTRODUCTION

Artificial Intelligence is a term that has long been recognized within academic circles. It was initially coined by John McCarthy in the mid 50's during a scientific conference aimed at establishing standard methods for this new field (Smith et al., 2006). Since then, the development of AI has closely followed advancements in computer technologies, including the storage and processing of vast amounts of data, faster data access, handling different types of data, and other related areas (Venkatesh, 2021). The availability of such technologies and access to large data sets have fueled the rapid progress of AI over the past decade, enabling its widespread application in various organizational contexts. As noted by (Hal Varian, 2018), significant progress has been made in areas like image recognition, speech recognition, and machine translation, allowing AI, as a general-purpose technology, to make a profound impact across numerous industries. This impact, as noted by (Dwivedi et al., 2021), can also be seen through a numerous research papers published in the field of various application of AI in education (Zawacki-Richter, Marín, Bond, & Gouverneur, 2019), healthcare (Rong, Mendez, Bou Assi, Zhao, & Sawan, 2020), agriculture (Misra et al., 2022), business and finance (L. Cao, 2020), robotics (Vrontis et al., 2022), marketing (Vlačić, Corbo, e Silva, & Dabić, 2021), transportation (Vlačić et al., 2021), day life, etc.

In order to enhance competitiveness, reduce costs and harness the various benefits offered by this innovative technology, organizations strive to integrate AI into their operational units. However, a question arises: Have innovative technologies always been readily adopted and swiftly implemented throughout organizations? Regarding intention to use AI and its adoption, scientists are often engaged in exploring factors at various levels, including individual, organizational, and contextual. At the individual level, factors such as perceived usefulness, perceived ease of use, attitudes, and individual characteristics may play a role in shaping the intention to use and accept AI. Organizational factors can encompass aspects such as organizational culture, leadership support, resources, and training (Lecic, Milic, Visnjic, & Culibrk, 2023). Contextual factors consider external influences, such as industry characteristics, regulatory frameworks, and societal norms. Different theories, which are used to explain technology adaption in general, are also used to explain adaption of AI as an innovative IT technology on individual or organizational level. The most common theories used on individual level are Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975), Theory of Planned Behavior (TPB) (Ajzen, 1985), Technology Acceptance

Model (TAM) (Davis, 1989), Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003), etc. On the organizational level, the two most common used are Technology-Organization-Environment (TOE) model proposed by (Tornatzky & Fleischer, 1990) and Diffusion of Innovations theory (DOI) proposed by (Rogers, 1995). All the above theories are also combined in the literature in an attempt of authors to predict more percentage of cases of acceptance of any technology.

Throughout history, humans have consistently pursued the adoption of new technologies to improve work efficiency, productivity, and overall system success by achieving faster results with fewer resources (Dwivedi et al., 2021). However, according to (Venkatesh, 2021), just like many times before, organizations today are facing with problems regarding adaption and use of innovative technologies which is influenced by many factors, and AI is not an exception. These problems are very often the result of employees' reluctance to accept and use new technologies, because AI can be seen as a technology which has a potential to replace their work (Burgess, 2018). Consider the steam engine revolution, where physical labor was gradually replaced by machines. Similarly, contemporary efforts today are focused on perfecting technologies that facilitate cognitive tasks. However, historical evidence indicates that every form of automation led to the fear of job displacement, alongside other accompanying obstacles, and this fear is even more justified considering estimation that job displacement due to automation could lead to up to a third of current working activities being impacted by 2030 (Manyika et al., 2017). While AI may be perceived as a potential threat that could replace human jobs, on the other hand it also offers opportunities for job performance improvement. AI systems can provide timely and accurate information, facilitate data analysis (Dabbous, Aoun Barakat, & Merhej Sayegh, 2022), and assist in the decision-making process (Bader & Kaiser, 2019), which is one of its most significant applications (G. Cao, Duan, Edwards, & Dwivedi, 2021). Therefore, it becomes crucial to focus on employees and explore the factors that influence the likelihood of organizations intending to adopt AI and those that may hinder such intentions.

2. FACTORS INFLUENCING INTENTION TO USE AI

Absence of grounded theory in research on information systems caused scientists to relay on theories from the field of social psychology in order to provide an explanation on factors that can predict Individuals' acceptance behaviour (Venkatesh, James, & Xu, 2012) (Kaur & Arora, 2021). Those theories mentioned earlier, TRA, TPB, TAM and UTAUT are based on the reasoned and planned individual behavior resulting from and consistent with people's conscious intentions regarding that behaviour (Fishbein & Ajzen, 1975).

TRA (Fishbein & Ajzen, 1975) is among the core and influential theories that profoundly shape human behavior and is used to predict behavioral intention or behaviour. It aims to explain how attitudes and behaviors in human actions are related. The theory suggests that behavioral intention, as a direct precursor to behavior, is determined by prominent information or beliefs regarding the probability that engaging in a specific behavior will result in a specific outcome (Dwivedi et al., 2017).

TPB (Ajzen, 1985) is an attempt to deal with limitations of TRA theory and represents its extended version. It introduced perceived behavioral control as a new construct which pertains to individuals' perception of the level of ease or difficulty related to engaging in a specific behavior. Based on the theory, the combination of perceived behavioral control and behavioral intention can directly forecast the specific behaviors (Dwivedi et al., 2017).

TAM (Davis, 1989), is an adaptation of TRA theory in order to be used for predicting behavioral intention specifically of users of Information systems. According to the TAM, two critical beliefs, namely perceived usefulness, and perceived ease of use, play a pivotal role in shaping individuals' behaviors towards computer acceptance.

UTAUT (Venkatesh et al., 2003), was developed through a comprehensive examination and integration of eight prominent theories and models. It has four core determinants of intention: effort expectancy, performance expectancy, social influence, and facilitating conditions. This theory is widely used by many scientists and is proved to explain higher percentage of variance than other theories. (Venkatesh et al., 2003) proved that the UTAUT model was capable of accounting for nearly 70% of the variability in behavioral intention, whereas other models and theories, using the same data, could only account for 17% to 53% of the variability in behavioral intention.

TOE model was developed by (Tornatzky & Fleischer, 1990) and is based on Contingency Theory of Organizations. It is dominantly used to explore IS acceptance on organizational level. Within this framework, three fundamental factors were recognized as influential in organizational adoption: technology, organization, and environment (Ibrahim, Yasemin, Sevgi, & Turetken, 2012).

DOI is proposed by (Rogers, 1995). The DOI theory perceives innovations as being disseminated through specific channels within a particular social system over time (Rogers, 1995). Individuals are viewed as having varying levels of readiness to adopt innovations, resulting in an observable pattern where the adoption of an innovation by the population follows a roughly normal distribution over time (Rogers, 1995).

2.1 Factors on individual level

On such grounds, (Dabbous et al., 2022) extended the technology acceptance literature by proposing a behavioral model which takes into account the peculiarities of AI. This study combines TAM and the TRA, in the context of developing country, and argues that when explaining the intention to use a new technology, it is important to integrate organizational, social, and individual factors. This model, with the aim to explain employees' intention to use AI, is based on five factors: perceived usefulness, job insecurity, self-image, habit and organizational culture. (Dabbous et al., 2022) excluded variable named ease of use, which could be considered in further research. Job insecurity, as defined by (Tsakonas & Papatheodorou, 2008) is a "perceived threat of job loss and the worries related to that threat". Studies shows that Perceived usefulness has been one of the significant predictors of intention to use technology (Venkatesh et al., 2003) and it refers to the degree to which a service is perceived as advantageous in efficiently and consistently accomplishing a particular task (Tsakonas & Papatheodorou, 2008). Self-image is defined as the extent to which an individual believes that utilizing an innovation will improve their standing within their social system (Dabbous et al., 2022). Habit is also one of the important factors which has significant influence on humans' behaviour. It is defined as the degree to which individuals engage in behaviors automatically due to learned patterns (Limayem, Hirt, & Cheung, 2007). No less powerful factor is organizational culture which responsibility lies in creating a suitable environment that fosters the adoption and utilization of this technology. Organizational culture encompasses shared values, beliefs, and underlying assumptions that are commonly held by members of an organization (Miron, Erez, & Naveh, 2004). The study of (Dabbous et al., 2022) contributed by implementing organizational culture in combination with habit in the proposed model which are also proved to have strong impact on intention to use AI.

Another study (G. Cao et al., 2021) focused its research efforts on intention to use AI specifically in the area of decision making by exploring managers attitudes. They developed integrated AI acceptance-avoidance model (IAAAM), which integrated UTAUT and technology threat avoidance theory (TTAT), with an intention to cover not just factors influencing technology acceptance, but also the factors influencing individual's technology avoidance intention. Their model consists of ten factors: Attitude (an individual's favorable or unfavorable attitudes toward using AI) (Dwivedi et al., 2017), Performance expectancy (the extent to which an individual perceives that utilizing AI will lead to improvements in job performance) (Venkatesh et al., 2012), Effort expectancy (the level of ease linked to the utilization of AI) (Venkatesh et al., 2012), Facilitating conditions (the extent to which an individual perceives the presence of organizational and technical infrastructure to facilitate the use of AI) (Venkatesh et al., 2012), Peer influence (the extent to which an individual perceives that significant others believe they should utilize AI) (Venkatesh et al., 2012), Perceived susceptibility (An individual's perception of the probability that using AI will result in making poor decisions) (Chen & Zahedi, 2016), Perceived severity (an individual's perception of the extent of adverse outcomes associated with using AI to make bad decisions) (Chen & Zahedi, 2016), Perceived threat (the degree to which an individual perceives the use of AI for decision-making as risky or harmful) (Chen & Zahedi, 2016), Personal wellbeing concerns (the level of apprehension and stress experienced by an individual due to the use of AI) (Agogo & Hess, 2018), Personal development concerns (the level of concern an individual has about the extent to which AI inhibits personal learning from one's own experiences) (Duan, Edwards, & Robins, 1995). The results of this study only partially confirmed hypotheses from UTAUT model which can be explained by different context of the study indicating that the UTAUT model and its associated factors may not comprehensively capture the context of utilizing AI for organizational decision-making. An essential implication is that organizations should consider individual concerns when implementing decision-making systems based on AI and is likely to be a key factor influencing managers' perceptions of using AI.

Also, another research done by (Chatterjee, Rana, Khorana, Mikalef, & Sharma, 2021) focused on the specific use of artificial intelligence in CRM. This study used modified UTAUT model in order to explain adoption and user behavior in this specific AI usage. The modification implied that some moderators and constructs used in UTAUT, such as social influence, are dropped from the model, and some new constructs, which are characteristic for AI in CRM, such as attitude, as a mediating variable, and CRM quality, CRM satisfaction and compatibility, as exogeneous variables, are included. This study is an

example of modifying existing model by adding new variables, which are specific for AI-CRM. By this study authors confirmed all formulated hypothesis, and argue that by introducing new variables, they strengthened the model (Chatterjee, Rana, Khorana, et al., 2021).

2.2 Factors on organizational level

In the study of (Chatterjee, Rana, Dwivedi, & Baabdullah, 2021) we can see an example of combining two theories TOE and TAM which are used for predicting AI adoption and behavioral intention on different levels – organizational and personal, here in the context of the manufacturing and production companies. The present study has investigated the influence of cultural factors on the adoption of a new technology (such as big data) within an organizational context.

Further, in the study of Venkatesh, who is the creator of UTAUT model, are given directions of further research in this area, suggesting four opportunities: 1) examining antecedents/determinants that are specific for certain technology, which could include: individual characteristics (such as personality), technology characteristics (such as quality), environmental characteristics (such as culture of innovations); 2) formerly mentioned variables can be used as a moderators in the new models; for instance, it is possible that individual characteristics can moderate the impact of one or more UTAUT predictors (such as performance expectancy) on intention or usage, and that can be case with other variables as well; 3) these mentioned variables can also have a direct influence on intention to use (a suitable example of that is an advancement from UTAUT to UTAUT2 model, adding habit as a predictor); 4) The outcomes and consequences commonly examined in the literature on technology adoption, such as intention, behavioral expectation, and usage, warrant further investigation (Venkatesh, 2021).

3. DISCUSSION AND CONCLUSIONS

Prior research on the adoption of AI has predominantly relied on theories and models of Information Systems/Information Technology adoption. However, it is questionable whether such models correspond to the specificities of artificial intelligence in full and whether there is a need to improve them through the introduction of AI specificities. To overcome the beforementioned problems and include all the significances of artificial intelligence, some of authors tried to combine and mix existing models and theories, while other tried to add new constructs in existing models. Research which resulted with new proposed model called IAAAM is done by Cao (G. Cao et al., 2021), and they argue that conventional models of technology adoption, such as TAM and UTAUT, are not adequate for studying the adoption of AI as they primarily concentrate on functional technologies and fail to comprehensively explain the decision-making process in the context of AI adoption. Similar problems exist when exploring other innovative non AI services (Raut, Célić, Dudić, Ćulibrk, & Stefanović, 2021), like e-government, which resulted in unified model of e-government adoption (UMEGA) by (Dwivedi et al., 2017). These two papers only partially confirmed hypothesis and showed inconsistent with prior models such as UTAUT, TAM, TRA, etc., which caused them to propose a new model. That is inconsistent with prior research, where UTAUT model was capable of accounting for nearly 70% of the variability in behavioral intention (considering previous research on classic IT technologies). Regarding future research, (Oliveira & Martins, 2011) believe that for the adoption of complex new technologies, it is crucial to integrate multiple theoretical models in order to attain a more comprehensive understanding of the phenomenon of technology adoption.

In support of the more profound research of the factors that influence individual behavior goes claim that a more pragmatic vision of the future, envisioning a collaborative context where AI works in conjunction with humans, rather than a scenario where AI replaces humans across industries (Sun & Medaglia, 2019). As Dwivedi adds, researchers have a significant contribution to make in examining the numerous obstacles to AI interaction and the psychological factors associated with change in the workforce and society at large. In (Dwivedi et al., 2021), which describes general perspectives on emerging challenges, opportunities and further agenda for research in AI, it is stressed that the social influence have also been identified as potential barrier to the wider acceptance and implementation of AI technologies. Social obstacles associated with unrealistic expectations towards AI technology and limited awareness of the values and benefits offered by AI technologies are identified as important (Sun & Medaglia, 2019).

From the extended literature review and personal experiences, authors propose to take in consideration the following specific factors that may also influence behavioral intention and AI acceptance: Ethics, Security, Privacy, and Trust. The presence of inherent bias within AI algorithms and the involvement of humans working closely with intelligent machines present substantial challenges in terms of trust, human

safety, and ethical considerations (Dwivedi et al., 2021). Also, unrealistic expectancies of AI, fear of change and many other variables are to be explored in the context of AI acceptance.

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OPTIMIZATION OF THE PRODUCTION PROCESS IN THE AUTOMOTIVE INDUSTRY WITH VALUE STREAM MAPPING METHODOLOGY

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Abstract: *One of the most important ways to achieve a competitive advantage in the market is to meet customer needs. Nowadays competition is more significant than ever before so it is necessary to establish a safe and reliable relationship with customers and thus gain customer loyalty. One of the most effective lean tools which gives the possibility to see the entire process in a somewhat simplified way and can be the initiator of many further changes is value stream mapping (VSM). Based on the collected data during the VSM walk, a visual review of the process was made and takt time was calculated. In this study, it was necessary to balance the workplaces, so that they are all approximately loaded, and this resulted in a reduced cycle time on the assembly line and many other additional benefits presented in the paper. This study also covers how the application of VSM improves planning flexibility in the automotive manufacturing process.*

Key words: *Value Stream Mapping (VSM), Lean tools, Automotive Industry, Takt time, Process Management*

1. INTRODUCTION

The automotive industry is considered one of the fastest growing industries in recent years, so it is necessary to set up a system that will be flexible and able to quickly react to the changes that are happening and be able to fulfill the required customer needs. Considering that the fulfillment of required delivery dates is one of the main goals of every company, it is important to have a production process whose duration will be in accordance with the deadlines when the products should be delivered to the customer. As it is a frequent case that various losses and delays occur during production, in situations where planned deadlines are not respected, it is necessary to analyze the causes that lead to delays and additional costs. In this regard, every company should strive to apply lean production.

Lean manufacturing is based on creating value for customers with as few resources as possible (Jordan et al., 2020). Over the last decades, this philosophy has been able to help companies in various industries work more standardized and efficiently and achieve better results with less investment (Cimermancic et al., 2022). The model that Shaman presented aimed to examine the nature of the relationship between lean thinking and value creation in supply chains, with the result that they are indeed closely related (Shamah, 2013). This concept allows flexibility, because, on the one hand, the focus is on what customers want, while on the other hand, the focus is on eliminating all kinds of wastage.

One of the very effective lean methods used in practice to solve these problems is value stream mapping. Jasti et al. investigated and proved the importance of VSM in finding different sources of losses in the auto a ncillary industry (Jasti et al., 2020). In this study, it will be shown how using it can help the company to reduce cycle and lead time, and additional costs and make sure that products will arrive at customers' plant when he expects them. Singh et al. made a comparison between the current and future states of the selected manufacturing unit, it has been found that there was a 69.41% reduction in cycle time, an 18.26% reduction in work-in-process inventory, and a 24.56% reduction in production (Singh & Singh, 2013). Vinodh et al. have improved labor productivity, quality and reduced flow time by applying the VSM method in the automotive industry (Vinodh et al., 2015). The goal of VSM is to identify areas for potential improvements, which will lead to reductions in costs, various types of wastage, waiting time, movement, and manipulation.

In section 2 will be shown a more detailed theoretical review of the VSM and the types of losses that occur. Then in section 3 are described the steps that were carried out during data collection and analysis of the current state of the process. In section 4 are shown the implemented changes that occurred as a result of the problem analysis from Section 3. Finally, in section 5 are stated conclusions of the VSM workshop.

2. LITERATURE REVIEW

In the lean methodology, the term 3M appears, which is an acronym of three Japanese words: muda, muri, and mura. In the Toyota production system, whose goal is to achieve better production productivity, the elimination of all wastages that don't add value to the products but affect the increase in production costs is one of the key points, and therefore muda, muri, and mura must be eliminated as much as possible (the ideal situation would be to eliminate 100%, but this is difficult to achieve in practice).

Muda is a Japanese word meaning waste. The most common wastes that occur during the production process can be classified into seven groups: transport losses, waiting losses, overproduction losses, storage losses, excessive finishing, scrap, and unnecessary movements. There are two groups of muda: activities that don't add value to the product but are needed in order to produce/deliver it to the customer and activities that don't add value to the product and aren't needed and they include the above-mentioned losses, so the application of the lean philosophy strives to reduce and eliminate them.

Muri is a Japanese word that means overload, excessive production. Muri can arise from mura, but in some cases, it can be caused by excessive removal from the process (muda). Overloading also occurs when machines or operators are used beyond capacity to complete all scheduled work tasks. Muri over a period of time can lead to employee absenteeism, illness, and machine breakdowns. What also leads to such problems are the changing customer requirements, for example in the case that the customer increases the size of his order disruptions occur. Given that lean methodology doesn't support stock availability, it is necessary to have a reliable supplier of raw materials for production, which will be able to increase the distribution of materials until production. Standardizing work can help avoid bottlenecks by designing work processes that will spread the workload evenly and won't overload any employee or equipment (Ostojic et al., 2010).

Mura is a Japanese word that means deviation or irregularity. Deviation refers to activities that are not predicted in the main production plan. An example of a deviation can be a change in the customer's requirements or an uneven production process (when the capacity of one means of work is greater than another, there is a build-up or waiting), which can lead to the impossibility of fulfilling the customer's requirements. Within the production process, mura can be eliminated with good production uniformity (heijunka). Tools that can contribute to the good implementation of heijunka within production are SMED and the 5S method (Sartor & Orzes, 2019; Bhamu & Singh, 2014; Singh et al., 2018; Singh et al., 2010; Gupta & Kumar, 2013).

VSM is a method that visually shows the flow of products, materials, and information within a process. This method provides an opportunity to look at the wider picture of the process that needs to be optimized (Rother & Shook, 1999). Through VSM the process is analysed from beginning to end. Each activity is shown on a drawing and that first draft is a map of the current state. It is important to create an optimization proposal for observed deficiencies or bottlenecks, which are displayed on the map of the future state. Opportunities for improvement are highlighted on the map, after which they are implemented to make the production/service process more productive and simpler. The key for value stream mapping is to see the whole picture as the sum of the individual parts and see how that step fits into the overall process and how changing it will affect the overall process. Hussain et al. study showed that it is very important to identify all value streams and their connections in order to gain useful insight for managers to improve the performance of the entire production process. This allows for a picture of how different types of changes or combinations of changes at multiple points in the process will affect the entire system (Hussain & Figueiredo, 2023).

A study by Vamsi et al. clearly shows that VSM brings a positive impact on the lead time, process inventory level, line speed, total process time, and reduced manpower. It helps the company to satisfy its customers in terms of quality, price, and delivery (Vamsi & Sharma, 2014).

Devi et al. evaluated current state mapping and implement future state mapping in a wet grinder manufacturing system. Current state mapping was developed by observation of cycle time, change over time, and non-value-added activities. So, a very important element of value stream mapping is the times to be measured/calculated (Devi et al., 2018):

Changeover time - is the time it takes to set up a machine or production line so that it can switch from working on one product to another. By shortening this time, benefits can be realized in the form of shorter production of more products or saving money. In order to accurately measure the time required for a change, it is necessary to start measuring the time as soon as the production of one product is finished and stop the measurement when the production of the next product begins.

Lead time - is the time between the start of the process to its completion. Reducing lead times can streamline operations and improve productivity, increasing performance and revenue. Conversely, longer lead times negatively impact sales and production processes. In manufacturing, lead time is often the time it takes to create a product and deliver it to the consumer. Factors that can affect delivery times include shortage of raw materials, breakdown of the means of transport, shortage of labor, natural disasters, and human mistakes (Ostojic et al., 2011).
Cycle time - a term that occurs in lean manufacturing and represents the amount of time it takes to complete a specific task from start to finish. In supply chain management, this time refers to how long it takes to fulfill an order for a particular product. Some of the key advantages of determining cycle time are increased profitability, more consistent production, satisfied customers, the ability to outperform the competition, better understanding of business spending.
Takt time - the time for which the customer requires a certain quantity of the product to be produced for him. Takt time has to be greater than cycle time, in order to meet customer requirements in time.
By monitoring these parameters, a clear picture of the process flow is obtained and after creating the desired state, a goal that needs to be reached is set, and whose achievement can be accurately monitored by monitoring the specified parameters. The recommendation for value stream mapping is the creation of maps on paper, without the use of software, so with teamwork, everyone becomes familiar with the method, but also with the complete process being mapped.
This research introduced how to improve a car seat assembly line using value stream mapping analysis, Kanban pulls production management, and process flow analysis. In this regard, the results that can be achieved with the VSM method are:

- Lead time reduction;
- Productivity and income increasing;
- Less work related injuries;
- Quality improvement.

3. METHODS

Steps that were carried out during the VSM workshop are:

- Forming a team for the workshop;
- Choosing the material to be followed;
- Checking the stock material in the warehouse;
- Monitoring of the material flow through the entire production process;
- Summarizing the collected data and sketching the current situation;
- Data analysis and improvement suggestions.

Before organizing the VSM workshop, it was necessary to assemble a relevant team that will analyze the current state of the process and make proposals for its improvement. After the team was formed, a gathering of members was organized as part of the first day of the workshop. Then, it was necessary to choose which material would be monitored and for which would be done the process mapping and subsequent process optimization. The decision was made based on the criteria of the size of the project, its impact on the entire range of production, frequency, and quantity of manufactured goods. Another criterion for the selection of monitored material was the number of operations through which the material goes, so the material that goes through the largest number of operations and is part of the largest number of products was chosen. The team went through the warehouse and the production plant in order to gather information and gain insight into the entire process, after which they created a value stream map and analyze the current state. The mapping process included activities from the exit of the material from the warehouse to the production, its entire movement through all operations in the production process, to the shipment and storage of finished goods in the warehouse. In order to gain insight into the entire production process, it was necessary to physically go through each operation and measure its duration in order to determine if there were any bottlenecks and intermediate stocks. Based on the collected data, sketching VSM of the current state (figure 1) was done and lead time and value-added activities were calculated.
The figure 2 shows a summary of the number of operations according to the following classification: a circle indicates add value activities, a square is check activity, a horizontal arrow is any movement within a process, a circle in a square is non value added activity, an inverted letter e is kanban location and a

triangle is symbol for stock. Next to each type of operation are indicated the time it takes, the amount of material, and the distance between locations/workplaces.

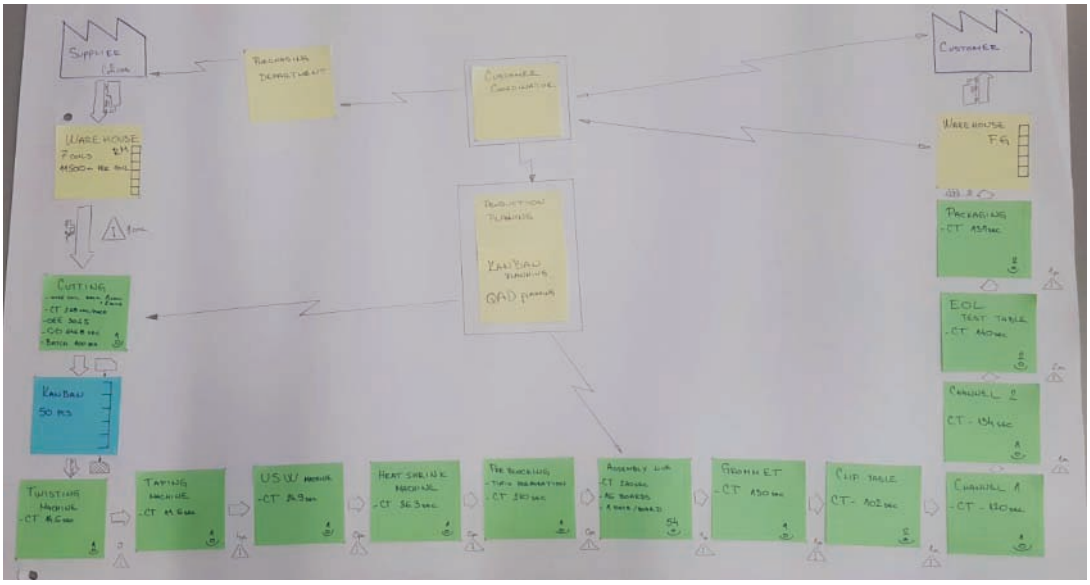

Figure 1: VSM of current state of the process flow

Based on the stock material, it was possible to produce 28,025 finished goods (for one part is necessary to spend 4.66 meter of wire). Considering that on average daily basis 1200 finished products are sent to the customer, this means that the stock coverage is almost 24 working days. Work in regular conditions takes place in two shifts, five days a week, which means that the time capacity for production on a daily basis is 54,000 seconds. Value added activities are 0.09% of the total time necessary for production.

Value Stream Mapping Process Summary					
Symbols/Elements	# of Steps	Time (Seconds)	Distance (Feet)	Inventory (Pcs.)	% Value Added
Operation	12	1126,98			
Necessary Non-Value Added	1	3600			
Inspeciton	1	140			
Transportation	6	0	470		
Inventory	16			27975	
Supermarket	2			50	
Buffer	0			0	
Total	38	4866,98 Seconds	470 Feet	28025 Pieces	0,089
Parts (Pieces) Shipped Per Day	1200				
	Hours	Minutes	Seconds		
Operating Time (Less Breaks & Lunch)	15	900	54000		
Dock To Dock =	Total Inventory (E-35) / Parts Shipped Per Day (B-38)	=	28025 / 1200	= 23,35	Days
				350,31	Hours
% Value Added =	Operation Time (C-5) / Total Time	=	1126,98 / 1265992	x 100 =	0,089

Figure 2: Summary of the process flow

4. RESULTS AND DISCUSSION

Based on the obtained data, it was observed that the cycle time needs to be reduced, in order to ensure that the required needs of the customer will be satisfied in the time in which he expects it. The takt time calculation is shown in the figure 3.

Takt/cycle time calculation	
Required quantities on weekly level from customer	1,200
Required quantities on daily level from customer	240
Number of working days in a week	5
Number of shifts in a week	10
Number of hours in a shift	8
Break time	0.5
Number of hours per shift reduced for breaks	7.5
Number of working hours in a day	15
Number of working minutes per day	900
Number of working seconds per day	54,000
Takt time	225
Planned cycle time	198

Figure 3: Takt/cycle time calculation

The takt time is the number of working seconds per day divided by the required quantities on a daily level from a customer. The planned cycle time is obtained when the coefficient for occurring losses, which is 12%, is applied to the takt time. This means that from the initial 225 seconds that are planned for the

production of one piece, it is necessary to produce it in 198 seconds when factors that lead to certain losses in time are taken into account, in order to satisfy the requirements set by the customer. During the VSM audit, the cycle time was 210 seconds per piece.

Figure 4 shows a graphical representation of the duration of all operations in the production process, where the horizontal lines indicate the current cycle time and the takt time to be achieved. Workplaces that are overloaded are marked with red circles, and workplaces that are not fully loaded are marked with green circles. Using production tracking software and based on the data that the software pulls through the implemented information system in production a graphic representation of the current state of all operations was formed, where the light green line represents the average duration of individual operations.

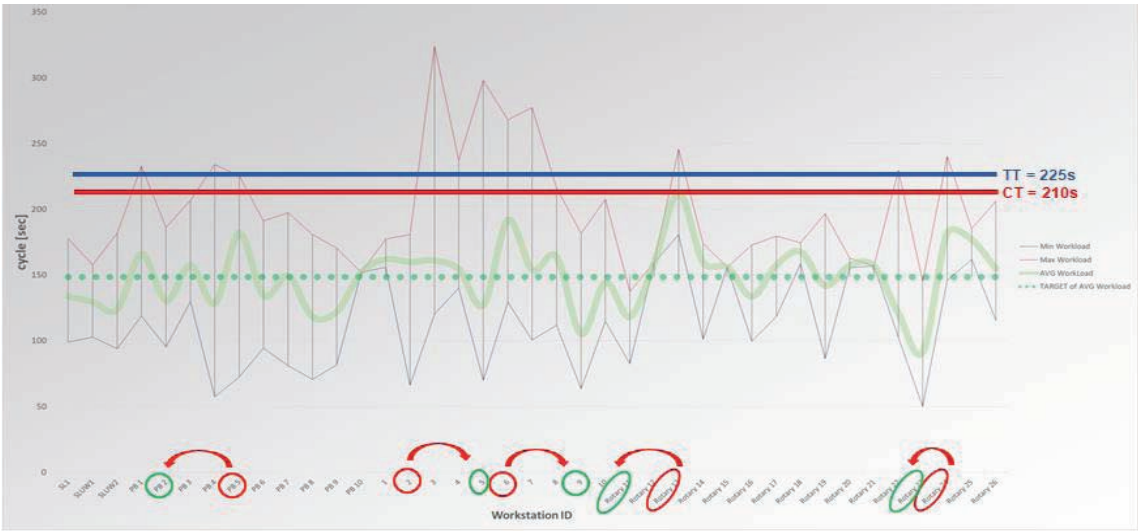

Figure 4: Summary balancing chart – current state

On the previous graph, deviations were observed regarding the workload of the workplaces, so it was necessary to transfer the workloads from certain workplaces to those that weren't too loaded, in order to balance the process. A team of process engineers was tasked with deciding which conductors would be transferred from one to processing at another workplace. Based on the five changes that occurred in the average duration of operations, a new graphic representation (figure 5) was obtained where it can be clearly seen that workplaces are much more closely loaded than was the case, and no large peaks or deviations can be observed. In this way, the planned cycle time of 198 seconds was achieved.

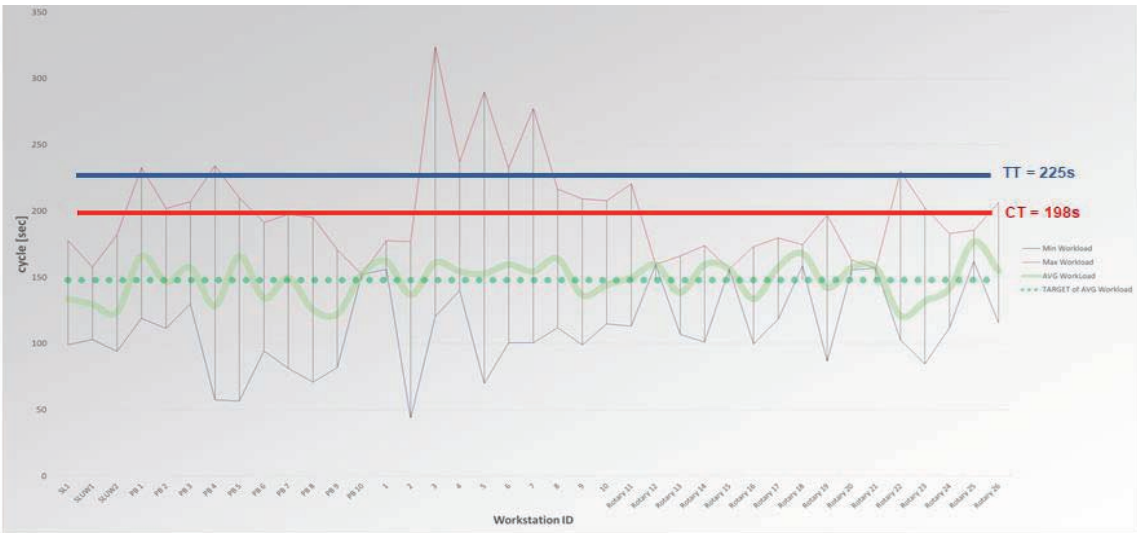

Figure 5: Summary balancing chart – after

For a better understanding of changes that occurred after the balancing, two graphs are shown below, where the first one (Figure 6) represents the display of the average duration of each operation before balancing and the second (Figure 7) represents the duration of operations after balancing, where it is easy to see there are no large deviations between the duration of operations, as well as where the cycle time has been lowered from 210 to 198 seconds. After the changes in the operation duration, the change that occurred in the VSM drawing is the data related to the cycle time on the rotary line for the assembly of conductors, which is now 198 seconds.

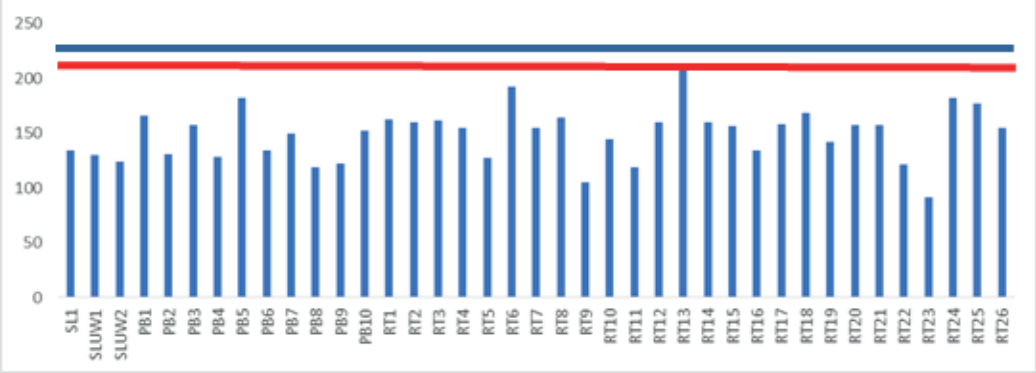

Figure 6: Average time of operations – before balancing

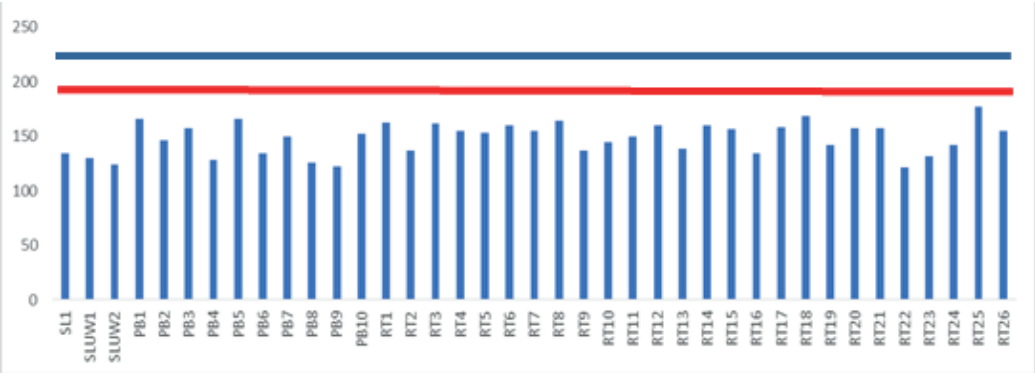

Figure 7: Average time of operations – after balancing

In the end, the lead time and value-added activities were calculated again and were made the comparison with the calculation that was performed at the beginning of the VSM workshop. Figure 8 shows a summary overview of operations, duration, inventory, and distance. Based on the current inventory, 13,209 finished goods can be produced, and considering that on a daily level 1,200 finished goods are delivered to the customer, the stock coverage is equal to 11 working days. The time capacity on a daily basis stayed unchanged and is 54,000 seconds. Value-added activities are now 0.19% of the total production time which led to the reduction of lead time by 52% (from 23 to 11 days).

Value Stream Mapping Process Summary					
Symbols/Elements	# of Steps	Time (Seconds)	Distance (Feet)	Inventory (Pcs.)	% Value Added
Operation	12	1101,45			
Necessary Non-Value Added	1	3600			
Inspeciton	1	140			
Transportation	6	0	470		
Inventory	16			13159	
Supermarket	2			50	
Buffer	0			0	
Total	38	4841,45 Seconds	470 Feet	13209 Pieces	0,184
Parts (Pieces) Shipped Per Day	1200				
	Hours	Minutes	Seconds		
Operating Time (Less Breaks & Lunch)	15	900	54000		
Dock To Dock =	Total Inventory (E-35) / Parts Shipped Per Day (B-38)	=	13209 / 1200	= 11,01	Days
				165,11	Hours
% Value Added =	Operation Time (C-5) / Total Time	=	1101,45 / 599246	x 100	= 0,184

Figure 8: Summary of the process flow after balancing

5. CONCLUSIONS

Lean way of thinking has become one of the main advantages today, and it is important to know and properly apply the methods it offers. The lean way of thinking in Serbia is still at a low level, but there is certainly an increasing interest and recognition of its benefits in the last few years, and the assumption is that this trend will only record growth in the future.

VSM method can be used to fulfill the set customer requirements in terms of the time he requires for product delivery, and also can be the initiator of various changes in the production process. The factory had problems with the time it takes to produce and deliver the goods, so had additional costs because it had to hire special deliveries in order to get the goods to the customer as soon as possible. By calculating the real cycle time, and balancing the load at the workstations on the assembly line, it was easier to fulfill the expected timing defined by the customer. The company didn't have extraordinary costs anymore, because of special transport and also there was no longer a need for working Saturdays and the costs for overtime wages were also reduced, which had a positive impact on the company's profit. Also, in addition to reduced cycle time, the lead time was reduced, the value-added activities have increased, and most importantly the goods have been delivered at the time they requested, which has resulted in increased customer satisfaction.

This method is also useful when a customer has a query, for example, he wants to introduce some changes to the existing portfolio, how much time does the supplier need to start manufacturing and delivering the changed products that the customer requested?

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APPLICATION OF ROBUST DESIGN PRINCIPLES ON THE EXAMPLE OF TOLERANCE ALLOCATION FOR A SPOOL TYPE PRESSURE RELIEF VALVE

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Abstract: *The functional properties of a mechanical product are usually defined by the geometrical specifications of its inherent subcomponents. Therefore, any deviation from the design's nominal assigned values, can potentially lead to loss of functionality and failure to meet quality criteria. In order to ensure product functionality such deviations have to be limited by the assignment and allocation of tolerances. The conventional product development process described in VDI 2221, however does not sufficiently emphasize the importance of tolerance design principles in the early stages of product development. This shortcoming has been met by integrating Taguchi's robust design methodology alongside the VDI guidelines, thus introducing the tasks of tolerance design and process planning to the product development engineer. In this contribution a use case for the application of such wholistic tolerancing approaches is being proposed. A spool type pressure relief valve thereby serves as a function assembly for studying the relationship of the valve's geometrical properties and its resulting functional performance. Functional testing, geometrical inspection and mathematical modelling of the transfer function, are the methodologies used for allocating appropriate tolerance values to the parts.*

Key words: robust design, tolerance design, pressure relief valve, functional tolerancing

1. INTRODUCTION

Products are primarily developed to fulfill specific functional requirements. Consequently, functional requirements become the central criteria for assessing product quality in the development process. (Bohn & Hetsch, 2020). In the case of mechanical products, functionality commonly arises from the geometry of the subcomponents. Hence the product designer assigns nominal values to the geometry to ensure the parts performance. Since all manufacturing and inspection processes are subject to imperfections, deviations from these specified nominal values have to be expected (Wang et al., 2019). In order to limit these deviations tolerance values are allocated in accordance with current standards such as ISO GPS. Tolerance allocation is in every way a highly responsible task that greatly affects the quality of the product as well as the cost of manufacturing. It is thereby suggested that manufacturing and design divisions should take part in the tolerance design process together to better balance the competing aspects of quality and cost (Hallmann et al., 2020). However according to the traditional product development methodology described in VDI 2221, manufacturing aspects are not taken into account before the detail design phase begins in which the final geometries are being specified (Bender & Gericke, 2021). Hence the VDI 2221 guideline for product development does not sufficiently emphasize the necessity for a parallel development of both the product- and the manufacturing process (Bohn & Hetsch, 2020). To address this shortcoming a complementary methodology emphasizing robust product design was formulated by Taguchi. This three-stage approach comprising concept design, parameter design and tolerance design is suggested to be employed alongside the conventional product development process as it aims for design concepts that are inherently insensitive to variations. To be distinguished from Taguchi's tolerance design stage, the tolerance design methodology is not concerned with robustness, but with control of the product's performance. It encompasses the tasks of tolerance specification, tolerance allocation and tolerance analysis (Goetz et al., 2021). The integration of both robust design and tolerance design methodologies into the traditional product development process has been demonstrated by Goetz. His findings suggest that the introduction of tolerancing methodologies in early stages of product design would also require a competency transfer from the tolerance experts towards the product designers, thus enabling them to develop robust products (Goetz et al., 2020).
Based on the literature review, this contribution recognizes the necessity for bringing competencies from the domains of tolerancing and manufacturing closer to the product development engineer. Building upon an earlier work aimed at teaching GD&T-principles, a use case for training in robust design

methodologies on the example of a hydraulic pressure relief valve is proposed (Scharf et al. 2023). Hydraulic valves offer an optimal scenario for conducting tolerance analysis, given that their functional attributes are primarily dictated by the geometrical properties of the valve's subcomponents. Moreover, the simple mechanical structure of a pressure relief valve renders the mathematical modelling of its transfer function relatively straightforward. Experimental data is acquired through both geometric measurements and functional testing to validate the accuracy of the produced mathematical model. In a conclusive effort, the model is employed to perform tolerance analysis, aiming to allocate appropriate tolerance values while adhering to the principles of robust design.

2. METHODS

Pressure relief valves (PRV) are predominantly employed as safety valves that activate during emergencies, ensuring hydraulic system pressure remains below a critical threshold. Two basic designs of PRVs have to be distinguished: Seat valves and linear spool valves. Despite the disadvantage of having a permanent leakage due to the annular gap between spool and housing, the latter design is more commonly used for control applications (Murrenhoff, 2014). The proposed PRV is based on a linear spool design consisting of four parts shown in Figure 1 (l). With increase in pressure on the high-pressure (HP) port the force on the spool surface rises, counteracting the preload force of the spring. Once the pressure reaches a level where the preload force is overcome, displacement of the spool occurs resulting in further compression of the spring. As pressure continues to rise, the spool eventually reaches a point where its control windows overlap with the housing's control edge. This action surpasses the set opening pressure, enabling the release of over-pressurized fluid to the low-pressure (LP) port.

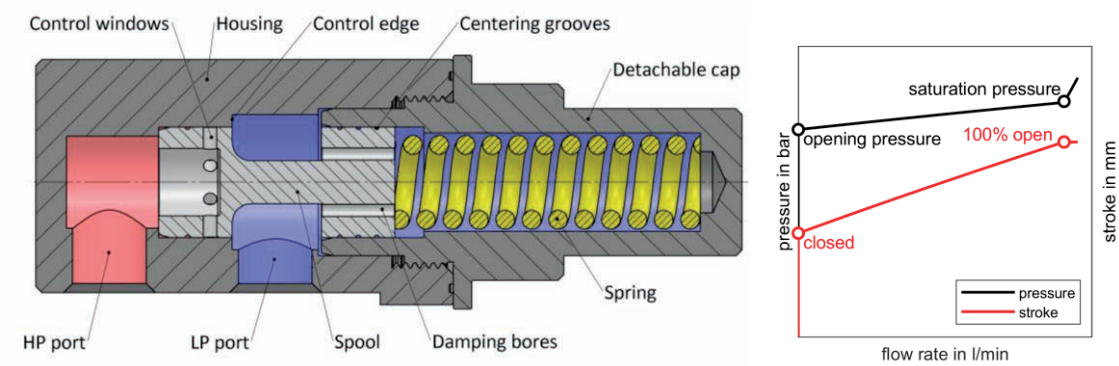

Figure 1: Pressure relief valve in spool design (l), characteristic curve for ideal PRV (r)

The flow passing through the control window is described in equation (1) as the flow through an orifice. Here A_{sp} represents the collective area of the control windows and ρ the density of the pressure fluid. For spool valves the flow coefficient α typically resides between 0.6 and 0.8 (Murrenhoff, 2014). In an ideal PRV, flow only occurs when the control windows of the spool overlap with the control edge, as indicated in the stroke and flow characteristic curves in Figure 1 (r). In reality flow already takes place before the opening pressure is reached due to presence of leakage flow in the annular gap between the housing and the spool. As seen in equation (2) the leakage flow Q_{li} is significantly influenced by variations in radial clearance r_c, owing to its cubic relationship. Unlike the flow through an orifice, the flow through a gap is also dependent on the fluid's kinematic viscosity ν making it sensitive to shifts in temperature.

$$Q_{cw} = \alpha\, A_{sp} \sqrt{\frac{2\,\Delta p}{\rho}} \tag{1}$$

$$Q_{li} = \frac{d_{sp}\,\pi\, {r_c}^3 \Delta p}{12\,\rho\, \upsilon\, l_c} \tag{2}$$

Based on equations (1) and (2) a parametric model was created in MATLAB and tested against a second model produced in the multi-physical simulation software AMESIM. Both models can produce characteristic curves and allow for the variation of design parameters to conduct design and tolerance

analysis. Furthermore a set of spools with variations in spool diameter have been tested on the hydraulic test bench and their dimensions obtained on a coordinate measurement machine, thus providing experimental data for the validation of the two models.

3. RESULTS

To confirm the validity of the two generated models, characteristic curves were obtained on the hydraulic test bench and then compared with simulation results from both models using the respective spool geometries. One spool was produced to achieve a minimal radial clearance of 20 µm, while the other was deliberately designed for a significantly larger radial clearance of 97 µm. As depicted by the characteristic curves in Figure 2, both the MATLAB and AMESIM models exhibit strong correlation and align with the curves obtained from the hydraulic test bench. A minor hysteresis can be seen between the upstream and downstream curves of the measured data, indicating frictional forces among the moving components that the mathematical models did not account for.

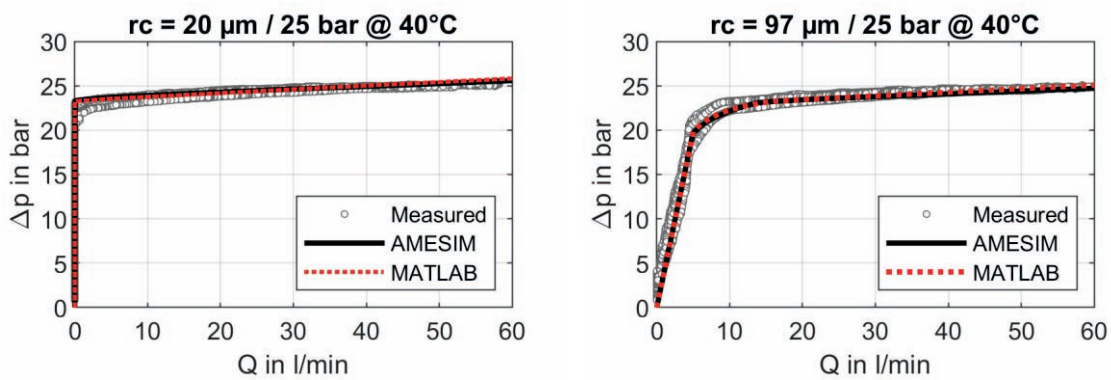

Figure 2: Obtained characteristic curves for radial clearance r_c 20 µm (l) and 97 µm (r)

4. DISCUSSION

Since the proposed PRV design was primarily intended for educational use, the maximum operational pressure during testing was limited to 50 bar. However, in industrial employments PRVs are typically operated at pressure rates exceeding 300 bar, leading to considerably higher leakage flow. Moreover functional tests were conducted at relatively consistent temperatures of 40°C, while maximum operating temperatures of industrial PRVs can reach up to 80°C, again resulting in an increase of leakage flow due to reduced viscosity. Consequently, tolerancing considerations regarding the control of leakage flow must be done under high-temperature and high-pressure conditions.

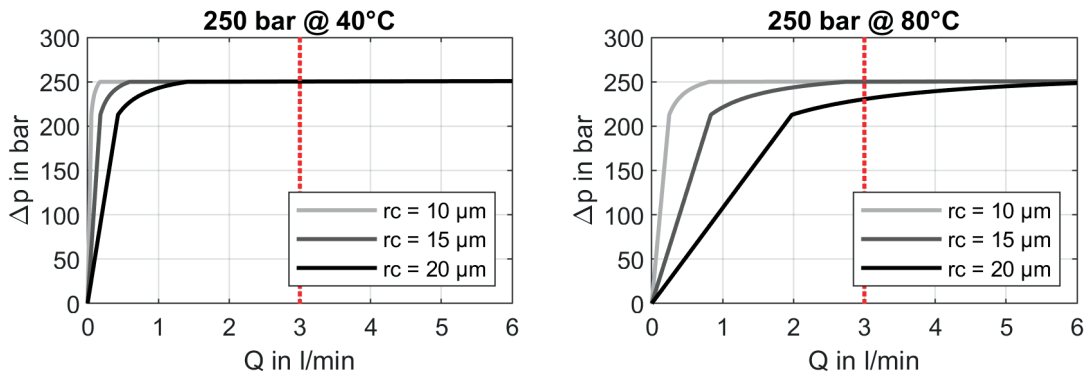

Figure 3: Leakage flow at increased pressure and temperature dependent viscosity @40°C (l) and @ 80°C (r)

Figure 3 shows two sets of characteristic curves at such heightened operating conditions. Here an opening pressure was set to 250 bar which in comparison to the curves in Figure 2 results in notably higher leakage flows. The right set of curves shows the same characteristic curves, but under an

operating temperature of 80°C which amounts to a kinematic viscosity of 10 mm²/s compared to 46 mm²/s at 40°C for the pressure fluid HLP46. Given that a PRV functions as a safety valve, engaging only during critical pressure overloads, a permanent leakage flow of substantial amount is undesirable. Such a flow would cause persistent losses, leading to poor energy efficiency of the hydraulic system. Consequently, a tolerable leakage flow can be established by lowering the radial clearance resulting in an appropriate tolerance allocation. Assuming that a leakage flow of 5 % of the nominal flow of 60 l/min would be tolerable, a radial clearance of around 10 – 15 µm could ensure the valves proper functionality under all operation conditions. A more tangible representation of this tolerance specification can be provided using the ISO fit H6/g5, which permits a clearance between the housing and spool ranging from 3 to 12.5 µm. Since fundamental tolerances of IT5 and IT6 are required for this fit, the manufacturing of both the spool and housing bore would typically require the use of grinding or honing machinery.

5. CONCLUSIONS

For the purpose of applying robust design principles within the scope of academic teaching a relatively simple function assembly in the form of a spool type pressure relief valve was proposed. While geometrical measurements and functional tests were conducted on a physical prototype of the PRV, two separate mathematical models were produced in order to study the relationship between geometrical properties and its functional characteristics. Main focus of these studies was on the leakage flow, typical for spool type valves, and how it could be controlled by the assignment of tolerances. By conducting variant analysis and tolerance analysis, appropriate tolerance values for the radial clearance could be allocated and evaluated with considerations from manufacturing aspects. Hence a wholistic approach for teaching robust design principles could be established by integrating elements from product development, tolerance design, inspection and manufacturing.

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MG-ZN-Y BIOCOMPATIBLE ALLOYS PRODUCED IN A LEVITATION FURNACE

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Abstract: *The Mg-Zn alloys have a controlled biodegradability in biological fluids. Alloys in the Mg-Zn system must be manufactured from high-purity raw materials, and the production process must be free of impurities from the crucibles. The mechanical properties of Mg-Zn alloys can reach values of tensile strength of 270 MPa and elongation at break of over 18%. The use of these alloys for bio-resorbable implantable devices does not allow the existence of a high level of impurities. For this reason, in the work has been used an installation for melting raw materials by levitation, which allows the metal alloy to be kept in an inert gas environment inside an induction coil, avoiding its contact with any other material. The induction currents generated in the levitational floating melt determine the mixing of the chemical elements and the homogenization of the alloy. In this paper, seven experimental Mg-Zn-Y alloys with different chemical compositions were produced and tested. To reduce the oxidation effect and to finish the grain, Y was added in the solid solution, as proportion from 0.5 to 5 wt. Microhardness tests and SEM microstructural analyzes were performed to evaluate the strengthening effects and the level of homogenization of the obtained solid solutions.*

Key words: Mg-Zn-Y alloys, biocompatible, levitation furnace, microhardness, microstructure

1. INTRODUCTION

The most important application that requires biodegradability is the use of temporary implants capable of supporting and repairing problem areas (fractures, facial or maxillofacial reconstruction, artificial grafts, etc.) for a limited period [1 - 3]. Using resorbable implants avoids surgical procedures to remove the implant, as it slowly dissolves in living tissues. The effect of progressive biodegradability is achievable with magnesium alloys. To obtain acceptable values for the mechanical, chemical or biocompatibility properties of implantable materials, high-purity magnesium-based alloys must be manufactured, to which biocompatible elements can be added, in different concentrations, with applications for restoring bone tissues or for the cardiovascular system.

It is a permanent concern of researchers to obtain a new class of Mg-based metal alloys with applications in the field of biocompatible materials, because they have properties of slow dissolution in biological fluids or living tissues. The mechanical tensile strength of magnesium is higher than that of biocompatible ceramic materials (hydroxyapatite), and the values modulus of elasticity and yield strength are closest to those of human bone. The longitudinal modulus of elasticity is about 50% of that of titanium alloys, which allows great flexibility, especially in the case of use for stents and orthopedic implants, only for small joints.

Magnesium is a macro-element with a benign action in the body, clinical studies proving that it has good resorbability and high biocompatibility in the case of implants used for bone fractures. At the same time, the density of Mg-base alloys is reduced, and Young's modulus of magnesium is close to that of bones (E = 10-30 GPa). Finally, magnesium alloys have controllable corrosion rates, which is why they can be considered resorbable in physiological environments. As a result, magnesium alloys have been considered acceptable candidates both for use in cardiovascular surgery and for the repair of bone problems [6, 7].

For biomedical applications, the composition of the material is considered a crucial factor, since many of the elements that make up the materials available for industrial applications are highly toxic to the human body. To improve the properties of magnesium, different alloying elements are used, especially those from the rare earth group. Magnesium alloys which are used as bio-resorbable alloys are part of

the following metallurgical systems: Mg - Ca (Ca = 1-3%); Mg - Zn (Zn ≤ 5%); Mg - Y; Mg - Ce; Mg - Zr; Mg - Zr (0.5-1%) - Ca (1-2%); Mg - Si (0.6% O) - Ca (0.2-0.4%) etc. Among them, Y has a high solubility in Mg solid solution and is often introduced together with other rare earths to improve creep and corrosion resistance. Moreover, most REEs form intermetallic phases with Mg and Al, having a pronounced effect on corrosion resistance [9 - 11].

Based on research in the field of metal biomaterials and orthopedic implants, biodegradable magnesium alloys were the best solution for making implants used in small extremity surgery, such as ankle, tibia, hand, or fist fractures.

From a metallurgical point of view, the synthesis of Mg-based alloys is an extremely difficult process due to the strong oxidation phenomenon that occurs in the atmosphere, which continues with the almost complete combustion of the pure metal or its alloys. Therefore, the processes of obtaining magnesium alloys must be carried out in controlled environments, using special equipment specially designed for this purpose (i.e., vacuum and/or inert atmosphere). Therefore, the paper presents the results obtained using a proprietary facility, for melting by levitation of the metallic material, which allows the protection of the melt with inert gas and a minimal contact of the liquid metal with the crucible.

2. THE OBTAINING OF METALLIC MATERIAL FROM THE Mg-Zn-Y SYSTEM

The Mg-Zn-Y biodegradable alloys were obtained using levitation melting equipment equipped with a medium frequency converter under inert atmosphere, from ERAMET laboratory – University Politehnica of Bucharest (Figure 1) [4].

Figure 1. Melting equipment in inert atmosphere by levitation equipped with medium frequency converter.

In the experiment, the following raw materials were used:

- Mg with purity of 99.5%, as grains with diameter of 2-5 mm, product code HP.Mg.2N5.100000.
- Zn with purity of 98.5%, as grains with diameter of 2-6 mm.
- Y with purity of 99%, as grains with diameter of 2-5 mm.

To obtain alloy recipes, technological calculations were carried out for a batch weight of 15 g, corresponding to the volume of the casting mold, considering the evaporation and oxidation losses specific to each element of approximately 10% wt. The chemical compositions of the metal alloys designed for the obtaining process are presented in Table 1.

Table 1: Experimental Mg-Zn-Y alloys

P1	P2	P3	P4	P5	P6	P7
Mg0.5Zn0.5Y	Mg1Zn1Y	Mg1.5Zn1.5Y	Mg2Zn2Y	Mg3Zn3Y	MgZn4Y	Mg5Zn5Y

To compact the granular mixtures and reduce the oxidation effects, the alloy mixtures were cold pressed in the mold, using a 20 ft hydraulic press, resulting in compacted products with a diameter of 15 mm and a height of 10 mm (Figure 2) [5].

Figure 2. Compacted buttons made from metal powders.

The buttons obtained by cold pressing were subjected to induction melting under an inert atmosphere (5.3 quality Argon), at a pressure of 2.4 atm. The metallurgical melting process of a batch lasted between 2 and 3 minutes, depending on the working parameter values adopted: medium frequency voltage U_{mf} = 480 - 500 V; medium frequency current I_{mf} = 55 - 65 A; working frequency f_{mf} = 60 - 70 kHz; power P_{mf} = 20 - 35 kW. The molten alloy was cast freely, also in argon atmosphere, into copper molds protected inside with refractory paint, to avoid the adhesion of the liquid metal (Figure 3).

Figure 3. Image during the levitation melting process of the Mg-Zn-Y alloy button inside the inductor coil.

After solidification, the end zones of the mini-ingots were removed and the cylindrical surfaces were mechanically machined by turning, to remove the zones of contact with the casting mould (Figure 4). Disc shape samples of 1.2 mm in thickness and 11 mm in diameter were taken from each alloy type for cell proliferation tests and metallographic analysis (Figure 4).

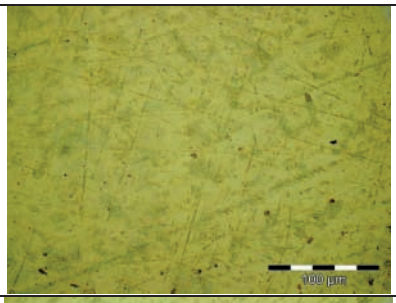
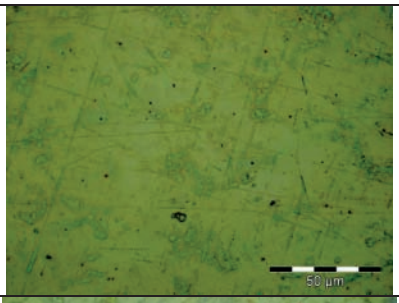
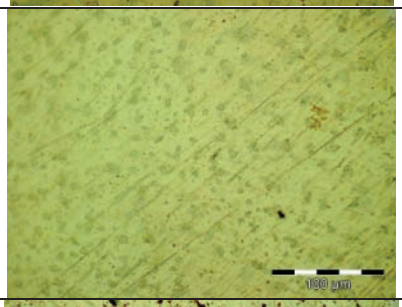
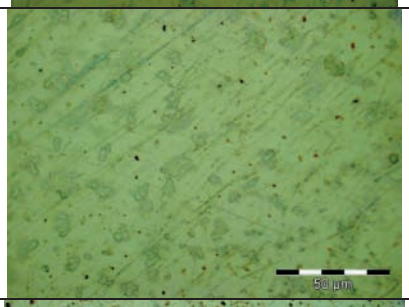
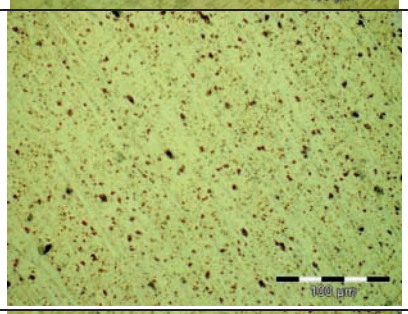
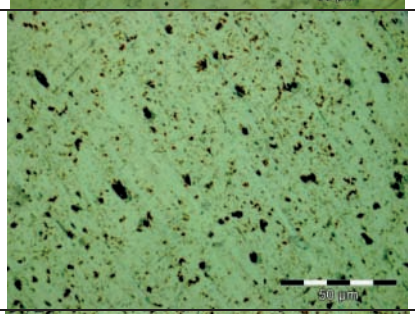
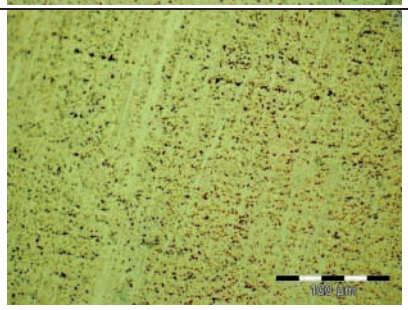
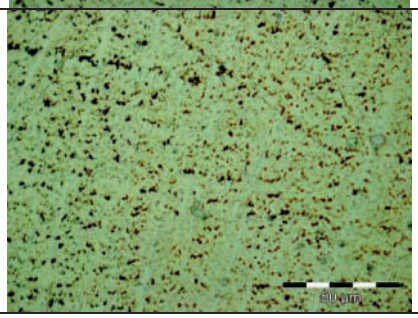
Figure 4. Mini-ingots casts and prepared for examination.

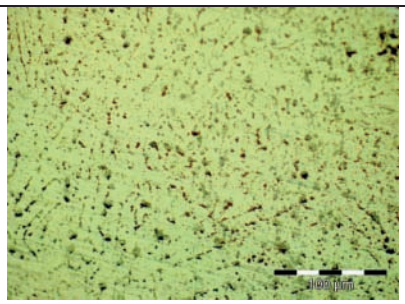
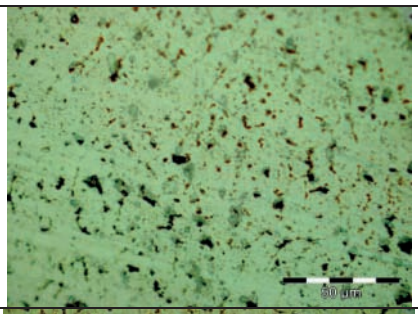
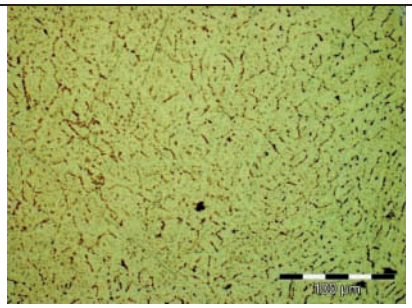
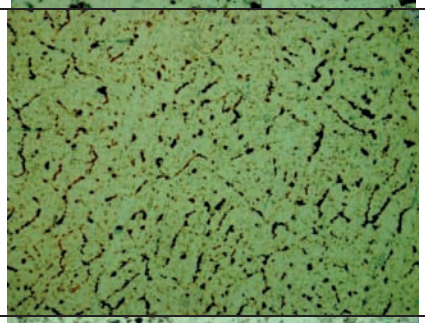
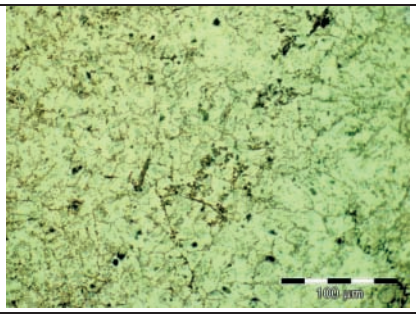
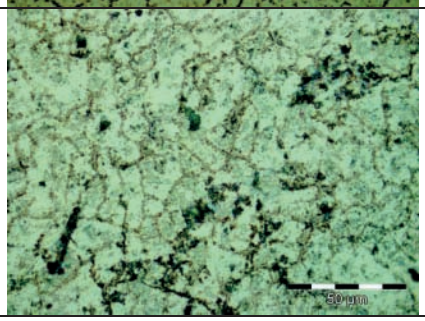
3. RESULTS AND DISCUSSION

3.1. Microstructural analyses of the alloys from the Mg-Zn-Y system

The microstructural analyzes were performed on the disc-type samples with a thickness of about 3 mm, taken with the IsoMet 4000 precision cutting machine from the LAMET laboratory. The samples were polished with metallographic abrasive papers in the sequence: Grit 500, 600, 800 then they were polished with abrasive powders (MicroPolish BH1103) with a grain size of 0.3 microns and MetaDi fluid polishing liquid impregnated on a textile support. The analysis of the polished surfaces was performed with the Olympus GX 51 microscope equipped with Analysis image processing software. The microstructural images of the samples are presented in Table 2.

Table 2: Microstructural analyses of the alloys from the Mg-Zn-Y system

Sample	Microstructure, x500	Microstructure, x1000
Mg0.5Zn0.5Y		
Mg1Zn1Y		
Mg1.5Zn1.5Y		
Mg2Zn2Y		

Mg3Zn3Y		
Mg4Zn4Y		
Mg5Zn5Y		

All the samples analyzed show a dendritic microstructure, with small precipitates of compounds (Mg7Zn3, Mg24Y5) having different morphologies, depending on the concentrations of Zn and Y alloying elements. From the binary diagrams Mg-Zn and Mg-Y for concentrations below 10%Y in the Mg-Y binary alloy, a compact hexagonal solid solution of the MgY type is formed, with separation of chemical compounds like Mg24Y5 type, and for the Mg-Zn binary alloy, a eutectic reaction occurs at the concentration of 29%Zn, with the formation of the Mg7Zn3 eutectic [8].

3.2. Microhardness analyses of the alloys from the experimental samples

To assess the degree of hardening of the advanced purity magnesium by adding biocompatible alloy elements such as Zn and Y, there were conducted microhardness tests on the surfaces of the samples, after grinding them with metallographic abrasive paper. The microhardness values were measured on the metallographically prepared surfaces, using the Shimadzu HMV 2T apparatus.
The measurement conditions were as follows: 25°C ambient temperature, 52% humidity, 0.1N pressing force, and 15 second indentation time. To highlight the mechanical homogeneity of the alloys, 5 measurements were made in different areas of the samples (edge and center), the values being presented in Table 3.

Table 3: Microhardness values for alloys in the Mg-Zn-Y system

Sample	Individual values, HV 0,1	Average value
Mg0.5Zn0.5Y	55.4; 57.4; 56,8; 58.4; 65.7	58,8
Mg1Zn1Y	62.1; 64.9; 67.4; 60.0; 65.3	63,9
Mg1.5Zn1.5Y	86.7; 80.7; 80.0; 87.9; 78.0	82,7
Mg2Zn2Y	76.7; 76.6; 82.0; 84.7; 85.5	83,5
Mg3Zn3Y	89.0; 98.2; 88.4; 81.8; 95,8	90.6
MgZn4Y	90.0; 90.4; 95.9; 88.7; 93.7	91,7
Mg5Zn5Y	94.0; 91.4; 94.9; 89.7; 96.7	93,3

4. CONCLUSIONS

The Mg-Zn-Y alloys can be successfully obtained in the levitation induction melting equipment under argon inert protection environment that allows the reduction of oxidation effects.
The purity of the alloys depends on the quality of the raw materials used and on the working conditions (inert gas protection for the melt, perfectly clean solidification molds, constant heating parameters, gas and smoke elimination during melting).
The homogeneity of the metal matrix of the Mg-Zn-Y alloys depends on the method of production. If granular materials of advanced purity are used, it is possible to better homogenize and distribute the alloying elements in the metal matrix, and the compression allows maintaining the shape of the sample during melting.
The combined analyses of the chemical composition, microhardness and metallographic examination reveal an increased compositional non-homogeneity of the Mg-Zn-Y alloys samples due to the very short melting time (about 2-3 minutes per batch) and the special conditions for obtaining in induction field and levitation effect. However, the materials obtained are mechanically and microstructurally stable.
The hardness of the Mg-Zn-Y alloy metal matrix increases with the Y content increase, the values ranging from 58.8 to 93.3 HV0.1.

5. ACKNOWLEDGEMENTS

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DEVELOPMENT OF AN IIOT-READY CONVEYOR SYSTEM

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Abstract: *In recent years, there is a growing trend of developing diverse Industrial Internet of Things (IIoT) devices and systems to support the advancements in industrial systems known as the Industry 4.0. New devices and systems are often developed with connectivity capabilities, however there are many already functioning devices and systems that are initially not able to connect to the network and become a part of the IIoT. This paper presents the development of an IIoT-ready conveyor system, where a traditional conveyor system is enhanced with an IoT module to adapt to the new industrial paradigm. Through the IoT module, the conveyor system can connect to the network and become part of the IIoT, thus allowing data acquisition, remote monitoring and control of the conveyor. The developed system consists of a conveyor belt, electric motor, variable frequency drive (VFD), programmable logic controller (PLC) and a dedicated IoT module that enhances the traditional PLC and enables the integration of the whole system into IIoT.*

Key words: Industrial Internet of Things, conveyor system, IoT module

1. INTRODUCTION

In the recent years, the industrial world has significantly changed through a digital transformation where an increasing number of devices are getting interconnected and becoming able to seamlessly communicate, share and analyze data, collaborate among themselves as well as with other services, processes and people. This transformation where traditional industrial systems are augmented with advanced digital technologies is also known as the fourth industrial revolution, or the Industry 4.0 (Al-Zubaidia et al. 2022, Bajic et al. 2020, Hauge et al. 2021, Hermann et al. 2016, Lasi et al. 2014, Salunkhea et al. 2022, Vaidya et al. 2018). One of the main aspects of the Industry 4.0 is networking, communication, exchanging data between devices, systems, services, which is known as the Industrial Internet of Things (IIoT). Through IIoT, smart devices and systems are embedded throughout the industrial ecosystem, generating real-time data insights that empower decision-makers to optimize operations, boost productivity, and unlock new levels of efficiency and innovation.

In order to achieve the IIoT paradigm, new devices and systems are often developed with inherent connectivity capabilities. However, many existing traditional devices and systems were not initially designed to connect to the network and be part of the IIoT. To enable the integration of these devices and systems into the IIoT, they need to be expanded with networking and communication capabilities, as well as other subsystems as required, such as sensing and data acquisition, identification and tracking, processing, data storage and analysis, etc.

One of the omnipresent systems in various industrial settings is the conveyor system, which plays a crucial role in carrying and transporting materials and products throughout the system. Among the different types of conveyor systems, the most commonly used variant is the conveyor belt. These belts typically consist of a rubber loop attached over two or more rotors, powered by electric motors. Traditionally they are controlled locally through a programmable logic controller (PLC). In today's era of IIoT, conveyor systems also need to be expanded with additional networking and communication capabilities, in order to enhance efficiency and productivity by enabling real-time monitoring, data collection, and analysis, predictive maintenance and streamlined operations. The addition of these capabilities facilitates seamless communication between conveyor systems and other components of the industrial system, enabling a more agile and responsive production environment. Such real-time monitoring and control capabilities offer insights to the state of the conveyor system at all times, and enable timely reactions in case of unwanted behavior or events.

This paper presents the development of an IIoT-ready conveyor system, where a traditional conveyor system is enhanced with an IoT module that allows the conveyor system to connect to the network and become part of the IIoT, thus allowing data acquisition, remote monitoring and control of the conveyor.

The developed system consists of a conveyor belt, electric motor, variable frequency drive (VFD), PLC and a dedicated IoT module that enhances the traditional PLC and enables the integration of the whole system into IIoT. The dedicated IoT module also enables upgrades to existing conveyor systems with low-cost investments and in short time since it uses widely available reliable components.

2. CONCEPTUAL SOLUTION

The simplest way of controlling the operation of the conveyor belt is by directly supplying voltage to the electric motor drive. This is typically achieved by using switches, buttons, and contactors, allowing easy on/off control and, with additional switches and contactors, changing the conveyor belt's rotation sense. However, this basic approach of controlling the conveyor belt lacks the ability to change the speed of the conveyor belt in a simple way. To enable control of both speed and direction of the conveyor belt, it is necessary to use additional control elements such as VFDs. VFDs allow users to easily adjust speed of the conveyor belt from 0 to 100% and change its rotation sense. The aforementioned ways of controlling conveyor belts allow only manual control. The disadvantage of manual control is that the operation of the conveyor belt is not automatically adjusted depending on the current state and needs of the industrial system. For automatically controlled conveyor belts, it is necessary to use additional control devices to coordinate the operation of the conveyor belt with other elements of the industrial system, such as changing the speed and direction of the belt movement depending on the current needs of the industrial system. One of the frequently used control elements in industrial systems are programmable logic controllers. PLCs are industrial computers that, using digital and analog inputs as well as communication interfaces for communication with other devices, collect data on the state of the industrial system. Based on the collected data, PLCs control the operation of industrial systems through their digital and analog outputs and communication interfaces. Consequently, PLCs can control the operation of conveyor belts to adapt their performance to the current needs and conditions of industrial plants.
The idea of this paper is to enable the implementation of the Industry 4.0 concept in a simple way on existing conveyor belts within industrial systems, thereby elevating their functionality to a more advanced level. The proposed conceptual solution is shown in Figure 1.

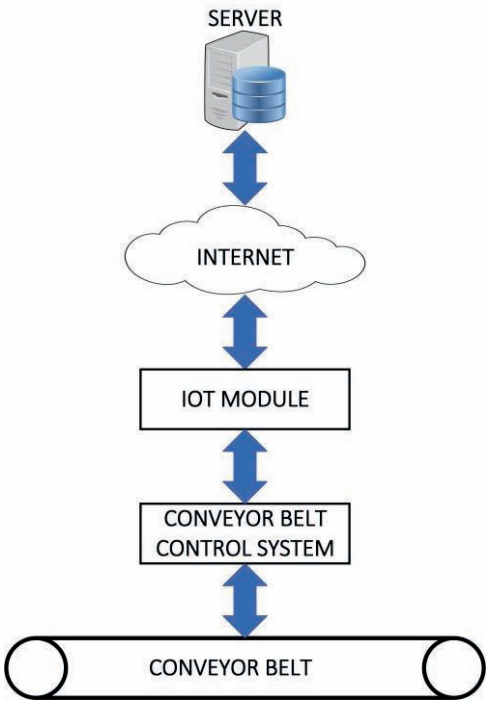

Figure 1: The conceptual solution

The conceptual solution is based on implementing of the Industry 4.0 concept using the IoT communication module on traditional conveyor belt transport systems. The IoT communication module is additionally implemented and connected to the existing conveyor belt control system and represents both the conveyor belt control system and the server application connection. The server application

collects data about the operation of the conveyor belt through the IoT module and based on data processing can send commands to control the operation of the conveyor belt. Additionally, the server application can be used to monitor the operation and assess the condition of the conveyor belt to plan the maintenance of conveyor belt elements in real time. This way, the proposed conceptual solution represents a straightforward and practical method for upgrading conventional conveyor systems, enabling them to seamlessly integrate into the Industry 4.0 paradigm, leading to improved efficiency, productivity, and overall performance.

The IoT module can be implemented in different scenarios, depending on the underlying type of conveyor belt control. If the simplest method for turning on and off the conveyor belt and changing its rotation sense using switches, buttons, and contactors is used for control, the digital outputs of the IoT module can be connected in parallel with control switches, buttons, and contactors. This way it is possible to control the conveyor belt manually from a remote location or automatically by sending commands from the server application. If the conveyor belt is controlled with a VFD, the IoT module can be connected to the VFD, which enables sending commands to the VFD. This way, the operation of the conveyor belt, changing the rotation sense of the conveyor belt as well as the speed of movement of the conveyor belt can be controlled from a remote location, manually or automatically based on the processing of collected data on the server application. If a combination of a PLC without and with a VFD is used for the operation of the conveyor belt, the IoT module can be connected to the PLC and in this way additional commands and parameters for the operation of the conveyor belt can be sent to the PLC from a remote location. In this case, the PLC remains the main control element for controlling the operation of the conveyor belt, and the IoT module only forwards additional information on how the operation of the conveyor belt should be controlled.

The proposed solution offers multiple advantages, whether implemented on existing conveyor systems or integrated into new transport systems. When applied to existing conveyor belts, it eliminates the need for major infrastructure changes, as it involves simply adding a communication module to enable new functionalities. This leads to significant cost savings and a streamlined upgrade process, since the IoT module uses low-cost widely available components, which have proven to be very reliable during operation. On the other hand, the implementation of the proposed solution on new transport systems requires only a minimal increase in initial financial investments, making it a cost-effective approach. In both cases, the conceptual solution empowers industrial plants to embrace Industry 4.0 principles without substantial disruptions or excessive financial burdens. By adopting this approach, companies can enhance their operations, improve efficiency, and unlock the full potential of their conveyor systems within the context of Industry 4.0.

3. IMPLEMENTED SOLUTION

A didactic model of a conveyor system was used to test the functionality of the proposed solution. The conveyor system consists of a 4m long conveyor belt driven by a motorized drum roller AX135 by Dyno Conveyors with a power of 250W and rotational speed of 25rpm. This is a three-phase asynchronous electric motor with a gearbox that comes in an IP66 packaging (Dyno Conveyors 2017). To control the operation of the conveyor belt, Mitsubishi didactic equipment is used, which includes a Mitsubishi PLC and a VFD. The motor is controlled by a VFD Mitsubishi D700-SC with 0.4 kW rated power at 200-240V, 2.5A rated current. The VFD parameters are given in Table 1. The rotational speed of the electric motor is set on the VFD by an analogue signal from the PLC, and the rotation sense by two digital signals (STF and STR signal at the VFD). The way of control of the rotational speed and sense is set in the P79 parameter.

The control PLC in the Mitsubishi didactic equipment is a small modular controller Mitsubishi X5UC-32MT/DSS-TS (MITSUBISHI ELECTRIC 2023) in combination with Analogue output module FX5-4DA-ADP and a 7“ HMI GT2107- WTSD which enables creating virtual command buttons and display of the current system settings. To add communication functionality with the server application, the IoT module presented in Tegeltija et al. 2023 was used, which was connected to the PLC via digital inputs and outputs. Figure 2 shows the used conveyor belt with connected Mitsubishi didactic equipment and the IoT module.

Table 1: VFD parameters

Parameter	Description	Value
P 1	Max. operation frequency	50 [Hz]
P 2	Min. operation frequency	0 [Hz]
P 7	Acceleration time	5 [s]
P 8	Deceleration time	5 [s]
P 9	VFD Over current	1.5 A
P 72	PWM frequency selection	4 [kHz]
P 79	VFD external control	3
P 80	Motor power	0.25 [kW]
P 82	Motor excitation current	1.17 A
P 83	Motor voltage	230 [V]
P 84	Motor frequency	50 [Hz]

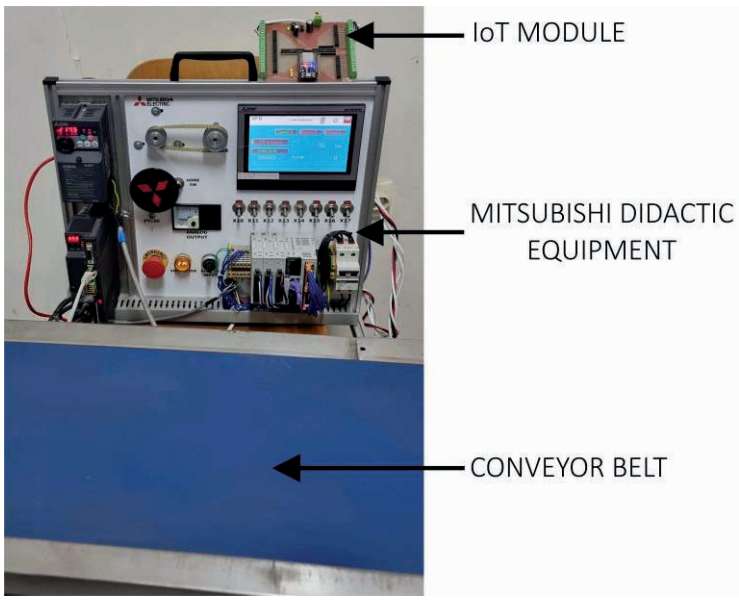

Figure 2: The implemented solution

In the implemented solution, the control of the conveyor belt is performed by the PLC that controls the operation of the VFD. Based on the commands from the PLC, the VFD controls the operation of the three-phase asynchronous electric motor, which in turn controls the operation of the conveyor belt. In this way, the rotation sense of the conveyor belt as well as the speed of movement of the conveyor belt are controlled in the interval from 0 to 100%. The PLC is connected to the IoT module, which is in turn directly connected to the internet, thus enabling the connection between the PLC and the server application, forwarding commands for controlling the operation of the conveyor belt from the server application and collecting data on the operation of the conveyor belt and forwarding them to the server application.

The WAMP server was used for implementing the server application with PHP scripts. The IoT module communicates with the server application to send collected data about the operation of the conveyor belt and to download data from the server application on how the conveyor belt should be operated. JSON (JavaScript Object Notation) data format is used for data exchange between the IoT module and the server application. The MySQL database management system was used to store the collected data. The database is organized in such a way as to monitor the current state of conveyor belt operation, as well as to track historical changes in conveyor belt operation. To test the control of the conveyor belt from a remote location, the C# test application of the IoT module described in the Tegeltija et al. 2023 was used, in which the values of the digital inputs were read, and the values of the digital outputs were directly set. In addition, an Android test application has been implemented that also enables the control of the conveyor belt operation in a frame where the operator can set the direction of the conveyor belt and the speed of the conveyor belt. Part of Android test application is shown in Figure 3. Notifications to operators or personnel in charge of conveyor belt maintenance in case of problems or necessary interventions are also implemented in the Android test application. Figure 4 shows an example of

notifications when it is necessary to check the belt tension and when it is necessary to lubricate the bearings, which represent some of the most common tasks of conveyor belt maintenance.

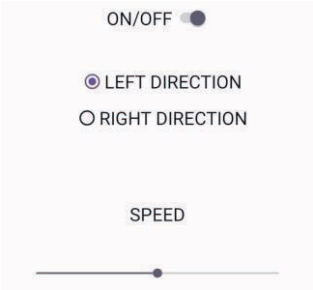

Figure 3: The implemented solution in Android application

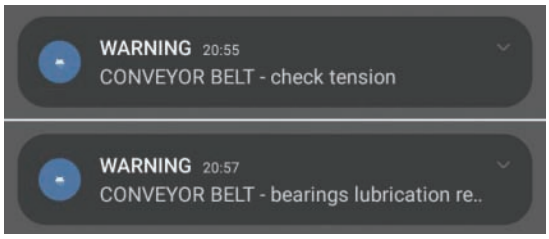

Figure 4: Examples of notifications

Moreover, a matrix based on WS2812B LEDs (WORLDSEMI CO., Limited 2017), with dimensions 8x32, is used to display additional information about the operation of the conveyor belt. The matrix arrangement of LEDs enables the display of various alphanumeric characters, allowing for the display of a more extensive information that is visible from a greater distance. The great advantage of controlling this matrix is that it is sufficient to use only one control signal, as the diodes are connected in series. Figure 5 shows an example of the displayed information, indicating the movement of the conveyor belt to the left by the two arrows and the current selection of the third speed of the conveyor belt, denoted as “S3” (shortened from Speed 3).

Figure 5: Additional information displayed on the LED matrix

4. CONCLUSIONS

This paper presents the development of an IIoT-ready conveyor system by upgrading a conventional conveyor belt with additional control systems and an IoT module, enabling connectivity and communication capabilities to integrate the conveyor system into Industry 4.0. The proposed conceptual solution is implemented and validated on a test conveyor belt with didactic control equipment. The experimental validation confirmed the system's operational status, allowing communication from the server application and an Android application for real-time monitoring and control of the system. The Android application also displayed timely notifications with suggested actions for users in predefined scenarios.

The main advantages of the proposed system lie in its ease of use and cost-effectiveness, as it only requires adding an IoT module to the existing conveyor system. This allows for easy upgrades of functional conventional conveyor systems, enabling their integration into the digital transformation of Industry 4.0. As much as the off-the shelf widely available components used for the IoT module are

reliable in initial tests, they are non-industrial components and require additional testing and analysis in real-world industrial plants. As a proof of concept, the Android application currently offers basic control and monitoring of the system's speed and rotation sense, along with displaying preset notifications in certain scenarios. However, there is potential for further development to incorporate more advanced functionalities. The presented research opens the door to future improvements and possibilities for enhancing industrial systems' capabilities in line with Industry 4.0 principles.

5. ACKNOWLEDGMENTS

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TRACEABILITY IN AGRI-FOOD PRODUCTION AND SUPPLY CHAINS

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Abstract: *Enabling the traceability of food products is a must in developing markets. This is closely related not only to safety issues but also to food quality, regulations, and conditions that should be strictly checked and maintained in supply chains. Many new technologies can be of help in implementing traceability like automatic identification technology, blockchain technology, the Internet of Things, and global positioning systems. This paper provides an analysis of traceability systems and supporting technologies, their benefits and challenges, and the regulatory frameworks governing their implementation. The findings contribute to the understanding of traceability in the agri-food sector and provide valuable insights for policymakers, researchers, and industry stakeholders.*

Key words: automatic identification, Internet of Things; blockchain

1. INTRODUCTION

The production and supply chain is a complex system linking many stakeholders, including producers, distributors, retailers, and consumers. There are growing concerns about product quality, safety, and sustainability. Traceability is a key feature that enables verification of previous product stages, locations, and characteristics throughout the supply chain.

Traceability is particularly important in the agri-food sector as it helps to protect public health. It enables the rapid identification of spoiled and contaminated food, minimizing food recalls and protecting consumers. Traceability also contributes to product quality and authenticity. Information from the traceability system, filtered for consumer use, can help consumers in doubt to make an informed choice. In most cases, this information relates to food processing methods, standards, and special dietary requirements (Fanelli, V., et.al, 2021). Traceability helps to build consumer confidence in the product, production, and supply chain.

In order to achieve product traceability there is a need to establish efficient supply chain management. A supply chain management system with logistics planning, optimization of distribution, procurement, and profit analysis must be provided with real-time information about each transformation from raw material procurement to the final product in retail. In this way, production and distribution costs can be cut down thus reducing waste that is of special importance for food products with short shelf life.

Digital technologies that can improve traceability systems include automatic identification technologies such as barcodes (linear, 2D, 3D) and radio frequency identification (RFID), but also technologies such as global positioning system (GPS), blockchain, and the Internet of Things (IoT). These technologies offer increased data accuracy, real-time monitoring, and improved interoperability between supply chain participants.

When implementing traceability systems one must bear in mind numerous challenges like cost of implementation, diverse standardization protocols across different regions and industries, data privacy and security, etc. The cost of implementation must not overtake the benefits of having a traceability system.

This review paper aims to present key components of traceability systems, and technologies used for implementation, and analyze the challenges and standards governing traceability practices. The review will also highlight recent advancements and emerging trends in traceability, such as automatic identification technology, global positioning system, Internet of Things, and blockchain technology.

2. COMPONENTS OF TRACEABILITY SYSTEMS, TRACEABILITY TECHNOLOGIES AND CHALLENGES IMPLEMENTATION

Traceability systems are complex systems consisting of numerous interconnected components that enable tracing the movement of products and ingredients throughout the whole production processes and supply chain. These components acquire information in each phase of product transformation and

also storing, and sharing information is enabled with the purpose to access and utilize these data effectively. The key components of traceability systems include data acquisition and storage, data accessibility and sharing, and traceability standards and protocols.

The fundamental components of traceability systems are labeling and identification. Every component of the product or final product, during the production process and throughout the whole supply chain needs to be uniquely labeled and identified. Different technologies can be used for this purpose like linear, 2D or 3D barcode, RFID (Radio Frequency Identification) tags, or other labeling techniques. Data related to labeled objects/products contain essential information, such as product name, substances, production date and expiration date, batch or lot number, origin, shelf-life, serial number, etc. Data acquisition, storing, and sharing at various stages of the supply chain in case of traceability is a must. Data can be acquired manually or automatically using technologies such as sensors (Zhang X., et.al, 2023), scanners, cameras, or IoT (Internet of Things) devices. These data are typically stored in databases or cloud-based systems for further sharing, processing, and analysis with the basic purpose of cutting costs of production, distribution, and waste. Data management systems, that include databases and cloud-based systems, should have thorough security measures in order to protect against unauthorized access (Prodanović R., 2020). When designing these systems, one must bear in mind the huge amount of data and that filtering and efficient data retrieval should be enabled.

Besides this information about the object/product, another essential information in the traceability system is its' location throughout the whole supply chain. GPS (Global Positioning System) technology leverages satellite-based navigation systems to determine the precise location of objects/products. GPS-enabled tracking devices can be attached to containers, vehicles, or even livestock, enabling real-time monitoring of their movement and location (Min, H., et.al., 2019). GPS enhances traceability by providing accurate geospatial data, allowing stakeholders to track the movement of products throughout the supply chain. It facilitates logistics management, route optimization, and delivery tracking, contributing to improved supply chain efficiency and transparency.

During each product transformation, information about the product and its' location can be corrupted. Blockchain technology enables the secure and transparent recording of transactions and data related to the movement of products (Mastilović J., et. al, 2023). Blockchain is a ledger system that is decentralized and distributed. It records and verifies transactions across multiple participants. Each transaction or event in the supply chain is recorded as a block, forming an immutable chain of information. Blockchain enhances traceability by providing a tamper-proof and auditable record of product provenance, certifications, and handling conditions. It enables stakeholders to verify the authenticity and integrity of data, increasing trust and transparency in the supply chain (Tegeltija S., et.al, 2022).

Since there can be numerous stakeholders requiring data from database management systems it is required to provide collaboration and communication among them. This implies the usage of communication protocols and interfaces for exchanging object/product data between different parties, which ensures continuous information flow.

Besides communication standards, basic parts of traceability systems are standards and protocols to ensure data consistency and harmonization across supply chains. These standards define the requirements for data formats, labeling, data exchange, and interoperability. International organizations, such as GS1, have developed standards for barcoding, labeling, and data synchronization. There are also standards implemented in the agri-food sector, such as the Safe Quality Food (SQF) standard or Organic certification, which provide guidelines for implementing traceability systems (Chen, H., & Prater, E., 2013).

As previously mentioned, product data can be acquired using sensors, scanners, cameras, or IoT devices. The IoT is the network of interconnected devices embedded with sensors, software, and connectivity capabilities. IoT devices collect and transmit data in real time, enabling continuous monitoring and tracking of products, environmental conditions, and processes. In traceability, IoT devices such as temperature sensors, humidity monitors, or RFID readers provide real-time data on product conditions and movements. This information is crucial for ensuring product quality, detecting anomalies, and enabling proactive decision-making throughout the supply chain. IoT enhances traceability by enabling seamless data collection, monitoring, and communication among supply chain stakeholders.

When implementing traceability systems in most cases there is a need for a combination of some of the previously described technologies to achieve optimal results, like product data accuracy and real-time product monitoring across the supply chain.

Traceability system implementation does not only bring benefits. Implementors must also be aware of potential problems and challenges in order to ensure successful traceability system implementation.

Some of the challenges can be the cost of implementation that can overtake benefits, the complexity of supply chains, the lack of standards, and legal challenges.
Implementation of traceability in production and product supply chain requires significant investments in software, hardware, infrastructure, and stakeholders' training. In most cases, stakeholders must adopt new procedures for which it takes time to achieve effectiveness, essentially in complex supply chains. Each stakeholder may have different systems (infrastructure, hardware, software, procedures), processes, and data requirements, making it challenging to achieve continuous traceability across the production and whole supply chain.
Another significant challenge is, in most cases, the lack of standardized systems. Each stakeholder may use diverse data formats, protocols, and coding schemes, which are difficult to integrate into the uniform information system. Also, data privacy and security are crucial in preventing unauthorized access. It has to be in compliance with regulations for data protection, such as the General Data Protection Regulation (GDPR). Balancing the need for traceability and transparency with data privacy concerns is an ongoing challenge.
Regulatory frameworks and standards play a crucial role in ensuring consistent and harmonized traceability practices across production and supply chains. In the agri-food sector, there are international bodies, such as the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), that have developed guidelines and recommendations for implementing traceability. These guidelines aim to enhance food safety, protect public health, and facilitate trade by providing a common understanding of traceability principles and best practices. International regulations, such as the Codex Alimentarius, also provide guidance on traceability requirements and the use of identification systems, labeling, and documentation in international trade. There are also industry-specific initiatives and certifications in promoting traceability often led by industry associations, certification bodies, or retailers. For instance, the Safe Quality Food (SQF) standard provides a framework for implementing traceability systems, risk assessments, and product recalls in the food industry. Organic certification programs also require traceability to ensure the integrity and authenticity of organic products. Additionally, sustainability certifications, such as Fairtrade or Rainforest Alliance, may include traceability as part of their standards.
Compliance with regulatory requirements not only ensures legal obligations are met but also enhances the effectiveness of traceability systems in improving food safety, quality assurance, and supply chain management.

3. CASE STUDIES AND INDUSTRY PRACTICES

Various case studies and industry practices demonstrate the successful implementation of traceability in agri-food production and supply chains. These advancements have brought about numerous benefits, including improved transparency, enhanced supply chain efficiency, and increased consumer trust. Here are some notable advances in traceability in agri-food sector:

- Farm-to-fork traceability systems: Farm-to-fork traceability systems provide end-to-end visibility of the supply chain. For instance, companies like HarvestMark and FoodLogiQ have developed traceability platforms that integrate data from multiple stakeholders, including farmers, processors, distributors, and retailers (Fang, L., & Ge, H., 2023). These platforms utilize technologies like barcoding, RFID, and blockchain to capture and share traceability information, allowing consumers to access detailed product information, such as production methods, certifications, and quality attributes.
- Supply chain transparency and visibility: Traceability systems have been instrumental in enhancing supply chain transparency and visibility. Walmart, for example, implemented a traceability initiative requiring its suppliers of leafy greens to use blockchain technology for traceability. By capturing data about the origin, handling, and transportation of leafy greens, Walmart achieved improved transparency, reduced response times during food recalls, and increased consumer confidence in the safety of their products (Hilten, M., et.al., 2020). Other retailers and food companies have also embraced similar initiatives to enhance visibility and build trust with consumers.
- Sustainability and ethical sourcing initiatives: Traceability systems are increasingly utilized to support sustainability and ethical sourcing practices. Companies like Nestlé and Mars have implemented traceability systems to ensure responsible sourcing of cocoa and palm oil. These

systems allow them to trace the origin of raw materials, assess environmental and social impacts, and verify compliance with sustainability certifications (Acierno, V., et.al, 2018). By integrating traceability into their sourcing strategies, these companies can promote transparency, support farmers' livelihoods, and address deforestation and human rights concerns in their supply chains.

- Consumer engagement and empowerment: Traceability systems are empowering consumers by providing them with access to information about the products they purchase. Apps and online platforms, such as OpenSC and Provenance, allow consumers to scan QR codes or product labels to access detailed information about the product's journey, sustainability credentials, and social impact (Obaid, T., 2016). This enables consumers to make informed choices aligned with their values, such as supporting fair trade, organic, or locally sourced products. By engaging consumers in the traceability process, these initiatives foster trust, accountability, and a stronger connection between consumers and producers.
- Improved recall management and crisis response: Traceability systems have proven instrumental in recall management and crisis response. During foodborne illness outbreaks or product recalls, traceability enables rapid identification of affected products, targeted recalls, and efficient communication with consumers. For example, in 2018, a romaine lettuce recall in the United States was traced back to a specific farm using blockchain technology, which facilitated quick removal of contaminated products from the market, protecting public health and minimizing economic losses for the industry (Jensen, A., et. al, 2013). Traceability enhances trace-back and trace-forward capabilities, reducing response times and the scope of recalls in the event of safety concerns.

These case studies and industry practices demonstrate the tangible benefits of traceability in the agri-food sector. By leveraging technology, enhancing transparency, supporting sustainability, and empowering consumers, traceability systems have improved supply chain efficiency, product safety, and consumer trust. These advancements serve as examples for other stakeholders in the industry, inspiring them to adopt and enhance traceability practices to meet the evolving demands of consumers and regulatory requirements.

4. TRENDS AND FUTURE DIRECTIONS

Emerging trends and future directions in traceability have great potential for further enhancing transparency, efficiency, and sustainability in the agri-food sector. It is noticed that there are some possibilities in key emerging trends, as follows:

- Implementation of artificial intelligence (AI) and machine learning (ML): AI and ML algorithms are being integrated into traceability systems to analyze and interpret large volumes of data since they can extract product information, real-time monitoring, anomaly detection, and predictive analytics, and thus can be used in risk assessment, and effective decision-making in areas such as inventory management, process downtime minimization, and quality control.
- Implementation of sensor technologies and real-time monitoring during product life cycle like temperature sensors, humidity monitors, and GPS trackers. Real-time monitoring helps make decisions on actions to maintain product integrity, optimize storage conditions, and prevent quality degradation.
- Blockchain-enabled supply chain traceability: Blockchain enables end-to-end traceability by creating an auditable record of every transaction and event in the supply chain. It offers benefits such as improved data integrity, enhanced security, and increased trust among supply chain participants.
- Enhancing interoperability and data exchange: by the development of standardized data formats, protocols, and interfaces that enable data exchange and interoperability.

As traceability technologies continue to advance, it is important to consider ethical and legal implications, including data privacy, security, and ownership. Addressing these concerns will be essential for maintaining consumer trust and ensuring the responsible use of traceability systems.

5. CONCLUSION

Traceability is one of the most important features of each production system, especially in agri-food production and supply chains, since it ensures the safety, quality, and sustainability of a product. The importance of traceability also can be in determining authenticity, and ethical practices, strengthening consumer trust and confidence, and enabling efficient supply chain management.

The components of traceability systems, such as identification and labeling, data acquisition, storage, sharing and accessibility, and traceability standards and protocols, work together to enable the effective tracking and tracing of products and ingredients throughout the whole supply chain.

However, implementing traceability systems is not without challenges. The cost of implementation, the complexity of supply chains, data privacy, and security concerns, lack of standardized systems, and legal challenges pose barriers to widespread adoption and effective implementation.

Regulatory frameworks and standards play a crucial role in ensuring consistent and harmonized traceability practices. International regulations, regional requirements, and industry-specific initiatives provide guidelines and requirements for traceability implementation, promoting transparency and accountability.

Case studies and industry practices have demonstrated the benefits of traceability in various areas, including farm-to-fork traceability systems, supply chain transparency, sustainability and ethical sourcing initiatives, consumer engagement, and improved recall management.

The future of traceability lies in using emerging technologies, promoting collaboration, and aligning traceability efforts with broader sustainability and circular economy initiatives. The integration of traceability with other digital technologies, such as AI, ML, IoT, and blockchain, has the potential to revolutionize supply chain management, product authenticity, and consumer trust. By embracing these emerging trends and driving continuous innovation, the agri-food sector can further enhance traceability practices, leading to safer, more sustainable, and transparent food systems.

In conclusion, traceability in agri-food production and supply chains is essential for ensuring food safety, quality, authenticity, and sustainability. By implementation of technological advancements, bearing in mind challenges, complying with regulatory and standard frameworks, and adopting best practices, stakeholders can foster transparency, efficiency, and consumer trust in the agri-food sector.

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CONCEPTUAL SOLUTION OF THE TRAINING KITS FOR CRITICAL INFRASTRUCTURE CYBER SECURITY – CASE STUDY: OPEN-LOOP PUMPED STORAGE HYDROPOWER

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Abstract: *Critical infrastructure (facilities, systems, networks etc.) is of key significance for any country and their security is of utmost importance. As computer networks are integral parts of critical infrastructure (CI) and highly vulnerable to malicious attacks, a special attention must be paid on cyber security (CS). Therefore, in this paper, the basis as well as key requirements for the development of training kits for testing the CS of CI are presented on the example of open-loop pumped storage hydropower (PSH). The training kits should be easily portable and easy to install and demonstrate.*

Key words: critical infrastructure, training kit, open-loop pumped storage hydropower

1. INTRODUCTION

The state, as an organization, is obliged to defend national security, i.e. protect its citizens, economy, and institutions. Historically, national security primarily focused on safeguarding against military threats. However, modern national security now encompasses protection against terrorism, crime, economic risks, energy vulnerabilities, environmental challenges, food safety, information breaches, and CI protection (Viganò et al., 2020).

As per the Law on CI of the Republic of Serbia (Službeni glasnik RS, 87/2018), CI refers to systems, networks, facilities, or their components. The disruption of their functioning or the supply of goods and services can have severe consequences for national security, public health and safety, property, the environment, citizen well-being, economic stability, and the functioning of the Republic of Serbia. The law identifies eight sectors as CI: energy, transport, water and food supply, health, finance, telecommunications and information technologies, environmental protection, and government operations.

Power system disruptions pose significant risks to national security and the economy (Ten et al., 2010). Today, power systems rely on complex Internet of Things (IoT) and Supervisory control and data acquisition systems (SCADA) vulnerable to various attacks (Maglaras et al., 2018), necessitating special attention in this sector. However, due to the complexity and interdependence of the telecommunications and information technologies sector, achieving the required level of security is challenging.

Numerous training programs and courses have been developed to address the CS of CI (Chowdhury & Gkioulos, 2021). Research has shown that the outcome of attacks on CI often depends on the lack of awareness and practical training among personnel (Ghafir et al., 2016). Adequate personnel training is crucial for achieving the necessary security level in CI.

This paper presents the conceptual solution of training kits used for examining and testing the CS of CI, using an open-loop PSH as an example. The paper is organized as follows: Section 2 presents the requirements for the desing of traing kits, while Section 3 briefly outlines the types and structure of PSH as well as different operating scenarios of the open-loop PSH. Based on these scenarios, Section 4 provides a proposal for the structure of the training kit, and Section 5 highlights the most important conclusions of the study.

2. REQUIREMENTS FOR THE DESIGN OF TRAINING KITS FOR CS OF CI

In order to increase the CS of CI it is necessary to develop a new kind of training kits which will facilitate presentation of the functionality of CS software. There are several key requirements:

- Training kit should adequately represent the functionality of the chosen CI. This implies the real motion of critical elements of infrastructure (flowing of water in PSH, moving of nuclear rods in nuclear power plants etc.).
- Training kit should comprehend all the necessary computer-controlled hardware (pumps, directional control valves, motors, actuators, sensors, etc.) as well as software (software for Programmable Logic Controller (PLC), Human Machine Interface (HMI), communication software etc.).
- Design of training kit should take into consideration the potential for various attacks to CI.
- Training kit should be portable. This implies that it should be embedded in no more than two suitcases. Also, suitcases should not be too heavy in order that one man can handle them.
- Training kit should be assembled on site in a relatively easy manner.
- Training kit should be able to stand freely on the table in order to be easily viewed.

According to these requirements a conceptual solution of a training kit for open-PSH is shown.

3. CASE STUDY: PUMPED STORAGE HYDROPOWER

This paper focuses on developing a training kit to examine and test the CS of the open-loop PSH. Hydropower plants produce electricity using kinetic energy of water, driving turbines connected to electricity generators. There are three types of hydropower facilities: impoundment, diversion, and pumped storage. PSH, with upper and lower water reservoirs, can be open-loop or closed-loop pumped storage systems, as shown in Figure 1.

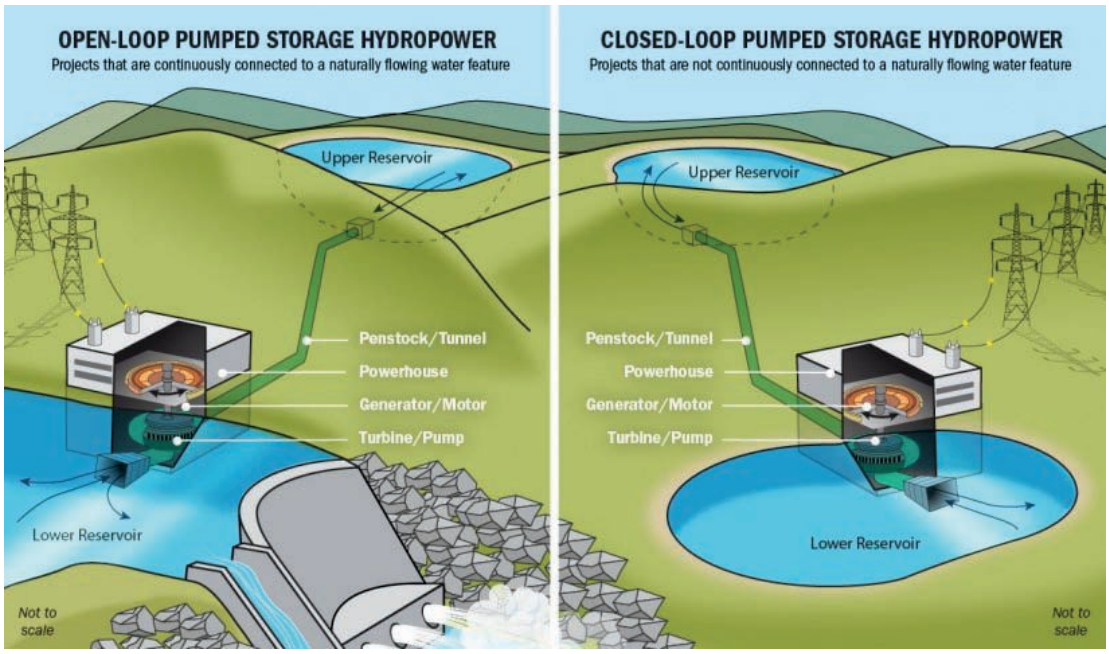

Figure 1: Different configuration of PSH (U. S. Department of Energy, 2023)

The first known use cases of PSH were found in Italy and Switzerland in the 1890s (*U. S. Department of Energy, 2023*). Now, PSH facilities can be found all around the world. In the Republic of Serbia, there is one open-loop PSH named "Bajina Bašta" (Figure 2). This PSH features an upper reservoir in the Beli Rzav river valley and a lower reservoir connected to the existing "Bajina Bašta" hydropower on the Drina river (Elektroprivreda Srbije, 2023-2).

Figure 2: PSH "Bajina Bašta" (Elektroprivreda Srbije, 2023-1)

3.1 Operating scenarios

Four distinct operational scenarios of a PSH can be defined based on the natural cycle of water circulation. These scenarios, suitable for simulation using a training kit, include:

- Normal operation mode;
- Reversible operation mode;
- Emptying the upper reservoir;
- Filling and emptying of the lower course of the river.

During the normal operation mode operation, water flows into the main, lower reservoir, and subsequently, it is directed through the turbine blades via the outlet to generate electricity. However, during drought conditions with minimal water levels, the hydropower ceases operation due to insufficient water supply. In cases when the inflow of water exceeds electricity production demands, the plant can switch to the reversible operation mode. Here, water is pumped from the main, lower reservoir to the upper reservoir until the upper reservoir reaches its maximum capacity.

The accumulated water is stored until it is required for electricity generation in the future. This process often involves utilizing the same turbines used for electricity generation, only now they operate as pumps to move water from the lower to the upper reservoir. When water inflow is low, and electricity demand is high, the operating mode "emptying the upper storage lake" can be initiated. In this scenario, water is discharged from the upper reservoir to the turbine blades, kickstarting electricity production by harnessing the stored potential hydropower within the reservoir.

During low electricity demand, water is stored in both reservoirs, potentially leading to reduced water levels downstream, endangering the ecosystem of the river. To maintain a minimum water level, careful control is essential. Conversely, during high inflow or flooding, overflow mechanisms such as special drains or additional pumps are utilized to prevent adverse effects.

4. TRAINING KIT STRUCTURE

A conceptual solution of suitable training kit for simulating various operating scenarios of PSH, like "Bajina Bašta," and potential cyber attacks on this CI is proposed in Figure 3. To enhance portability, the complete model is divided into two units housed in separate suitcases. Upon opening, these suitcases are placed side by side on a work table using internal mounting holders.

The left suitcase contains two reservoirs, labeled 1 and 2, representing the main, lower and upper reservoirs, respectively. The lower part of right suitcase features a larger reservoir labeled 3, representing the main river flow (natural body of water). A small 3D-printed turbine is positioned above reservoir 3, which rotates when water overflows from reservoirs 1 and 2 into the main stream. Capacitive sensors (labeled S1-S6) are installed in each reservoir to detect minimum and maximum water levels.

The proposed training kit for open-loop PSH, involves using electromagnetic 2/2 directional control valves (labeled R1 and R2) to control the flow of water from the lower and upper reservoirs (reservoirs 1 and 2,

respectively) to the turbine and the main stream of the river (reservoir 3) to simulate electricity generation. Pump P2 enables the water flow from the lower to the upper reservoir, while pump P1 is utilized for simulating the natural flow of the river in continuous mode by transferring water from the main stream (reservoir 3) to the lower reservoir (reservoir 1).

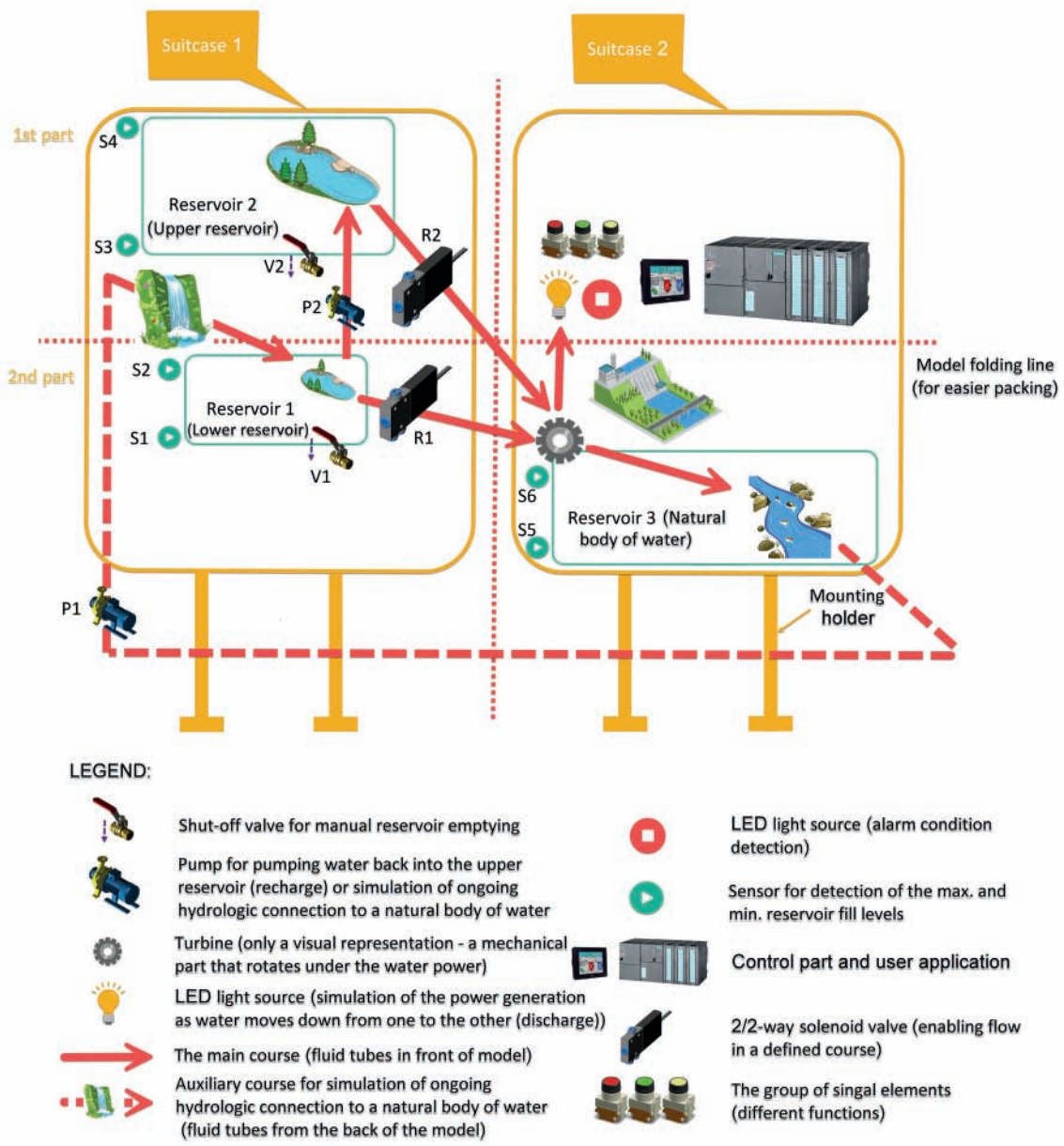

Figure 3: Conceptual solution of the open-loop PSH training kit

The control elements, including a PLC, HMI panel, two Modbus Remote Terminal Units (RTU), and a router, are placed in the upper part of the right suitcase. The PLC serves as the primary control device, while the HMI panel simulates a SCADA system for managing and monitoring the PSH operation. Modbus RTUs provide remote data transmission as sensors and actuators are located at remote points from the main control center in actual hydropower plants. Some sensors (S1-S4), pump P2, and directional control valve R2 are connected to one Modbus RTU, while pump P1 is connected to the second Modbus RTU to simulate the natural flow of the river (it cannot be the target of attack). Furthermore, sensors S5 and S6 and directional control valve R1 are directly connected to the PLC's inputs and outputs. The router enables communication among all the network devices and establishes a connection with the "outside world." Signal lamps, buttons, switches, and other control elements are used to simulate electricity production, system start/stop, and other operations.

Prior to closing the suitcase, it is necessary to manually activate shut-off valves V1 and V2 to drain water from reservoirs 1 and 2, respectively. In the next step, it is necessary to initiate the flow of water from

reservoir 3 through reservoir 1, activating pump P1, and discharging water outside using shut-off valve V1.

4.1 Normal operation mode

In the initial step of this scenario, pump P1 is activated to transfer water from reservoir 3 (representing the main river course after the dam) to the lower, i.e., the main reservoir (reservoir 1), simulating the water cycle. In the second step of this scenario, directional control valve R1 is switched on, releasing water onto the turbine to simulate normal electricity production.
However, for drought simulation purposes, pump P1 needs to be stopped. Additionally, if the water level in the lower reservoir (reservoir 1) reaches a minimum, indicated by sensor S1, or if other monitored parameters not included in the training kit necessitate it, pump P2 and/or directional control valve R1 must be turned off (if activated) to simulate the shutdown of the hydropower.

4.2 Reversible operation mode

The reversible mode can be initiated automatically when sensor S2 detects the maximum water level in the lower reservoir (reservoir 1), or manually based on other monitored parameters not included in the training kit. In this mode, pump P2 is activated, allowing water to flow from the main reservoir (reservoir 1) to the upper reservoir (reservoir 2). The process stops automatically when sensor S4 detects the maximum water level in the upper reservoir (reservoir 2) or manually based on other monitored parameters not included in the model.
In the training kit, for the sake of clarity and better comprehension of the process, the pump used for transferring water between the reservoirs (reservoirs 1 and 2) is separated from the turbine connected to the electric power generator. In reality, there is often only one turbine serving both purposes, generating electricity and facilitating water transfer between reservoirs.

4.3 Emptying the upper reservoir

In the course of implementing this scenario, directional control valve R2 is activated, initiating the release of water from the upper reservoir to the turbine blades. The activation can occur upon receiving a signal from the control level indicating the need for electricity production from the reserve. However, the process is automatically halted when a signal is received from sensor S3 indicating that the water level in the upper reservoir (reservoir 2) has reached a minimum, or based on monitoring other parameters not included in the training kit that lead to the same conclusion.

4.4 Filling and emptying of the lower course of the river

When the water level in the main stream of the river (reservoir 3) drops to a critical point that could endanger biological conditions, sensor S5 is triggered, and the "maintenance of the biological minimum" mode is automatically initiated. In this mode, directional control valve R1 is activated, utilizing part of the accumulated energy to maintain the water level necessary for preserving the biological conditions. Conversely, if there is a substantial inflow of water into the main, lower reservoir, leading to significant overflow into the river, or if there is a considerable increase in water level downstream, sensor S6 is triggered. This activation prompts the reactivation of pump P1, allowing excess water from the river drainage stream (reservoir 3) to flow back into the lower reservoir (reservoir 1).

4.5 Potential attacks

During the conceptual design of the training kit, the potential for various attacks on PSH was taken into consideration. In addition to the regular fluid connections and tubes for water flow in the mentioned scenarios, various "overflows" were predicted. For instance, in the event of an attack that would affect the maximum water level detection in the lower reservoir (reservoir 1) and upper reservoir (reservoir 2), leading to "false" signals from sensors S2 and/or S4, it is possible to redirect water through additional connections and tubes to the main stream of the river (reservoir 3). This simulation allows for the representation of an undesirable situation, where there would be a "reservoir overflow" scenario, while still ensuring the protection of the equipment and related components in the best possible manner. Other potential attack scenarios were also considered during the development of the training kit to ensure comprehensive evaluation and preparedness.

5. CONCLUSIONS

This paper presents the basics for the development of the training kits for examining and testing the CS of CI. The necessary conceptual requirements for the design of training kits are developed. The case study of conceptual design of a training kit for testing the CS of the open-loop PSH is given. Future research will be related to 3D modeling and physical realization of the mentioned training kit, programming of defined operating scenarios, and at the very end, testing of different types of malicious attacks.

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Development of a user application for optimizing the procedure of compressed air consumption calculation

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Abstract: *The procedure of reading and processing data from measuring devices or sensors is often difficult due to the need for manual recalculation of the obtained data on the computer. In this work, the consumption of compressed air was read from the "AirBox" measuring device. When transferring the read data to the computer, they are converted into a CSV file format. Up to now, the processing of that data on the computer involves manual recalculation of the consumption by the user using the entered expressions for the consumption of compressed air. In order to avoid manual calculation of compressed air consumption, a user application was developed which, based on the received CSV file, determines consumption and provides graphical and textual accompanying explanations. At the end, the validation of the work results was carried out. Possible errors and the time required for calculation are reduced.*

Key words: *Application development, Pneumatic systems, Energy efficiency, consumption of compressed air*

1. INTRODUCTION

Compressed air (CA) is a very widespread form of energy in industry. Accordingly, quality and rational consumption should be taken into because CA is an expensive source of energy. The cost of electricity for the production of CA can rise up to 20% of the cost of total electricity consumption in the industry (Blagojevic, 2020). The first step in reducing the consumption of CA is to measure current consumption.

Problems in pneumatic systems that lead to increased consumption as well as ways of saving are not easy to quantify. One of the reasons for this is that accurate and invasive measurements are necessary at the point of application of the compressed air system (CAS) (Eret, 2012). On the demand-side, the inefficiency of CA manifests itself in three ways: leakages, artificial demand and inappropriate uses, which can lead to the consumption of over 50% of the available CA (Abela, 2022). Among these losses, the most visible and significant sources of CA losses are leakages. CA leakage accounts for 20% to 40% of total CA losses (Dudic, 2012).

Determining possible sources of losses, as well as detecting faults in the CAS in the form of additional consumption of CA, leads to the selection of an adequate device for measuring indicators in the case of CA consumption. It is possible to use a wide range of devices, from gas detectors, ultrasonic detectors and thermal cameras, to portable devices and sensor stations. According to the mentioned ways of CA losses, the Air Box device, type GHDA-FQ-M-FDMJ-A, from Festo, was specifically selected.

The measured data from the Air Box must be transferred to the computer for further processing. The usual procedure according to the manufacturer's recommendation implies that the data is transferred to the computer using the manufacturer's specialized software through RS232 socket. The procedure for connecting the computer to the measuring device is shown in Figure 1. Doing so, files in CSV format are stored on the computer. The obtained files can be processed on the computer using software such as MATLAB, Excel, and the like. The CSV file also contains data that is not directly related to consumption calculation, such as date and time, file name etc. Concretely, when calculating the consumption of CA, it is necessary to manually select the rows and columns from the CSV file on the basis of which the software will calculate the consumption.

2. COMPRESSED AIR FLOW MEASUREMENT

In this work, the Air Box is used as a device to measure the flow of CA. On the basis of the collected data, the consumption of CA is calculated. Also, the Air Box measuring device can be used to determine air quality and to measure values such as pressure and temperature. Also, in this way, other indicators of CA losses in pneumatic systems can be reached. Functionality and proper use of Air Box can be found in the user manual of the device (Festo, 2006).

Figure 1: Connection of computer with Air Box measuring device

2.1 Compressed air consumption calculation

The current way of calculating CA consumption implies the appropriate selection of parameter values from the downloaded CSV file. An equation for the calculation of total CA consumption is:

$$Q = \sum_{i=1}^{n}(t_i - t_{i-1})\frac{(q_i+q_{i-1})}{2} \tag{1}$$

where:
Q – is total measured consumption [Nl]
t_i – is i^{th} time moment of flow measurement [s]
t_{i-1} – is i^{th-1} moment of flow measurement [s]
q_i – is flow measurement in the ith time moment [Nl/min]
q_{i-1} - is flow measurement in the i^{th-1} time moment [Nl/min].
The sum represents the digital equivalent of the CA flow integral, at discrete time instants.
The difference between (t_i - t_{i-1}) represents the selected period of time when the measurement with the Air Box was made. So, for the predetermined value of the selected period of time, this difference is constant and does not have to be calculated every time. Instead, a constant value t_p can be entered. Equation (1) is now simplified by extracting the constant terms in front of the sum:

$$Q = \frac{1}{2}t_p\sum_{i=1}^{n}(q_i + q_{i-1}) \tag{2}$$

where *t_p [s]* is the selected period of time, and represents the time that elapses between two consecutive CA flow measurements. The value of the selected period of time for measuring CA consumption within this work is 0.05 seconds and, in this case, depends on the Air Box device.

3. USER APPLICATION FOR AUTOMATIC CALCULATION OF CA CONSUMPTION

For automatic calculation of the total CA consumption, a desktop application was developed, and it is shown in Figure 2. It is adapted to the end user with a variety of different functions, which are shown below. The application was developed in the C# programming language within Microsoft Visual Studio and contains several buttons for control. There are two ways of displaying uploaded files, graphically and in the form of a table. The visibility of calculation results and the possibility of exporting them in a PDF file were one of the primary goals during developing the application. On the graph of CA consumption, it is possible to determine the time interval within which the consumption of CA is observed by moving left-right vertical lines (green and orange). These vertical lines are located on the left and right sides of the graph. This is very important because, in a visual way, it is easy to determine one complete working cycle of a pneumatic system with a start and end time point.

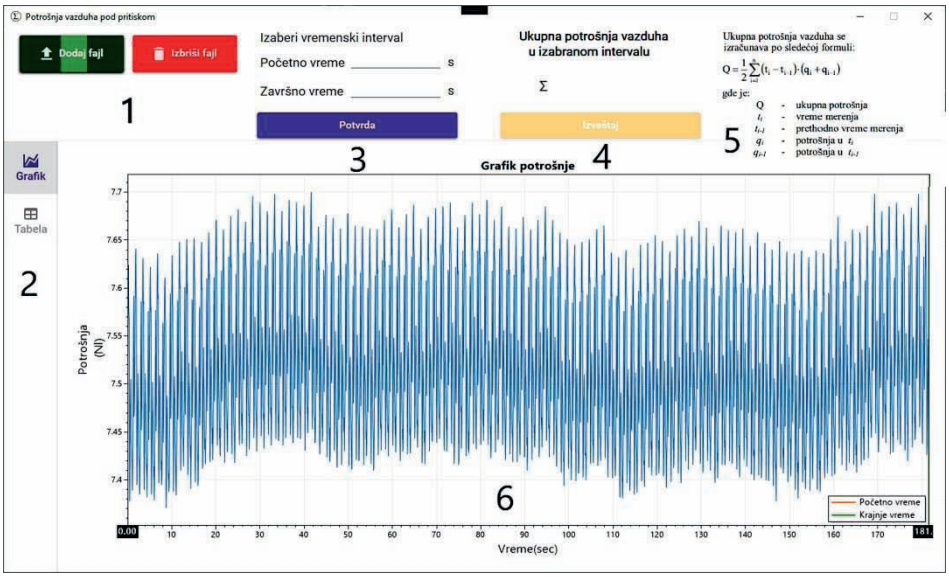
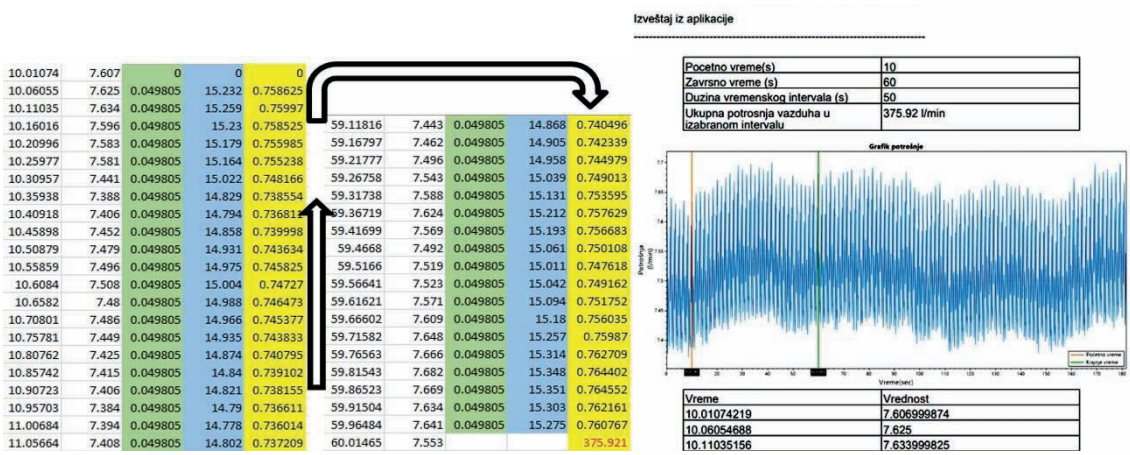


Figure 2: Application layout

The interactive panel given in Figure 2 consists of the following elements: (1) Button *Dodaj fajl* (the customized file with the measurement results from Air Box is inserted into the application, button *Izbriši fajl* serves to delete the inserted file (label 1)), (2) The *Grafik* and *Tabela* buttons (select the way of displaying the loaded data in the application itself (label 2)), (3) In the *Početno vreme* and *Završno vreme* (the desired interval is selected and after that, by pressing the *Potvrda* button, the application is informed to apply the formula to the given values (label 3)), (4) Field to display the results with the button *Izveštaj* below (pressing this button, a PDF file is created and by generating the report, data on the consumption of CA is obtained in graphic or table form, as well as the selected time interval and consumption of CA (label 4)), (5) Display of the formula (label 5) and (6) Display of graphics for the loaded file (label 6).

4. RESULTS AND DISCUSSION

By generating the report, data on CA consumption is obtained in graphic and/or table form, as well as the selected time interval. In order to validate the results, it is necessary to make sure that the created application accurately calculates CA consumption within the observed time interval. This can be checked by comparing the results obtained by the previous way of calculating the consumption of CA and the result given by the application. In this particular case, a file called Log2206.MSR was used for validation purposes. File names are automatically set in the measuring device. After uploading file Log2206.MSR into the application, the values that enable further manipulation are obtained. For one example, by choosing a time interval between 10 s and 60 s, the consumption of CA is 375.92 Nl/min, Figure 3, right.



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10.16016	7.596	0.049805	15.23	0.758525
10.20996	7.583	0.049805	15.179	0.755985
10.25977	7.581	0.049805	15.164	0.755238
10.30957	7.441	0.049805	15.022	0.748166
10.35938	7.388	0.049805	14.829	0.738554
10.40918	7.406	0.049805	14.794	0.736812
10.45898	7.452	0.049805	14.858	0.739998
10.50879	7.479	0.049805	14.931	0.743634
10.55859	7.496	0.049805	14.975	0.745825
10.6084	7.508	0.049805	15.004	0.74727
10.6582	7.48	0.049805	14.988	0.746473
10.70801	7.486	0.049805	14.966	0.745377
10.75781	7.449	0.049805	14.935	0.743833
10.80762	7.425	0.049805	14.874	0.740795
10.85742	7.415	0.049805	14.84	0.739102
10.90723	7.406	0.049805	14.821	0.738155
10.95703	7.384	0.049805	14.79	0.736611
11.00684	7.394	0.049805	14.778	0.736014
11.05664	7.408	0.049805	14.802	0.737209

59.11816	7.443	0.049805	14.868	0.740496
59.16797	7.462	0.049805	14.905	0.742339
59.21777	7.496	0.049805	14.958	0.744979
59.26758	7.543	0.049805	15.039	0.749013
59.31738	7.588	0.049805	15.131	0.753595
59.36719	7.624	0.049805	15.212	0.757629
59.41699	7.569	0.049805	15.193	0.756683
59.4668	7.492	0.049805	15.061	0.750108
59.5166	7.519	0.049805	15.011	0.747618
59.56641	7.523	0.049805	15.042	0.749162
59.61621	7.571	0.049805	15.094	0.751752
59.66602	7.609	0.049805	15.18	0.756035
59.71582	7.648	0.049805	15.257	0.75987
59.76563	7.666	0.049805	15.314	0.762709
59.81543	7.682	0.049805	15.348	0.764402
59.86523	7.669	0.049805	15.351	0.764552
59.91504	7.634	0.049805	15.303	0.762161
59.96484	7.641	0.049805	15.275	0.760767
60.01465	7.553			375.921

Izveštaj iz aplikacije

Pocetno vreme(s)	10
Zavrsno vreme (s)	60
Duzina vremenskog intervala (s)	50
Ukupna potrosnja vazduha u izabranom intervalu	375.92 l/min

Grafik potrosnje

Vreme	Vrednost
10.01074219	7.606999874
10.06054688	7.625
10.11035156	7.633999825

Figure 3: Excel table for manual calculation procedure (left), generated PDF report (right)

With the manual calculation of CA consumption, an Excel table was used with all necessary rows and columns obtained from the MSR file. Equation 1 was applied, for the calculation of CA consumption. The obtained result of CA consumption is 375,921 Nl/min, which is identical to the result obtained automatically, using the developed application. The CA consumption results are provided for one, same period of time and are given in the Excel table in Figure 3, left.

5. CONCLUSION

In this paper, the need to facilitate obtaining measurement results from an appropriate measuring device was recognized. Namely, it is often necessary to adjust files with measurement results stored in the memory of the measuring device using additional software. Only customized files can be further processed on the computer in order to analyze the obtained data. Depending on the number of measurements, the process of transferring data from the measuring device to the computer may take some time. Additionally, if it is necessary to manually extract the types and columns with the required data from the downloaded files on the computer, then this procedure becomes more time-consuming. In this sense, this paper presents the idea of speeding up and facilitating this procedure with a single user application offering a universal solution for processing data obtained by measurement. Since the user does not have to manually select data fields, the possibility of error is reduced in this sense.
The advantages of the application are the display of measurement results for the selected time range in the form of a table and graph, as well as the generation of a report with measurement results in PDF format. The disadvantage of the current version of the developed application is the time that is needed for the conversion of the MSR file with data into a CSV file with data using the MSR software converter from the manufacturer. Also, after conversion, it is necessary to load the CSV file into the developed application. Future work will be to reduce the time and number of conversion steps and to directly load the file source (MSR format) obtained from the measuring device to the developed application. In this way, the mentioned shortcoming of the current version of the application would be eliminated.

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WHETHER TO IMPLEMENT ROBOTIC SOLUTIONS IN LEAN INDUSTRIAL SYSTEMS: A DECISION BASED ON FINANCIAL INDICATORS

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Abstract: *The successful finalization of the project is crucial for every organization, regardless of whether its operations are structured according to Lean principles or not. Industry 4.0 enabled the implementation of robotic solutions that significantly contributed to business improvement. In every company decision should be based on the fact. Financial indicators represent only one of the criteria that should be followed when deciding on projects in a company. This study examined financial metrics following the implementation of a robotic solution in a particular company. According to the analysis, all of the indicators examined are above the minimum acceptable level. The break-even point, profitability index, and net present value were examined.*

Key words: Robotics, Lean industrial systems, financial indicators, Industry 4.0

1. INTRODUCTION

Today there is a need for continuous improvement of performance. For that reason, companies are enrolling on different projects. Those projects can refer to technical innovations, product innovations, manufacturing improvements, etc. One of the biggest problems refers to the potential failure of the project. Every company's main concern in realizing the project refer to time and cost.

Industry 4.0 affects the fact that the main focus in improving a company's business is the improvement of technology. In general, Industry 4.0 is widely accepted because of its automation and enhanced computing capacity (Gualtieri, Rauch, & Vidoni, 2021). Automation is very important for Industry 4.0. Automation enables quality improvement of performance related to manufacturing.

For Industry 4.0 automation is of exceptional importance. Robotics represent one of the elements of Industry 4.0 which is suitable for improving the implementation of various processes in the company. Robots can perform simple pick-and-place activities and far more complex ones that include cutting, receiving and delivering welding… Today, the implementation of robotic solutions extends to various industries, from agriculture, through metal processing, to the pharmaceutical industry. Robots can repeat a large number of operations, can perform activities in collaboration with humans, or can be used for other solutions. The implementation of robots allows workers to focus on more creative tasks that enable productivity improvement and company growth.

The purpose of industrial robots can be linked to achieving enviable results when it comes to errors, defects, and downtimes, and accordingly, they are suitable for leading in Lean industrial systems. In this way, by investing in robotics, Lean industrial systems can realize better results when it comes to investment return time (Oztemel & Gursev, 2020).

Robotics is a technology that enables the performing of different tasks in the industry. Robotics can be used for continuous minimization of costs thereby also increasing productivity. Today, companies are reviewing the possibilities of applying robotics to improve further operations (Chen, et. al., 2021). Robots are transforming the market thanks to their rapid development and the possibility of combining them with different devices.

The application of advanced robotics can be seen as a significant project. In this sense, it is very important to implement robotic solutions in the foreseen period and with predefined costs. Also, as in other cases, the implementation of robotic solutions must have its justification.

In this sense, this paper deals with the research on the financial effects of the implementation of robotic solutions.

2. METHODS

Regardless of the industry within which a company operates, the performance of the entire production process must be continually improved due to the ongoing rise in competitiveness and the current economic climate. If the company has a well-established position, it also has to change strategies to keep it (Porter, 2004).

The fourth industrial revolution has made it possible for many industries to use cutting-edge robotic solutions. Advanced robotic solutions can significantly improve various manufacturers' productivity and efficiency if properly implemented. In previous research, Return on Investment is observed, and in this paper, research is upgraded by analyzing the net present value, internal rate of return and profitability index. Those financial indicators are analyzed in the company engaged in the production of construction equipment. The company operates in accordance with Lean principles, showing a commitment to improving operations, processes and procedures.

Analyzing financial indicators is critical in directing the organization toward Lean principles such as waste reduction and operational excellence. Net present value, internal rate of return and profitability index provide measurable insights into the Lean principles' effectiveness. Those indicators support the financial stability of the company. In addition to financial sustainability, it provides the feedback of commitment to continuous improvement and customer value creation. The decision was made to implement the robot for the welding activity after taking into account the significant amount of time that the worker allocates to performing necessary non-value-added activities. Also, more of the third of the cycle time is expenditure on welding preparation. In the case of robot welding, switching from one execution position to another is done much more quickly than in the case of manual welding. Additionally, piece manipulation is considerably quicker.

The financial indicators examined in the case study are summarized below.

2.1 Net Present Value (NPV)

Net present value can be calculated as the sum of the present values of incoming and outgoing cash (Gaspars-Wieloch, 2017). NPV indicate if the project will result in profit or loss. The difference between discounted inflows and outflows represents NPV. The formula for the NPV is:

$$NPV = \sum_{k=0}^{n} \frac{NCF_k}{(1+i)^k} \tag{1}$$

Where:
NCFk – net cash flow generated in year k
k – Number of periods
i – Discount rate

A higher Net Present Value indicates which project is better to choose. If Net Present Value is positive, it indicates that the project is acceptable. The discount rate is based on the ratio of owned and borrowed funds, risk, interest rates, inflation rate, financial policy and other factors. To assess the efficiency of the investment, a decision can be made based on the weighted average cost of capital (WACC), which is calculated as:

$$WACC = \frac{E}{E+D} * R_E + \frac{D}{E+D} * R_D * (I - T) \tag{2}$$

Where:
E – Equity
D – Debt
RE – Cost of Equity
RD – Cost of Debt
T – Tax

NPV determine the present value of all the future cash flows. Cash inflows and cash outflows are discounted when NPV is calculated. A project is worthwhile if a project's financial return is bigger than the

investment (Archer & Ghasemzadeh, 1999). The discount rate that is used reflects the risk of the project (Arshad, 2012).
Decisions made based on the NPV should be as follows:

Table 1: NPV decision-based

	Decision
NPV > 0	Investment is eligible for consideration
NPV < 0	The investment will result in financial losses
NPV = 0	There must be an additional interpretation

NPV is one of the main tools for industrial investment evaluation (Magni, 2015). When one company is considering a lot of different projects, NPV can be used for ranking them. The main advantages of using NPV are consideration of money value in time, enabling comparison of different projects by their duration, and the possibility to use NPV even when the rate of return varies over the course of a project. On the other side, the main disadvantage of NPV is a number of steps which include estimation. During the project, a lot of changes can happen and influence NPV significantly. Also, it is not appropriate to compare different sizes of projects.

2.2 Profitability Index (PI)

The ratio of discounted benefits to discounted costs is known as the profitability index (PI) (Grau, 2012). PI is an evaluation tool that has a wide real-life application. The PI can be used for comparing similar investments that are considered. PI is one of the many methods available to determine the effectiveness of a proposed investment. The PI formula is:

$$PI = 1 + \frac{NPV}{I_0} \tag{3}$$

Where I_0 refer to the initial investment.
The profitability index can be used in different cases, for short or long-term decisions making. Also, it can be used in the case of the positive net present value of projects in order to compare some of them. It is very useful when economic resources are scarce (Al-Rikabi, 2021). In general, the profitability index represents the relationship between the benefits and costs of the project. Since any value below 1.0 would imply that the project's present value (PV) is less than the initial investment, a profitability index of 1.0 is logically the lowest acceptable measure on the index. The main advantages of PI refer to providing information on whether an investment will increase company value or decrease, it aids in selecting the project when allocating capital and considers all project cash flows. On the other side, the main disadvantage of the PI is that it may always provide the best decision when it is used for the estimation of mutual projects.

Table 2: PI indications

	Indication
PI > 1	Anticipated discounted cash inflows exceed discounted cash outflows
PI < 1	The outflow deficit exceeds the discounted inflow deficit
PI = 1	Any positive or negative result from the project is minimal

If the PI is greater than 0, a project should be taken into consideration. If the PI is less than 0, a project should be rejected. In the case that PI is equal to 0, there is indifference about this project.

2.3 Breakeven Point (BEP)

By comparing an asset's market price to its initial cost, the breakeven point for a trade or investment can be identified. The breakeven point is reached when the two prices are equal.
The formula for the breakeven point in units is:

$$BEP = \frac{FC}{CMPU} = \frac{FC}{SPPU - VCPU} \tag{4}$$

Where:
BEP – Break Even Point
FC – Fixed Cost
CMPU – Contribution Margin per Unit
SPPU – Selling Price per Unit
VCPU – Variable Cost per Unit
In Figure 1 breakeven point is graphically presented.

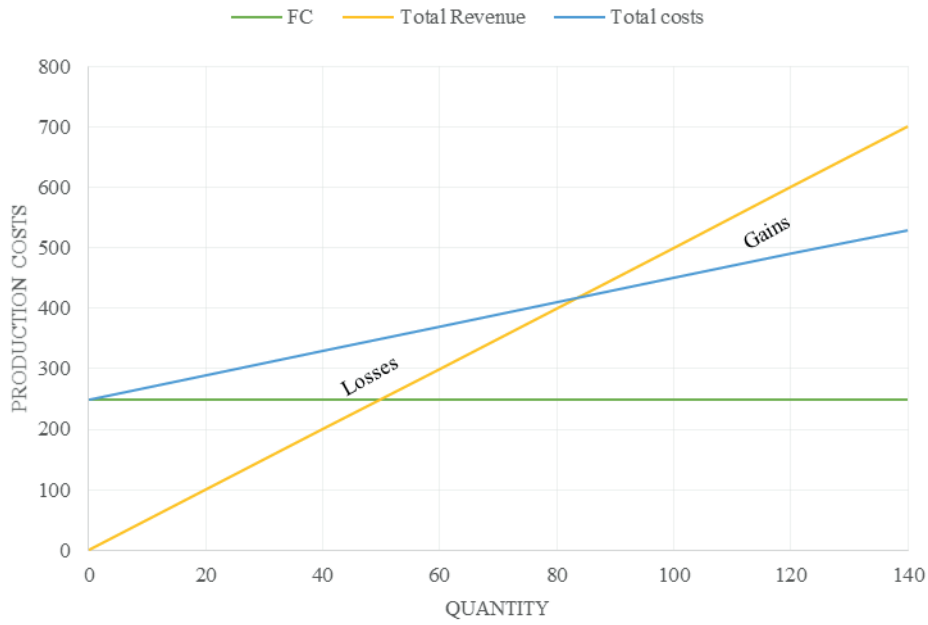

Figure 1: Breakeven point

As can be seen from Figure 1, the breakeven point is the production level at which revenues are equal to expenses. Below the breakeven point, the company realizes a loss, while above this point, a profit is realized. The breakeven point is the point at which the company makes neither a loss nor a profit. The breakeven point may also be worth calculating:

$$BEP = \frac{FC}{CMPU} * SPPU = \frac{FC}{SPPU - VCPU} * SPPU \tag{5}$$

Equation (4) represents the breakeven point in units and equation (5) represents the breakeven point in sales value. In this case, the breakeven point is the level of sales where total revenue and total costs are equal. In accounting terms, it primarily refers to the production level at which revenue will equal the production costs. A breakeven point indicates the elements of trading that must be met in order to avoid a loss of an initial investment in a business or project. The main benefits of calculating the breakeven point are fact-based decision-making, revealing costs that have not been anticipated and obtaining funding from investors.

3. CASE STUDY

This work is considering financial indicators in implementing the robot cell in the manual cell place. The company should be able to make some decisions on the projects from the obtained financial indicators. Financial indicators are not the only indicators that should be analyzed. In the next research, quality and safety indicators will be analyzed. As it is defined in the previous research (Nikolic et. al., 2022), the process of deciding on project implementation consists of five steps:

- Value stream mapping
- Choosing the cell to be replaced
- Choose of robot
- Predicting future statement
- Making decisions based on KPIs

The research was done in a company engaged in the production of construction equipment. In the observed company it is conducted that implementing of robotic cell in the place of a manual cell would contribute to the process improvement in multiple ways. In the case of the implementation of the robot cycle time is reduced from 126:20 to 96:17. This research is analyzing NPV, PI and breakeven point in order to overview the effects that the company will realize in the case of implementing a robotic solution instead of a manual workstation. NPV can be described in one sentence as today's value of invested cash. The most important about NPV is the discount rate which is affected by inflation. If NPV is positive it means that today one euro is worth more than one euro in the future. There will be 60 periods included in the calculation. In Table 1 it is presented Net Present Value, cash inflows, cash outflows, as well as discounted inflows and outflows. The cash inflows include revenue increases and cost savings while cash outflows include initial investments, operating and training costs, maintenance costs and financial costs related to the project part invested from the loan.

Table 3: NPV

Year	0	1	2	3	4	Total
Inflows	121.500	243.000	243.000	263.250	263.250	
Outflows	310.000	20.000	20.000	20.000	20.000	
Discounted inflows	121.500	194.400	173.571	167.675	149.574	**806.720**
Discounted outflows	310.000	16.000	14.285	12.738	11.363	**364.386**
Cumulative	121.500	**315.900**	**489.471**	657.146	806.720	

Using the NPV function, it can be seen that the difference between the present value of cash inflows and outflows over a period of five years is 442.334 euros. As NPV is higher than 0 euros, it indicates the profitability of the project. WACC for this project is 12%. The return period is 2,34 years. The profitability index is 2,21. The profitability index is greater than 1.0, which is the index's lowest acceptable measure. In the next table, the breakeven point is presented, as well as data that are necessary for the calculation of this indicator

Table 4: BEP

	Manual workstation	Robotic workstation
Quantity	90	120
Product price	600	600
Sales revenue	54.000	72.000
Variable costs per unit	420	400
Total variable costs	37.800	48.000
Fixed costs	9.800	8.500
Profit	**9.600**	**18.200**
Breakeven point	**54**	**43**

In Table 3, the breakeven point in the case of the manual workstation and in the case of installing the robotic workstation can be seen. The breakeven point for a manual workstation is 54, whereas, for a robotic workstation, it is 43. This indicates that the company begins to realize a profit after 54 pieces, or 43 pieces of the sold product. As a result, the company starts to realize profit earlier than in the case of a manual workstation.

4. CONCLUSIONS

Industry 4.0 enable the implementation of various solutions that contribute to the improvement of companies' operations. Regardless of advanced technologies, it is important for each individual company

that the decision to invest in such solutions is adequate. Due to the high costs of some solutions, it is necessary for companies to determine how the investment will contribute to business improvement in the future and whether this improvement will meet management expectations and market demands. Given that the price of such solutions is often the biggest problem, this paper deals with the implementation of robotic solutions and examines the impact on financial indicators in case of implementation. The company in which the implementation of the robotic solution was examined deals with the production of construction equipment. The business of this company is based on Lean principles. In the previous research, a manual workstation, which should be replaced with a robot, was identified. Financial indicators that are observed in this case are NPV, PI and breakeven point.

The NPV in the case of implementation of the robot in the place of the manual workstation is 442.334 euros. This is in accordance with the theoretically defined assumption that it is necessary for the NPV to be greater than 0. When it comes to the PI, it is 2.21, while the investment return period is 2, 34 years.

The breakeven point for a robotic workstation is 43, or 54 for a manual workstation. This points to the fact that by implementing a robotic solution and saving on costs, the company will start generating profits earlier.

On the basis of all analyzed financial indicators, the conclusion is that a robotic solution should be installed instead of a manual workstation. The invested funds will be returned in an adequate period of time, the value of the capital will increase and a larger profit will be generated thanks to the difference in the costs that will be realized.

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A MACHINE LEARNING PIPELINE IMPLEMENTATION USING MLOPS AND GITOPS PRINCIPLES

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Abstract: *Automating machine learning model development and deployment improves speed, efficiency, reproducibility, scalability, reliability, and cost efficiency. It enables organizations to iterate quickly, scale effectively, reduce errors, and stay competitive in the rapidly evolving field of machine learning. The aim of machine learning operations (MLOps) is to automate the entire lifecycle of the model, from development to deployment and management in production. The paradigm of MLOps refers to the practice of applying DevOps principles and practices to the machine learning lifecycle. It combines various disciplines such as machine learning, software engineering, data engineering, and operations. Different MLOps tools are available. Each tool has its own strengths and features and its usage depends on specific requirements, infrastructure, and preferences. Organizations can combine MLOps and GitOps concepts to achieve more efficient and controlled deployments and management of ML models. In this paper we describe the machine learning pipeline that we created using available tools and following MLOps and GitOps practices.*
Key words: machine learning, MLOps, GitOps, CI/CD, operations, workflow orchestration

1. INTRODUCTION

Machine learning has become an ubiquitous term in the operations sector, buzzing with significance. Companies are actively integrating intelligent systems into their legacy infrastructure. Machine learning (ML) teams typically comprise a diverse set of professionals, including data scientists, software engineers, and machine learning engineers. MLOps enhances team collaboration by bridging the gap between development and operations, thereby improving the reliability of product development, deployment, and management (Kreuzberger et al. 2023, Testi et al. 2022). MLOps (Machine Learning Operations) is a paradigm that emphasizes the operational aspects of the machine learning lifecycle, encompassing implementation, deployment, monitoring, and management of machine learning products. By leveraging Continuous Integration/Continuous Delivery (CI/CD) practices, MLOps enables the automation of the deployment process, facilitating efficient software development (Subramanya et al. 2022).
GitOps practices and existing ML tools enhance the development and deployment of ML models, making it more efficient and straightforward. GitOps is an infrastructure and application deployment methodology that leverages Git workflows and CI/CD. All configuration files are treated as code, known as infrastructure as code (IaC), providing declarative descriptions of the desired system state. In GitOps, these files serve as the single source of truth for infrastructure and application deployments, enabling automated processes to reconcile the actual state with the desired state. Similar to how application source code generates consistent application binaries during builds, GitOps ensures that each deployment consistently generates the same infrastructure environment (Alonso et al. 2023, Yuen et al. 2021).
Various ML tools and models are available in both practice and the market. However, it's worth noting that not all ML tools in the market align seamlessly with every business's requirements. Research papers often provide comprehensive assessments of these tools and methodologies, outlining their advantages and disadvantages (Schlegel and Sattler (2022)). In this particular study, our aim was to explore and analyze the processes and open source tools that can be effectively applied to a machine learning problem following GitOps practices and providing infrastructure as a code (IaC). We created end-to-end MLOps workflow by applying the knowledge we acquired. When incorporating machine learning models into an existing legacy system, it is crucial to carefully select tools that seamlessly integrate with the system and align with the capabilities of the existing teams. In this paper we are describing practices and tools that can be applied to a legacy system with web application deployed on a cloud kubernetes cluster. We described an end-to-end MLOps architecture and workflow that takes into account software engineering practices, tailored specifically for this system.

2. OVERVIEW OF UTILIZED TOOLS

2.1 Model development and experimentation

Data scientist usually use Jupiter Notebook for writing the code. Notebooks are easy to start and use. At the beginning when you are developing proof of concept (POC) this can be enough. Once you have the POC it is time for experimentation phase. In this phase models, hyperparameters and algorithms can change in order to get the best solution. It starts to be hard to keep track of all those models, and results. It is important for results to be reproducible, and to know what model, data, and hyperparameters gave specific results. Also, in real life, after some time data sets can change. In these cases notebooks are not enough. Based on various tool reviews and considering the presence of existing legacy systems, we have opted to utilize Iterative AI Tools consisting of data version control (DVC), Continuous Machine Learning (CML) and Git Tag Ops (GTO), that enable us to effectively monitor and replicate our experiments, and also track ML model lifecycle.

Data versioning is a vital role in MLOps and it is challenging to handle when the dataset is large. Usually Git is used for versioning the code, but it is not meant to be used for versioning large data. Due to its limited upload capacity, this option is not suitable when dealing with large data. However, in such cases, DVC can be a valuable solution. DVC is an open-source platform-independent versioning system for ML applications. It helps machine learning teams manage large datasets, make projects reproducible, and collaborate better (Hewage and Meedeniya 2022). DVC enables the storage of files in a remote storage location, overcoming the limitations associated with handling substantial amounts of data. Metadata files with information about files are stored in git, but actual data is stored in DVC. That metadata file is used for data retrieval from DVC.

During the development of a model, we typically follow a series of steps, including data preprocessing, training, and evaluation. In DVC, these steps are referred to as stages. Each stage consists of a command and its dependencies, and it allows for the addition of outputs. The outputs generated by one stage can serve as inputs to subsequent stages. Stages are described in a .yaml file, which provides a clear overview of what is expected from each stage. DVC determines the order in which the stages should be executed and can cache the results of stages that haven't changed. This caching mechanism helps save time by running only the stages that have been modified. However, if the requirements file is changed, all stages will be executed. Moreover, if the dependencies for a particular stage are not met, that stage will not be executed. Outputs produced by stages can be versioned using DVC or git.

These stages, with input and output, can be viewed as experiments within the GitOps approach. In this context, experiments correspond to Git commits, eliminating the need for a separate database. Moreover, we can create distinct branches for individual experiments, allowing for parallel exploration. An editor extension further enhances the process, providing a user-friendly interface to visualize and track experiments. With the dashboard, there's no requirement to save all experiments. Instead, we can selectively choose a few and generate Git commits, discarding the rest. This lightweight, command-line tool can be seamlessly integrated into DevOps workflows, facilitating efficient experimentation.

In addition to DVC, the iterative enterprise encompasses Continuous Machine Learning (CML), which plays a vital role in enabling CI/CD for ML projects. CML relies on GitLab or GitHub actions to effectively manage ML experiments, track modifications, and automatically generate reports containing essential metrics and plots within each Git pull request. When a team of people is developing a ML model, they typically create a pull request and also include plots and metrics in the comments. Frequent iterations between data scientists are often necessary, as they need to reach a mutual understanding of the meaning and context behind these screenshots. With CML reports are automatically generated and displayed in the PR comments. In this way the entire team gains awareness of the conditions under which these plots and metrics appeared. This simplifies collaboration and pull request reviews, eliminating the need for additional screenshots, enhancing the efficiency of the development workflow.

By leveraging DVC and CML, we have successfully addressed the development and experimentation aspects of the model within a GitOps paradigm. Moving forward in the end-to-end pipeline, the next crucial component to consider is a model registry. A model registry serves as a valuable tool for cataloging ML models and their respective versions. It enables seamless discovery, testing, sharing, deployment, and auditing of models from your data science projects (GTO 2023).

To fulfill our model registry requirements, we will utilize the GTO (Git Tag Ops) tool developed by Iterative. As a product from the same company, GTO seamlessly integrates with DVC and CML, ensuring compatibility across the entire workflow. GTO follows the GitOps approach, eliminating the need for

separate databases or servers, and solely relies on the DVC and Git repository. Additionally, GTO provides support for model promotion to specific stages, allowing the model to be effectively utilized within designated environments. By assigning a specific stage and utilizing the model registry, we establish a structured approach to manage and track the progression of the ML model throughout its lifecycle. This allows for easy version control, collaborative development, and seamless integration with the deployment pipeline for subsequent stages, such as model deployment and serving.

2.2 Serving a model

To serve our model, we have two options: utilizing a REST API for real-time predictions or using a scheduler for batch processing. In the context of our ML model within a legacy system, we have chosen to adopt real-time predictions through a REST API. Our approach involves starting with a Flask application, which serves as the foundation for our system. To create a robust web server, we connect uWSGI to Flask. uWSGI acts as an application server, facilitating communication with Flask using the uwsgi protocol. To enhance connection handling reliability, we incorporate Nginx as a reverse proxy. Nginx acts as an intermediary between client requests and our Flask application, ensuring efficient and secure communication. By combining Flask, uWSGI, and Nginx, we establish a comprehensive architecture for serving our model and providing real-time predictions via a REST API. (Relan 2019)

2.3 Deployment and Scalability with Containerization

There are third-party tools available for containerizing ML models. These tools are typically designed to be user-friendly and offer support for various platforms. However, one drawback is that they are often presented as black boxes, making them difficult to debug. Additionally, there is uncertainty regarding their compatibility with air-gapped networks. Therefore, we have chosen to create our own Dockerfile to have more control and flexibility in these aspects. To containerize the ML model (Karamitsos 2020) using Docker, we will follow a two-stage approach defined in the Dockerfile. In the first stage, we will download the model from the GTO registry using DVC. The downloaded model will then be stored in a specified path.

Moving on to the second stage in the Dockerfile, we will install all the necessary dependencies required for serving the ML model. This ensures that the container has all the required software components to run the model successfully. Additionally, to enhance security, we will configure the container to run as a non-root user, mitigating potential risks.

Finally, the Dockerfile will enable the container to serve the ML model, allowing it to handle incoming requests and provide predictions or insights based on the input data. Our ML model will not be directly exposed to the public network. Instead, we will have a backend service that will communicate with the model via its API.

By leveraging Docker technology and following this approach, we can encapsulate the ML model along with its dependencies and security measures within a self-contained and portable container. This containerization process greatly simplifies the deployment and scaling of the model across various environments, ensuring consistent performance and ease of management (Filippou 2023).

3. CONTINUOUS INTEGRATION AND WORKFLOW EXAMPLE

Figure 1 shows the MLOps pipeline for CI/CD. During the experimentation phase, we will create different branches for model testing and hyperparameter tuning. These branches correspond to the development environment, which is meant for separate ML model testing. Training input data, test data and model are stored on a remote storage, using DVC. Whenever we push something to these branches, GitHub actions are triggered, and a CML report is printed in the comments. We will also utilize GitHub actions to register and push the model in the GTO registry. If a model with the same name already exists, its version will be incremented, and the tag will be pushed to the Git repository.

In our Git repository, we have three additional branches: "main", "staging" and "production." The "main" branch corresponds to the development environment, while the "staging" and the "production" branch refers to the staging and production environment, consequently. In development environment, the model is seamlessly integrated with the existing legacy system and thoroughly tested together. This integration and testing phase ensures that both the model and the code function harmoniously within the larger system. Once the model and code pass all the necessary tests in the development environment

it is deployed to staging environment, following the process shown in Figure 1. A staging stage serves as a checkpoint to ensure the model is thoroughly evaluated before moving it to production. When the model successfully passes all the required tests in the staging environment, the staging branch is prepared for merging into the production branch.

When we are satisfied with an experiment and the model in a specific (experimental, development, or staging) branch, and when we want to deploy this model to the specific environment (development, staging, or production), we create a pull request (PR) to merge this branch with the branch that represents the environment where we want to deploy the model. We can only merge the experimental branch into the development branch, the development branch into the staging branch, and the staging branch into the production branch. This approach ensures that the model successfully traverses all the required environments and passes all necessary tests. It is expected that, after merging and utilizing CI/CD processes, this code and the model will automatically end up in the development and staging environment.

When a pull request (PR) is created, a GitHub action will be triggered. In the first step of the action, the corresponding model for the branch being merged will be obtained. Leveraging DVC, a simple 'dvc pull' command is sufficient to download the required model based on the metadata stored in the Git repository for that specific branch. Once obtained, the model will be assigned a 'dev', 'staging' or 'production' stage, depending on the branch to which the code is being merge, indicating that it is ready for further testing or validation. The model version, along with its associated artifacts, will then be pushed to the model registry. Moving on to the second stage of the action, the model will be packed into a Docker image. The Docker image will be built using the instructions provided in the Dockerfile. To ensure proper versioning, the image will be tagged using the git commit hash, which serves as a convenient way to associate the image with the specific code corresponding to it. Additionally, the image will be pushed to the container registry, making it accessible for deployment and utilization. Finally, when GitHub actions are triggered, a CML report is printed in the comments of the PR.

By following this workflow, the GitHub action automates the process of obtaining the required model, building the Docker image, and versioning it appropriately. This streamlined approach simplifies the deployment and management of the ML model, ensuring that the correct model and corresponding code are utilized in each image.

When the model successfully passes all the required tests in the staging environment, the staging branch is prepared for merging into the production branch. A pull request (PR) is created for this purpose. We repeat the GitHub actions for model promotion and pushing to the registry, but this time the model is promoted to the "production" stage. However, it's important to note that the code and model changes are not directly applied to the live environment. The deployment strategy for the production environment can vary depending on the specific problem and requirements. Some strategies may include automatic promotion without customers noticing the deployment, while others may require temporary unavailability of the system during manual trigger-based deployments. Since the deployment strategies for the production environment are highly specific to the problem at hand, it is beyond the scope of this paper to delve into them further. By adhering to these practices, we ensure a controlled and reliable deployment process that incorporates collaboration, thorough testing, and appropriate promotion of the model and code to the production environment.

In our workflow, we prioritize a collaborative and controlled approach for applying changes to the production environment. To ensure quality and consistency, we have specific requirements in place. Firstly, we require at least one PR approval, signifying that the proposed changes have been reviewed and accepted by the team. Additionally, we expect all tests, as defined in the GitHub repository, to pass successfully. To maintain a structured and reliable deployment process, direct pushes to the main, staging or production branches are not allowed.

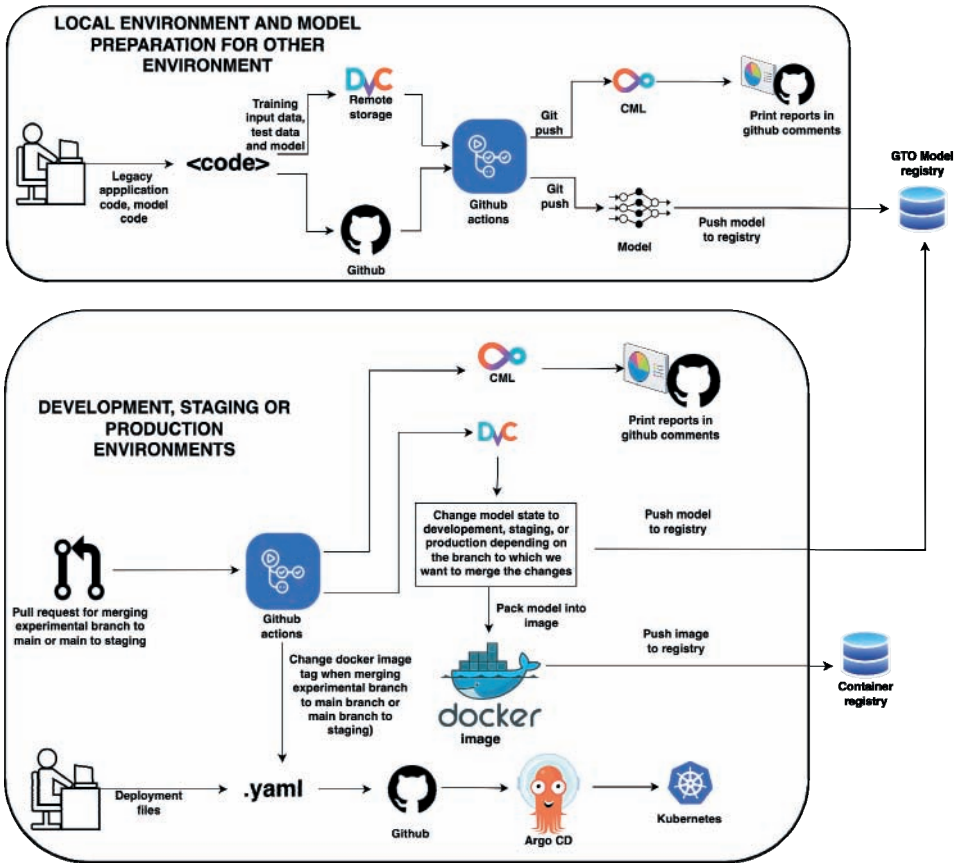

Figure 1: ML pipeline for CI/CD

4. DEPLOYING TO KUBERNETES

To maintain the GitOps approach throughout the deployment phase, we have established a separate repository to store all the deployment-related files for ML model and also the existing legacy code. For deploying the model, we will leverage the Argo CD tool. Argo CD is a declarative, GitOps continuous delivery tool designed specifically for Kubernetes environments (Argo 2023). In our deployment setup, Git repositories serve as the source of truth, defining the desired application state. We will have a deployment file that represents the native Kubernetes operator (Kubernetes 2023). This file will specify details such as the container image with its tag, the command to be executed, the required resources, and health checks. Additionally, we will have a separate file for the service definition that specifies the deployments. We will have all these files for every environment. So we will have three sets of these files. To utilize Argo CD, it will be installed in the Kubernetes cluster. Argo CD provides a user-friendly UI that simplifies tracking and monitoring of the deployed applications across various environments. In the YAML files we will provide information about the Git repository and the branch we want to deploy from. Argo CD will then compare the provided YAML files with the current state of the cluster, identifying any discrepancies. Argo CD looks at the provided yaml files and to the cluster and tells if it is out of sync. When you initiate a sync operation in Argo CD, it will deploy any differences detected between the desired state defined in the Git repository and the current state of the cluster. It offers an automated sync policy, which means that every time a commit and push occurs in the Git repository with changes to the manifests in the tracking Git repository, Argo CD will automatically perform the deployment.
In Figure 1, we can see how Argo CD fits in the whole pipeline. In addition to pushing the versioned and staged model to the model registry and pushing the Docker image to the registry when merging the experimental branch to the development branch or development to staging, GitHub Actions will include a third step. This step will modify the repository's deployment files by updating the Docker image tag for the specific environment. For example, if we are merging the experimental branch to the main branch, it will modify the deployment file for the development stage, allowing us to observe the new container in the development stage. Similarly, it will update the staging deployment file when merging the main branch to staging. This process enables Argo CD, which is set to automatic sync policy, to compare the

newly provided YAML file and identify the changed Docker tag. As a result, Argo CD will automatically deploy the new model and image to the corresponding environment. Additionally, Argo CD will update the environments every time the developer makes some changes to the deployment metadata files.
By leveraging Argo CD's GitOps approach, we ensure a streamlined deployment process, where the desired state is defined in Git repositories and seamlessly synchronized with the Kubernetes cluster. This setup enables easy tracking, automated deployments, and ensures consistency across different environments.

5. CONCLUSIONS

In this paper, we described the machine learning pipeline that can be applied to the legacy software system already deployed in the cloud. Using this end-to-end pipeline, the process can be fully automated using open-source GitOps tools. These tools have helped us automate the entire ML model development lifecycle, from training to deployment. The proposed workflow ensures that ML models are always up to date and in sync with the latest changes in the code. It enables us to version and track not only the model code but also the data, hyperparameters, training configurations, and experiments. By maintaining a history of experiments and their associated results, we can make more informed decisions about model improvements and optimizations. By incorporating GitHub Actions, following GitOps principles, and utilizing GitOps tools, you can streamline the development, deployment, and maintenance of ML models, fostering collaboration, reproducibility, and overall quality. In our future work, we will attempt to implement the proposed pipeline using the recommended tools. Additionally, we will explore deployments strategy in order to apply it to the production environment. Finally, we will explore methods for model retraining and monitoring.

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METAL ADDITIVE MANUFACTURING WITH TOPOLOGY OPTIMIZATION METHODOLOGY FOR INNOVATIVE STRUCTURAL DESIGN

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Abstract: *Metal additive manufacturing (MAM) is an exciting manufacturing process that has recently received a lot of scientific attention due to its ability to develop stress-optimized structural elements and products in a material-efficient, cost-effective manner. Indeed, MAM also known as rapid prototyping or three-dimensional printing of metal products, is one of the most promising aspects of manufacturing highly complex geometries. It is now regarded as a source of opportunities for achieving true design-optimized manufacturing through topology optimization methodology. This methodology can improve material distribution by generating complex geometries that are easily built layer by layer using data from a three-dimensional (3D) model. The article is intended to explore the current state of process development and investigates the future potential of topology-optimized design approaches for MAM in developing lightweight and effective products. It discusses the most recent research efforts and topology optimization applications on various products and how current techniques can produce structural elements with significant weight reduction. The study demonstrates the need for additional research in industrial structure optimization and design, and it emphasizes the importance of integrating appropriate material, process, structure efficiency, and performance characterization when using topology optimization to pursue flexible and high-performance products.*

Key words: additive manufacturing, computer-aided engineering (CAE), 3D printing, topology optimization

1. INTRODUCTION

Modern manufacturing aims to create sophisticated products that are functional, precise, light in weight, and, ideally, low in cost and production time. Additive manufacturing (AM) is a promising manufacturing technique that has met these expectations and promises many more. Originally designed for rapid prototyping with polymers (Pellens et al., 2020), this manufacturing process drew a lot of attention and sparked the development of other manufacturing techniques with similar methodologies for the development of products with complex geometries. The properties of the functional parts produced by AM are similar to those produced by traditional manufacturing techniques, but without material subtracting, allowing for the development of new product designs and solutions that are more appealing to the industry. Product design optimization and material advancement are regarded as the most important factors for innovative design solutions for products that can be manufactured using AM (Gebisa & Lemu, 2020). AM technologies enable the creation of products from a diverse range of materials, such as metals, polymers, ceramics, and composites (Uralde et al., 2022; Armstrong et al., 2022), and as a result, it is widely used in almost every industry, including aerospace, automotive, biomedical, energy, tooling, and construction (Uralde et al., 2022).

In recent years, most of the research has been focused on developing perfect algorithms for topology optimization (TO) of products that can be accurately manufactured with AM. Topology optimization is a sophisticated numerical iterative tool for creating parts with optimized material distribution within the constraints of a specific design while meeting specified load conditions, effectiveness, and boundaries (Pellens et al., 2020; Gebisa & Lemu, 2020; Zhu et al., 2021). This tool can be used to advance AM technology if successful algorithms are developed (Gebisa & Lemu, 2020). Metal additive manufacturing (MAM) undoubtedly made the greatest impact across a variety of industries (Armstrong et al., 2022). In addition to producing products with complex geometries that would be challenging to produce using any other conventional manufacturing process, it is expected to result in significant energy and material savings, lowering costs, and reducing environmental impact (Uralde et al., 2022). Lattice and topologically optimized structures are two examples of geometrically complex structures, primarily used to provide specified mechanical properties such as stiffness and impact absorption (Abdi et al., 2018). Indeed, topology optimization of structures and the use of lattice infill are two dominant strategies for designing

next-generation lightweight structures (Wu et al., 2021). The combination, i.e., topology optimization of multi-scale structures, thus holds the promise of overall superior performance (Wu et al., 2021).
The lattice structure is a porous material that emphasizes the potential coexistence of efficiency and weight reduction (Abdi et al., 2018). It is created by repeatedly using lightweight unit cells that have excellent properties and require little material (Abdi et al., 2018; Alkebsi et al., 2021). These cells can be categorized as 2D or 3D and have the potential to have different aesthetics and characteristics (Gao et al., 2019). Furthermore, it has a high degree of stiffness and energy absorption (Abdi et al., 2018). To problems with multiple objectives or uncertain loading conditions, lattice structures have the intriguing property of being more resilient than topology-optimized solutions (Abdi et al., 2018; Gao et al., 2019).
Topology optimization is a newer structural optimization technique that is based on design variables. Depending on the domain and design properties, structural optimization can be used in both continuum and discrete structures. The optimal solution for the perfect design is obtained systematically over several iterations. Figure 1 depicts the process of topology optimization (Zhu et al., 2021).
When designing topology-optimized structures, AM allows engineers to overcome the limitations of traditional manufacturing techniques, allowing them to focus on designing lightweight and high-performance structures (Zhu et al., 2021). The combination of topology optimization and additive manufacturing is an important step toward combining structural design and manufacturing. Aside from the vast manufacturing potential, AM introduces new engineering constraints and challenges, such as precision, structural connectivity, additional support structure, surface roughness, material properties, and so on (Zhu et al., 2021).

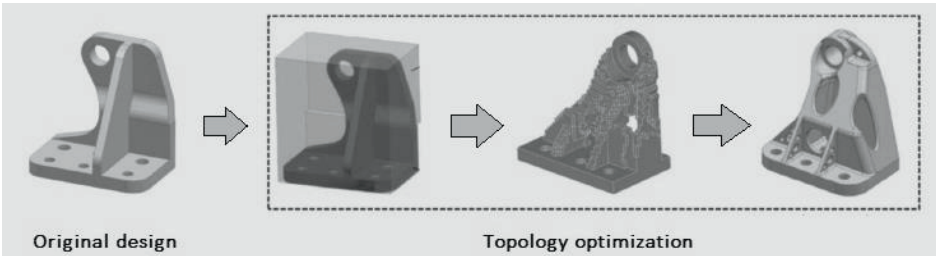

Figure 1: Topology optimization of an aerospace bracket design results in a weight reduction of 18% (Zhu et al., 2021)

This article covers several topics, including the basics of the TO process with discussions on its constraints, the benefits of its application, and the combination of AM and TO when producing metal parts in the second section. The third section provides a general description of metal additive manufacturing techniques and classifications, as well as the discovered relationship between design and redesign in additive manufacturing processes and discusses the process's sustainability and challenges. The last section concludes with a summary of the challenges and possible next steps.

2. TOPOLOGY OPTIMIZATION OF STRUCTURES FOR ADDITIVE MANUFACTURING

Topology optimization of structures provides a design solution with optimal size, shape, and material distribution while meeting product performance expectations. Depending on the manufacturing process, this technique combines Computer-Aided Design (CAD), Finite Element Analysis (FEA), and various algorithms (Gebisa & Lemu, 2020). CAD is used to create the initial model that will be used in FEA software to analyze stress and displacements when the part is subjected to specific loading conditions. This data is critical for TO, which involves removing sections of the part that do not carry any loads or have significant deformations. There are numerous topology optimization techniques, as shown in Table 1 (Ibhadode et al., 2023). The structure's design is modified within the constraints of known essential requirements. There may be goals like maximizing stiffness, as well as constraints like maximum deformation, stress, mass, or other variables that are critical to the part's performance (Gebisa & Lemu, 2020). The process continues with remodeling and correction of the obtained topologically optimized structure in CAD. The new design is validated in FEA software before it is used in manufacturing. With FEA the optimization is simplified to the analysis of properties of finite elements (Abdi et al., 2018).
Structural TO techniques provide numerous advantages in design, including time, processing energy, and material savings (Gebisa & Lemu, 2020). The best TO solution for a specific design can only be obtained by following the proper steps throughout the process. The first step is to establish clear criteria, which is

followed by data collection and proper variable identification and definition (Gebisa & Lemu, 2020). The following step is to define evaluation criteria and to specify when the optimization process should be stopped (Gebisa & Lemu, 2020). The last step is to identify constraints (Gebisa & Lemu, 2020).

Topology optimization is an excellent design tool for creating specific designs that can be manufactured by AM, a new process that produces parts layer upon layer, allowing for easy and quick production of products distinguished by shape, materials, and functional complexity (Gebisa & Lemu, 2020). It can be used for new designs and redesigns of existing lightweight products with solid or cellular structures within. Figure 2 depicts the product development process using TO. The initial design of the structure in CAD software is topology optimised to a new design over several iterations in which variables and constraints are calculated (Pellens et al., 2020). After obtaining the final design, the following step is using AM to produce the structure. Although additive manufacturing has the potential to produce parts with complex geometries and shapes with high accuracy, the new design can introduce new constraints, defects, a lack of connectivity between layers, additional support structures, surface roughness, and other issues (Zhu et al., 2021). For maximum product performance, deep integration of product design and manufacturing with considerations of AM constraints and material properties is required (Zhu et al., 2021).

Additive manufacturing with TO in mechanical design and manufacturing is an intriguing topic for many researchers, with applications in a wide range of industries. However, due to the requirements of multiscale and multi-functional structures, topology optimization and its numerical design schemes still have a lot of content to develop (Pellens et al., 2020; Zhu et al., 2021). To realize the integration of material, structure, process, and performance, AM itself must be improved by predicting and controlling its material mechanics behaviors, and fabricating more complex functional structures (Zhu et al., 2021).

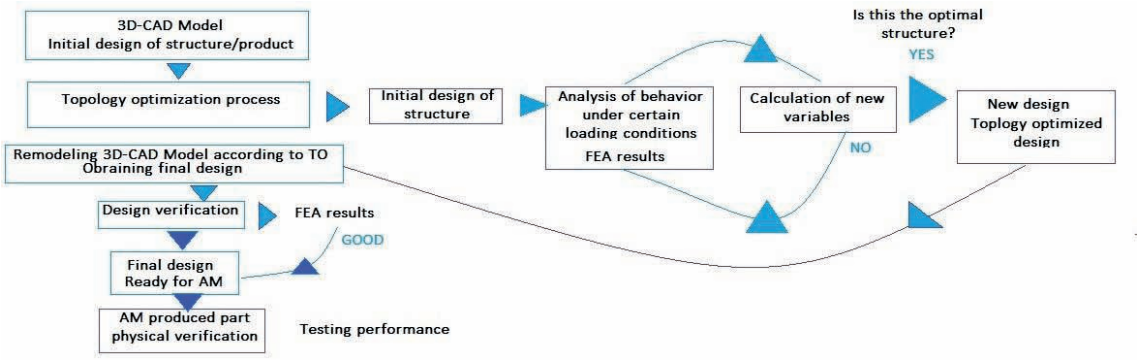

Figure 2: Topology optimization in the process of product development

Table 1: Topology optimization classification (Ibhadode et al., 2023).

Topology optimization	Density-based	Solid isotropic material with penalization
		Rational approximation of material properties
		Coined from the hyperbolic trig. function SINH
	Hard-kill	Evolutionary structural optimization
		Bi – evolutionary structural optimization
	Boundary variation	Level set
		Phase field
	Non-gradient methods	Genetic algorithm
		Particle swarm optimization
		Simulated annealing
		Artificilal inteligance

The advantages of combining TO and AM in machine design and manufacturing have resulted in a wide range of applications in industries such as aerospace, automobiles, aviation, medicine, and so on (Pan et al., 2020). The design of parts with high stiffness while being small and light results in lower fuel consumption, increased quality, and carrying capacity (Alkebsi et al., 2021). Cellular and lattice structures are primarily used in the design of engineering elements and parts and are regarded as an excellent solution for lowering manufacturing costs while increasing carrying capacity. Lattice structures' excellent properties make them ideal for the development of structures with improved manufacturing

performance (Pan et al., 2020). Furthermore, lattice structures are biocompatible and strong, with the ability to be designed to mimic the shape of human tissue and bone to replace diseased organs (Pan et al., 2020). Figure 3 shows two examples of products fabricated with TO and AM (Wu et al., 2021).
Topology optimization generates lattice structures with enormous potential for AM lightweight designs, but there can be issues such as overhang constraints, and each part must be additionally supported to prevent warping and collapsing (Gao et al., 2019). Removing the support materials after AM can be a waste of time, energy, and materials, as well as cause part damage. Topology-optimized self-supporting structures may be a solution to this problem.

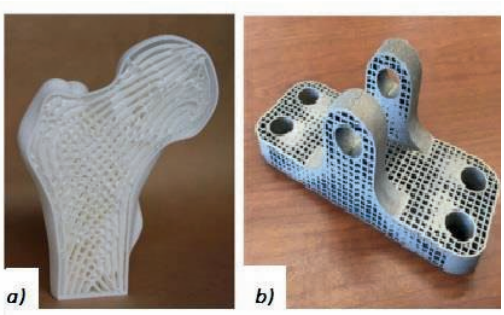

Figure 3: 3D multiscale structures designed with topology optimization and produced with AM, a) bone-inspired infill structures, b) variable density lattice structure (Wu et al., 2021)

The combined use of lattice structure and additive manufacturing technology is a game changer in industrial design. AM technology allows for design flexibility, a wide range of sizes, the use of different materials, the creation of a program for automatic processing, and the saving of energy and money [8Pan et al., 2020). Support materials must be added when designing lattice structures with suspended geometry, which results in material waste and increases post-processing time (Pan et al., 2020).

3. METAL ADDITIVE MANUFACTURING

Metal additive manufacturing (MAM) began in the early 1990s with the creation of a binder jetting printer (by Ely Sachs and co-workers), which used inkjet printer heads to spray layers of metal powders with adhesives that held them in place, resulting in a 3D part (Pragana et al., 2021). The next steps in evolution led to the use of high-energy lasers for metal powder processing and the development of direct metal laser sintering (DMLS), which was based on the technology proposed for additive manufacturing of polymers (Pragana et al., 2021). The use of an electron beams thermal energy source in MAM began in the late 1990s, with the development of the so-called "3D welding" technique, which combined traditional welding techniques with robotics (Pragana et al., 2021). This process opened new possibilities for using an electric arc and computer-aided manufacturing (CAM) software to control the movement of the tool as it built the 3D metal part layer by layer. This is known as wire-arc additive manufacturing (WAAM), and the feedstock is welding wire. MAM techniques have been continuously developed and improved over the years.
Different classifications of processes were made in various literature as AM techniques evolved. The most fundamental classification is based on the following criteria: base material (polymer, ceramics, metals); bonding method (direct and indirect process); and raw material input state (liquid, molten, powder, solid layer)(Frazier, 2014; Yakouta et al., 2018). Another classification of AM systems exists to differentiate technologies: powder bed, powder feed, and wire feed systems (Armstrong et al., 2022; Frazier, 2014). These systems can use a variety of energy sources: electron beams, lasers, arcs, and so on. According to the EN ISO/ASTM 52921 (2015) standard, additive manufacturing processes are classified into seven types based on adhesion and bonding method: VAT photopolymerization, material jetting, material extrusion, powder bed fusion, binder jetting, direct energy deposition, and sheet lamination (Pragana et al., 2021; Yakouta et al., 2018). Binder jetting (BJ), powder bed fusion (PBF), sheet lamination (SL), and direct energy deposition (DED) are four of these categories that are now used to manufacture metal parts. When it comes to metals, the other three categories, vat photopolymerization (VP), material jetting (MJ), and material extrusion (ME), are mostly used as indirect additive manufacturing (Pragana et al.,

2021; Yakouta et al., 2018; Zhang et al., 2018). These metal-testing processes are in the early stages of development; commercial systems do not exist (Zhang et al., 2018).
MAM processes can be direct or indirect, depending on the stage of final product development, whether they are produced according to design and requirements, or if additional traditional manufacturing processes are required to obtain the final product (Pragana et al., 2021). Indirect MAM is used in conjunction with processes such as investment casting, sand casting, die casting, and injection molding, and it is primarily used for 3D printing of nonmetallic materials such as polymers, photopolymers, ceramics, waxes, resins, and composites (Pragana et al., 2021). The MAM process consists of several stages that vary depending on the type of product created. Before printing larger quantities, it is sometimes necessary to print a prototype to determine sustainability. Furthermore, certain parts necessitate the use of postprocessing treatments and quality inspections. Figure 4 depicts a schematic representation of the MAM's basic workflow.

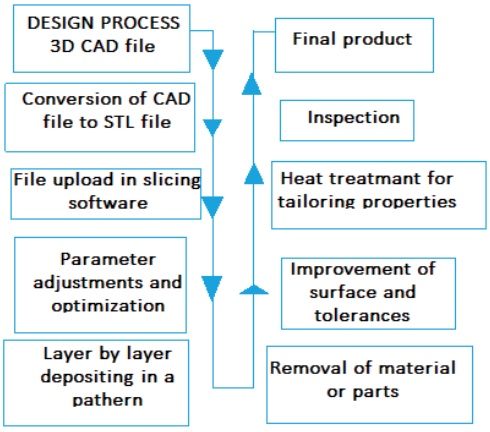

Figure 4: Basic workflow of MAM process

Additive manufacturing processes are thought to be less efficient than traditional manufacturing methods. There are up to 85% differences in energy consumption when using wire feedstock versus powder feedstock (Bambach et al., 2017). Power consumption has a significant impact on process costs, but little research has been conducted on this topic. Hybrid process combinations can accelerate process integration on an industrial scale by increasing build-up rates (Bambach et al., 2017).

4. CONCLUSIONS

This paper aims to summarise fundamental knowledge of topology optimization and additive manufacturing techniques for metal product fabrication. It discusses the benefits of using TO tools in design and manufacturing, as well as how TO and AM work together to create high-performance, multifunctional, and lightweight structures. In conclusion, this article discusses the stages of structural optimization for AM, as well as how to apply these methodologies. It emphasizes the importance of structural design optimization based on novel configurations such as lattice structures within design constraints and functional requirements.
The field of MAM is exciting and advancing at a rapid pace (Armstrong et al., 2022; Yakouta et al., 2018). Innovative methods and applications continue to emerge, and more R&D is required to address challenges in:

- process control and modeling to ensure quality, consistency, and reproducibility across AM machines,
- optimization and design of practical industrial structures,
- characterization of the performance of scale-related lattice structures,
- understanding relationships between topologically optimized structures and material properties,
- effect of the AM process on material anisotropy and fatigue performance,
- design and manufacturing of complex multi-material functional systems,
- influence of AM processing parameters on microstructures, surface features, and mechanical properties by experiments or modeling
- hybrid and multi-material additive manufacturing.

This knowledge can be used to predict and optimize the desired physical and mechanical properties, as well as to create strategies for AM materials design or inverse design. Metal additive manufacturing has expanded its applicability in recent years; therefore, further research incorporating `numerical tools such as topology optimization methods, parameter optimization in additive manufacturing, and incorporating designs using graded cellular structures under mechanical and thermal loads is required. Many limitations and challenges exist in recently developed metal additive manufacturing processes, such as process repeatability, complex thermal stresses, and material microstructural implications (Yakouta et al., 2018). These factors influence the density of additive parts, and thus all mechanical properties and material properties.

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DETECTION OF ANOMALIES ON THE SURFACE OF WORKPIECES PRODUCED ON CNC MACHINES

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Abstract: *Poor working conditions, insufficient technology, and other factors can all have a substantial impact on the quality of manufactured components throughout the CNC manufacturing process. Poor quality is usually obvious in the form of surface abnormalities among work item flaws. Detecting these flaws guarantees both a defined quality and a high qualifying percentage. A non-manual visual inspection strategy for anomaly identification is necessary to overcome these challenges. Visual inspection automation in industrial products, such as defect inspection and anomaly recognition, is a crucial task in computer vision. As a result, ASAD (Autonomous workpiece surface anomalies detection) based approaches have grown in popularity among manufacturers for surface anomaly detection because they provide an efficient solution to address the disadvantages of human inspection such as low accuracy, poor real-time performance, subjectivity, and labor intensity. This paper describes the application of the Segment Anything Model (SAM) and Convolutional Neural Networks (CNN) to the analysis and image processing of workpieces produced on CNC machines to detect surface scratches and anomalies.*

Key words: image segmentation, instance segmentation, semantic segmentation, computer vision, work piece elements

1. INTRODUCTION

Modern production is based on CNC machines, and one of the most important tasks is ensuring high product quality (Wang *et al.*, 2018). However, the presence of anomalies or defects on these surfaces can lead to significant issues, such as reduced functionality, compromised structural integrity, and increased product failure rates. Traditionally, surface inspection in manufacturing settings has relied heavily on manual labor, human visual inspection, and conventional non-destructive testing (NDT) techniques. While these methods have served their purpose, they are often time-consuming, labor-intensive, and prone to human error. With the rapid advancement of artificial intelligence (AI) and computer vision, these techniques are increasingly being used for surface anomaly detection (Tao *et al.*, 2018).
Autonomous Workpiece Surface Anomaly Detection (ASAD) is an innovative approach that utilizes artificial intelligence (AI) and machine learning techniques to autonomously detect and classify anomalies or defects on the surfaces of workpieces in manufacturing processes (Saberironaghi, Ren and El-Gindy, 2023). ASAD aims to enhance the efficiency, accuracy, and reliability of surface inspection, ultimately improving product quality and reducing costs associated with manual labor and rework. Object detection algorithms can operate in real-time, enabling ASAD to detect and classify anomalies as workpieces move along the production line. This ensures prompt identification and immediate corrective actions, minimizing the impact of faulty workpieces on subsequent manufacturing processes.
This study explores the use of the Segment Anything Model (SAM) (Kirillov *et al.*, 2023) and Convolutional Neural Networks (CNN) for the analysis and image processing of workpieces produced on CNC machines to detect surface scratches and other anomalies (Medojevic and Ilic, 2023).

2. METHODS

The analysis of the quality of the workpieces begins after the completion of the CNC milling/turning process. The workpiece is transported to the quality control area and placed on rotating rollers (Fig 1.), two cameras that record the object being analyzed from above and from the side as it rotates. The cameras are based on a 5-megapixel OV5647 sensor, with adjustable focal length, 1/4" CCD size, 2.0 aperture, 6mm focal length, and 60.6° (diagonal) viewing angle. Moreover, the best sensor resolution is 1080p.

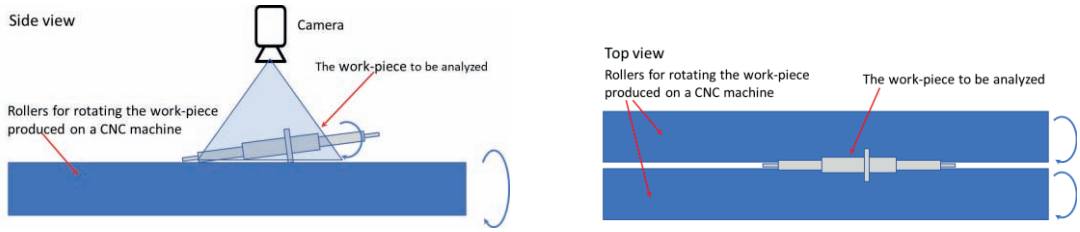

Figure 1: Quality control area with rollers

An overview of the workpiece anomaly detection system is presented in Fig. 2. The segment anything model (SAM) is capable of zero-shot generalization, so it can be used for the segmentation of objects in images without initial training (Kirillov *et al.*, 2023). The SAM model can analyze images from a wide range of areas, including biomedical, agricultural, and autonomous driving, as well as objects manufactured on CNC machines.

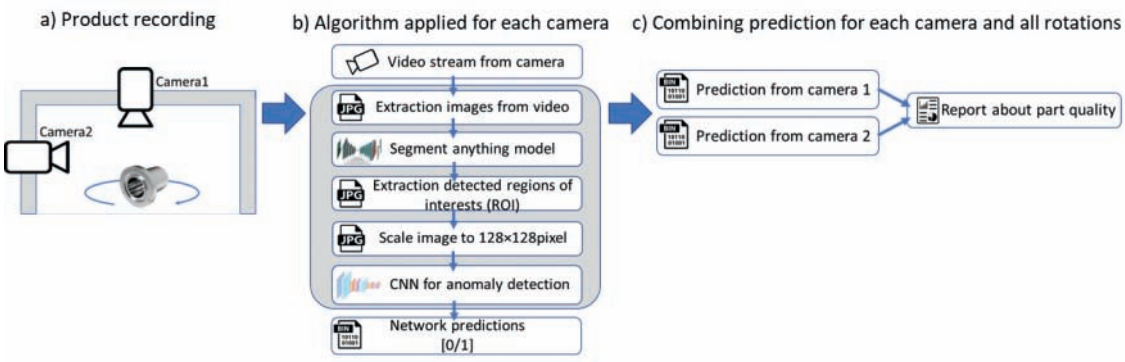

Figure 2: Overview of system for detection of work piece anomalies

Based on the bounding boxes detected using the SAM model, parts of the image are selected, which are then cropped and scaled to a standard size and then sent to a convolutional network (CNN) that is used to detect anomalies on the surface of the workpiece. The SAM model can be used to detect the position of complete workpieces, but also in the case of analyzing more complex workpieces consisting of several parts, the SAM model can determine the positions of each of the segments that would be individually cropped (see Fig 3) and then sent to the CNN network for anomaly detection.

The size to which the cropped image will be scaled depends on the type of element being analyzed, as well as whether we are analyzing the complete element or individual segments of the workpiece. If the complete working element is analyzed using a convolutional network, the cropped image is scaled to the dimension 512×512, but if we decide to analyze the segments of the workpieces individually, then we can scale each segment to a smaller dimension of 128×128.

CNN is a type of neural network commonly used for image and video processing tasks. The image to be processed is fed to the input layer of the convolutional network. The CNN network model used for the detection of anomalies on the product surface is located on the input layer of the expected image with dimensions of 512×512 pixels (complete workpieces) or 128×128 pixels (segments of workpieces). After the input layer, there are several convolutional and pooling layers, followed by a pair of fully connected layers. At the output of this convolutional network, one value is obtained, where the value 1 indicates the correct product, and 0 indicates incorrect products.

The dataset for training the CNN networks is generated by selecting a few good products, and as many damaged products as possible with scratches and other surface anomalies that need to be identified. Each of these products is then placed on a rotating platform and recorded using two cameras. In this way, several hundred images from different angles are collected for each product. When labeling images of correct products, all selected images can be automatically assigned label 1, which indicates that the image shows a defective product. However, when labeling an image of defective products, it may happen that damage is visible on some parts of the product, pictures where such damage is visible are given a label of 0. However, when labeling images of defective products, depending on the recording angle of such a damaged product, it may only be visible from some angles and not from others. If damage is visible

on the extracted images of such a working element, label 0 is assigned, and if the damage is not visible, label 1 is assigned. To automate the labeling process as much as possible and reduce the time for manual labeling, an active learning procedure can be applied to identify inconsistencies in data labeling in the dataset (Ilić and Tadić, 2022).
The cameras are connected to the Raspberry Pi Compute Module 4 (RPI CM4) I/O board, which runs algorithms based on machine learning. CM4 is a System on Module (SoM) that includes a CPU, memory, eMMC Flash, and power circuits. The module enables the utilization of the hardware and software stack in customized systems and form factors. Individual frames are taken from the video stream, and each frame is processed using the segment anything model to determine the bounding boxes.

3. RESULTS

Figure 3 shows a) an image of one of the workpieces produced on a CNC machine b), and c) an image generated by the SAM model where all the detected segmentation masks on which the detected segments of the workpiece can be seen are shown in different colors, and image d) they can be seen bounding boxes around the detected segments of the workpiece.

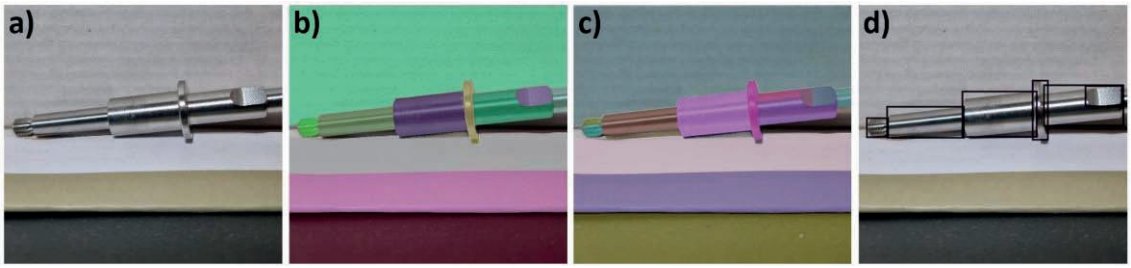

Figure 3: a) Original image of workpiece produced on CNC machine, b,c) Image processed with the SAM model, d) bounding boxes around the detected segments of the workpiece.

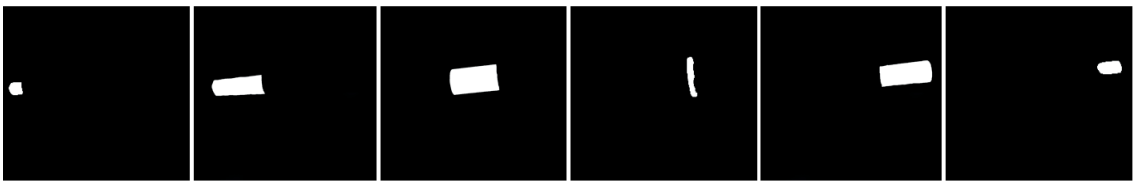

Figure 4: Segmentation masks generated by the SAM model

Figure 4 shows some of the segmentation masks of detected workpiece segments.
This project is still in the development phase, the CNN anomaly detection network was tested on a preliminary dataset that was generated based on available workpieces that were recorded while rotating on rollers in the control area. More than 15,000 images were extracted from such videos. The dataset was then split into 80% for training and 20% for testing. The accuracy of detection of anomalies and scratches on extracted images is 91.3%.

4. DISCUSSION

In this approach, objects are rotated on rollers and individual images are extracted from the video stream, resulting in recordings from multiple angles, allowing the machine learning model to detect scratches on workpieces from the angle of recording where the scratches are most visible. The product to be analyzed is placed on rotating rollers, while the process is video recorded with a 15 images per second frequency, so that in a few seconds, several hundred images of one product taken from several angles can be obtained. The developed software solution is primarily intended to detect surface scratches by gripping machine tools and classify results into two categories - products without surface scratches, and products with scratches. As work piece elements produced on CNC machines have highly reflective surfaces, so scratches are not easily noticeable, each of the images extracted in this way is analyzed by a convolutional network. Since there are a large number of images of the same object, if the scratches are

not detected from some angle, it is enough to detect them from the angle from which they are most noticeable. As the paper reflects early project development stage, the provided approach still hasn't been tested in relevant environment, and the preliminary results obtained, still need to be validated via practical deployment.

5. CONCLUSIONS

The presented approach for autonomous detection anomaly on workpiece surface offers significant benefits over manual checking, including increased efficiency, enhanced accuracy, comprehensive coverage, cost savings, data-driven insights, and scalability. By leveraging AI and machine learning technologies, ASAD revolutionizes surface anomaly detection in manufacturing, enabling improved quality control and increased productivity.
Similar environments for ASAD can be easily scaled up or adapted to different manufacturing settings, product types, or surface materials. It can accommodate variations in workpiece sizes, shapes, or surface textures, making it suitable for a wide range of manufacturing types. Such environments are suitable to integrate ASAD into existing production lines or quality control systems, due to efficient implementation and deployment.

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DIGITAL KAIZEN: OPPORTUNITIES AND CHALLENGES IN INDUSTRY 5.0

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Abstract: *Kaizen, a continuous improvement methodology, serves as a fundamental element for companies to maintain their competitiveness in an increasingly demanding market. The advent of Industry 4.0, with the support of Kaizen, has been considered to answer these never-ending demands by bringing significant transformations in manufacturing processes through the integration of digital technologies. However, most of the Industry 4.0 implementation challenges report a lack of human resources, as one of the biggest managerial obstacles. Therefore, society moved toward the next phase of the industrial revolution, Industry 5.0, which has a focus shift beyond automation to the integration of human intelligence with advanced digital systems. Thus, Industry 5.0 promotes a human-centric approach to implementing digital sustainable technologies for continuous improvement – Digital Kaizen. This research examines Digital Kaizen, as Industry 5.0 continuous improvement methodology enabled by advanced technologies, mostly human-cyber-physical systems (HCPS) and artificial intelligence of things (AIoT) to be used to improve the workforce's productivity, rather than simply to replace workers.*

Keywords: Digital Kaizen, Smart Manufacturing, Continuous Improvement, Literature Review

1. INTRODUCTION

In an increasingly competitive market, companies must constantly seek ways to improve their processes and maintain their competitiveness. Kaizen, a renowned continuous improvement methodology, has long been recognized as a fundamental element for achieving these objectives (Janjić *et al.*, 2019). With the emergence of Industry 4.0, the integration of digital technologies has brought significant transformations to manufacturing processes, enabling companies to address the ever-increasing demands of the market. However, despite the benefits of Industry 4.0, many implementation challenges persist, with a notable obstacle being the lack of human resources in managing these transformations (Bajic *et al.*, 2021; Papetti *et al.*, 2020; Rikalovic *et al.*, 2022).

Recognizing the limitations of Industry 4.0 and the need for a human-centric approach, the concept of Industry 5.0 has emerged as the next phase of the industrial revolution (European Commission, 2021, 2022). Unlike its predecessor, Industry 5.0 emphasizes the integration of human intelligence with advanced digital systems, moving beyond mere automation (Bajic, Suzic, *et al.*, 2023; Ghobakhloo *et al.*, 2023). This paradigm shift aims to leverage the strengths of both humans and technology, promoting a collaborative and synergistic relationship to achieve sustainable improvements in manufacturing processes (European Commission, 2019).

Within the framework of Industry 5.0, a continuous improvement methodology known as Digital Kaizen has gained prominence (Dang-Pham *et al.*, 2022). Digital Kaizen harnesses the power of advanced technologies, particularly human-cyber-physical systems (HCPS) and artificial intelligence of things (AIoT), to enhance the productivity of the human workforce. Unlike previous industrial revolutions, where technologies often replaced human labor, Digital Kaizen in Industry 5.0 seeks to leverage these technologies to empower and augment human capabilities, leading to increased efficiency and performance (Wang *et al.*, 2022).

This research examines and explores the concept of Digital Kaizen as a continuous improvement methodology within the context of Industry 5.0. By integrating advanced technologies, Digital Kaizen offers new opportunities to improve productivity and performance, while fostering a harmonious collaboration between humans and intelligent systems. This study aims to shed light on the implementation and benefits of Digital Kaizen, providing insights into how organizations can leverage this methodology to enhance their workforce's productivity and efficiency, ultimately leading to sustained competitive advantage.

This research is organized as follows. The traditional Kaizen and Digital Kaizen in Industry 5.0 theoretical background is described in Section 2. Section 3 explains the opportunities and challenges of Digital Kaizen in Industry 5.0. Finally, Section 4 derived the discussion and conclusions of Digital Kaizen, highlighting its

potential to drive continuous improvement and create a more resilient and adaptive manufacturing environment.

2. BACKGROUND

2.1 From Traditional Kaizen to Digital Kaizen

Kaizen, a continuous improvement methodology originating from Japan, has a rich scientific background and has been widely adopted by organizations globally (Janjić *et al.*, 2019). Initially developed in the manufacturing sector, Kaizen has evolved to encompass various industries and has become a key element in driving organizational excellence. The scientific foundation of Kaizen lies in its ability to systematically identify and eliminate waste, inefficiencies, and non-value-added activities within processes (Sridhar *et al.*, 2023). This methodology draws heavily from the principles of Lean thinking, which focuses on reducing waste and maximizing customer value (Sundararajan and Terkar, 2022). Kaizen emphasizes employee involvement, data-driven decision-making, and the pursuit of incremental improvements. The success of traditional Kaizen has led to its transition into the digital realm, known as Digital Kaizen. The integration of digital technologies with Kaizen principles presents new opportunities for organizations to further enhance their continuous improvement efforts.

The shift to Digital Kaizen is driven by advancements in technology, such as AIoT, big data analytics (BDA), and cloud computing, which have provided organizations with unprecedented access to vast amounts of data and real-time insights (Dang-Pham *et al.*, 2022). This enables more accurate problem identification, root cause analysis, and data-driven decision-making. Finally, Digital Kaizen also emphasizes the concept of "smart manufacturing" which integrates digital technologies and automation to create highly efficient and adaptive manufacturing systems leading to increased efficiency and productivity. The use of AI and machine learning algorithms in Digital Kaizen allows for predictive and prescriptive analytics, enabling companies to anticipate potential issues and take proactive measures (Ming *et al.*, 2019).

2.2 Digital Kaizen for Smart Manufacturing in Industry 5.0

The scientific literature lacks evidence of the practical implementation of Industry 4.0 after a decade since its emergence (Bajic *et al.*, 2021; Rikalovic *et al.*, 2022). The global hype surrounding Industry 4.0 shifted the focus toward fully automated manufacturing, neglecting the importance of the human factor (Demir *et al.*, 2019; Jiao *et al.*, 2020). The aim was to transition from traditional to smart manufacturing (Meng *et al.*, 2018) by leveraging advanced technologies (Bajic *et al.*, 2021; Rikalovic *et al.*, 2022). This vision of smart manufacturing foresees the integration of physical objects and software through the Industrial Internet of Things (IIoT), enabling the exchange of manufacturing data among different components (Bajic *et al.*, 2021; Rikalovic *et al.*, 2022). However, both industry and academia have consistently highlighted the challenge of excluding the human aspect from the manufacturing process (Neumann *et al.*, 2021).

Recognizing the significance of human assets in companies and the limitations of excluding the human factor from manufacturing processes, the European Commission (EC) has shifted its focus from a technology-oriented approach to a sustainable, resilient, and human-centric strategy (European Commission, 2021). The EC emphasizes that human workers surpass machines and robots in terms of dexterity, intelligence, flexibility, and creativity (European Commission, 2021, 2022).

In response to this perspective, the concept of Industry 5.0 has been introduced (European Commission, 2021, 2022). Industry 5.0 emphasizes the role of the research and innovation sector in supporting the industry's long-term service to humanity. It highlights the need for a human-centric approach and emphasizes the integration of advanced technologies, including artificial intelligence, robotics, and edge computing (European Commission, 2020) into a sustainable manufacturing environment. Similarly, to Industry 5.0, Digital Kaizen emerges as a transformative approach that places significant emphasis on the value of human contribution and continuous improvement using digital technologies. Industry 5.0 represents the evolution of industrial processes, where advanced technologies like automation, artificial intelligence, and robotics are integrated with human capabilities to create a harmonious and productive working environment recognizing the importance of human skills, creativity, and problem-solving abilities (Nahavandi, 2019). Digital Kaizen aligns with this vision and seeks to leverage digital technologies to augment human potential and foster a culture of continuous improvement.

Figure 1. represents a dynamic Industry 5.0 ecosystem interconnected with Digital Kaizen, as a continuous improvement concept (adapted from (Fraga-Lamas *et al.*, 2021). The nodes represent various advanced technologies, namely: AI, IoT/IIoT, robotics, Big Data, cloud/fog/edge computing, and so on (Angulo *et al.*,

2023; Bajic, Suzic, *et al.*, 2023) that enable resilience of manufacturing system. These nodes are interconnected, symbolizing the integration and collaboration between different technological components. Besides, the usage of advanced technologies provides sustainability reflected in waste reduction, energy consumption, and process optimization. At the center of this network, visualize a group of human figures representing the human workforce, engineers, and data scientists. They are depicted as active participants, engaged in collaboration with the technological nodes. This representation highlights the human-centric approach of Industry 5.0, with humans working alongside and leveraging the potential of advanced technologies. Surrounding the network, visualize circular arrows representing the continuous improvement process of Digital Kaizen. These arrows symbolize the iterative and ongoing nature of improvement, emphasizing the idea of continuous learning, adaptation, and optimization. This reflects the commitment to continuous improvement within the Industry 5.0 ecosystem, where both humans and technologies evolve and enhance their capabilities over time.

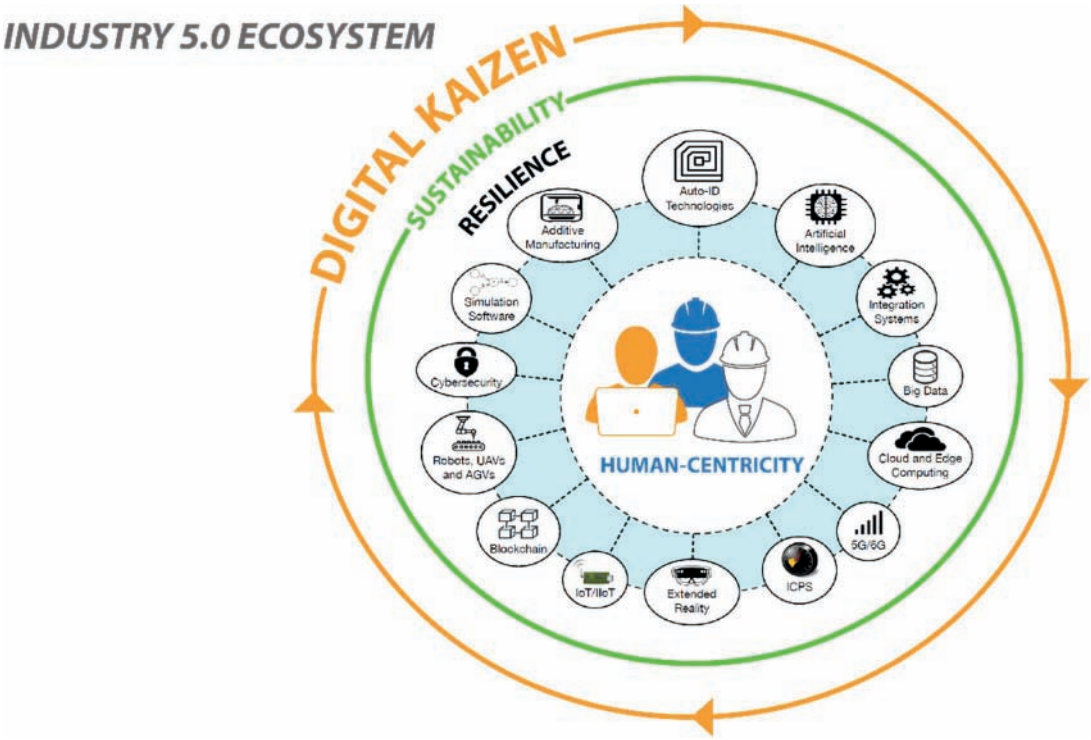

Figure 1: Industry 5.0 ecosystem interconnected with Digital Kaizen

3. OPPORTUNITIES AND CHALLENGES OF DIGITAL KAIZEN IN INDUSTRY 5.0

3.1 Opportunities of Digital Kaizen

Kaizen is rooted in the philosophy of incremental and continuous improvement, aiming to create a culture of constant learning and innovation within an organization (Sridhar *et al.*, 2023). It emphasizes the collective effort of all employees, from top management to frontline workers, in identifying and implementing improvements at all levels of the organization. Unlike large-scale transformation projects, Kaizen focuses on small, incremental changes that, when accumulated over time, lead to significant improvements in quality (Sundararajan and Terkar, 2022).

In today's world, the process of digitalization has become deeply integrated into social processes, thereby impacting the contexts in which human actions take place. By integrating advanced technologies into a human-centric and sustainable manufacturing environment, Industry 5.0 aims to harness the unique capabilities of human workers while leveraging the potential of digital innovations. This approach seeks to foster a harmonious collaboration between humans and technology, leading to increased productivity, innovation, and overall societal well-being (Papetti *et al.*, 2020). Therefore, the key elements of Digital Kaizen in Industry 5.0 with a focus on humans and continuous improvement include:

- Human empowerment: Digital Kaizen acknowledges that humans possess unique qualities, such as critical thinking, emotional intelligence, and adaptability, which are essential for innovation and complex decision-making. It aims to empower individuals by providing them with the tools,

training, and support to take an active role in driving continuous improvement efforts(Dang-Pham *et al.*, 2022; Ghobakhloo *et al.*, 2022).

- Skill development and upskilling: Industry 5.0 places a premium on skills that complement technological advancements. Digital Kaizen promotes ongoing skill development and upskilling initiatives to ensure that the workforce remains adaptable and capable of effectively utilizing digital tools. This includes training programs, mentoring, and cross-functional collaboration to foster a learning culture (Ghobakhloo *et al.*, 2022; Roblek *et al.*, 2021).
- Human-machine collaboration: Digital Kaizen recognizes that the combination of human expertise and technological capabilities can yield superior results. It promotes collaboration between humans and machines, where technology automates routine and repetitive tasks, freeing up human workers to focus on higher-value activities such as problem-solving, creativity, and innovation (Angulo *et al.*, 2023; European Commission, 2019).
- Continuous improvement mindset: In Industry 5.0, organizations need to continuously adapt and improve to remain competitive. Digital Kaizen instills a mindset of continuous improvement at all levels of the organization. It encourages employees to seek out inefficiencies, identify areas for improvement, and experiment with new approaches. This culture of continuous improvement ensures that organizations remain agile and responsive to evolving market conditions (Janjić *et al.*, 2019).
- Data-driven decision-making: Digital Kaizen leverages data analytics and insights to drive decision-making processes. By collecting and analyzing data from various sources, organizations can gain valuable insights into operational performance, customer behavior, and market trends. This data-driven approach enables informed decision-making and identifies areas where continuous improvement initiatives can be implemented (Bajic *et al.*, 2020, 2022).

3.2 Challenges of Digital Kaizen

The implementation of traditional Kaizen requires active participation and engagement from employees at all levels, a culture of continuous improvement, effective communication channels, and the support of management to foster a collaborative and learning-oriented environment (Sundararajan and Terkar, 2022). However, the transition to Digital Kaizen presents its own challenges. Some of the biggest issue when implementing Digital Kaizen in Industry 5.0 refers to:

- Change Management and Organizational Readiness: The successful adoption of Digital Kaizen requires organizational change and a shift in work processes. Managing and overcoming resistance to change from employees, stakeholders, and existing organizational structures poses a challenge. It necessitates effective change management strategies, leadership support, and employee engagement to foster a positive attitude towards digital transformation and continuous improvement initiatives(Bajic, Moraca, *et al.*, 2023).
- Workforce Resistance to Change: The successful implementation of Digital Kaizen relies on a skilled workforce capable of effectively utilizing digital tools and technologies. However, upskilling and reskilling the workforce to adapt to new technologies and tools presents challenges ((Bajic et al., 2021). It requires identifying the necessary skill gaps, designing, and implementing training programs, and fostering a continuous learning culture within the organization (Dang-Pham *et al.*, 2022). Besides, in Industry 5.0 vast amounts of data from various sources, including sensors, machines, and customer interactions are generated. Effectively collecting, managing, analyzing, and extracting valuable insights from this data requires skilled data professionals to handle the data in real-time or near real-time (Bajic *et al.*, 2021).
- Technological Integration and Complexity: Industry 5.0 involves the integration of advanced technologies, which can be complex due to the diverse range of technologies and their interdependencies. Ensuring seamless interoperability, compatibility, and synchronization between these technologies poses a challenge in terms of technical implementation and system integration (Rikalovic *et al.*, 2022).
- Cybersecurity and Data Privacy: With the increased connectivity and reliance on digital technologies, ensuring cybersecurity and protecting sensitive data become critical challenges. Safeguarding against cyber threats, implementing robust security measures, and adhering to data privacy regulations are essential. It requires continuous monitoring, threat detection mechanisms, and encryption techniques to mitigate risks and maintain data integrity and privacy (Bajic *et al.*, 2021; Rikalovic *et al.*, 2022).

- Cost and Return on Investment (ROI): Implementing Digital Kaizen involves substantial investments in technology infrastructure, training programs, and process improvements. Assessing the costs and evaluating the expected return on investment pose challenges. Organizations need to carefully analyze the potential benefits and costs associated with Digital Kaizen initiatives to ensure long-term sustainability and ROI (Bajic et al., 2021).

Addressing these scientific challenges requires multidisciplinary approaches, including advanced engineering, organizational behavior, data management, cybersecurity, and financial analysis. Organizations need to leverage scientific research, best practices, and collaboration between academia and industry to overcome these challenges and achieve successful implementation of Digital Kaizen in Industry 5.0.

4. DISCUSSION AND CONCLUSIONS

This research highlights the transformative potential of Digital Kaizen in driving continuous improvement and fostering a more resilient and adaptive manufacturing environment. The integration of digital technologies and data analytics in the Kaizen methodology offers new avenues for process optimization, waste reduction, and increased productivity. By leveraging real-time data and advanced analytics tools, organizations can identify bottlenecks, anticipate potential issues, and implement timely corrective measures. Moreover, Digital Kaizen enables enhanced collaboration and knowledge sharing across teams and departments, facilitating faster problem-solving and innovation. The ability to rapidly adapt and respond to changing market demands and unforeseen disruptions is paramount in today's dynamic business landscape, and Digital Kaizen emerges as a powerful approach to achieving this agility.

However, successful implementation requires a holistic approach encompassing not only technology adoption but also a cultural shift towards data-driven decision-making, employee empowerment, and a learning mindset. As organizations continue to embrace Digital Kaizen, they position themselves for greater competitiveness, resilience, and success in an increasingly complex and challenging smart manufacturing.

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EXPLORING TECHNOLOGY ADOPTION TRENDS: EMPIRICAL INSIGHTS FROM A EUROPEAN MANUFACTURING SURVEY

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Abstract: *This article investigates the adoption trends and implications of advanced manufacturing technologies in Serbian manufacturing companies. The objective is to analyze the evolving manufacturing landscape and provide insights into technology adoption patterns. The study utilizes the European Manufacturing Survey (EMS)—Serbian data set, which includes responses from 280, 240, and 147 manufacturing companies in the years 2015, 2018, and 2022, respectively. Through data analysis, changes in the adoption of advanced manufacturing technologies over time are aimed to be identified. Additionally, the study seeks to determine whether there is a growing trend in technology adoption. The research contributes to a deeper understanding of the dynamics surrounding technology adoption within the context of Serbian manufacturing, offering potential implications for companies' future strategies and development in a rapidly changing manufacturing landscape.*

Key words: Smart Manufacturing, Technology Adoption, European Manufacturing Survey (EMS)

1. INTRODUCTION

The traditional manufacturing industry has recently been confronted with a significant global threat, attributed to the rapid expansion and advancements in digital technologies that enable the seamless integration of interconnected intelligent components within the shop floor (Bianco et al., 2023; Ciric et al., 2021; Todorovic et al., 2022). This integration, forming the foundation of the Industry 4.0 concept, has been made feasible by the increasing adoption of information and communication technology by manufacturing organisations (Negri et al., 2017; Rakic et al., 2021).

Furthermore, over the past few years, a gradual rise in complexity and demands has been witnessed in the manufacturing sector (Hofmann & Rüsch, 2017a). These changes can be ascribed to various factors, including heightened market volatility, intensified global competition, and a growing demand for highly customized products, leading to shortened product life cycles (Prester et al., 2018; Todorovic et al., 2020). As a result, significant challenges are faced by companies in meeting these demands, particularly concerning cost-effectiveness, flexibility, adaptability, stability, and sustainability (Fatorachian & Kazemi, 2018; Ford & Despeisse, 2016). Traditional methods of value generation appear insufficient in addressing these growing difficulties (Ćirić & Lalić, 2016; Hofmann & Rüsch, 2017b; Nagy et al., 2019).

Additionally, rapid technological breakthroughs have revolutionized the manufacturing industry, creating new business opportunities and challenges (Ciric et al., 2020; Stefanovic et al., 2020; Todorovic et al., 2020). Trends such as digitalization, the internet of things, the internet of services, and cyber-physical systems (CPS) have gained considerable relevance in this context (Kusiak, 2018).

Throughout its evolution, Industry 4.0 has been shaped by the challenges and impacts brought about by the COVID-19 pandemic (Siriwardhana et al., 2020). The manufacturing industry, which is crucial to economies worldwide, has been significantly impacted by the COVID-19 pandemic (Bianco et al., 2023). Resilient and sustainable manufacturing practices are deemed essential to mitigate the pandemic's negative impacts and enable a smooth recovery (Hussain et al., 2021). The adoption of advanced technologies can play a critical role in enhancing risk preparedness and ensuring operational continuity, supporting economies and livelihoods amidst these unprecedented challenges (Dakovic et al., 2020; Hussain et al., 2021; Sofic et al., 2022).

In light of the available data from 2015, 2018, and 2022, the investigation of technology adoption patterns in Serbian manufacturing companies over the years (source: European Manufacturing Survey) and the identification of any differences or trends that may have emerged is the aim of this article. Specifically, the focus is on the adoption of various technologies within the context of Smart Manufacturing.

The following research question is proposed:

- *How has the evolution of technology adoption in Serbian manufacturing companies been from 2015 to 2022?*

Through the analysis of data from different years, a comprehensive understanding of the technology adoption landscape in Serbian manufacturing companies is aimed to be gained, and insights into the dynamics and trends associated with the adoption of Smart Manufacturing technologies over time are provided.
The rest of the article is structured as follows. Firstly, the introduction outlines the purpose of the article and introduces the research questions. The second section briefly provides an overview of the research flow and delves into the theoretical foundations of Smart Manufacturing. The third section explains how data was collected and analyzed for the research. In section four, the results and discussion are presented. The conclusion summarizes the findings and provides directions for future research.

2. THEORETICAL BACKGROUND

To establish the theoretical foundation, the authors of this article aim to address the research question posed in the introduction. We selected and extracted the most influential papers encompassing literature on Smart Manufacturing from the Elsevier Scopus database, which stands as one of the world's largest scientometric databases.
Table 1 shows the research flow; the concept of smart manufacturing was researched within the article title, abstract and keywords to establish their connection. The research string used for the search can be seen in the table, including limitations in the document type, language and year of publication, and the final number of observed papers. Among all the research papers available, only the most highly cited ones were selected as the most relevant sources, based on the Scopus indexing database. The inclusion of previous articles covering the European Manufacturing Survey was regarded as essential by the authors. Consequently, we incorporated a second research strand that encompasses a significantly smaller body of literature but serves as the foundation for drawing conclusions and making parallels with previous studies.

Table 1: Literature review research flow

Research String	Limitations	Time span	Number of publications
"Smart Manufacturing"	Document type: Journal articles, Conference Papers Language: English	2015-2023	3,964
"European Manufacturing Survey"	Document type: Journal articles, Conference Papers Language: English	2015-2023	48

Industry 4.0 is primarily driven by four key factors: Internet of Things (IoT), Industrial Internet of Things (IIoT), Cloud-based manufacturing, and Smart Manufacturing. These drivers play a vital role in transforming the manufacturing process into a fully digitized and intelligent one (Vaidya et al., 2018).
The key idea of Industry 4.0 is rooted in advanced manufacturing, with Smart Manufacturing being employed (Frank et al., 2019). Tao et al (2019) defines Smart Manufacturing as a common strategic priority among major manufacturing initiatives, including Industry 4.0 and the Industrial Internet (Tao et al., 2019). A flexible production system is used, where procedures are automatically adjusted for different products and varying environmental conditions (Kamble et al., 2018). The possibility of large-scale production of customized items with sustainable resource use is made possible by the improved quality, productivity, and adaptability offered by Smart Manufacturing (Kang et al., 2016a).
The main support structure for internal operational operations within the Industry 4.0 framework is provided by technologies for Smart Manufacturing (Ciric et al., 2020; Kang et al., 2016b; Miloradov et al., 2022). The use of multiple technologies, including sensors, computing platforms, communication technology, data-intensive modeling, control, simulation, and predictive engineering, in conjunction with existing and future industrial assets is known as Smart Manufacturing (Kusiak, 2018). Smart Manufacturing makes use of the ideas of Cyber-physical systems, the Internet of Things (and everything), Cloud computing, Service-oriented computing, Artificial intelligence, and Data science (Jankovic-Zugic et al., 2023; Sofic et al., 2022).

Significant roles in promoting Smart Manufacturing are played by both digital twin and big data. The possibility of cyber-physical integration is enabled by manufacturers' ability to control real-time, two-way mappings between physical items and their digital representations (Qi & Tao, 2018).
The fifth industrial revolution will be initiated upon the full integration and harmonious coexistence of its three key elements: intelligent devices, intelligent systems, and intelligent automation with human intellect and the physical world (Nahavandi, 2019; Raut et al., 2018). These elements represent the fundamental components that will enable the realization of the fifth industrial revolution, where intelligent devices, systems, and automation collaborate seamlessly with human intelligence and the physical environment, driving significant advancements in manufacturing and technological progress (Hussain et al., 2021; Nahavandi, 2019; Siriwardhana et al., 2020).

3. RESEARCH METHODOLOGY

For the purpose of this article, basic statistical methods were employed, specifically relying on descriptive statistics, to examine the adoption of Smart Manufacturing technologies within manufacturing companies in Serbia. The data used for this analysis was obtained through a survey conducted under the international project European Manufacturing Survey (EMS), which is coordinated by the Fraunhofer ISI Institute in Germany. The primary focus of EMS is on technological and organisational innovation in manufacturing companies, encompassing various aspects of manufacturing processes (Ćirić et al., 2016; Marjanovic et al., 2019). The survey is conducted every three years and targets manufacturing companies under NACE Rev 2 codes from 10 to 33, with more than 20 employees.
The dataset used in this article consists of responses from Serbian manufacturing companies. It includes 285 responses from the year 2015, 240 responses from 2018, and 147 responses from the 2022 round of the survey. Due to the COVID-19 pandemic, the latest survey was postponed by one year and conducted in 2022, officially concluding at the beginning of 2023.
Within the questionnaire, companies were asked about the technologies they currently employ in their production processes. Our analysis identified technologies falling within the domain of Smart Manufacturing. We used this information to compare the use of Smart Manufacturing technologies in 2015, 2018, and 2022. In this manner, we aimed to discern trends in the adoption of these technologies over time.

4. RESULTS AND DISCUSSION

This section presents the research results on the adoption of 12 different Smart Manufacturing technologies, as shown in **Figure 1**, illustrating the adoption trends in Serbian companies and comparing the data from 2015, 2018, and 2022.

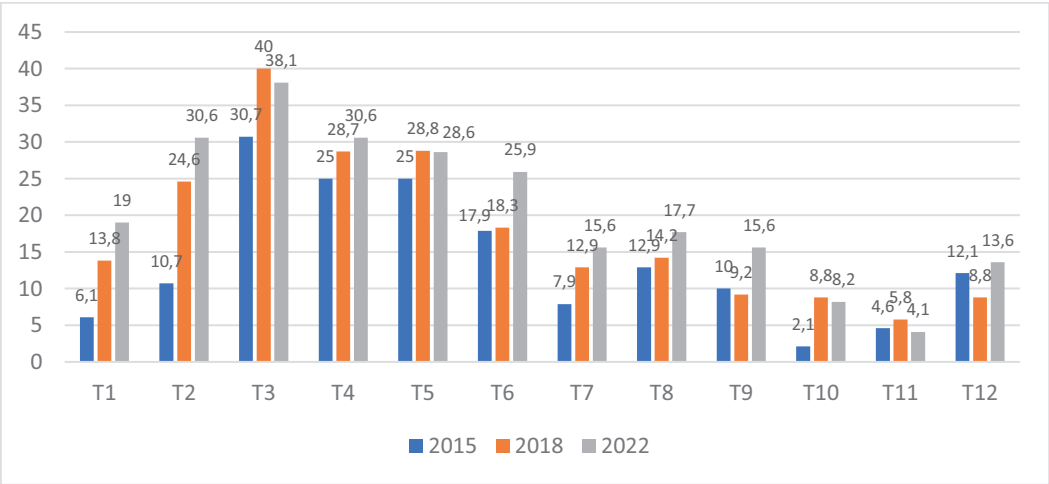

Figure 1: Adoption of Smart Manufacturing Technologies in Serbian Companies: A Comparative Study of 2015, 2018, and 2022

Based on the analysis of the adoption trends of various Smart Manufacturing technologies in Serbian manufacturing companies, several key findings can be observed:

- *Mobile/wireless devices for programming and controlling machinery and/or facilities* (T1) saw a remarkable increase in adoption, with its usage rising from **6.1%** in **2015** to **19%** in **2022**. This significant growth indicates that Serbian companies are increasingly recognizing the benefits of mobile-based solutions in enhancing machinery control and production processes.
- *Digital solutions to provide drawings, work schedules, or work instructions* directly on the shop floor (T2) exhibited substantial growth, with adoption rates climbing from **10.7%** in **2015** to **30.6%** in **2022**. This trend suggests that Serbian manufacturing companies acknowledge the value of incorporating digital tools in their daily operations to improve productivity and decision-making.
- *Software for production planning and scheduling* (T3) maintained its significance and demonstrated steady growth over the examined period. Although there was a slight decline in its adoption rate between 2018 and 2022, it remains considerably high overall at **38.1%**. This indicates that scheduling technology plays a crucial role in streamlining production operations and optimizing efficiency.
- *Digital Exchange of product/process data with suppliers/customers* (Electronic Data Interchange EDI) (T4) and *Near real-time production control system* (T5) both experienced moderate growth, with adoption rates increasing from **25%** to **30.6%** and **28.8%** respectively from **2015** to **2022**. These technologies play essential roles in facilitating seamless communication and real-time data monitoring in manufacturing processes.
- *Techniques for automation and management of internal logistics* (T6) showed noticeable growth, with adoption rates rising from **17.9%** in **2015** to **25.9%** in **2022**. The increasing interest in automation solutions, such as Warehouse Management Systems and RFID, indicates a growing recognition of their potential to optimize logistics operations.
- *Product-Lifecycle-Management-Systems* (PLM) or *Product/Process Data Management* (T7) saw gradual growth in adoption, with usage increasing from **7.9%** in **2015** to **15.6%** in **2022**. PLM systems are becoming more valued by Serbian manufacturers for efficiently managing product and process data throughout the lifecycle.
- *Industrial robots for manufacturing processes* (T8) and *industrial robots for handling processes* (T9) exhibited sustained growth, with adoption rates climbing from **12.9%** and **10%** respectively in **2015** to **17.7%** and **15.6%** in **2022**. The continuous interest in robotics indicates their increasing importance in enhancing precision, efficiency, and safety in production processes.
- *3D printing technologies for prototyping* (T10) experienced significant growth, with its adoption rate rising from **2.1%** in **2015** to **8.2%** in **2022**.
- *3D printing for manufacturing of products, components and forms, tools* (T11) showed a slower growth rate in 2022 (4.1%) compared to 2018 (5.8%) and 2015 (4.6%), possibly due to maturing technology and companies becoming more selective in its application.
- *Technologies to recuperate kinetic and process energy* (T12) demonstrated fluctuating adoption rates, with usage declining from **12.1%** in **2015** to **8.8%** in **2018** before rebounding to **13.6%** in **2022**. The varying adoption rates may reflect the ongoing efforts of Serbian companies to explore sustainable practices and energy-efficient solutions.

5. CONCLUSION

The adoption of advanced technologies can be more challenging for emerging countries (e.g. Serbia), as their economies have historically been centered around the extraction and commercialization of commodities (Dalenogare et al., 2018). However, the findings from the comparative study conducted in this article show the opposite - a positive trajectory of Smart Manufacturing technology adoption in Serbian companies is reflected. A growing interest in implementing smart technologies is highlighted by the observed trends. Technologies T1, T2, and T3 stand out with the highest adoption growth rate in 2022, while only one technology, T11, experienced a decline.

Manufacturers are now able to better, more rapidly, and more economically meet customer expectations thanks to developments in information technology. Manufacturers are increasingly using data to support a range of cutting-edge production models, such as mass customisation, sustainable manufacturing, flexible manufacturing, intelligent manufacturing, and cloud manufacturing (Dakic et al., 2019; Tao et al., 2018). But it has proven difficult to fully utilize data, particularly for small and medium-sized manufacturing

enterprises (Tao et al., 2018; Tao & Zhang, 2017). In order to better understand how technology adoption differs depending on the size of the company and the industry it serves (which is also covered by the European Manufacturing Survey), the authors plan to investigate this topic in future research.

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INTRODUCING HYBRID LEARNING TO LEARNING FACTORIES

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Abstract: *The ongoing digital transformation of the manufacturing industry needs to be met with new forms of education and training to maintain a highly skilled workforce. New professional education concepts need to provide effective learning content that is industry-relevant, of high quality, and easily accessible. To tackle these challenges, the paper presents a methodology for developing a course founded on a combination of didactic approaches including blended and hybrid learning, active learning, and flipped classroom. According to industry needs in South-East Europe, the course design is then applied to selected topics around a smart assembly workstation, i.e., human-robot collaboration, enhanced quality control, and lean manufacturing 4.0. The trainings will be offered online, via E-learning and through the partners' Learning Factories, i.e., hands-on. Examples of different concepts are presented in each Learning Factory.*

Keywords: Learning Factory, hybrid learning, professional education, Industry 4.0.

1. INTRODUCTION

The concepts of hybrid learning and Learning Factories (LF) have recently become increasingly popular means of education (Abele et al., 2019; Raes et al., 2020). In the sector of manufacturing, new, emerging technologies and digital transformation create increasing demands on upskilling and education of the existing workforce to stay competitive (Tvenge & Martinsen, 2018). To keep up with these needs, optimized training concepts need to be explored that can provide enhanced flexibility, availability, and efficiency to the industry. To do so, this paper presents a methodology for development of hybrid training courses centered around LFs. In addition, several use cases of a pilot course on the topic of Industry 4.0 are provided.

1.1 Hybrid, blended and flipped learnin

Hybrid learning is often used synonymously with the term blended learning, both describing education that combines face-to-face learning with online learning (Hrastinski, 2019). Even combining different instructional methods, pedagogical approaches, and technologies can be considered blended learning (Sharma, 2010). While the term hybrid learning seems to be more widely adopted in practice, blended learning is more commonly used in research. The lack of clear and universally agreed-upon definitions leads to inconsistencies in the literature on the subject. Consequently, Hrastinski recommends researchers and practitioners to carefully define their understanding and perception of the terminology (Hrastinski, 2019).
In the context of this paper, hybrid learning is considered a combination of in-person and remote (online) learning, both carried out synchronously (at the same, specific time). Blended learning refers to a combination of asynchronous online learning (on the learner's own schedule) and synchronous in-person learning, as depicted in Figure 1.
Another related concept is flipped classroom, which is an instructional method that reverses the traditional sequence of classroom activities and homework (Tucker, 2012). Learners consume instructional content

(e.g., via pre-recorded videos) at home before attending class, where they engage in group discussion, problem-solving, and teacher-guided activities (Tucker, 2012).

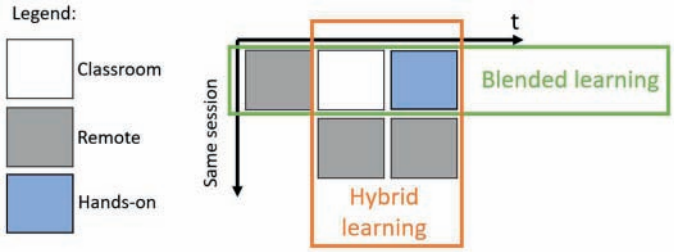

Figure 1: Example course structure with the distinction of hybrid and blended learning

For example, significant increases in student performance have been shown in the case of hybrid learning (Joyce et al., 2014), for blended learning (Cavanagh, 2011), and for flipped classroom (Baepler et al., 2014). Among the reported advantages compared with traditional teaching approaches are flexibility in terms of location (synchronous online activities in hybrid learning) and time (asynchronous learning activities in blended learning) for the learners, making education more inclusive and accessible (Saichaie, 2020), Figure 1. Furthermore, flipped classroom has shown to provide more frequent opportunities for students to interact with peers and instructors, affecting the in-class learning experience positively (Lage et al., 2000). Moreover, diverse instructional methods and interactive multimedia content can be incorporated into the learning to serve different learning styles (Kolb & Kolb, 2013).

1.2 Learning Factory (LF)

LFs are facilities that resemble a manufacturing environment by providing simplified representations of processes and multiple workstations. In that way, real value chains, including organizational aspects, are simulated and can be used for training purposes. In fact, LFs have gained considerable popularity as effective platforms for learners to acquire practical skills required in real-world manufacturing environments through hands-on learning via e.g., problem-solving, and experiential learning.

The growing interest in LFs is also evident in the formation of national and international scientific communities, the increasing number of publications on the subject and the engagement of manufacturing sectors (Nixdorf et al., 2022).

The educational approach used by LFs is founded on a combination of didactic concepts of active and experiential learning, which emphasizes the learner's engagement and participation in the learning process and its reflection. It includes activities such as problem-solving, discussions, group work, and hands-on experiences (i.e. "learning by doing") (Abele et al., 2019).

Even though LFs have proven to be an effective means of preparing learners for careers in the manufacturing industry (Abele et al., 2017), several limitations and drawbacks have been reported. These include their resource-intensive operation, limited flexibility and scope of individual facilities, and limited accessibility, i.e., they are only regionally available (Abele et al., 2017).

2. HYBRID COURSE DESIGN

2.1 Didactic approach

The proposed course design combines various didactic approaches (see Table 1). Its focus is on hybrid and blended learning, flipped classroom, and constructive alignment. By centering it around LFs, valuable hands-on learning experiences are provided (e.g. problem-solving or experiential learning).

Constructive alignment (Biggs, 2014) is integrated to formulate clear and measurable learning outcomes in line with Bloom's taxonomy (Krathwohl, 2002. Generally, learning outcomes of lower levels of Bloom's taxonomy (e.g., remember) are most suitable for pre-class (online) learning segments while in-class or hands-on training sessions are intended to tackle higher-level learning outcomes (e.g., apply, evaluate).

The course is also utilizing the benefits of hybrid learning and blended learning via the flipped classroom approach. Blended learning concepts with online learning are the core of pre-class learning activities. The goal of pre-class learning is to lay the knowledge-foundation for the second aspect of blended learning, the in-class hands-on training sessions at the learning factories. Learning before meeting in-person will help utilize the time and resources at the learning factories effectively making space for active learning activities such as problem-solving. The online pre-class segment also enables learners to adapt learning to their schedule which brings significant advantages for working professionals.

Hybrid learning elements are incorporated by including synchronous online sessions during which interaction and knowledge sharing between learners and teachers of different LFs is promoted.
The proposed course is designed to be carried out as a joint effort by several LFs allowing for sharing resources and expertise and widening the training scope. Video conferencing tools enable interaction between learners and instructors present on-site at the various participating learning factories.

Table 1: Components of the theoretical basis of proposed course design with main features listed

Learning factory	Hybrid & blended learning	Flipped classroom	Constructive alignment
• Active learning • Problem-based learning • Experiential learning • Project-based learning	• Blend of in-person & online learning in sequence • Learn at own schedule • Hybrid synchronous learning • Personalized/tailored learning	• Student-centered • Reversal of traditional teaching • Pre-class learning • In-class activities • Flexible learning environment	• Outcome-based • Intended learning outcomes (ILOs) • Alignment ILOs & learning activities • Assessment & feedback

2.2 Course design

Based on the principles laid out in subsection 2.1, a course containing hybrid learning paths was designed. This course features three LFs with distinct infrastructures (LF 1, LF 2, and LF 3). As summarized in Figure 2a, the course contains a combination of online learning (synchronous and asynchronous) and in-person attendance. It is built around a common manufacturing-related challenge which is addressed during the hands-on sessions at the different LFs.
During the asynchronous pre-class learning segment, learners engage with assigned online material before the first synchronous event. During this introduction event, instructors from the participating LFs will introduce the manufacturing challenge and furthermore address questions that may have arisen during the prior online-learning segment. This session is held hybrid, i.e., in presence and online at the same time to increase accessibility.
The subsequent synchronous event comprises the hands-on training where learners meet at the respective regional LF where they will tackle the common challenge by applying one of the topics/methods they have gained theoretical knowledge about during the pre-class segment. The topic/method and associated hands-on activity are developed in accordance with the available equipment and expertise at the respective LF. Active learning aspects associated with LFs (see Table 1) like group work enables to include non-technical learning outcomes, such as collaboration, communication, and leadership skills.
The group work segment extends beyond the hands-on training. Groups are asked to summarize their experiences and outcomes from the hands-on training and present it to other groups who were active in another LF. This is done in an online debriefing session, scheduled at least a week later to give sufficient time and flexibility for team members to prepare (e.g., arrange meetings among them). In the debriefing session, conducted online, learners and instructors from all LFs participate and each group presents their hands-on experience to other trainees, thereby practicing their communication and presentation skills and providing space for discussions.
The possible paths an individual learner can take within the proposed course design are illustrated in Figure 2b. The main variation for the different learning paths is due to the hands-on training. Whether a learner takes path (I), (II), or (III) depends on which LF the learner has access to (i.e., usually a domestic LF). Completion of the course will require a learner to successfully take part in all course elements along the specific learning path.
Assessment can be conducted at multiple stages of the learning path. Asynchronous online learning can be assessed on a learning management system (e.g., quiz questions). During the hands-on training instructors assess individual and group performance according to the intended learning outcomes. The final assessment can be performed during the debriefing session, e.g. with the help of peer-review.
In previous studies, LFs have been enriched by either blended (Andersen et al., 2019) or hybrid learning (e.g. via virtual reality) (Riemann et al., 2021). In contrast, the present course design provides an advantageous combination of both concepts providing flexibility and accessibility for learners, a wider scope of the training, and shared resources (e.g. learning content creation) and instructor-expertise.

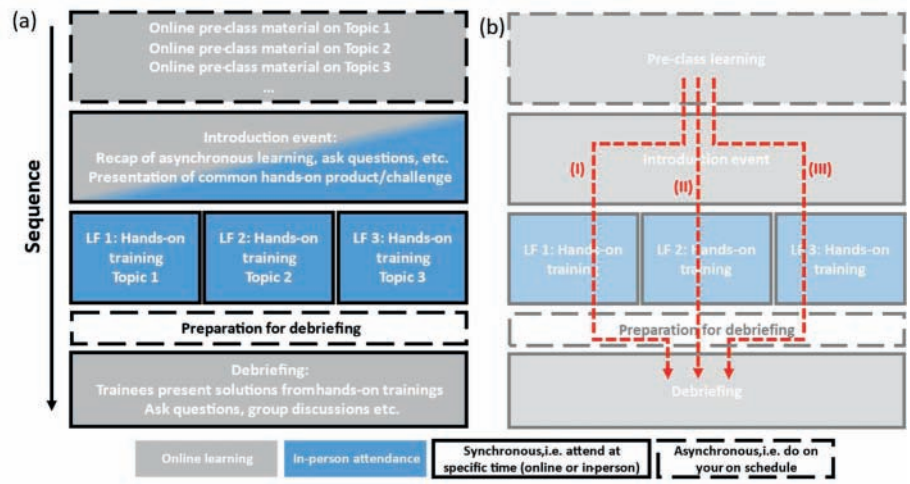

Figure 2: (a) Course design with three participating Learning Factories. (b) Individual learner's possible paths in course.

Possible challenges include the reliance on technology necessary for the hybrid format leading to additional costs and risks due to technical problems. An increase in planning workload to synchronize all activities is also expected.

3. MORPHOLOGY FOR HYBRID LEARNING

Based on the different concepts described in the previous sections, a morphology is proposed for hybrid learning, Figure 3. It is based on the three categories of hybridization:

- Trainer – what is the location of the trainer?
- Trainee – what is the location of the trainee during the session?
- Equipment – what is the location of the equipment?

All these options were "overlapped" with all ideas that were generated how to deliver the training in practical situations. That is how three different streams were generated:

I. E-Learning, through online learning platforms (e.g., EIT Manufacturing's Skills.move). This option does not require hardware equipment, the trainer has already uploaded the material on the online platform and no interaction is needed. The trainee can access the training from anywhere, using a computer or even mobile devices, i.e., entirely self-paced.

II. Hands-on learning. This training is in the heart of the LF and it is the crucial part in delivering the training because the equipment is enabling the opportunity to gather own experiences. Further, it is the competitive advantage of a LF compared to other training providers.

III. Hybrid learning: This is the most flexible option because it can be tailored to the needs of the training and the capabilities/capacities of the trainer, however, it may also be the hardest to realize due to required supportive IT technologies that not only enable remote attendance but possibly also control Remote trainer or remote assistant can lead the training and the trainees can be remote or in a remote LF with a suitable equipment.

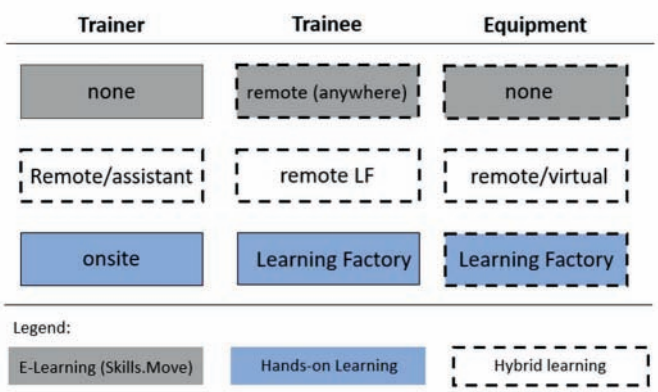

Figure 3: Morphology design for Hybrid Learning in the Learning Factories.

4. USE CASES IN THE LEARNING FACTORIES

In this section, several examples of hands-on trainings are outlined. These are meant to be embedded in a course designed according to Figure 2, i.e. learners will follow a learning path as exemplified in Figure 2b containing pre-learning segments, hybrid introduction event, and debriefing. The use cases are focused on the topic of a smart assembly station including Lean and Industry 4.0 concepts.

- Smart Learning Factory – Skopje, Skopje: The training covers a Smart Poka Yoke Station that is installed and will aid the process of assembly by an operator. The on-site trainer will be responsible to guide the trainees in making the assembly process as efficient as possible. The trainees will acquire skills for analyzing an assembly instruction, develop a new one and program the Smart Poka Yoke Station by themselves. The training is primarily aimed for engineers and operators, but engineering students and production managers can take part as well. The remote trainees can aid the process of designing new assembly instruction.
- Faculty of Mechanical Engineering and Naval Architecture, Zagreb: A training will be offered around Enhanced Quality Control (EQC) to reskill and upskill individuals in quality control and its enhancement through machine vision through hands-on workshop. They will discuss with the trainer and other participants to identify potential quality issues, such as errors in assembly sequence, missing components, or damaged parts. Once identified, participants will choose one relevant issue to address. They will design and implement a machine vision system using existing components, select suitable algorithms, optimize performance through hardware and software enhancements, and critically evaluate the effectiveness of their solution. The EQC training equips learners with competencies in artificial intelligence, digital transformation, problem-solving, and critical thinking, which are essential skills for Industry 4.0 and 5.0.
- University of Tartu, Tartu: The training provided in this LF focuses on learning technical skills for integrating and programming a collaborative robot manipulator (cobot) to complete a vision-guided assembly task. The practical task is intended to showcase collaborative flexible manufacturing where the workspace may change but the robot is able to adjust due to the adaptive nature of the task completion algorithm. The learners are expected to programmatically control the manipulator and implement a reactive control algorithm that takes a video stream of the work area as input. To ensure that the acquired skills are applicable for a wide range of tasks with different robot manipulators and vision systems, the training leverages ROS2 (Robot Operating System) as the main development tool.
- FabLab, Sarajevo: The training features advanced cobot vision integration, Enhanced Quality Control (EQC), and the mini Poka Yoke Station. Participants gain hands-on experience in programming cobots for vision-guided assembly tasks using UR. They also learn EQC skills, identifying quality issues, designing machine vision systems, and optimizing performance. Additionally, they enhance assembly efficiency using a mini Poka Yoke Station. FabLab Sarajevo offers a comprehensive learning environment, equipping learners with practical skills for Industry 4.0.
- TU Wien Pilot Factory Industry 4.0, Vienna: The training focuses on industrial maintenance, e.g., for operators to get accustomed to the technology of cobots via E-learning (Mayrhofer et al., 2021), then carry out maintenance tasks with a cobot hands-on (Nixdorf et al., 2022). In this way, this use case can be leveraged to localize the fault, diagnose the fault and disassemble the product after a failed inspection. To connect E-learning with hands-on learning and debrief trainees after the course, a hybrid approach can be realized. However, at this stage hybridization of hands-on activities is not planned. It is suggested that cognitive subtasks, such as visual inspection, can be carried out remotely, while the manual subtasks require presence.

5. CONCLUSIONS

This paper proposes how new industry-driven topics will be delivered through innovative hybrid learning pathways. The authors employ a blended and partly hybrid approach for the proposed trainings. In line with previous work on leveraging LF networks (Nixdorf et al., 2023), accessibility of LFs is an increasingly demanded topic, especially for South-East Europe. The official trainings will be conducted in the last quarter of 2023 and the collected data from the feedback will be used to optimize the hybridization. It is emphasized that further research needs to be done on hybridization of hands-on trainings, e.g., by virtual environments or remote access to training equipment.

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CHALLENGES AND OPPORTUNITIES OF BLOCKCHAIN TECHNOLOGY REGULATION

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Abstract: *Accelerated technological development has brought many novelties, among which is distributed ledger technology (DLT), often called blockchain (BC). BC is perceived as a peer-to-peer distributed immutable ledger that could revolutionize economies, societies and even our daily lives. All protocols for dealing with data and transactions are coded with an algorithm, so there is no need to trust the other contracting party or the intermediary. With the concept of decentralization and the absence of hierarchy, BC wants to avoid all traditional intermediaries and any regulation. The question arises, are BC-technologies really decentralized and who controls them? What are the consequences if decision-making in BC is influenced by small groups of people or corporations? This article, in an attempt to answer these questions, explores technological scandals in which there have been significant deviations from the basic principles of BC (The DAO Hack, Parity's Smart Contract Bug on Ethereum and Facebook's Libra). Analysis of the above scandals suggests that decentralization is threatened and the current regulatory status of BC is substandard. It was shown that BC technology, due to its deterministic nature, cannot provide solutions for all life situations and that human judgment is irreplaceable.*

Keywords: *Blockchain technology, regulation, technological scandals*

1. BLOCKCHAIN TECHNOLOGY – DEFINITION AND CHARACTERISTICS

Blockchain technology (hereinafter: BC) is a product of accelerated digital development. BC is perceived as a peer-to-peer distributed immutable ledger that could revolutionize economies, societies, and even our daily lives. Although it is already widely used, BC still represents an insufficiently clear technology for the general public, so it is necessary to describe it more closely. It is about distributed ledger technology (hereinafter: DTL). This means that the data is recorded simultaneously on all computers in the network, and not in one, central place. In principle, the validity of new transactions or authorized data transfer is not approved by one central point, such as central ledger, but by the network participants themselves, using the consensus protocol. After approval, transactions are recorded as a new changed state of data on the BC, which is visible as such to network participants. In short, it is a concept based on the use of a cryptographically protected chain of transaction blocks through a "hash" function, which further means that the content of the block cannot be changed without changing the content of all other blocks that precede it (Cvetković, 2020:128). The verification and consent processes are fully automated. All protocols for handling data and transactions are coded with an algorithm (Shein, 2019).
The principles on which the BC technology system was originally founded are different from traditional systems, for which it is crucial to have a central administration (which makes decisions on behalf and for the account of the members), so an intermediary relationship is established there. A characteristic of BC (unlike traditional systems) is that it is formed as an equal, all participants have the same status, which is the result of solid coding, and it is not even necessary to have trust in the other contracting party, i.e. in the intermediary (Čulinović-Herc, 2022:698-699). The concept of decentralization in record-keeping and the absence of control by a central body aims to bypass traditional intermediaries, such as regulatory agencies, central banks (Nakamoto, 2008), as well as the establishment of a code of conduct and to avoid the adoption of any legal regulations.

1.2 Features of Blockchain tehnology

The characteristics of BC, in addition to equality and independence in relation to traditional systems, also include technological elements such as: immutability, data verification and decentralization.
Immutability, as a technological characteristic of BC, arose from the fact that in the blockchain chain there are several network participants (computers), and they are responsible for ensuring the accuracy of the data. In traditional transactions, unknown intermediaries and unknown participants (computers) do

not trust each other about the accuracy of information. Unlike traditional institutions (banks, government institutions and similar authorized intermediaries) responsible for maintaining and controlling such records, blockchain is designed to be immutable. Each record (as part of a unique block) entered into the blockchain is secured by a unique cryptographic key (Makoto Yano, 2020:3-4).

Data verification in BC is related to the ability to store and share information through blocks in a peer-to-peer network. Identical copies of blocks (which are functionally record-keeping inserts) are jointly verified by members of the network, using the consensus method. The verified information is contained in blocks that have been added to the chronological chain of existing and approved blocks using a cryptographic signature. Essentially each block has loaded data about all previous blocks (transactions) within one blockchain. The importance of BC technology is that it ensures the authenticity of digital data: trust in the classical legal relationship is replaced by verification through data in blocks in the above mentioned way. BC concept is transparent and enables efficient (fast and cheap) transmission of information in wide IT networks (Cvetković, 2020: 129).

Decentralization is a key characteristic but also the biggest challenge of BC because it is global in terms of the composition of participants, and cross-border in terms of the nature of transactions. The initiator of the BC is the first potential addressee of the regulation, but since he no longer has control over it after "commissioning the BC", it is not pragmatic to impose regulatory requirements on him. It should be kept in mind that the BC network may be technologically decentralized, but that legally and factually one person controls the network because he has the computing power needed for network consensus (Čulinović-Herc et al., 2021:330).

1.3 Types of Blokchain technology systems and decision-making methods

BC systems differ from each other according to various criteria, whether public or private, with or without permission, and in terms of achieving consensus. BC is public when anyone can access it and use it to conduct a transaction, i.e., private (or semi-private) when only a limited and predetermined number of participants can access the system (e.g., only banks and insurance companies). Further, BC can be divided into "permissionless" and "permissioned", depending on who can execute transactions and who can verify them. If anyone can execute and verify transactions, it is a permissionless BC. If authorization is required to execute or validate transactions, or both, the BC is called permissioned (Čulinović–Herc, 2022: 159).

BC, as we stated, promises, on the principles of democracy and immutability, safety and independence of participants, guaranteeing traffic on a well-programmed algorithm. With the concept of decentralization and the absence of hierarchy, BC wants to avoid all traditional intermediaries and any regulation. The question arises, are BC-technologies really decentralized and who controls them? What are the consequences if decision-making in BC is influenced by small groups of people or corporations? These questions arose in cases where the programmed algorithm led to unexpected problems and the need to make a decision on the further fate of BC participants. The decision about it is most often made by influential members of the BC-community, that is core developers. In BC-systems that are based on access approval, that is, which are not public, it is somewhat logical because that BC remains in the control zone of the entity that established it and opened access to the network only to selected individuals. However, key developers have an equally important influence in public BC. Their behavior is not regulated by regulations, ethical rules or rules of conduct, and this represents a potential risk.

2. TECHNICAL SCANDALS THAT SHOOK THE BC COMMUNITY

The technical scandals that we will present in the following part of the paper show that even BC systems are not perfect and that they need human intervention. In that case, the decision made should be without the influence of subjective factors (conflict of interest, political influence, etc.), and as a rule, it must be adopted according to the same rules of procedure.

In the paper, we used a descriptive method followed by an analysis and a synthetic method to prove our hypothesis that BC systems are not perfect and that they need human intervention without the influence of subjective factors.

2.1 Attack on The DAO and Implementation of a "Hard Fork"

A Decentralized Autonomous Organization (DAO) is a set of smart contracts (Neitz, 2019:18) on the *Ethereum* BC network, on which the cryptocurrency called *ether* is traded. Smart contracts are computer protocols that execute, monitor and/or document legally relevant actions (especially the execution of contractual obligations) conditioning them on digitally confirmed results. A smart contract differs from a classic contract in that it is self-executing, i.e. obligations are fulfilled with little or no human activity. Their concept was created by lawyer and cryptographer Nick Szabo in 1994, and he described them as computerized transaction protocols that execute the terms of a contract (Szabo, 1994). Immutability, i.e., unstoppability of smart contracts is both their advantage and disadvantage. The DAO in question was founded in 2016 to enable the financing of startup projects in a joint virtual organization Garcia (Rolo, 2019). Jentzsch, a theoretical physicist, came up with the idea that crowdfunding for startups is not carried out for each new one separately, but through investments in DAOs. The DAO was the one who invested those funds in startups or projects by selecting the token holders in the DAO, i.e. its members. During the DAO's initial token offering in May 2016, around USD 150 million worth of virtual currency was raised, breaking the record for funds raised through crowdfunding. However, on June 16, 2016, there was an attack on the DAO due to the existence of certain flaws in its code. Namely, the code had a programmed, so-called protection of the minority. Token holders who would vote against a project accepted by the majority could initiate a split of the DAO. A minority could transfer their tokens/ethers to a new DAO (further: DAO child) which was subject to the same rules as the initial DAO (Karapetsas, 2016). But the partition protocol was hard-coded.

In other words, after the DAO split process started, it took at least 48 days for the virtual currency to "sit on the account" of the split initiator. The attacker took advantage of flaws in the coding of the protocol. After activating the DAO split function, the code would first mark the tokens/ethers, which will pass to the child DAO, but did not simultaneously update the account balance of the initial DAO. In addition, the code did not protect the sharing protocol from, so called recursive call. It is a term used to refer to a function that "calls itself". The attacker was able to "recursively call" the split function and retrieve the funds multiple times before the split hodogram reached the point where the code itself checks the ether balance of the DAO account. By abusing a recursive call, on June 16, 2016, the attacker managed to appropriate about 3.6 million ethers from the DAO, which was approximately a third of the entire DAO's assets. After the announcement of the event, the value of ether almost halved. So, two factors made the attack possible. The code was not protected against recursive calls, and the smart contract was not programmed to update the balance at the same time as the currency was sent. Basically, it's about coding flaws.

An intense discussion ensued in the BC community about what needed to be done. The attacker published an open letter to the ethereum community (Gautham, 2016), claiming that the misappropriation was not illegal because the code was legal. He considered that it was not legitimate to consider his transaction null and void because everything was acquired precisely according to the terms of the smart contract. Due to the split protocol explained above, the BC community had 27 days to decide on how to recover the system from the attack before the attacker initiated a proposal to transfer ether to their account (Güçlütürk, 2018). The community considered the application, the so-called "soft or hard forks", as well as whether to do anything at all. A "soft fork" would mean that all (future) transactions, which would withdraw funds from the DAO, would be considered void. Transactions that took place before the soft fork were applied would be valid. A "hard fork" would erase the history of all DAO transactions since the beginning of activity.

Opponents of both solutions relied on the philosophical underpinnings of the ethereum blockchain. They claimed, like the attacker, that "the code is the law" and that everything the code allows is legitimate. The application of a "hard fork" threatened the principle of record immutability as one of the most important features of BC.

Key developers proposed a soft fork vote that began on June 22, 2016. The decision was made by a majority and was supposed to be implemented on June 30, 2016. However, due to additional security flaws, the "soft fork" was abandoned (Güçlütürk, 2018). After that, the discussion about the "hard fork" began. It was argued that the attack was too serious to ignore. The decision to implement the "hard fork" was voted and accepted by the majority of miners (eng. miners) of the ethereum community. The "hard fork" was completed on July 20, 2016, and the funds were returned to investors (del Castillo, 2016). According to some authors, this decision was imposed by seven key developers. Thus, a new version of the Ethernum network was formed, with different rules from the original ones.

From this example, it is evident that the BC community deviated from the basic technological settings of BC (code = law). The decision was made under the influence of key developers. On the other hand, the decisions that were voted once were abandoned in the execution procedure ("soft fork"), which shows serious deficiencies in the management system and the way of decision-making in the BC community.
This event certainly raised doubts about the BC technology and started a discussion about the need to regulate it. It is noticeable that human decision proved to be irreplaceable, although all problems should have been foreseen and solved in smart contracts.

2.2 Parity Contract Bug

Parity is a trading company founded by Gawin Wood (otherwise the co-founder of Ethereum) together with the Ethereum Foundation's DEV team. They were also the authors of the Solidity program for programming smart contracts. Parity developed the so-called wallet with multiple signatures (multi-sig wallet). The characteristic of this wallet is that the transaction requires the use of two or more private keys, which is more secure than one. The vulnerable MultiSig wallet was split into two contracts to reduce the size of each wallet and save gas: A library contract called "WalletLibrary" and an actual "Wallet" contract consuming the library (Breidenbach et al., 2017). Parity was accidentally exposed to a bug in smart contracts, which allowed one user to unilaterally change the owner names and usage parameters of other people's wallets that contained 150 thousand Ether (Parity Technologies, 2017). This allowed an attacker to make himself the owner of three wallets and transfer ether from those wallets to wallets under his control. Around the same time this happened, a group of white hat hackers exploited this flaw and made themselves to the owners of the next 593 wallets, which had more than 377 thousand ether, only to have the wallets returned to their rightful owners after Parity fixed the problem. But in eliminating that problem, an even bigger mistake was made. It was noticed that the new, improved smart contract was not activated, and during its activation, the beginner, employed at Ethereum, first made himself the owner of the entire library of smart contracts. By controlling the library of smart contracts, control was also established over all multi-sig wallets. Therefore, the activation of the new program led to the freezing of 584 wallets with more than 500 thousand ether. In order for the wallets to be returned to their rightful owners, a hard fork had to be applied again, which the injured wallet owners advocated for. However, the key developers rejected that possibility, and the ether currency remained permanently frozen on those wallets.
In this scandal too, we see that in case of errors in smart contracts related to BC, the decision on the fate of "equal" participants is made by only a few key developers. In addition, it is noticeable that in these two unprecedented technical scandals, the same measures were not applied to eliminate deficiencies, which is a deviation from the original principles of BC.

2.3 Facebook Libra and forced moratorium

On June 18, 2019, the Internet giant Facebook announced the creation of a consortium of financial and technology companies aimed at establishing a global cryptocurrency with stable value called Libra. It is planned to create an open blockchain through a new programming language, which will serve development teams in the future for creation of smart contracts. Just a few hours after the announcement that BC will be used for a new global cryptocurrency, the US Congress issued a statement. Financial Services Committee Chairwoman Maxine Waters demanded a moratorium on Facebook's further steps until Congress and regulatory bodies examine the announced Libra project.
The attempt to further develop BC technology (by creating a global cryptocurrency) based on the original principles seems to have posed a great danger to the real world, and the political influence of one of the strongest financial powers was used to stop Facebook's announced project. Therefore, even in the Facebook project, the decision on its further development was made outside the BC community, under the influence of politicians.

3. DISCUSSION AND CONCLUSION

The implementation of the “hard fork” in the case of the DAO attack and the lack of its implementation in the case of Parity are examples of the large influence of a small number of key developers in attack situations. It turned out that different decisions were made in similar cases. This creates a state of high legal and ethical uncertainty. Were the key developers in the first case biased and protected investors "from trusting them" or maybe they insisted on implementing a hard fork because they themselves were

affected by that attack? How does this reconcile with the basic principle of permanence and immutability of records at BC and of decision-making in a participatory manner? Not only was the code changed, but the basic principles on which BC-technology rests were called into question.

The above-mentioned questions show us that BC management has not moved far from management in a traditional way because a significant part of the decision-making process is not explicit, and the users are not completely independent. In the case of Facebook, there is an obvious political influence from which BC, by its very nature, wants to distance itself, and as it is evident, it is not able to resist it with its original principles. The decision-making and management procedure of BC technology, in all three mentioned cases, indicates that the idea of participatory democracy, which is important for BC, has been abandoned. If the management of a public BC is so strongly influenced by a small number of influential persons, those persons are bound to embed their biases and conflicts of interest in the network (Werbach, 2018:528-529).

The analysis of the mentioned technical scandals indicates numerous shortcomings in the automatic management of BC technology, i.e. that they require human reaction and decision. At the same time, it is evident that there are no established rules of conduct or legal responsibility of influential members who make decisions related to the entire BC. It would be necessary to start adopting ethical principles in the decision-making system of BC, as a step towards later legal regulation, which would regulate and ensure the management of potential conflicts of interest arising from the fact that decisions about changing the code are made by people.

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ANALYSIS OF MICROBIOLOGICAL SAMPLES USING THE SEGMENT ANYTHING MODEL

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Abstract: *This paper describes the application of the Segment Anything Model (SAM) to the analysis and image processing of microbiological samples containing common types of bacteria and yeast that can be found in various environments. The SAM model was tested on images from the AGAR dataset, which contains 18,000 images of microbiological samples containing five microorganisms such as Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Escherichia coli, and Candida albicans.*

Key words: *image segmentation, instance segmentation, semantic segmentation, computer vision, microbiology*

1. INTRODUCTION

Microbiological contaminants such as bacteria, fungi, viruses, yeast, and protozoa are of great interest, and concern to food manufacturers due to the potential risk of food poisoning or food spoilage (Maruthamuthu et al., 2020) (Talo, 2019). The increasing demand for digital microbiological data presents an opportunity for microbiologists and laboratory professionals to easily detect microorganisms (Egli et al., 2020). This change can personalize diagnostics and treatments, improve digital data quality, and reduce healthcare costs. Conventional culture-based methods for microbial detection are time-consuming, while digital imaging has attracted attention for its rapid approach. Digital microbiology also has the potential to significantly impact public health and pathogen surveillance. To embrace digitalization, microbiology laboratories must develop expertise in digital medicine and food analysis, including data handling, perception, and infrastructure (Soni et al., 2022).

In recent years, methods such as computer vision, artificial intelligence (AI), and machine learning (ML) trained on large amounts of labeled data, have been increasingly used for automated analysis of medical images and microbiological samples (Goodswen et al., 2021). These methods could be used for the recognition of four different types of microorganisms: bacteria, algae, protozoa, and fungi (Rani et al., 2022). Convolutional neural networks and models such as ResNet-50 can be used to determine the category of microbiological samples (Majchrowska et al., 2021) (Rani et al., 2022) (Talo, 2019). Semantic segmentation is a computer vision method used to analyze images of microbial samples when it is necessary to precisely determine different regions of the image based on their semantic meaning, assigning a class label to each pixel in an image (Zawadzki et al., 2021). Models such as Faster R-CNN and Cascade R-CNN can be used to count colonies of bacteria in images of microbiological samples that can detect individual objects and determine their class. The instance segmentation method aims to provide a detailed understanding of the image by distinguishing between different instances of individual bacterial colonies within an image and assigning each pixel belonging to unique colonies (Zawadzki et al., 2021).

The Segment Anything Model (SAM) developed and trained by Meta company, is used for image segmentation (instance segmentation) (Kirillov et al., 2023). This model was trained using over one billion masks on 11 million images. The SAM model has the possibility of zero-shot generalization, so it can be used for the segmentation of objects in images without additional training. The SAM model can analyze images from a wide range of areas, including biomedical, agricultural, autonomous driving, etc.

2. METHODS

In this study we used the AGAR dataset (Majchrowska et al., 2021) (Annotated Germs for Automated Recognition) that contains 18,000 images, 12,750 higher-resolution (4000×6000px) and 5250 lower-resolution (2048×2048px) images of microbiological samples in Petri dishes. This dataset contains five microorganisms: Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Escherichia coli, and

Candida albicans. The microbial cultures were incubated on Trypticase Soy Agar (TSA) plates at 37°C for 18-24 hours. The images from this dataset were taken under diverse lighting conditions with two different cameras.

Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Escherichia coli, and Candida albicans are common types of bacteria and yeast that can be found in various environments, including food microbiology or clinical environment. These microorganisms are commonly studied in microbiology and often used as model organisms for various research purposes, including drug discovery, understanding pathogenicity, and studying host-microbe interactions.

The data flow diagram of the process for the detection and identification of individual bacterial colonies based on the SAM model is presented in Figure 1. The procedure starts with recording a microbial sample using a camera (P1) that generates a digital image that is processed using the SAM model (P2). After the image (D1) is processed using the SAM model, a new image (D2) is obtained in which the bacterial colonies are marked with different colors. As a result of this processing, a CSV (D3) file is also generated that contains the coordinates of the bounding boxes as well as a large number of image files with segmentation masks of each of the identified microbial colonies (D4). The disadvantage of the current version of the SAM model is that it cannot determine the classes of detected objects. An additional convolutional neural network (CNN) should be used to determine the classes of identified items. To identify the classes of individual colonies, it is necessary to crop (P5) smaller images of individual microbiological cultures (D5) from the image of the microbiological sample (D1) using the coordinates of the bounding boxes from the CSV file (D3). Images of individual microbial colonies are then sent to the CNN network (P4), which tries to determine what type of bacteria or yeast is present in that image. In the next step (P5), each of the images from the segmentation mask set (D4) is assigned microbial classes determined by the CNN network (P4).

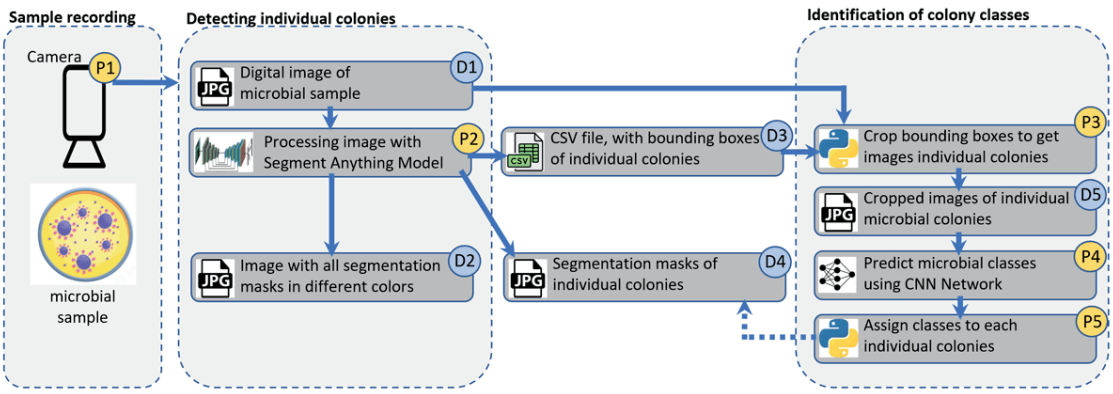

Figure 1: Data flow for detection and identification of individual bacterial colonies

3. RESULTS

After processing the microbiological sample image, the SAM model generates a series of segmentation masks that are saved as separate files for each detected object. Along with the segmentation masks, the model produces a CSV file containing the bounding box coordinates, area, and several other parameters for each detected object, Fig.2. Figure 3 shows a) an image of a microbiological sample, b) an image where the bounding boxes from the SCV file are drawn over the same image sample at the positions where microbiological colonies were detected.

id	area	bbox_x0	bbox_y0	bbox_w	bbox_h	point_input_x	point_input_y	predicted_iou	stability_score	crop_box_	crop_box_	crop_box_w	crop_box_h
0	6275	879	783	97	83	928	800	1.01563251	0.976960719	0	0	2048	2048
1	5426	797	837	85	79	864	864	1.012376785	0.987010598	0	0	2048	2048
2	7662	841	323	101	96	864	352	1.011579633	0.989614427	0	0	2048	2048
3	6675	1502	592	88	93	1568	672	1.011025429	0.990754545	0	0	2048	2048
4	8226	1238	747	103	99	1312	800	1.011019468	0.986357629	0	0	2048	2048
5	10555	721	386	110	121	800	416	1.010838509	0.990380108	0	0	2048	2048
6	6990	1437	993	101	86	1504	1056	1.009401202	0.98650378	0	0	2048	2048
7	9878	250	836	108	108	288	928	1.009243488	0.985229075	0	0	2048	2048
8	7668	1205	924	101	99	1248	928	1.005910873	0.986789286	0	0	2048	2048
9	7275	1595	533	101	95	1632	544	1.005382538	0.984997272	0	0	2048	2048
10	10983	1378	588	107	125	1440	608	1.004524469	0.98830992	0	0	2048	2048
11	8511	1129	1021	108	98	1184	1056	1.004201531	0.989136755	0	0	2048	2048
12	5916	1638	1094	88	82	1696	1120	1.004196286	0.989404619	0	0	2048	2048
13	6455	1349	464	87	91	1376	544	1.002831221	0.986910999	0	0	2048	2048
14	5113	871	724	92	72	928	736	1.002191186	0.974146247	0	0	2048	2048

Figure 2: CSV file with CSV file with the bounding box of detected objects

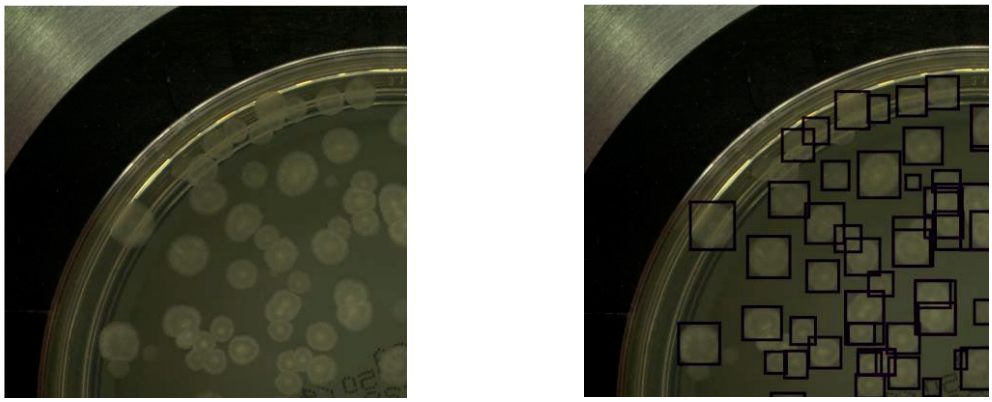

Figure 3: a) Original image of microbiological samples, b) bounding box drawn over the original image

Figure 4 shows a) an image of a microbiological sample and b) an image generated by the SAM model where all detected segmentation masks of individual microbial colonies are shown in different colors.

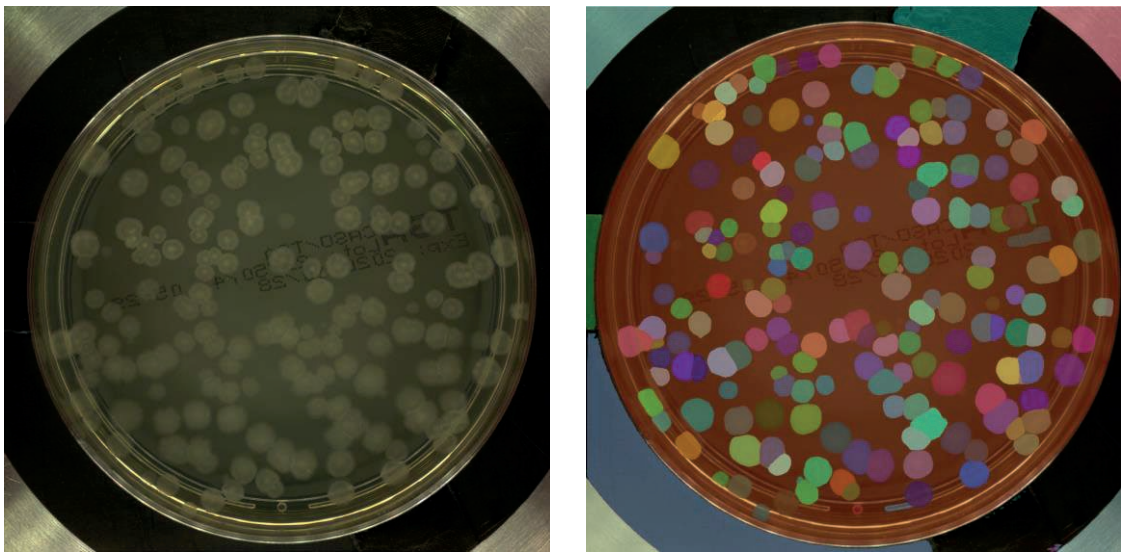

Figure 4: a) Original image of microbiological samples, b) Image processed with the SAM model

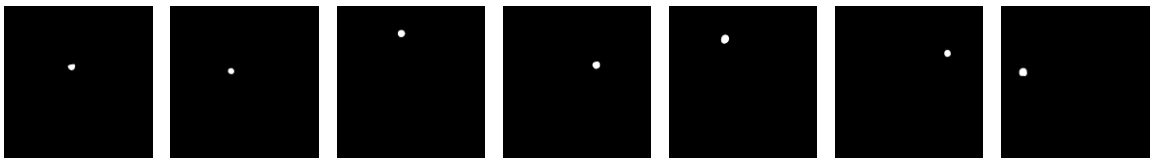

Figure 5. Segmentation masks generated by the SAM model

Figure 5 shows some of the 190 segmentation masks that are the result of processing image 2 using the SAM model.

The precision of SAM model predictions can be determined using Intersection over Union (IoU) metrics (1), which allows comparing predicted bounding boxes with bounding boxes from the dataset.

$$UiO = \frac{Area\ of\ Overlap}{Area\ of\ Union} \tag{1}$$

Since the AGAR dataset does not contain mask files for example segmentation, if we want to determine the accuracy of the predicted masks, we would need to manually label the images from this dataset before calculating the accuracy.

4. DISCUSSION

Models such as Faster R-CNN and Cascade R-CNN (Majchrowska et al., 2021) were previously employed for microbe detection, in this study is used the novel Segment Anything model, which, in addition to object detection, also provides precise instance segmentation. Another significant difference between the R-CNN model and the approach based on the SAM model is that before the R-CNN model is used for image processing, it is necessary to collect images for a dataset, perform labeling, and training of the model. If we want to use SAM models to detect microbial cultures, we can simply download pre-trained models that are trained on datasets containing images from a large number of different domains.

5. CONCLUSIONS

Digitalization, computer vision, and artificial intelligence will have a significant impact on the methods of testing microbiological samples in laboratories. Rapid detection of microorganisms on analyzed articles using automated methods will prevent contaminated products from entering the market and withdrawing them from the market. The Segment Anything model showed excellent results in the processing of images of microbiological samples without additional training. Since the SAM model generates a CSV file with the coordinates of the identified objects, this model can be easily integrated into software that counts microbial colonies on Petri dish images.

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Production automation with the help of SolidCam tools

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Abstract: *Automation of production processes is crucial for improving efficiency and reducing manual labor in the manufacturing industry. SolidCam facilitates automation through various tools such as Automatic Feature Recognition (AFR) and IMachining that identifies and extracts machining features from CAD models, eliminating the need for manual feature programming. The software's toolpath optimization algorithms automatically generate the most efficient toolpaths, reducing machining time, minimizing tool wear, and improving surface finish. This paper presents an improved virtual simulation methodology of the milling process. The process begins with defining the toolpath and determining how to create paths that link to each other within SolidCam. With IMachining, automatic path detection is enabled, after which the tool that needs to be used is selected. When the path is selected, the processing method is determined and at the end the G code is generated which shows the coordinates for milling and additional operations if they are selected. It is also linked to the tool list that is passed on to the operators. Benefits using this kind of automation are discussed and compared with the traditional approach without using automated processes.*
Key words: *SolidWorks, SolidCam, automation, milling, simulation*

1. INTRODUCTION

In today's rapidly evolving manufacturing landscape, the integration of advanced technologies has revolutionized the way products are designed, developed, and produced. One such transformative technology is Computer-Aided Manufacturing (CAM). CAM systems have emerged as indispensable tools that bridge the gap between design and production, offering numerous advantages to industries across the board. By leveraging the power of computer software and hardware, CAM has ushered in a new era of automation, precision, and efficiency in manufacturing processes. CAM is the computerized process of manufacturing. This is currently applied by most of the heavy and medium industries in developed and some developing countries. CAM can be defined as the use of computer systems or software to plan, manage, and control the operations of a manufacturing plant through either direct or indirect computer interfaces with the plant’s production resources. SolidCam iMachining is the de-facto standard Gold-Certified integrated CAM-Engine for SolidWorks. It provides seamless, single-window integration and full associativity to the SolidWorks design model. All machining operations are defined, calculated and verified, without leaving the SolidWorks windows. SolidCam supports the complete range of major manufacturing applications in Milling, Turning, Mill-Turn and Wire cut electro-discharge machining (Sultana et al., 2016). The great importance of all new technologies, materials, machinery, progressive methods and information tools that enable more efficient use of starting materials, produces a more cost-effective, fast enough to produce reliable and quality products and above all success in the market in an increasingly challenging competitive environment (Dubovska et al., 2013). The primary objective of CAM is to streamline and optimize the production workflow by automating various tasks, eliminating human error, and maximizing productivity. CAM software seamlessly integrates with Computer-Aided Design (CAD) systems, enabling the conversion of virtual designs and models into machine-readable instructions. These instructions, often in the form of G-code, direct sophisticated machinery such as Computer Numerical Control (CNC) machines, robots, and 3D printers, facilitating the efficient and precise manufacturing of complex components and products. CAD-system includes three main components (Holovnia et al., 2021):

1. CAD is a technology aiming at applying computer systems in order to facilitate the projects creation, modification, analysis and optimization.
2. CAM is a technology that lies in applying computer systems with the aim of planning, managing and controlling manufacturing operations through a direct or an indirect interface with the manufacturing resources of the enterprise.

3. Computer-aided engineering (CAE) lies in applying computer systems in order to analyze the geometry of CAD, modeling and studying the product behavior with the aim of its further design improvement and optimization.

CNC machine tools complete the product design and manufacturing lifecycle, and more often than not they have to communicate with upstream sub-systems, such as CAD, Computer – aided process planning CAPP and CAM. The final result from a CAM system is a set of CNC programs that can be executed on a CNC machine (X.W. Xu and S.T. Newman, 2006).

The rest of the paper is organized as follows: Section 2 presents the literature review. Section 3 presents the simulation of CNC machining process and individual acts necessary for the design of machining on CNC machining centers. Along with that, Section 3 describes the methodology and Section 4 proposed system that has been developed and tested. In Section 5 the research's conducted study is described in detail and results are presented and discussed. Finally, Section 7 holds the conclusions.

2. LITERATURE REVIEW

In the process of science and technology development, traditionally structured systems become increasingly complex. At the same time, competition on the market is growing. Under these conditions, traditional non-automated design methods are ineffective. CAM and CAD technologies have revolutionized the manufacturing industry, offering numerous benefits throughout their history. Scientific and methodological aspects of CAM/CAD system implementation are revealed in the following papers.

Ciric D., Lalic B. et al. (Ciric D. et al., 2021) introduce a bibliometric analysis approach to review mass customization scientific production. The most productive journals are mainly in industrial engineering, production, operational, and manufacturing research, among the ten most influential articles are the ones that are mostly published in journals oriented towards management sciences. The relevant papers listed below are from the field described in the aforementioned paper.

Ficko M. et al. (J. Balic et al., 2000) researched the automatic programming of CNC machine tools. They explored the various ways of programming in CNC machines. The paper defines the areas of development of the CAM program crucial for the development of such programming.

In their work, Jorge Andre´s et al. (García Barbosa et al., 2014) used parametric programming in order to get higher flexibility of the manufacturing process. The ball milling process was simulated and verified in a virtual model of the Siemens NX7 product lifecycle management machine tool. This process was developed with an additional module of integrated simulation and software verification.

Rozmarina Dubovska, Jaroslav Jambor and Jozef Majerik introduced (Dubovska et al., 2013) an improved methodology of the virtual simulation of turning and milling technological process of the selected components in the CAD/CAM system. During the experiment, it was proven that the simulations of the proposed cutting paths work in the real world.

Nazma Sultana et al. (Nazma Sultana et al., 2016) researched a Simulation Study of a Spur Gear Machining and G-code Generation for CNC Machine. In the paper, SolidCam iMachining is studied and the detailed procedures of the machining process of a spur gear from stock material.

Nikola Vitulic, Zoran Jurkovic and Mladen Perinic in their paper (Nikola Vitulić et al.,2011) show the implementation of advanced CAD/CAM systems and simulation tools used at the Institute for Industrial engineering and management for designing processing processes and tools. The paper presents virtual simulations and verification of machining on an automated turning machining center with a new one defined post-processor for the control system EltroPilot and provides an overview of the current state of conventional NC programming as well as StepNC.

Boogert, et al. (R.M.Boogert et al.) developed a module which automatically calculates tool paths and cutting conditions for metal cutting operations in which necessary algorithms had been designed to generate reliable numerically controlled programs.

CNC machines appeared in 1980, and with them came the need for automatic production of components. Roberto S.U. Rosso Jr et al. (Roberto S.U. Rosso Jr et al. 2020) paper proposed a novel approach to use this standard with an emphasis on CAD/CAM systems and vendors as well as machine control vendors.

Y. V. Petrakov and A. V. Myhovch introduced (Y. V. Petrakov et al. 2020) analysis of the control made of two straight arcs of a circle. The analysis is automatically integrated into the iMachining Solid CAM module for processing parts.

In their work Jie Yan and Danqing Chen (Jie Yan et. al, 2019) use the connector terminal's three-dimensional entity as the model. The model is imported into the software for 3D analysis of finite elements. The Logopress 3 plugin in SolidWorks is used to suggest mold designs.
Ciric D. et al. (Danijela Ciric et. al, 2020) researched application of ICT solutions in manufacturing companies in Serbia. The research showed that in order for Serbian companies to start the process of reindustrialization and keep pace with trends, it is necessary to implement all or at least some elements of Industry 0.4, including the application of various software solutions.
In their work, Djakovic M. et al (Dakovic M. et al., 2020), showed systemic risks in the engineering industry. The focus of the paper is the time per tasks and the delays. Simulation of CNC machining process explained below significantly reduces budgetary risks.
SolidCam is used to mimic the NC programming processes, as well as the processing of molded parts simulation. Although this trend of application and development of SolidCam systems is encouraged, it is necessary to look back at previous experiences, proposed methodologies and devices, in order to reach significant conclusions in future research and for researchers to contribute to the development of this field.

3. METHODOLOGY

Organizations may successfully deploy production automation with the use of SolidCam tools by following the methodological stages, which will boost productivity, lower costs, and enhance product quality in manufacturing operations.
The major stages of the SolidCam manufacturing project creation process are (SolidCam, 2021):

- CAM-Part definition

This stage includes the definition of the global parameters of the Manufacturing Project (CAM-Part). A number of Coordinate Systems, that describe the positioning of the part on the CNC machine, have to be defined. Optionally, defined Stock model and Target model can be used for the rest material calculation.

- Operations definition

SolidCam enables to define a number of milling operations. During an operation definition geometry has to be selected, after that the tool from the Part Tool Table should be chosen (or define a new one), machining strategy and a number of technological parameters also must be defined.
Individual acts necessary for the design of machining on CNC machining centers in the CAD/CAM system.

SolidCam methods and properties used in methodology:

- Creating a 3D model
- Choosing between mill, mill turn or turning depending on what type of part has to be created and determining the geometry.
- Selecting the machine mode of CAD/CAM system and choosing which CNC machine will be used and determining the position of the coordinate system.
- A stock can be added. SolidWorks model, SolidWorks configuration can be added or clicking on a part will add a box around the extremity.
- If iMachine is used there is an option to select iMachine tool.
- When everything is set, the tool is applied and processing starts from the selected part. Selecting Simulation and SolidCam will show the tool in action.

The flow consists of steps related to activating the Solidworks program and creating a 3D model. SolidCam is integrated into the SolidWorks program. Firstly, variables related to the SolidWorks application, model, drawing, view, dimension, and annotation objects are defined. The following step is choosing between mill, mill turn or turning depending on what type of part has to be created and determining the geometry. After saving the model in SolidWorks, the coordinate system and Mac CoordSys number are defined. The next step is that the CoordSys Manager is automatically opened where the position of the coordinate system is set. After the coordinate system is set, the Milling part data window is opened where stock is set and it is also possible to get supplies. When all the parameters are set, the targets are defined, the targets represent the fields over which the simulation will be performed. The last step is to activate the simulation process, milling. After all the necessary parameters have been defined, the simulation is started.

4. RESULTS

After the 3D model has been created in SolidWorks, SolidCam tool is used and fully integrated into SolidWorks. The appearance of the SolidCam tool is shown in Figure 1.

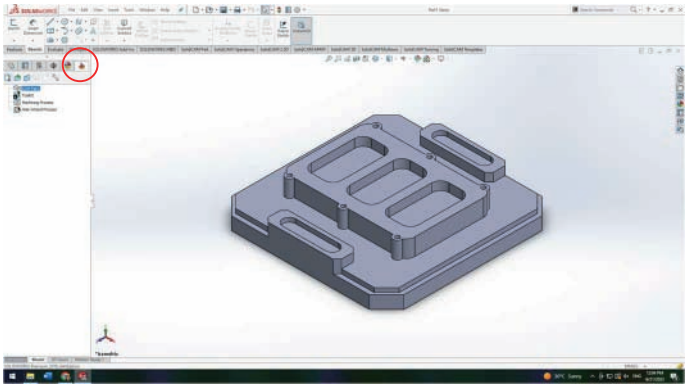

Figure 1: SolidCam tool

Figure 2. shows the CAM tree that displays options for Milling, Mill - Turn, and turning. The milling option is selected for CNC milling, a subtractive process using 3-, 4-, and 5-axis milling machines and cutting tools. The part is saved in SolidWorks and data for milling is entered. The AWEA 1000 - FANUC CNC machine is selected for simulation. The coordinate system is set, and the Mac CoordSys number, for which the value 1 is set, and position number are defined. The top center of the model box is set, and the height of axes can be modified. In the Modify by delta field, the Z axis is shifted by 2 mm.

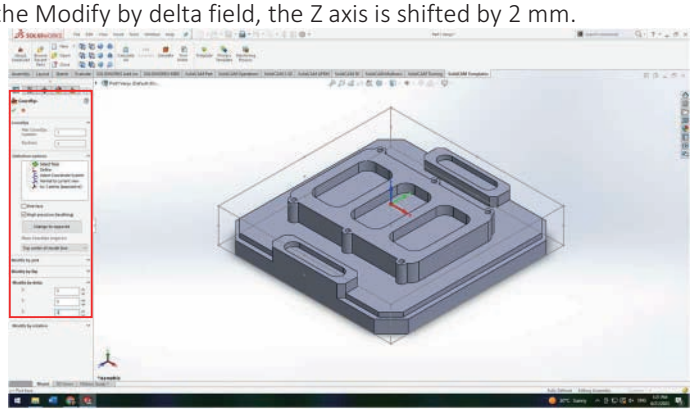

Figure 2: Setting the coordinate system

After the coordinate system parameters have been saved, a new CordSys Data window opens automatically. Figure 3. shows the parameters for the coordinate system that can be adjusted and changed at any time during the simulation setup process. In each of the offered levels (planar, radial and rear) it is possible to set the corresponding parameters. An important parameter is the clearance level. Clearance is the absolute Z location the tool rapids before feeding down in the Z axis. It is also the height the Z axis position during rapid moves to get from one cut to another with the same tool. For the displayed model, the corresponding parameters are automatically set after the previous step of setting the coordinate system.

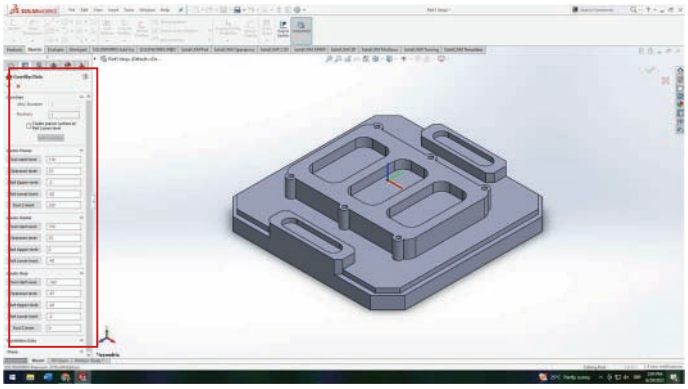

Figure 3: CorsSys Data parametars

CordSys Manager opens next. In the field shown in Figure 4., the settings of the manager that have not been changed are visible. The Milling part data window, which is also shown in Figure 4., opens automatically, where it is possible to set the stock. It is also possible to get any supplies which are needed. Stock can be obtained in several ways. First is by a 3D model from SolidWorks, a configuration from SolidWorks or, what was done in the example, just by selecting the part.

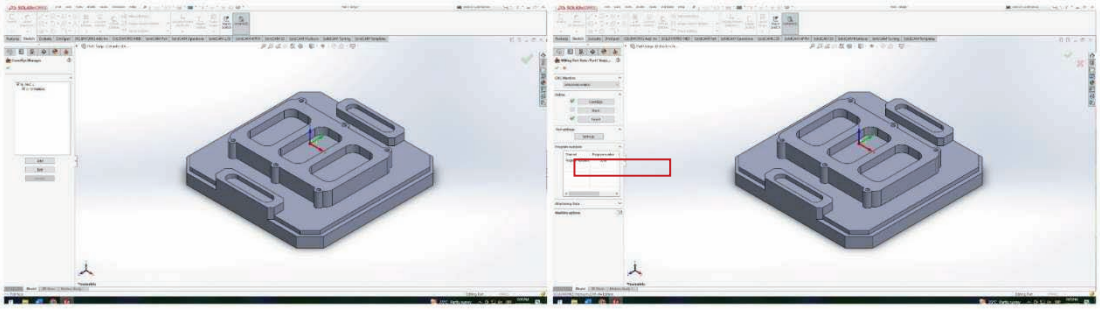

Figure 4: CordSys Manager and Miling Part Data window – stock definition

Stock enables additional box to CAD model. Figure 5. shows the parameters for the shown model. This model had a 2mm in the X, 2mm in the Y and 2mm in Z direction. After checking the parameters, adding a box around the model was selected and clicked again on tick.

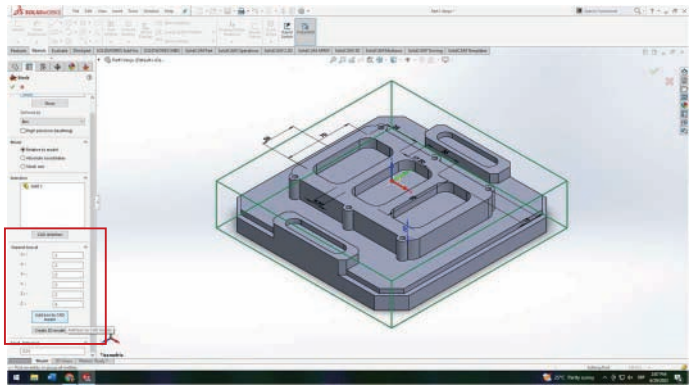

Figure 5: Adding Box to CAD model

When all mentioned parameters are set, it is finally possible to define the targets. Previously, the stock was set, which is why the model is now automatically selected. At any moment, it is possible to deselect a part and manually select it again, during which it becomes pink as shown in Figure 6.

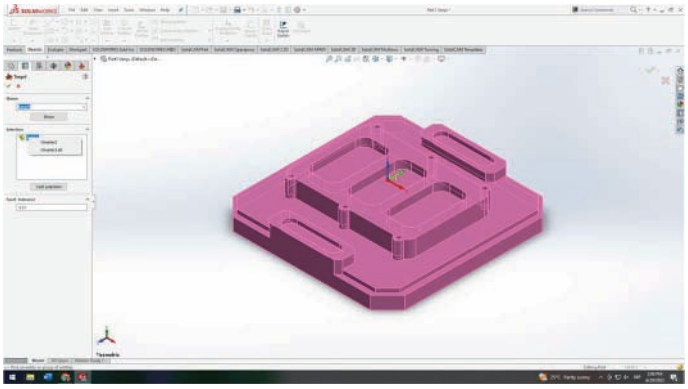

Figure 6: Defining targets

To start a simulation in Miling, click on the tick to open the Miling part data window, add additional information, and set program numbers for the part material. The iMachining database is selected, and the simulation starts with the first operation, the Profile operation. The geometry is contoured, and the tool was selected. In addition to the profile in the Level field, the upper level is defined at -2 as well as the depth profile at 40. The delta value is left at 0.When all the specified parameters are set, the selected operation is saved, after which the simulation is finally started. The simulation is started by simply clicking on the Simulate icon in the SolidCam Operation field.

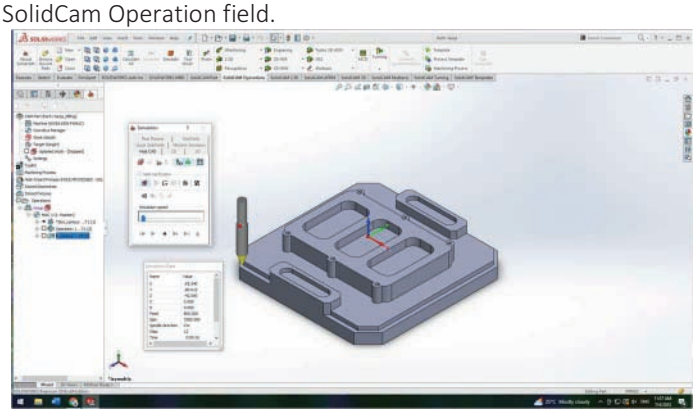

Figure 8: Simulation of object contour processing

The simulation of model processing can be shown on each individual part of the model in the same way as it is shown for the contour of the object.

5. DISCUSION

CNC machine programming requires less human labor thanks to SolidCam automation. As a result, toolpath creation is sped up and setup times are decreased, thus improving production efficiency. Automation reduces human error, resulting in consistently precise and dependable machining operations. The sophisticated algorithms and simulation abilities of SolidCAM provide fine-grained control over toolpath creation. Tight tolerances and higher surface finishes are produced as a result of this accuracy, which also improves part quality. The possibility of expensive mistakes and rework is decreased by the ability to model and test toolpaths prior to real machining. For complicated machining tasks like mill-turn operations, multi-axis milling, and 5-axis machining, SolidCAM's automation features are very useful. It makes these complex activities easier to program, enabling them to be used by a wider range of production facilities. Production expenses may be considerably decreased by automation using SolidCAM technologies. This includes lower labor costs, better tool utilization, and less material waste as a result of fewer mistakes. Cost reduction also benefits from the ability to produce effective toolpaths and shorten machining times. It might take a while to setup and become ready for machining. This procedure is streamlined by SolidCAM automation, enabling quicker machine setup and changeovers. More frequent task changes and effective CNC machine use are made possible by shorter setup periods.

6. CONLUSION

SolidCam tools have shown to be quite helpful for companies and factories when it comes to production automation. In order to streamline and optimize production processes, SolidCam, a computer-aided manufacturing (CAM) program, provides a wide range of features and capabilities. As a result, production efficiency, accuracy, and cost are all increased. The ability of SolidCam technologies to automate numerous production operations is one of their main benefits. SolidCam can automate procedures including toolpath generation, machining operations, and component programming through the use of sophisticated algorithms and intelligent programming. With this automation, less manual labor is needed, there is less chance of human error, and the manufacturing cycle is accelerated. Additionally, advanced simulation and optimization features are offered by SolidCam tools. Before starting the actual manufacturing, users can virtually mimic the machining process to look for any problems or collisions. This not only saves time, but also avoids expensive mistakes and machinery damage. Additionally, users of SolidCam may optimize cutting parameters, reduce material waste, and improve toolpath efficiency, all of which increase productivity and lower production costs. The smooth connection of SolidCam with CAD tools like SolidWorks is another essential component of production automation with SolidCam. Through this interface, design data may be transferred without any interruption, guaranteeing precise part representation and removing the need for manual data entry. Iterations may be completed more quickly thanks to the strong interaction between CAD and CAM, which also speeds up the transition from design to production. Additionally, a variety of machining techniques, including as milling, turning, wire EDM, and multi-axis machining, are supported by SolidCam. Due to its flexibility, producers can adapt various machining techniques and handle a range of production requirements under a single software platform. The manufacturing process is streamlined, setup time is decreased, and productivity is increased thanks to the capacity to handle complicated parts and multi-axis machining jobs. In conclusion, manufacturing processes and industries benefit greatly from production automation thanks to SolidCam technologies. SolidCam improves production productivity, accuracy, and cost-effectiveness by automating processes, improving toolpaths, offering cutting-edge simulation capabilities, and integrating seamlessly with CAD applications. Utilizing SolidCam technologies can improve efficiency, save manufacturing time, eliminate errors, and boost market competitiveness.

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CHALLENGES OF USING QUANTUM COMPUTING TECHNOLOGY: A SOFTWARE DEVELOPERS PERSPECTIVE

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Abstract: *Quantum computing is a novel technology that operates on fundamentally different principles than classical computing. Despite their differing principles, both technologies share the common goal of creating solutions for specific problems that need to be tested and verified. The software development process has evolved and solidified over time within classical computing. However, the use of quantum computing technology with existing software development approaches is still an unresearched topic. This paper examines the challenges faced by software developers when working with quantum computing technology within the framework of the established software development process used in classical computing.*

Key words: quantum computing, software development process

1. INTRODUCTION

Quantum computing represents a groundbreaking technology that operates on principles fundamentally distinct from classical computing. Concepts such as entanglement and superposition enable problems that couldn't be solved using classical computing to become possible [2]. Some areas that could greatly benefit from this are physics, where complex simulations could be performed, as well as the world of finance, where numerous optimizations could be achieved. Due to the intensive development conducted by leading companies in the IT world, it is expected that quantum computing will start being applied in the software industry in the next few years [6].

Classical computing has a well-established software development paradigm [7]. The software development process in classical computing has evolved over time, guided by research and practical experience. Numerous works have investigated various aspects of classical software development, such as solution design, implementation, validation and testing, and deployment [4][9]. However, the integration of quantum computing technology within the current paradigms remains largely unexplored. The introduction of quantum computing technology also presents unique challenges to software developers.

To date, limited research has been conducted on the integration of quantum computing technology with the established software development process. While some works have touched upon specific aspects of quantum software development, such as algorithm design and optimization [3][11], a comprehensive analysis of the challenges faced by software developers remains a critical research gap. Understanding these challenges is vital for the advancement of quantum software engineering and the successful integration of quantum computing technology into real-world applications.

In order to advance the field of quantum software development, it is essential to understand the challenges faced by software developers when working with quantum computing technology within the context of the established software development process used in classical computing. The integration of quantum computing into the existing software development process necessitates the exploration of new techniques and methodologies to harness the power of quantum systems effectively.

This research objective is to address this research gap by examining the challenges faced by software developers when working with quantum computing technology within the established software development process used in classical computing. In order to address the objective, we used comparative research strategy for designing an empirical case study [10]. By identifying and analyzing these challenges, we can gain insights into the necessary adaptations and enhancements required for effective quantum software development. Additionally, we aim to provide recommendations for addressing these challenges and propose directions for future research in the field.

The rest of the paper is structured as follows. In section 2 we present background and research context, where main focus is on explaining concepts like quantum computing and quantum software engineering. Section 3 gives an overview of research method used in this study. In the Section 'Findings' we described

case study we have made, and lessons learned from the case study. In the last section, we have discussed relation between findings in the related studies and the findings conducted in this study, as well as what future works should focus on.

2. BACKGROUND AND RESEARCH CONTEXT

The integration of quantum computing technology within the established software development process used in classical computing necessitates a thorough understanding of both the existing software development practices and the unique characteristics of quantum computing. In this section, we provide an overview of the quantum computing specifics as well as the potential benefits and applications of quantum computing in software development.

2.1 Quantum Computing

Quantum computing operates on principles fundamentally distinct from classical computing. Understanding the quantum software engineering is tightly coupled with understanding the quantum computing. As discussed in [1], currently most of the quantum languages are lower-level programming languages. Using those languages, programmers can directly manipulate low-level concepts e.g., quantum gates and circuits.

Survey [5] gives thorough overview of research related to quantum computing technology. Main building blocks of the quantum computers, qubits, are discussed in great details. Most important properties of qubits are superposition and entanglement, which give quantum computing power to overcome the power of classical computers in particular use cases [6]. However, it also introduces unique constraints, such as quantum noise, limited qubit coherence, and the need for quantum error correction.

2.2 Quantum Software Engineering

To date, the integration of quantum computing within the software development process has received limited attention in the literature. The concepts that are supposed to define the concept of quantum software engineering are presented in the paper [8]. The importance and need for quantum software engineering are emphasized by the fact that 100 researchers have signed the manifesto of quantum software engineering as a set of concepts on which quantum software engineering should be based.

In the paper [1], the authors discuss what is required to create quantum software that would be used in industry. They utilize an example of the conventional software development process, which includes the phases of requirement specification, design and architecture, development, testing, debugging, and maintenance. The result of the research conducted in the paper is the presentation of challenges that arise from quantum computing in certain phases of software.

There are couple of research discussing specific topics regarding quantum software engineering, such as testing and refactoring of the quantum code [3][11], but comprehensive analysis of the challenges faced by software developers during quantum software development process remains a unresearched topic.

The research presented in this paper aims to bridge the gap between classical and quantum software development processes. By investigating the challenges faced by software developers when working with quantum computing technology within the established software development process, we can provide insights into the necessary adaptations and enhancements required to effectively harness the power of quantum systems. This research also contributes to the broader field of quantum software engineering and serves as a foundation for future studies in this emerging area.

3. RESEARCH APPROACH

This research objective is addressing the challenges faced by software developers when working with quantum computing technology within the established software development process used in classical computing. In order to address the objective, we've been working on a quantum software development project. This project is specially designed to be able to be solved using both classical and quantum computing. We used comparative research strategy for designing an empirical case study. The case study consists of 3 steps which aimed to show all of the difficulties faced by experienced software developer in classical computing when attempting to solve a problem using quantum software development process. The steps followed in the examined case study were as follows:

1) Defining an abstract model of the software development process: software development process based on the well-known software development process in classical computing should be chosen and all of the components of that process have to be followed in the case study.
2) Defining the problem to be solved: in order to achieve comparative analysis, it was necessary to choose problem which could be solved using both classical and quantum computing.
3.) Applying the defined model of the development process during solution creation: In every step of the defined model, difficulties faced by software developer are noted and result of the analysis of all notes should be lessons learned.

Software development process we used in this case study consists of following components: problem defining, design and architecture, development, debugging and testing. Goal of the case study is addressing all of the difficulties faced by software developer in every single phase and try to summarize those difficulties in a couple of lessons learned.

4. FINDINGS

4.1 Solution implementation

Project described in the previous section is implemented by one of the authors of this research. As a first step, we needed to define an abstract model of the software development process which should be followed during the whole lifecycle of the project. Because all of the author's experience comes from the classical software development process, one type of the well-known software development process was chosen for this project. Defined development process consists of the following phases: (1) Requirements specification, (2) Solution design, (3) Solution implementation, (4) Debugging, and (5) Solution validation (testing).

Well-known phases like maintenance and deployment are intentionally excluded from this project because the aim of this research is to show experience of the software developer during the process of creating solution, not to investigate whole product's life cycle.

The next step which was intended to be done was defining the problem to be solved. It was important to choose a problem which could be solved using both classical and quantum technology, because only some kind of problems could be solved using quantum computing [3]. For this project, we chose the searching problem – problem of finding element in an unstructured collection of elements. When said unstructured collection, it means that collection of elements is not sorted or ordered in any way. Also, the type of data in the collection is not important, solution should be generic and data type should not be a limitation. Solution implemented by the developer is intended to be as performant as possible. The most important thing was that solution should be created using the defined software development process. Iterations over the phases are allowed.

As a first phase of the development process, specifying requirements in this project was not a big issue. The problem of finding element in the collection of data is one with most software developers are familiar with. The was no need for specifying subtasks or splitting the problem into smaller problems.

Phase of solution design started by making decision which programming language and platform to use. Because author's experience comes mostly from .NET and C# world, for implementing this project, Q# was chosen. The next step was an attempt of finding publicly available solutions for defined problem. The initial search only showed that there are a lot of knowledge gaps related to theory which should be additionally considered. Because current state of quantum software development requires programming on the low level, it was very challenging to be able to understand existing solutions and to use their full potential. A lot more time than expected is used for this phase. In the end, Grover's algorithm is chosen as the one to be implemented.

The phase of implementation started by exploring Q# and the quantum environment it comes with. Unlike various of ready for use solutions C# provides developers with, Q# is a low-level language which allows developers to have lot of control to the quantum gates and qubits itself. For somebody with classical software development background only, it was very hard to start being used to program hardware-level components. Implementing solution required numerous back iterations to the previous phase in order to understand theory and concepts in more detail. Also, this phase took much more time than expected in order to complete it.

The first phase of validating implemented solution is debugging. In the world of quantum software development, debugging is not a straightforward process as we know it in software development. Visual Studio, as an IDE used for implementing this project, allows us to put breakpoints and go through the code.

This feature helps developers up to some point, because reading the state in quantum computing means losing the information. This phase also required iterating back to the previous phases and reviewing the theory behind the actual implementation.
The last step in defined software development process is validating and testing of the solution. First approach for validating solution was manual process which included preparation of input values and checking if output is as expected. On the other side, automated testing in the solution is not achieved in this project. Besides the fact that Q# has a support for writing unit tests, it is very hard to test specific steps of the process when state of the system cannot be replicated and any interference with the state of the system could have an impact on the state itself.

4.2 Lessons learned

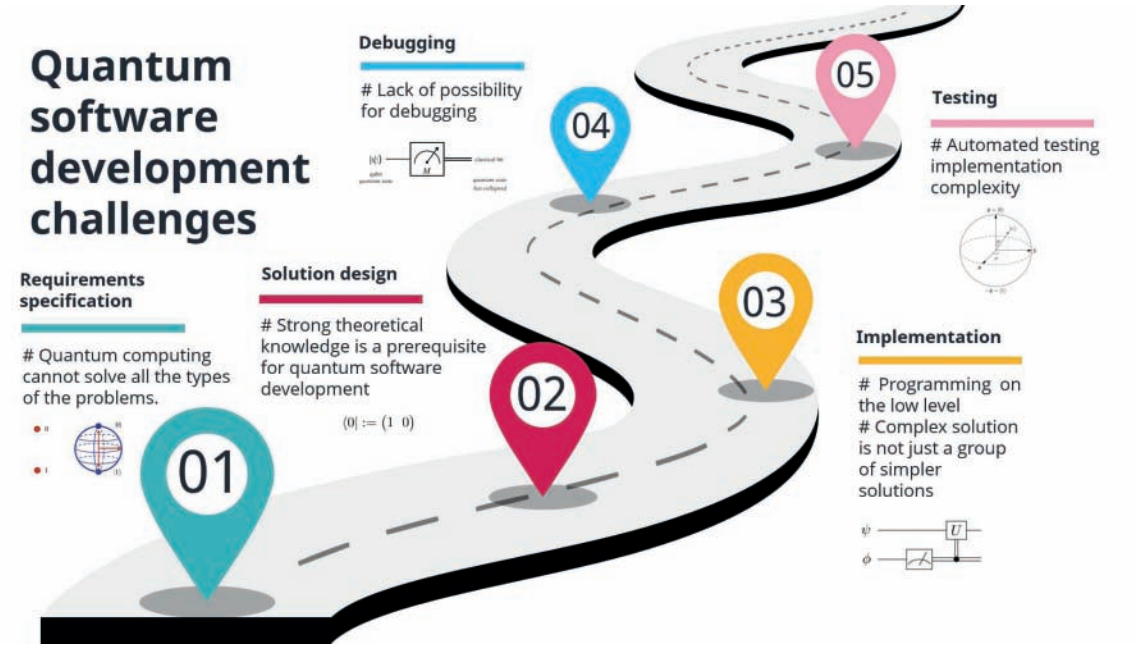

Figure 1: Quantum software development challenges infographic

Working on the project which is based on quantum software development shows that there are lot of differences compared with the software development process in classical computing. In this section, difficulties faced during the development process are shown.
1. Quantum computing cannot solve all the types of the problems. When requirements of the software product are considered, it is highly important to consider could the problem being solved using quantum computing. Considering the fact that quantum software engineering and quantum computing are new technology, it is wort of trying to solve some problem using quantum computing, but developers should be aware that result could show lower performances compared to the one created using classical computing.
2. Programming on the low level. Using of the programming language Q# have been more difficult than using its classical equivalent C#. Programming in quantum computing requires strong knowledge of low-level programming, directly on quantum gates or qubits itself. Previous experience gathered from industry projects was not so useful in order to be able to solve problems in the quantum world.
3. Strong theoretical knowledge is a prerequisite for quantum software development. Designing solution in the classical computing requires investigation of possible solution and the previously accumulated knowledge is very helpful. The hardest part in that process is choosing the appropriate one between many of the offered solutions. All the designer needs in understanding of pros and cons of the solution. In the world of quantum computing, firstly, there are not so many available solutions. Designing the solution requires strong knowledge of quantum and quantum computing concepts. Experience on this project showed that there must be a proof made by physicists or mathematicians for some solution before it is used in quantum computing world. This phase consumes a big amount of time and it seems pretty

unnatural for software developer to understand so many theory concepts and particularly physics concepts in order to be able of making a solution.

4. Complex solution is not just a group of simpler solutions. In classical computing, developers are approaching complex problems by splitting it into a couple of smaller problem. Working on this project showed that solving a problem in quantum computing is not just combining well-known gates and qubits and getting the solution that way. It requires strong theoretical knowledge and theoretical proof in order to be applicable in quantum computing.

5. Lack of possibility for debugging. This challenge represents the hardest part of the whole process. Being able of putting breakpoint somewhere in the code or reading human-readable logs is somethings that really make programmers' life much easier. In the world of quantum computing, that is not possible because reading the value means losing the power of quantum computing. This part is something that creates very bad development experience.

6. Automated testing implementation complexity. Core concepts of the quantum computing, as superposition and entanglement are preventing developers of writing automated tests. When we tried to come up with solution to check some parts of the solution, it was not possible because of the fact that any measurement could damage the state and lead to the incorrect results.

5. CONCLUSIONS

Result of the conducted use case is a list of difficulties faced by software developers which tried to apply software development process model characteristic for classical computing in the quantum software development. Identified challenges have shown that there is a big difference between those two types of computing and that it is not easy for experienced software developer to start working on quantum computing project. There should be a lot of preparation before someone used to work in classical computing to be able to start working in quantum computing.

Although there are significant skills requirements that software developer needs to have in order to work on quantum project, experience from this project showed that development process established in classical computing was totally applicable to the quantum software development process. Phases were ordered in the appropriate and very natural way and helped software developer to create a product which should ultimately fulfill all the requirements specified at the beginning.

Results collected from this project confirm what is previously concluded by researchers in [2]. Authors have identified differences between classical and quantum software development process by phases of the development process. They have found that programming on the low level, deep understanding of quantum physics, as well as lack of possibility to debug code in standard way are something that is not characteristic for classical computing. Project described in this research confirms that those differences represent challenges for software developers and they should be aware of them before starting working on quantum software development environment.

Quantum software engineering is still not broadly applied in the software development industry, but once it has, this study should be reapplied. Evolution of quantum programming languages should be additional motivation to investigate how challenging it is for software developers to start working on the quantum software projects. Because quantum software engineering is at the beginning, this topic should be very interesting for many future studies.

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DRAWING AUTOMATION APPROACH USING SOLIDWORKS API

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Abstract: *The automation of repetitive processes included in the design phase represents an emerging trend in the CAD industry. Automation plays a crucial role in the reduction and minimization of time-consuming and error-prone tasks. In technical drawings it provides a higher level of precision by ensuring that standards and design principles are applied uniformly across all drawings. The aim of the paper is to improve the drawing process in terms of modification efficiency and quality, leading to a shortened time required to complete a design and accelerate time to market. In this paper, the automation process for creating drawings is proposed using SolidWorks API macros. In order to create standardized documentation, a macro is created in which tasks related to views, dimensions, formats, and annotations are unified and automated. With the suggested technique, new drawings can be made with minimal user input based on the CAD model.*

Key words: SolidWorks, API, macro, CAD drawing

1. INTRODUCTION

Organizations are progressively moving towards mass customization and design automation in order to remain competitive in the market, fulfill customer requirements, and retain design quality. In a recent whitepaper by SolidWorks (Dassault Systèmes, 2022), it is stated that according to studies, 63% of engineers have encountered demands for customization, and 26% expect a growing rate in the upcoming years. A tremendous increase in recent years has raised new research questions related to faster design while simultaneously maintaining the same level of quality. Design automation is one of the approaches used for the elimination of errors and shortening time by extracting information from the knowledge base comprising previous experiences, standards, and logical relations between variables. Along with the development of computer-aided design (CAD) systems, it is feasible to develop macros, applets and software tools that can support a variety of engineering processes, including the design and manufacture of machine components (Tzotzis et al., 2020).

Configurations represent a low level of design automation and are mostly used with larger groups of similar products. Dimensions can be easily stored in only one file with variations in dimensions, eliminating the need for numerous models. This approach is applicable to the creation of parts, but drawing generation remains an area of discussion in research and academia.

Detailed technical drawings convey the design purpose of the object that needs to be manufactured and assembled. Additionally, another benefit to the manufacturer is the transmission of a plethora of information related to the required specification, form, and function. Clear and precise instructions are required to guarantee that the finished product meets predefined requirements, but generating drawings brings a lot of challenges if the person is not proficient and knowledgeable enough. On the other hand, the amount of time that is required represents another drawback of manual drawing creation.

Numerous CAD softwares are used in the creation of three-dimensional (3D) models and technical drawings, and consequently, a two-dimensional (2D) technical drawing can be generated based on a 3D model. Technical drawings include orthogonal projections and views, annotations, dimensions, and different types of lines. To achieve automation of the aforementioned process and address this challenge, a Solidworks macro is proposed. The approach is tested on several drawings and compared against the manual drawing process and its length.

The remainder of the paper is structured as follows: Section 2 represents related field work, while Section 3 represents a methodology for drawing automation utilizing the SolidWorks Application Programming Interface (API). Section 4 depicts a discussion of the results obtained and reported in Section 3. Finally, Section 5 discusses the study's conclusions and limits, as well as future research objectives.

2. RELATED WORK

In order to reduce time needed for the human design process, design automation is proposed as a set of predefined codes used to automatically complete operations. Crucial step is strictly adhering to a set of predetermined procedures that should be identified based on knowledge base and previous experience. The design automation process consists of four steps that are recurring and identified by Sirigiri et al(Sirigiri & Esanakula, 2022). The first step is related to reviewing the whole design process, followed by the recognition of repetitive tasks that should be taken into consideration for automation. Subsequently, the development of rule-based design steps for custom features or components is the next phase and, in the end, implementation is performed using SolidWorks API functionalities.

In Figure 1, a schema is presented for a knowledge-based system for CAD modeling proposed by (Jayakiran Reddy et al., 2018). Every system must be linked to a knowledge base that comprises experience and knowledge rules applied by design professionals. Domain expertise and standards are used as support in building a knowledge base. Besides international standards, each organization has its own internal standardization and rules for drawings that should be taken into consideration when developing a system. Domain specialists are individuals who perform these tasks manually on a daily basis and can define the business logic that will be implemented. A domain expert has a goal to find the optimal solution among the standards to accurately represent the design intent, which is the functionality of the product being represented. This goal can be attained if the dimensions are defined according to predefined guidelines to ensure that the original objectives are met and cannot be derived from the geometry of the model. The knowledge base is stored in such a way that a program can retrieve the data whenever the system necessitates it without human interaction. The user has only access to a graphical user interface that is connected to the inference engine, which employs logical rules and regulations to find a solution to the query submitted by the user.

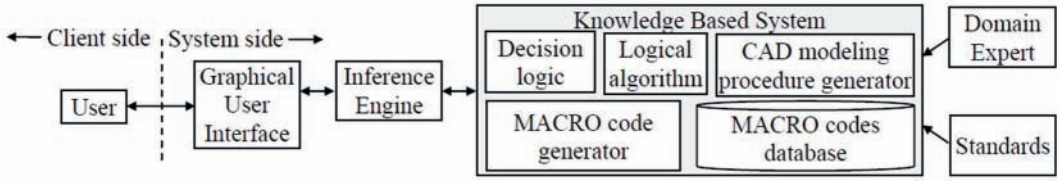

Figure 1: Schema for knowledge-based system for CAD modeling (Jayakiran Reddy et al., 2018)

The illustrations on engineering drawings are based on orthogonal projection views and dimensions and annotations. In engineering drawings, dimensions are frequently used to indicate the measurements and positions of specific geometric components. Research related to the automation of the drafting process is mostly focused on automatic dimensioning.

Focus on the elimination of redundant or insufficient dimensions was proposed in approach by (Sui et al., 2013). All dimensions on a technical drawing are changed to a non-directed graph, and traversing adjacent non-directed graph matrices is used for the determination of redundant or insufficient dimensions.

Li et al. proposed an automatic approach for dimensioning engineering drawings of mechanical products based on usage of the curve chain (Li & Yang, 2020). A geometric topological structure between elements is established. Dimensions within the chain are classified as absolute dimensions in the curve chains generated above, whereas dimensions between chains are classified as relative dimensions. Results have shown that redundancy is avoided with this approach.

Raffaeli et al. proposed an approach for automatic generation of technical drawings for gear motors product family and for testing technical drawings with the aid of feature recognition algorithms (Raffaeli et al., 2016) A scheme is corresponding to variants of the same product family and consists of rules related to views, dimensions and positions of them on drawing, and it is entered in the off-line phase by a designer using a dedicated graphical interface. The second phase relates to repetitive and autonomous use of the system to develop dimensioned drawings.

Not only does the mechanical industry involve product design automation, but also methodology for furniture design, specifically coffee tables, is proposed by (Manavis et al., 2022). Two case studies were proposed, and one of them is based on SolidWorks APIs that are based on Visual Basic for Applications (VBA). Estimated time with the traditional way of design is approximately 85 minutes, and with SolidWorks VBA application it required 3.4 seconds. Indisputably, design automation reduces the time required for manual processes with implementation in numerous industries.

3. METHODOLOGY

This section provides an in-depth description of the SolidWorks API, covering its key components and functions. It explains the programming languages supported by the API, the accessible libraries and resources, and the integration options with external applications and data sources. The report emphasizes the flexibility and extensibility of the proposed SolidWorks API macro, which allows researchers to customize the methodology to their own requirements.

Proposed methodology is based on the SolidWorks API, a popular CAD product used by many industries with the usage of VBA. It represents a programming language that is used for automation of tasks by writing macros. Visual Basic is an object-oriented programming (OOP) language that necessitates knowledge and understanding of object-oriented design and how objects are formed and implemented (Zeid, 2015).

The SldWorks interface is the highest-level object in the SolidWorks API stack. All other interfaces exposed in the SolidWorks API object hierarchy are accessible via SldWorks and IModelDoc2 interface is located just beneath the SldWorks interface and provides access to the three core Solidworks document types: parts, assemblies, and drawings (Buric et al., 2021). Each document type has its own object IPartDoc, IAssemblyDoc, and IDrawingDoc and a set of related functions. IDrawingDoc is used for proposed methodology in view of the fact that it provides access to functions that execute drawing operations in SolidWorks.

Component Object Model (COM) automation is used to interact with SolidWorks software programmatically with scripts in programming (Carlberg et al., 2016). A user interface action calls a programmed function in the programming tool, which then triggers a defined operation in the CAD system that should be proceeded based on selected features. Due to its relationship with VBA, which is an object-oriented SolidWorks API function with objects, methods are used for performing operations on objects, while properties represent features or attributes of specific objects. In Table 1, all methods and properties that are used in methodology are shown with additional details for each method or property in terms of functionality and return values. Due to the version of SolidWorks, the names of the methods or properties can be differently formed compared to the ones shown in Table 1.

Table 1: API methods and properties used in methodology

API Method/Property	Explanation of functionality	Return/Property value
ActiveDoc	Connects to currently active document	Model document
NewDocument	Creates a new document with specific template	Newly created document
GetConfigurationNames	Get the names of the configurations in this document.	Array of the names of the configurations in the order they are created in document
Create1stAngleViews2	Generates three typical orthographic views (first angle projection)	True/false
Create3rdAngleViews2	Generates three typical orthographic views (third angle projection)	True/false
GetPathName	Gets the full path name for this document, including the file name	Full path name for this document including the file name as string
CreateDrawViewFromModelView3	Creates a drawing view on the current drawing sheet using the specified model view	Pointer to the newly create IView object (drawing views found in a drawing document)
ViewDisplayShaded	Sets the current display mode to Shaded	None
InsertModelAnnotations3	Inserts model annotations into the currently selected drawing view of this drawing document	Array of inserted IAnnotation objects
InsertCenterMark3	Inserts a center mark in a drawing document.	Center mark
SaveAs	Saves current document to specified format and name	True/false

The flow consists of steps related to activating the Solidworks program, opening a part, and making a new drawing for an opened model with a specified template. Firstly, variables related to the SolidWorks application, model, drawing, view, dimension, and annotation objects are defined. Initialization of the swApp variable with the current SolidWorks application and the swModel variable with the active document. The following step is binding to SldWorks and connects to the active model, and if the model is not opened, the user also has an option to open the model. It checks whether there is an active document

open in SolidWorks, and if not, a message box is displayed to handle errors. A new drawing document is created using the NewDocument method with the specified template name, paper size, and scaling factors. To provide a user interface (UI) for a SolidWorks API macro, users can use forms or dialog boxes to allow users to input parameters, select different options, and interact with the macro. For the purpose of methodology, a simple VBA message box (MsgBox) is created, and it accepts arguments and receives simple user input to choose whether first or third angle projections should be used in a specific drawing. In Figure 2, the message box is depicted.

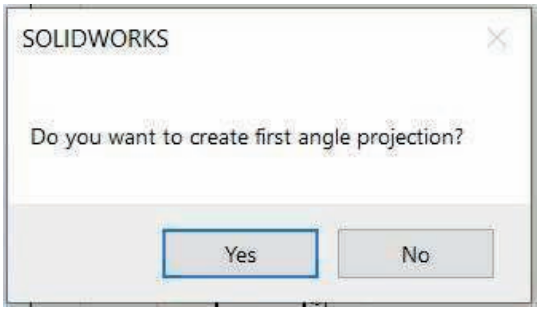

Figure 2: MsgBox in the beginning of the process

The outcome of the function is determined by the button that the user clicks, in this case Yes or No. If the user selects Yes, the first angle drawing is created, while No, conversely, will create the third angle drawing. Based on the user response, either the Create3rdAngleViews2 or Create1stAngleViews methods are called to create the appropriate views in the drawing.

The following step involves placing standard views into the sheet format as well as adding isometric view, annotations, and dimensions. The CreateDrawViewFromModelView3 method is used to create an isometric view in the drawing. In each case (First or Third Angle), specific positioning values of X and Y coordinates of the isometric view are adjusted to the position of other views. The ViewDisplayShaded method is called to display the isometric view with a shaded appearance. The InsertModelAnnotations method is called to insert model annotations (dimensions and notes) in the drawing, while the InsertCenterMark3 method is used to insert a center mark at a required position in the drawing.

Finally, the last step is related to saving drawing documents and exiting the Solidworks application are the final steps with the SaveAs method. Each drawing at the end of the process is automatically saved in DWG and PDF formats in a predefined location.

4. RESULTS AND DISCUSSION

In this section, results of the proposed methodology for automating the drawing process utilizing a SolidWorks API macro are presented. Simple 3D model is used for testing purposes, and following that, the model is opened, and standard views based on the user's preference are generated. Users had a chance to open their part and to choose through message box whether it will be drawn in the first or third angle. After selection, three default views are generated in both cases but in different positions on the paper, including also isometric view in shaded display mode. Annotations, dimensions, centerlines and centermarks are automatically applied in both situations and Figure 3 reflects the outcome of the proposed macro.

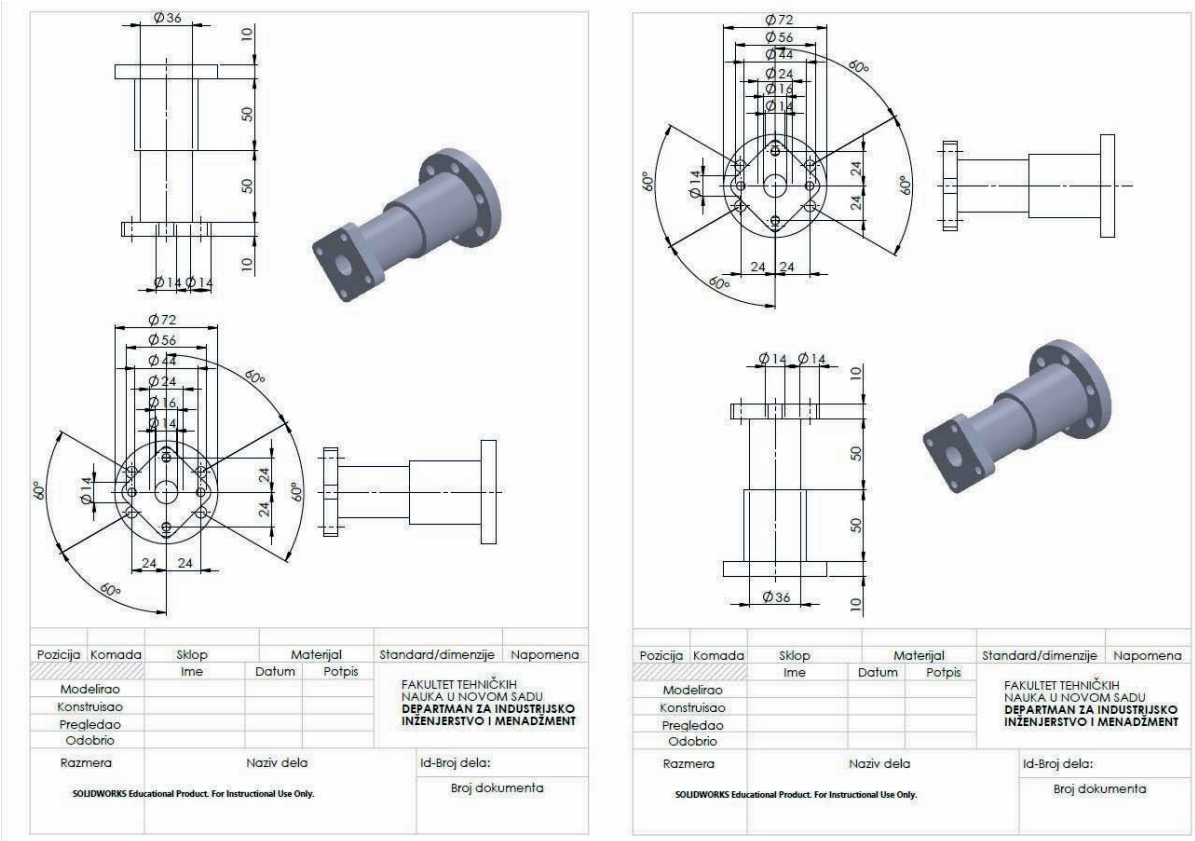

Figure 3: First Angle (left) and Third Angle drawings (right)

Nevertheless, methodology demonstrated great results in terms of saving time when talking about creation of drawings. Manually generating the first or third angle a drawing and saving lasted around 81 second, but executing the macro only required 6 seconds. Compared to manual time for creating or drawing with proposed macro time is reduced by 92.59%. Even if minor adjustments are required in order to make corrections to automatically created drawing, it is unquestionably faster compared to the entire manual process. The knowledge base can be expanded with various rules related to drawing generation, views and annotations and thus contribute to the improvement of the current version of macro.

5. CONCLUSIONS

The aim of the paper is to present the development of drawing automation in SolidWorks API using VBA. The primary goal of this work is to reduce time and inaccuracies in engineering drawings. In comparison to manually created drawings, it includes minor variations that can be easily addressed manually by an engineer or design expert at the end of the process. Automation of designing tasks can minimize conventional and tedious processes.

As a result, it's critical to keep everything simple and widely understandable. It is tested on a smaller group of similar products so future research will be in terms of testing it with a larger set of models. For more precise findings, a larger group of models should be evaluated, but the creation of macro should be centered on a similar set of products, so it should still be adapted to the needs of a specific group of products. Future research will include, in addition to parts, assemblies that will have Bill of Material (BOM) and numerous sheets to collect all drawings related to all parts in assembly.

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Demystifying Sonar Tool Estimates in the Contexts of Familiar and Unfamiliar Software Projects: An Empirical Study with Junior Developers

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Abstract: *Developing a high-quality software product requires complete familiarity with the software product requirements and constraints. However, developers are often assigned to projects they are unfamiliar with, making project properties hard to understand for them. Sonar tool is one of the most popular Automated Static Analysis Tools that nowadays has become an integral part of software development process. The objective of this study is to evaluate the usefulness of the Sonar tool in the context of familiar and unfamiliar projects. More specifically to investigate the accuracy of Sonar's estimates while the remaining three assess the perceived refactoring difficulties, Sonar issue and fixing instructions as possible reasons for differences in estimates. A repeated measurements experiment in the context of a university course was designed and involved two sessions during which the subject refactored Sonar issues identified in familiar and unfamiliar projects. In total 60 students completed assignments, who in two sessions combined refactored 5,179 Sonar issues by violating 138 different Sonar rules. This study showed that estimates provided by Sonar are less accurate for familiar projects. Plausible explanations are that the refactoring and understandability of Sonar tool issue description seem to be more challenging in unfamiliar, compared to familiar projects.*

Key words: Empirical Software Engineering, Technical Debt, SonarQube

1. INTRODUCTION

In order for developers to deliver high-quality software, their familiarity with the software project is essential. For developers to be *familiar* with projects, they need to understand the context and decisions made from the beginning of the project. Including decisions regarding software design, architecture, and requirements [1]. Thus, the concept of familiarity surpasses the understanding of the code itself. However, developers are often assigned to projects they are unfamiliar with, making project properties hard to understand for them. This requires developers to familiarize themselves with the project by reviewing the code base and available documentation.

Various software tools can be used to aid developers while reviewing code base and identifying potential issues in projects. Automatic static analysis tools (ASAT) provide feedback in the form of analysis reports [2]. Sonar[1] as one such tool has proven to be very useful for identifying various quality issues [2, 3]. It provides a set of *code smell* detection rules for different programming languages and various metrics that are used together as means for identifying and estimating the cost of remedying issues in a code base [4]. Furthermore, Sonar's reports aid developers in identifying potential suboptimal software design and implementation choices [2. 5]. This phenomenon is conceptualized as technical debt (TD) [6]. Benefits of the Sonar tool are that it provides effort estimates, issue descriptions and instructions for refactoring the source code to remediate the identified TD issues. Such instructions can significantly affect the productivity of developers, especially if they are novice or junior [7, 8]. Where novice developers are often unfamiliar with projects assigned to them.

In the past years, several studies have been conducted that have focused on defining the accuracy of estimates provided by Sonar tool [3. 7, 8, 9]. The general conclusion is that the Sonar tool gives an overestimated remediation time and that the level of criticality identified for each issue does not match the perception of junior developers [3, 8].

In practice it is very common to have new members joining ongoing projects. For them the code base is unknown—*unfamiliar project*—while for other team members it is a known code base or *familiar project*. Managing such teams requires clear expectations regarding Sonar's estimates and how they translate to

[1] Sonar: https://www.Sonar.org/

the newly joined team members vs others. However, to the best of our knowledge there are no studies that intentionally compared the use of Sonar tool in the contexts of familiar and unfamiliar projects.
The objective of this research is to investigate the usefulness of Sonar's analysis reports in the contexts of familiar and unfamiliar software projects. We investigated the accuracy of the provided estimates and the perceived understandability of Sonar's feedback by junior developers in the context of these two types of projects. We designed and conducted an experiment within a university course. The experiment consisted of two separate sessions, i.e. *repeated measurements design* [10, 11], where students in the first session were tasked with refactoring identified TD issues in prior unknown to them open-source projects (unfamiliar projects) while for the second session they were first instructed to designed and implement projects from scratch and generate Sonar's report with TD issues used for refactoring in the second session (familiar projects).

2. RELATED WORK

In this section, we selected important papers for the research we conducted. All papers can be divided into two subgroups: (1) empirical research that dealt with the use of ASAT tools in projects that were familiar to the respondents, and (2) empirical research that dealt with the use of ASAT tools in projects with which respondents were not familiar.
Regarding empirical research in the context of familiar projects, Tan et al [18] designed an empirical study in which they used 20 Python and 16 Java projects, observing their first 2000 commits on repositories, with the aim of trying to estimate in what percentage the identified TD is resolved independently. They used the Sonar tool for analysis. As the initial commits on the repositories were examined, it exactly corresponds to the way of work that we also checked in our research where projects were created from the very beginning. In the research, the results were obtained that almost half of the Sonar issues are self-fixed.
While in the context of unfamiliar projects, Nunes et al. [19] analyzed the impact of two different ASAT tools on projects implemented in modern development environments. The focus was on web applications and how ASAT tools affect the identification of potential vulnerabilities. Sonar tool was not one of them.
Vassallo et al. [20] included 176 open-source projects in their research in order to investigate whether and in what way developers accept the results of the ten different ASAT tools. The results showed that more than 60 percent of developers pay attention to the results of the analysis and are ready to accept them as a regular practice. In another paper, Lenarduzzi et al. [23] used unknown projects up to twelve years of age. The research focused on evaluating the usefulness of Sonar when translating a system architecture from monolithic to microservices. The results showed that after a short period of time, TD in the microservice architecture is significantly less compared to monolithic systems and that Sonar proved to be very useful.
With this brief review of papers that focused on examining the performance of ASAT tools in different areas of their application, we can also find the basic motivation for conducting such research. Namely, we see great scope in examining the impact of ASAT tools on the work of developers, depending on their familiarity with the project.

3. METHODOLOGY

The methodology is designed following the guidelines from *Wohlin et al.*[11], while the replicability of the study is supported with a publicly accessible replication package (https://bit.ly/3p70R7u}).
The goal of this study is formally expressed using GQM template [27]: A*nalyze* the Sonar tool analysis report *for the purpose of* evaluation *with respect to* usefulness *from the point of view of* junior developers *in the context of* unfamiliar and familiar software projects. Following this goal, the study focused on four aspects that were embodied in the following hypothesis:

- H_1: Remediation estimates provided by Sonar tool are more accurate in the context of familiar projects compared to unfamiliar project context.
- H_2: Issue descriptions provided by Sonar tool are easier to understand in familiar compared to unfamiliar project context.
- H_3: Fixing descriptions provided by Sonar tool are easier to understand in familiar compared to unfamiliar project context.
- H_4: Familiar projects are easier to refactor compared to refactoring unfamiliar projects.

The experimental sessions were designed as one factor with two treatments. The experiment relied on a within subject repeated measurements design with two objects. Figure 1 summarizes the experimental design, while the remaining paragraphs further elaborate the concepts presented in the figure.

Figure 1: Experimental design

Subjects are senior year students of Information systems engineering curriculum. The subjects were sought as a proxy for junior developers since. The **object** of the study is the Sonar analysis report of the unfamiliar projects, for the first session, and of familiar projects, for the second session. The analysis report consists of identified Sonar issues that are characterized with estimated time for remediation, issue description, fixing description and issue categorization. **Independent variable** is *project type* with two levels: *unfamiliar* projects and *familiar* projects. **Dependent variables** are calculated times for fixing Sonar issues (H_1), perceived understandability of Sonar's issue description (H_2), perceived understandability of Sonar's issue fixing instructions (H_3), and the perceived refactoring difficulty (H_4).

The **session protocol** presents three groups of activities, which are: (a) *The initial activities* included training on the usage of the Sonar tool and project diary, which was one of the data collection instruments, (b) *Session preparation activities* differed for the first and second session. During the preparations for the first session, students selected, and lecturers checked and approved an open-source project found in the public repository (https://github.com). During the preparations for the second session, subjects used the provided software specification, to design and develop a software solution using .NET/C\# technology. This solution was seen as a familiar project that is analyzed during the second session. Finally, in (c) *experiment sessions* subjects had to remediate the identified issues and to record the data to project diary.

Data collection was realized using three data collection instruments: the profiling survey, Sonar tool and project diary. Profiling survey was implemented as an on-line (web) survey, and it was executed at the beginning of the course, thus before the experiment sessions. The survey contained a total of six different closed-typed questions, and there was no possibility to skip any of the questions. Survey questions probed subjects' programming experience, familiarity with code refactoring, as well as with ASAT tools and with the concept of technical debt. Subject used the project diaries to record the data. Within the project diary, each of the remediated issues had to be characterized with data such as issue ID, estimated and actual remediating time, assessment of the perceived refactoring difficulty, understandability of issue description and fixing instructions.

The **data analysis** of the Sonar tool's remediation estimates, and test the H_1, the mean magnitude of relative error (MMRE) and mean relative error metrics (MeRE) were used. These metrics are defined in the literature [3], and it is calculated for each subject as:

$$MMRE = \frac{1}{n}\sum_{i=1}^{n} MRE_i \qquad MRE_i = \frac{|T_A(i) - T_E(i)|}{T_A(i)} \qquad MeRE = \frac{1}{n}\sum_{i=1}^{n} RE_i \qquad RE_i = \frac{T_A(i) - T_E(i)}{T_A(i)}$$

where n is the total number of Sonar issues remediated by subject. MRE_i represents the magnitude of the relative error for the i-th issue, RE_i represents a relative error for the i-th issue, $T_{A(i)}$ stands for actual time the subject used to remediate the i-th issue, and $T_{E(i)}$ stands for the time estimate for remediating the i-th issue. Low *MMRE*, *MRE*, *MeRE* and *RE* values means that the differences between estimated and actual times for remediating the issues are also small, thus making the estimates more accurate. The formulas were, therefore, used to calculate: (a) are there any differences between the measurements in two sessions, and (b) which session has higher mean relative error. Consequently, the H_1 is tested using two statistical hypotheses $H_{\{1.1\}}$ that relies on *MMRE*, and $H_{\{1.2\}}$ that relies on *MeRE*. The remaining hypothesis were tested based on subjects' assessment of the perceived understandability of the Sonar's issue description (*PID*) for H_2, the perceived understandability of the Sonar's fixing instructions (*PFI*) for H_3, and the perceived refactoring difficulty (*PRD*) to eliminate each identified issue for H_4.

4. RESULTS

Demographics: The research was done in the context of a software engineering university course with fourth year undergraduate students at the University of [*Anonymized for review*] enrolled at Information Systems Engineering study program. In total *72* students attended the course and *60* of them participated in the experiment as subjects. Most of the subjects have between *2* to *4* years of programming experience (Figure 2.Q1). Also, about one fourth of participants (Figure 2.Q1a) have worked in industry. The profiling

survey analysis revealed that participants are largely unfamiliar with TD concept and ASAT. A summary of the demographics data is presented in Figure 2.

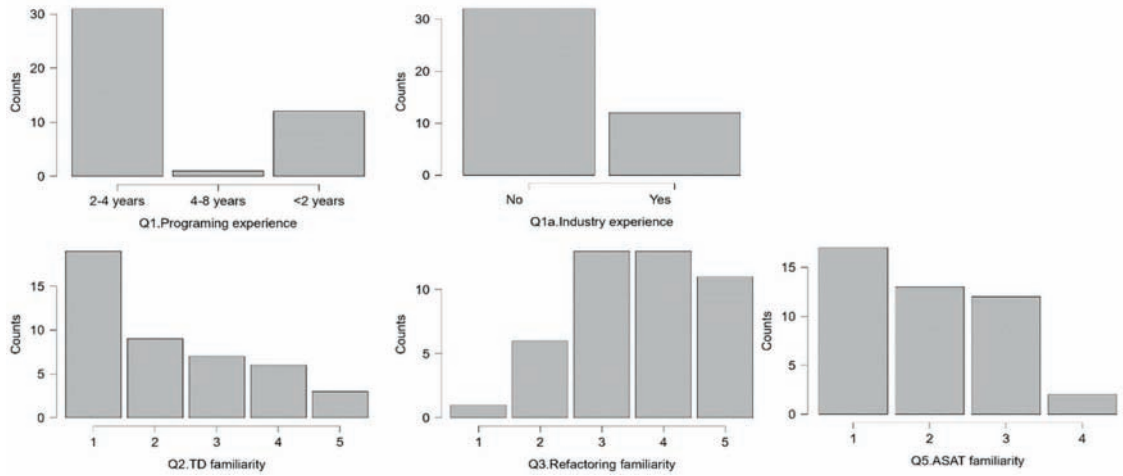

Figure 2. Demographics: Q1. Years of programming experience, Q1a. Experiences working in industry, Q2. Familiarity with the TD concept, Q3. Familiarity with refactoring practices, and Q5. Familiarity with ASAT tools.

The dataset consists of *2268* refactored Sonar issues in the first session and *1016* refactored issues in the second session. Out of these issues, *135* unique Sonar rules were violated in the first and *43* unique rules were violated in the second session. In total, *40* unique (or overlapping) rules were present in both sessions. Rule category wise, the majority of the violated rules are categorized as *bug* and *code smell.* Consequently, it can be asserted that the complexity of all the remediated issues, in both sessions, is highly similar.

Hypotheses testing relied on the following statistics: *Shapiro-Wilk* test was used to check the normality assumption of the data. The *Wilcoxon signed-rank* test was used as a non-parametric alternative to paired *t-test* to test the differences between the paired values from two sessions. For all tests we set the significance criterion as *0.05*. Finally, *Rank-Biserial Correlation* (r_B) was used to test the effect size and interpreted according to Goss-Sampson [28]. Calculated *W* statistics and *p*-values for each variable MMRE, MeRE, PID, PFI, and PRD, and for each session: unfamiliar projects, and familiar projects. Based on the test results the normality assumption can be accepted for *MMRE* and *MeRE* measured in first session ($p > 0.05$), while rejected for the remaining variables ($p < 0.05$). Thus, a non-parametric Wilcoxson Signed Rank test was used to assess the differences.

Hypothesis H_1 is tested using two variables, *MMRE* for testing the differences between the measurements using two-sided test. And variable *MeRE* for assessing the higher relative error in estimated time for the issues remediation. It can be concluded that the Sonar Tool overestimates the time needed to remediate the identified issues in both the unknown and known project context—hence the negative *MeRE* values. It can also be concluded that developers need more time to remediate the issues when working on unfamiliar projects, compared to time needed for working on familiar projects. Test of hypothesis H_2 indicates that developers perceived the Sonar issue descriptions less understandable in session s_1 (unfamiliar projects) compared to s_2 (familiar projects). The third hypothesis is tested using the *PFI* variable and both one and two-sided test, suggesting that perceived understandably of fixing instructions provided by Sonar tool does not differ session wise. The fourth hypothesis was tested by comparing the *PRD* variables using one-sided, paired test, for which the null hypothesis was rejected, leading to conclusion that the perceived refactoring difficulty in unfamiliar project context is more difficult, compared to refactoring of familiar projects. Figures 3 and 4 present the box plots for tested variables.

Table 1: Hypothesis test results

Hypothesis	Wilcoxon Signed Rank Test (p < 0.05)	Decision
$H_{1.1}^{0}: \mu_{s1}(MMRE) = \mu_{s2}(MMRE)$ $H_{1.1}^{A}: \mu_{s1}(MMRE) <> \mu_{s2}(MMRE)$	V = 204, p = 1.691e^{-7} (two-sided)	Rejected
$H_{1.2}^{0}: \mu_{s1}(MeRE) = \mu_{s2}(MeRE)$ $H_{1.2}^{A}: \mu_{s1}(MeRE) <> \mu_{s2}(MeRE)$	V = 1657, p = 2.399e^{-8} (one-sided)	Rejected
$H_{2}^{0}: \mu_{s1}(PID) = \mu_{s2}(PID)$ $H_{2}^{A}: \mu_{s1}(PID) <> \mu_{s2}(PID)$	V = 148, p = 0.009226	Rejected
$H_{3}^{0}: \mu_{s1}(PFI) = \mu_{s2}(PFI)$ $H_{3}^{A}: \mu_{s1}(PFI) <> \mu_{s2}(PFI)$	V = 129, p = 0.6247 (two-sided)	Accepted
$H_{3}^{0}: \mu_{s1}(PFI) = \mu_{s2}(PFI)$	V = 129, p = 0.3123 (one-sided)	Accepted

$H_3^A: \mu_{s1}(PFI) > \mu_{s2}(PFI)$ $H_4^0: \mu_{s1}(PRD) = \mu_{s2}(PRD)$ $H_4^A: \mu_{s1}(PRD) <> \mu_{s2}(PRD)$	V = 434, p = 2.022e $^{-05}$	Rejected

Finally, the **effects sizes** are calculated for hypotheses using Rank-biserial correlation. For all hypotheses the effect size is *large* with (*95%* confidence interval), except for H_3 the effect size is small (r_β=0.12).

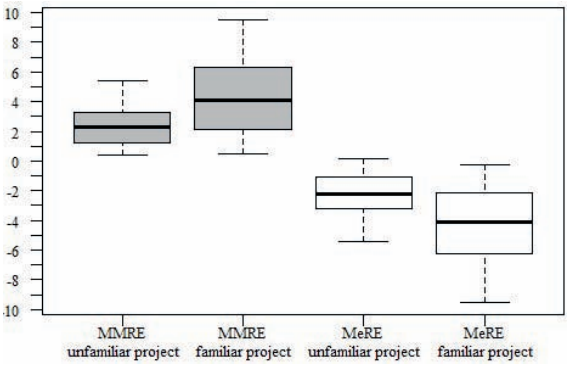

Figure 3: Box plots for MMRE and MeRE.

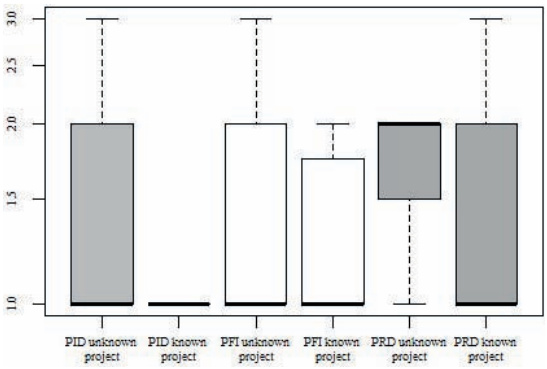

Figure 4: Box plots for PID, PFI, and PRD.

5. CONCLUSIONS

This paper presents the findings of an empirical study that was conducted in the context of a university course, with an objective to investigate the impact of the project familiarity on the usefulness of feedback generated by Sonar tool. Our findings confirm previous studies that Sonar overestimates remediation effort [3, 8], which is a case for both types of projects as well. However, the estimates are more accurate for the unfamiliar projects than for the familiar ones. Furthermore, it seems that the understandability of the fixing instructions provided by Sonar is not impacted by project type, while Sonar's descriptions of identified issues were significantly less understandable for unfamiliar projects. The plausible explanation is that fixing instructions are decontextualized and sufficiently self-explanatory, while understanding issues descriptions require understanding of the targeted code base for which issues were identified. Finally, the data showed that developers tend to understand easier the Sonar's issue descriptions when they are involved in the project from the start. Also, this study showed that estimates provided by Sonar tool are less accurate for familiar projects. One plausible explanation is that in such projects *refactoring* seems to be less challenging.

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Automatic part creation in SolidWorks using API functions

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Abstract: *The SolidWorks API (Application Programming Interface) is a set of tools, functions, and interfaces that allows interaction and automation of various aspects in SolidWorks software. By leveraging the SolidWorks API it is possible to automate repetitive design tasks, integrate SolidWorks with other software systems, create custom design applications, extract data for analysis and reporting, and enhance productivity for SolidWorks users. Using macro API calls are recorded to allow multiple executions with a simplified part creation process. This paper presents the use of SolidWorks API and macros for generating part within the SolidWorks environment. With macros is possible to generate a part by providing only input dimension values. After creating the part with the use of the macro recorder, the code was edited and the code for entering the input parameters was defined.*

Key words: SolidWorks, API, automation, part

1. INTRODUCTION

Most of design tasks are routine in nature. The demand for CAD-based (Computer Aided Design) tools and software that can automate common daily tasks has surged as a result. These activities either focus on tiny, straightforward assemblies or bigger, more intricately constructed ones. The primary goal in any situation is to provide high-quality items as quickly as possible, while also saving time. The SolidWorks API can be used to automate the development of parts in SolidWorks, which can greatly increase productivity and simplify design procedures. Applications can be created as well as parts with SolidWorks API, which eliminates the need for manual modeling and repetitive operations. Modern design has made life much easier by reducing time wastage and maintaining proper usage of resources. By using SolidWorks products having the same mechanical characteristics and shapes, the corresponding entity model library can be created through parametric design. This can improve design efficiency and simplify design work (Avitus Titus and Liu Xue Bin, 2013). The SolidWorks API provides a powerful set of tools and functions that enables a user to interact with SolidWorks programmatically. API is a software development tool which enables integration between different applications by providing a code in a programming language within another application (Prince et al., 2003). The Microsoft Component Object Model (COM) technology, which enables cross-language program communication, serves as the foundation for the SolidWorks API. The API provides access to a broad variety of functionality, enabling programmers to automate processes including creating and changing part models, assemblies, and drawings as well as accessing and editing features, dimensions, materials, and other design elements. API is a tool to write a code in a programming language within another application. As a result, a direct integration between different applications can be developed (Prince et al., 2003). SolidWorks is one of the applications which support API with different programming languages such as C++, Visual Basic, and Visual Studio. SolidWorks API automates the design and the assembly operations by creating codes in a specific programming language and it has been applied for different design methods (Farhan et al., 2012). The following are typical tasks that can be completed utilizing the SolidWorks API: generating new drawings, parts, or assembly documents, adjusting the dimensions, adding features, or modifying the characteristics of an existing document, creating design variations or carrying out design assessments using automation, obtaining data from SolidWorks documents, such as dimensions, mass characteristics, or a bill of materials, to improve the SolidWorks user experience, bespoke user interfaces and forms are created and interacting with databases, other software programs, or external systems. This article discusses the benefits of using the CAD system's programming interface to build custom programs (macros) that can help users to automate a variety of processes using a straightforward graphical user interface (GUI). This shortens the design process and obviates any potential errors. There are many CAD software packages with API functionality. SolidWorks CAD is chosen in this paper due to its user-friendly features and support for API capability. The paper is organized as follows: related work is described in Section 2. Methodology for part automation using SolidWorks macro

API is presented in Section 3., Section 4. Represent the results of work. The research is briefly reviewed in the final section, which also offers closing thoughts and suggestions for future work.

2. RELATED WORK

Numerous academics have used the API of numerous CAD systems to create tools and applications, and they consistently came to the conclusion that the benefits and advantages of the API are substantial.
A bibliometric analysis technique is presented by Ciric D., Lalic B. et al. (Ciric et al., 2021) to review mass customized scientific production. The most successful journals are mostly those devoted to industrial engineering, production, operational, and manufacturing research; among the ten most significant publications are those that are frequently printed in management sciences-focused journals. The following list of pertinent publications comes from the subject area covered in the aforementioned study. Esanakula Jayakiran Reddy et al. (Reddy, E. J. et al., 2016) researched knowledge based intelligent design system for bearings library construction using SolidWorks API. Bearing's dimensions change during the design process depending on the working or loading conditions anytime an assembly component is changed, but their geometry does not. It takes time and effort to recalculate the appropriate dimensions each time a component is changed. A computer program is created for design calculation purposes in order to reduce time consumption. To create the CAD model, the output of this program is connected to the SolidWorks program via a database. Design and modeling tasks have been automated as a result. The appropriate bearing is chosen once the user has entered the input data and clicked the Calculate button to calculate it based on the loading conditions in the background using created computer programs and intelligent design systems as well as standard imperial formulas. The GUI's combo box field shows the outcome. After the Model button is clicked, the CAD model is generated.
With this work, Yayakirin tried to develop an intelligent design system and succeeded in reducing the modeling time. However, the presented example is simple and applicable to simpler bearings. An additional problem may be the software version. The SolidWorks API is tied to certain versions of the software, and if the software is updated, it is necessary to adapt the code.
K.Balachandar et al. (K.Balachandar, 2020) show macro assisted design automation of piston and connecting rod using SolidWorks API. They defined the design automation steps shown in Figure 1.

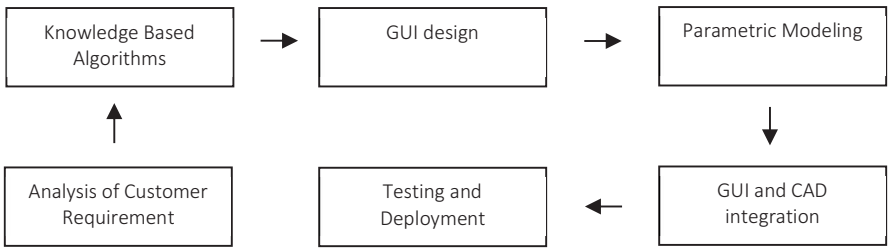

Figure 1: Design Automation Steps

Systemic risks in the industry of engineering are demonstrated by Djakovic M. et al. (Dakovic M. et al., 2020). The paper's main points are delays and time spent on each activity.
Abstraction levels and corresponding design levels are summarized in 6 basic steps by Sadiq M. Sait and Habib Youssef (Sait and Youssef, 2006). CAD subproblem level is idea, problems at this level are solved with CAD tools. Followed by architectural level based on architectural design. The third step is on logic level and represents logical design, next is physical design and finally fabrication.
Ciric D. et al. (Danijela Ciric et al, 2020) researched on the use of ICT solutions in Serbian industrial businesses. The study revealed that implementation of all or at least some parts of Industry 0.4, including the use of various software solutions, is required for Serbian businesses to begin the process of reindustrialization and keep up with trends.
Amel Meddahi et al. (Amel Meddahi et al., 2009) explained SolidWorks API offers several functionalities to define the suitable trajectory of the robot. The trajectory is related with the relative position and orientation of the end-effector and 3D encountered object model.
Fang Zhou and Zhang Li-Na (Fang Zhou and Zhang Li-Na, 2012) defined a transformation from a VB script to a VC++ program on the caliper. The first step of modeling based on the SolidWorks API is to record the modeling process using the SolidWorks macro recording tool followed by transformation into a VC++

program. After creating the model and recording the modeling process from the Macro recorder, since the recorded codes are VBA codes, they are transformed into VC++ codes for further development.
Although the SolidWorks API is used in all areas, it is essential to take a look back at earlier experiences, methodology, and technologies in order to draw meaningful conclusions from ongoing research and to advance this subject. In the following work, the application of macros is shown, the VBA (Visual Basic for Applications) code is explained and cleaned.

3. METODOLOGY

Before starting the creation of the model, recording with the help of macros was started. To record and replicate actions taken with the SolidWorks interface, the SolidWorks macro is used. A macro contains calls to the API that are equivalent to operations performed in the user interface. The macro enabled the recording of mouse movements, menu decisions, keystrokes, and zooming in and out of the model. Macro commands are accessed via Tools where the Macro Menu is located. Selecting Macro recording in the upper left corner opens the commands for starting, stopping and stopping the recording. Before starting the creation of the model, the recording was started by clicking on Run. Appearance of running macros is shown in Figure 2.

Figure 2: Macro recording

For the purposes of this work, a model was created that represents the flashlight shown in Figure 3.

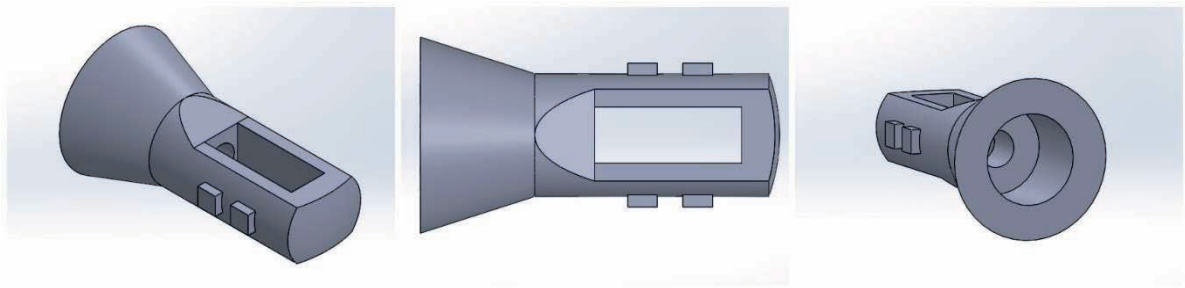

Figure 3: Example – flashlight

After the model is drawn the macro is saved. From the macro menu, Run is selected and the previously saved macro is selected. This starts the process of making the model according to the previously completed steps. All the steps that needed to be done to draw the flashlight are automated in two steps (Play and selecting the required macro).
The code is explained from start to finish below. A more detailed examination of the macro code shows how powerful and easy to understand macro codes are. Macro code usually needs to be edited to complete automation task. The following text explains the lines of code that show key steps of creating a flashlight model. There are two procedures in the code, declarative and main. In declarative procedures, input lines of code that are necessary are displayed:

```
Dim swApp As Object
Dim Part As Object
Dim boolstatus As Boolean
```

Dim swApp As Object - This line declares a variable named swApp of type Object. The swApp variable is typically used to represent an instance of the SolidWorks application.
Dim Part As Object: This line declares a variable named Part of type Object. The Part variable is typically used to represent a SolidWorks part document.
Dim boolstatus As Boolean: This line declares a variable named boolstatus of type Boolean. The boolstatus variable is typically used to store a true/false value indicating the status of a particular condition.
In SolidWorks automation, these lines of code are often used to declare and initialize variables that will be used in later code logic. While Boolean is used to store logical values, the Object data type is flexible enough to store a variety of object kinds.
The next block represents the connection to SolidWorks, necessary for the model to be clickable:

Sub main()
Set swApp = Application.SldWorks
Set Part = swApp.ActiveDoc

Set swApp = Application.SldWorks: This line assigns the swApp variable the reference to the SolidWorks application. Application represents the current instance of the SolidWorks application, and SldWorks is a property or method that returns the instance of SolidWorks. By setting swApp to Application.SldWorks, the swApp variable is initialized to hold the reference to the SolidWorks application.

Set Part = swApp.ActiveDoc: This line assigns the Part variable the reference to the active document in SolidWorks. swApp.ActiveDoc returns the currently active document in SolidWorks (which can be a part, assembly, or drawing). By setting Part to swApp.ActiveDoc, the Part variable is initialized to hold the reference to the active document. These lines of code are often used at the beginning of a SolidWorks VBA macro to set up the necessary references to the SolidWorks application and the active document.

In the following bit line of code:

boolstatus = Part.Extension.SelectByID2("Line1", "SKETCHSEGMENT", 9.06096124160229E-02, 2.1781156830776E-04, 0, False, 0, Nothing, 0)

The SelectByID2 method is used to locate a sketch segment with the name "Line1" at the supplied coordinates in the sketch plane. The outcome is saved in the boolstatus variable. Next block of code *"Line1"* is the name or identification of the chosen object, next *"SKETCHSEGMENT" is* the kind of object that needs to be chosen. Finally, the coordinates for X, Y and Z are defined and extra parameters depending on the situation.

Next important line: Set skSegment ***= Part.SketchManager.CreateLine(0#, 0#, 0#, 0#, 0.039624, 0#)***

First *Set skSegment shows that the* resulting line sketch segment object will be stored in the variable skSegment, which is declared and initialized in this line.

Part.SketchManager alludes to the Part object's corresponding sketch manager object. A part or component is represented by the Part object in CAD (Computer-Aided Design) software.

CreateLine() to create a line sketch segment, execute the createLineSketch method on the SketchManager object. If some other tool was used, such as 3PointArc, SelectedByID, the name of the used tool would be written in place of CreateLine. The rest of the line of code remains the same (the parameters for X, Y and Z change). And *(0#, 0#, 0#, 0#, 0.039624, 0#)* represent the coordinates of the line segment.

The creation of the revolve feature is shown in the following line of code:

Set myFeature = Part.FeatureManager.FeatureRevolve2(True, True, False, False, False, False, 0, 0, 6.2831853071796, 0, False, False, 0.00254, 0.00254, 0, 0, 0, True, True, True)

Set myFeature: This variable is declared and initialized in this line to hold the finished revolve feature object.

Part.FeatureManager: It alludes to the part object's connected feature management object.

FeatureRevolve2: This function creates a revolve feature for the FeatureManager object.

The next important part of the model is the opening inside the flashlight handle. Openings, holes and cutouts in SolidWorks are created using the Extrude Cut tool. The following line of code shows the application of the mentioned tool.

Set myFeature = Part.FeatureManager.FeatureCut4(True, False, False, 1, 0, 0.00254, 0.00254, False, False, False, False, 1.74532925199433E-02, 1.74532925199433E-02, False, False, False, False, False, True, True, True, True, False, 0, 0, False, False)

Within this line, the arguments that are passed to the Cut Extrude method are defined. The parameters and settings for the FeatureCut4 operation within the CAD software are defined using these arguments. The software and its associated documentation will determine the precise significance and effect of each argument. The opposite operation to Cut Extrude is Boss Extrude. Boss Extrude feature is used to create a solid feature by extruding a sketch in a specific direction. In code, the Boss Extrude operation is formulated in the same way as Extrude Cut and is passed the same parameter types. Another key operation used in the creation of the model is Mirror, which was used on the finished model. A feature or collection of features can be duplicated over a chosen plane or planar face using the Mirror feature.

Set myFeature = Part.FeatureManager.InsertMirrorFeature(False, False, False, False)

In this line, mirror features are created in the active document based on the selected features.

4. RESULTS

The specific advantages of automated component generation in SolidWorks employing API capability are highlighted in detail by the findings. The study initiative raised user happiness, enhanced design effectiveness and quality, and enabled breakthroughs in CAD automation inside the company. Main result

of presented research is reduction in design time. Reducing design time was the main goal of automated part creation. The research produced a considerable decrease in design time across diverse test cases by using API-driven automation scripts. The automated procedure was, on average, 30% quicker than the manual part fabrication. For difficult or repeated design projects, this time savings is especially substantial. Human mistake in part creation was removed by automation. Dimensions, clearances, and material requirements were all applied consistently in line with predetermined criteria. Engineers that used the automated technique noticed a significant increase in the uniformity of the designs across several projects. Errors that result from manual part fabrication are frequently expensive and time-consuming to fix. Automation, on the other hand, greatly decreased the frequency of design faults. Fewer design errors mean fewer prototyping and manufacturing errors, resulting in reduced production costs.

5. CONCLUSIONS

The integration of systems and applications as well as the automation of repetitive tasks are all made possible by the SolidWorks API. Because API makes it possible to expedite design processes, reduce error rates, and work more effectively, productivity has grown. Customized plug-ins and macros can automate time-consuming tasks, create complex geometry, and execute simulations or analysis. With macro recording, automating repetitive tasks is easy to do without any programming skill. Despite the advantages of both macro recording and the API, the SolidWorks API offers greater customization, flexibility, and control over the design process. Users can increase productivity by automating tasks, create workflows that are specific to their design processes, improve accuracy and consistency in design, access advanced design features outside the scope of the default user interface, and integrate SolidWorks and other software systems. Users are able to work more productively, handle challenging design problems, and produce outputs of greater quality because to these advantages. Results:

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WHO JUDGES THE TURING TEST BETTER: EXPERTS OR CHATGPT?

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Abstract: *The continuous advancement of language models, such as ChatGPT-4, has brought remarkable improvements in their conversational capabilities, blurring the lines between human and machine interaction. The use of the Turing test becomes particularly relevant in the context of distinguishing machine-generated output from human responses. This paper investigates the comparative performance of human experts and ChatGPT-4 in evaluating the Turing test. To conduct the study, a dataset comprising human and ChatGPT-3 responses to HR interview questions was curated. People working in software companies were recruited, while ChatGPT-4 served as a machine-based judge. In the Turing test, human participants exhibited lower confidence in their decisions compared to ChatGPT-4, but ultimately reached 90.91% accuracy in rating conversations, while ChatGPT-4 demonstrated an accuracy of 59.1%. This study can serve as a starting point for exploration into the evaluation of human experts and ChatGPT-4 performance in the Turing test, and the idea of machines aiding in the difficult task of differentiating between humane- and machine-generated text.*

Key words: Turing test, ChatGPT, Empirical Study

1. INTRODUCTION

The *Turing test* (Turing, A.M., 2009) has long served as a benchmark for differentiating between humane- and machine-generated text. As artificial intelligence (AI) systems continue to advance, the Turing test becomes increasingly significant in efforts to accurately identify and attribute text to its rightful source. Through its training on vast amounts of diverse data, *large language models* (Radford et al., 2018) such as ChatGPT-3.5 and ChatGPT-4[1] have developed an exceptional ability to understand and respond to human queries, generating coherent and contextually relevant text. It is important to remain aware of the ethical considerations and potential challenges that arise with such advancements. By acknowledging the presence of AI-generated text, we can leverage its benefits while also maintaining transparency and accountability in our digital interactions.

In Turing's imitation game (Turing, A.M., 2009), also known as the Turing test, a human interrogator engages in a conversation with two participants, one being a machine and the other a human. The interrogator is unaware of which participant is human and which is a machine. By subjecting both a human and a machine to a conversation through text-based communication, the test aims to evaluate whether the machine's responses can be indistinguishable from those of a human. While the role of the imitating player (machine) in the test was thoroughly investigated through the years, the role of the interrogator has also become the subject of research (Hernández-Orallo, 2020). The simple fact that humans are employed as interrogators has been seen to be something that undermines the test's credibility by some (Hayes and Ford, 1995) and as an important indicator of human imperfections by others (Warwick and Shah, 2016).

The *inverted Turing test* is the first proposal of a test where the judge is a machine (Watt, 1996). In the inverted Turing test, the judge is the one being evaluated. The inverted Turing test checks if the system's powers of discrimination are equivalent to those of an expert human judge. This is different from the reverse Turing test (Von Ahn et al., 2003), with its implementations usually known as CAPTCHAs, where the judge (machine) is not evaluated. The reverse Turing test brings the idea of the test being totally automated, as the human or machine to be detected does not have to be compared against a real human.

(Hernández-Orallo, 2020) states that relying on humans to judge the result of the Turing test usually leads to problems of subjectivity, bias, reliability, and scalability. The study is mostly focused on the idea of

[1]Advanced natural language processing models, developed by OpenAI, based on "Generative Pre-trained Transformer" architecture: https://openai.com/blog/chatgpt

machines replacing the role of humans in the Turing test and the task of evaluating intelligence. The study presents the idea that humans can be selected and trained to become better judges in the Turing test, but that in the end, they will reach an evaluation quality plateau because of their mental resources, motivation, and capability. This plateau can nonetheless be broken by machines. Similarly, this paper explores the idea that machines can possibly take the role of discriminators between human- and machine-generated text. To the best of our knowledge, there are no studies that directly compare human and machine performance in distinguishing between human-generated and machine-generated text.
The objective of this study is to investigate the comparative performance of human experts and ChatGPT in judging a version of the Turing test. Specifically, it investigates their ability to distinguish between human- and machine-generated answers to HR interview questions used in recruiting software engineers. In order to achieve the objective, we designed a two-phase empirical protocol. The rest of the paper is organized as follows: Section two provides a comprehensive explanation of the methods used in the empirical study, while section three presents the results from the experimental phase. The Discussion section is dedicated to analyzing the results and finally, in the last section, conclusive remarks and findings of the study are drawn.

2. METHODS

In the first phase of the study, human and machine-generated conversations were collected. In the second phase, a version of the Turing experiment was conducted on humans and ChatGPT-4.

2.1 Data collection

Ten questions were collected from internet blogs presenting the most common HR interview questions in the field of software engineering. Two types of questions were collected: experience-based and opinion-based questions. Each conversation, either with humans or generated by AI consisted of five randomly chosen questions from the collected set of questions. Answers from humans were collected through an online meeting, and answers from ChatGPT-3.5 were collected using the OpenAI API.

2.1.1 Interviews

An online meeting was held on Teams with each of the participants. Before the meeting, participants were instructed to answer the questions as they would in a real HR interview setup. Participants were cautioned against disclosing personal information to safeguard their anonymity. For questions about previous experience, they were instructed to share only permissible information.
Participants were asked five randomly chosen questions from the collected set of questions. The meeting transcript was collected to obtain the answers. Participants were then asked to confirm the validity of the obtained answers. They were allowed to change the wording and add omitted information to the transcript, but were not allowed to add information that was not said during the interview.

2.1.2 Prompting ChatGPT-3.5

ChatGPT answers were collected by prompting the gpt-3.5-turbo model through the OpenAI chat completion API. A Python script was written for generating prompts and collecting the answers. Prompting was done by following the best practices and strategies for getting a better response from the chatbot provided by OpenAI (OpenAI Platform, 2023).
Twelve conversations were generated by ChatGPT-3.5. Each conversation consisted of five random questions. The answer to each of the questions was collected by providing the model with information about the questions and answers that were previously generated in the conversation. This way, the model had the context of the conversation the same way the human did. The model was tasked to answer the questions as a person with a job in software development would in a real HR interview setup. Also, it was provided with the characteristics of the job position, preferred technology, and level of experience of the person with a job in software development. Lastly, it was instructed to respond using approximately the same number of sentences as the human providers used in their answers, which was between two and four sentences.
Characteristics of the person the model was imitating were set up to match the characteristics of the interviewees who gave answers in the first part of the data collection phase. Six different examples of characteristics were produced. Prompting the model with different characteristics of the human allowed

for different answers to the same question. Also, the model was prompted with the same characteristics twice with a different value of the temperature parameter. For each conversation, a random value of the temperature was chosen from the interval [1, 1.5]. Responses with higher temperatures display greater linguistic variety, while the low one represents grammatically correct and deterministic text (Ippolito et al., 2019). Testing showed that answers obtained with a temperature higher than 1.5 become logically incoherent, so temperatures higher than 1.5 were not considered.

2.2 The Turing experiment

For the experiment to be valid, the observer should not have advanced knowledge of the entity that is providing the answers, as they can use this knowledge to bypass the discrimination (Watt, 1996). For this reason, the questions are answered by ChatGPT-3.5, and judged by ChatGPT-4, a different identity. Also, none of the participants who answered the HR interview questions in the data collection phase of the experiment didn't participate in the Turing experiment. It is also to the best of the researcher's ability ensured that the human judges have no personal connections and knowledge of the people who were providing the answers. A Django application was created for administering the experiment on humans, and ChatGPT-4 answers were collected using the official ChatGPT website.

2.2.1 Human experiment

When participants agreed to take part in the research, they were sent the link through which the experiment was accessed. The link contained a unique code by which each participant was identified.
Each participant was shown three HR interview conversations. In order to avoid the situation where the conversation is evaluated as if it was generated by a machine because it resembles the conversation that was previously shown to the participant, it was decided to only show one machine-generated conversation to each of the participants. The three conversations were randomly chosen and the order of the human-generated and machine-generated conversations was random. Although the number of human and machine-generated conversations was predetermined, participants were not aware of this. They were told that the ratio of human-generated to machine-generated conversations was unspecified.
Some previous studies showed that the perception of humanness changes as participants go through successive evaluations (Candello et al., 2017) and that the evaluation of the first question-answer can affect the evaluation of the subsequent pairs (Ariely, 2010). Having this in mind, participants were presented with one conversation at a time, without the possibility of revisiting previous conversations. This approach minimizes the chances of direct comparison. On the other hand, the possible influence of the first evaluation is still present.
Prior to running the experiment, the research was tested on pilot participants to identify and correct issues with the study setup. The test helped determine the time duration provided to participants for rating the conversation. Each conversation was shown to the participant for 5 minutes and during this time participant was able to rate their level of confidence that the answer was given by a human, using a Likert scale of 1-4.

2.2.2 ChatGPT-4 experiment

For each of the 24 conversations that were collected in the first phase of the research, ChatGPT-4 was prompted to decide whether the answers were given by a human or machine. The prompt consisted of the same explanation of the task that the humans were given at the beginning of the experiment. Similarly, to humans, the model was instructed to give a rating of the level of confidence that the answer was given by a human using the same Likert scale that was given to humans. Prompting was done by following the best practices advised by OpenAI (OpenAI Platform, 2023), and by using the chain of thought zero-shot prompting method (CoT zero-shot) (Kojima et al., 2022).

3. RESULTS

3.1 Participants

For both the data collection phase and the Turing experiment, participants were people working in Novi Sad, Serbia. For the data collection phase, there were 11 software developers and one Quality Assurance tester. For the Turing experiment, people with job positions in software companies besides development were included. All participants self-reported knowledge of English on a scale of 1 (able to have a simple

conversation) to 10 (can communicate fluently). Eight men and four women between the ages of 24 and 45 were interviewed. The mean age was 31 (SD=9.577) and their self-reported knowledge of English on a scale of 1 to 10 was 7.5 (SD=1.931). Information regarding participants' job positions and years of experience was used for composing examples of characteristics of the human ChatGPT-3.5 was prompted to answer as.

For the Turing experiment, there were 24 participants, 18 males and 6 females between the ages of 22 and 46. Their mean age was 28 (SD=6.169) and their self-reported knowledge of English on a scale of 1 to 10 was 8.6 (SD=1.213).

3.2 Turing experiment

The Shapiro-Wilk test suggested a significant deviation from the normal distribution for the AI ratings (statistic=0.91, p-value=0.052). The Wilcoxon rank-sum test was applied in order to assess the significance of the difference between human and AI ratings of the same conversations. Aggregated human rating of each of the conversations was established as the median of all ratings given by humans for that conversation. The ChatGPT model gave the same answer when being prompted multiple times, so no aggregation was done, and only one extracted rating the model gave was taken. The Wilcoxon rank-sum test yielded a statistically significant result (statistics=2.441, p = 0.014), indicating a substantial difference between the paired ratings being compared. Figure 1 shows density distributions of absolute rating errors for (A) humans and (B) ChatGPT-4, and Figure 2 shows confusion matrices for humans (A) and ChatGPT-4 (B) judges.

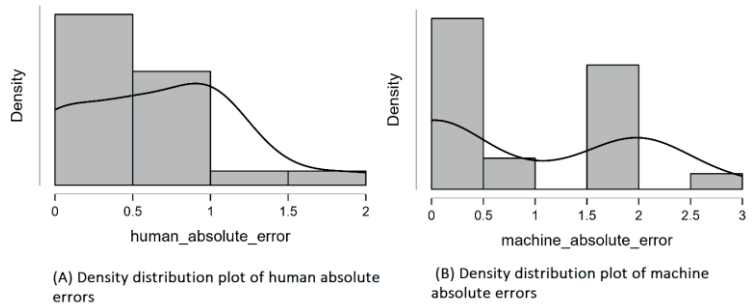

Figure 1: Density distributions of absolute rating errors

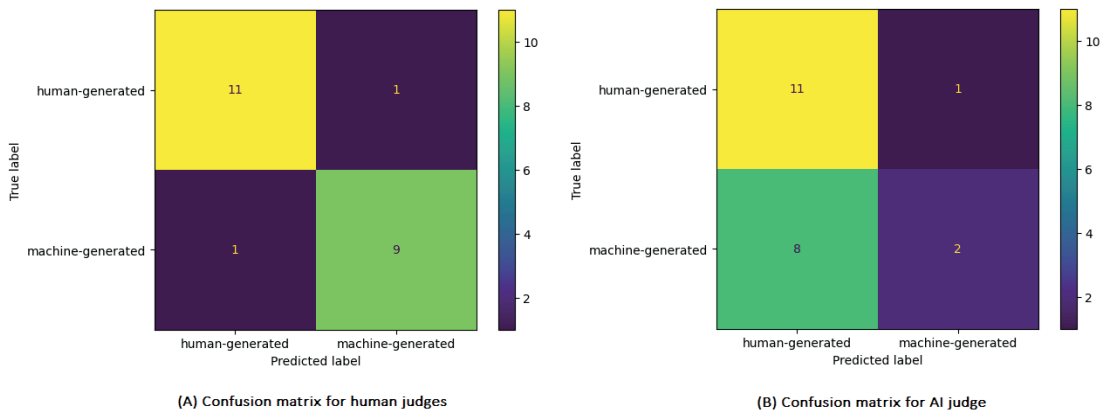

Figure 2: Confusion matrices of ratings

ChatGPT-4 successfully rated human-generated conversations, but only managed to correctly rate two out of ten machine-generated conversations. Human accuracy reached 90.91% while ChatGPT-4 demonstrated an accuracy of 59.1%, only marginally better than random chance.

Although human judges reached higher accuracy, it is also valuable to examine with what level of confidence. Figure 3 shows distribution plots of ratings of human-generated conversations by human judges (A) and AI judge (B) and their ratings of machine-generated conversations (C) and (D).

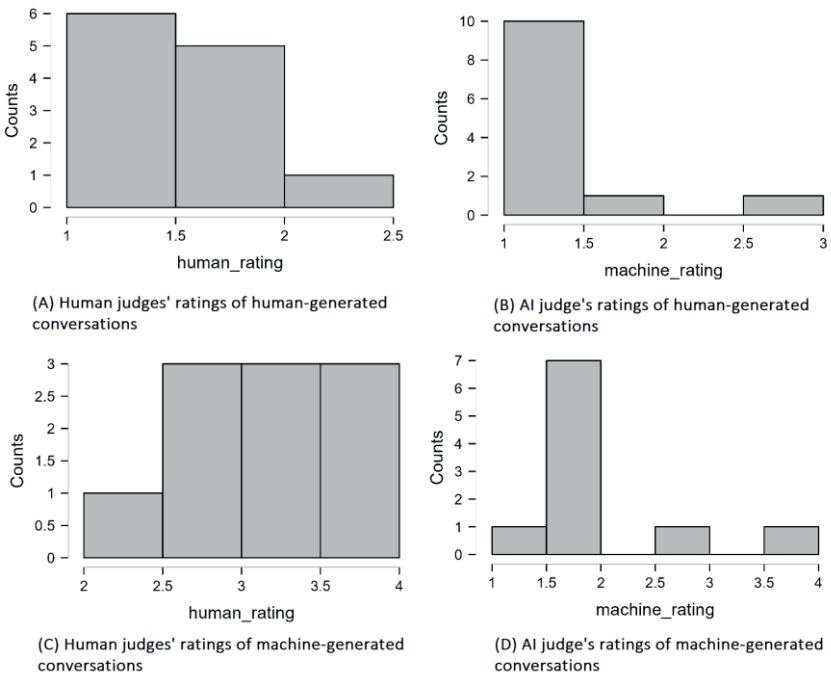

Figure 3: Distribution plots for ratings

4. DISCUSSION

Density distributions in Figure 1 show that both humans and ChatGPT-4 made errors, but in the case of the ChatGPT-4 judge, there was a greater number of ratings with an absolute error between 1.5 and 2. With the rating interval width of 4, these errors indicate that ChatGPT-4 inaccurately rated conversations with lower confidence. Confusion matrices shown in Figure 2 confirm this. ChatGPT-4 correctly rated a small proportion (20%) of machine-generated conversations, and this factor may account for the statistically significant difference between ratings provided by humans and ChatGPT judge.

With a 1 rating denoting high confidence in human-generated conversations, ChatGPT-4 mostly rated human-generated conversations correctly with high confidence (90.91% of correct ratings), while humans tended to be less confident (54.54% of correct ratings). This tendency of human judges to give ratings with lesser confidence was true for machine-generated conversations as well (33.33% of correct ratings). Although ChatGPT-4 correctly rated only two machine-generated conversations, the model showed low confidence (rated with a 2) in seven out of eight cases.

The limitations of the study should be taken into account when interpreting the results. The first limitation relates to the small number of human participants in the Turing experiment and the limited amount of conversation examples. This may restrict the generalizability and robustness of the findings. Additionally, certain effects could be overlooked and more evident in studies involving a significantly larger number of participants and data points. With this in mind, this study represents just a starting point for the investigation of the performance of human experts and ChatGPT-4 in evaluating the Turing test.

Another limitation is the lack of interactive conversations in the Turing test design; participants only evaluated static conversations. Interactive conversations could introduce considerable variability, affecting the study. Providing recorded conversations ensures standardized experiences for subjects, enabling answer comparability. Another thing that should be taken into account is that the majority of participants were Serbians, but the language of the study was English, and this could have also caused some difficulties (even though the participants were controlled by making the advanced level of English a criterion for participation).

5. CONCLUSIONS

Results showed that humans performed better in the Turing test but were less confident in their decisions than ChatGPT-4, especially when it comes to human-generated conversations. The biggest difference between human judges and ChatGPT-4 was in rating machine-generated conversations. While human judges showed good performance in rating both human- and machine-generated conversations,

ChatGPT-4 correctly rated primarily human-generated conversations and incorrectly rated the majority of machine-generated conversations, although with lower confidence.
For future research, it would be valuable to explore the reasoning strategy behind the judge's decision, both human and ChatGPT-4's. Furthermore, exploring how various prompts and contexts given to ChatGPT-4 can influence its performance could be worth investigating. This could potentially reveal common mistakes and propose approaches to effectively address them.

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INDUSTRIAL INTERNET OF THINGS (IIOT) - SECURITY WEAKNESSES AND MOST COMMON TYPES OF ATTACKS – A SYSTEMATIC LITERATURE REVIEW

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Abstract*: In recent years there has been a growing interest in the Industrial Internet of Things (IIoT) coming from business and scientific communities alike. One of the elementary concepts of the proposed Industry 4.0 is the IIoT which proposes the implementation of the regular Internet of Things (IoT) concept on a much larger scale within the industrial facilities, thus interconnecting devices in industrial settings. While the main focus of the scientific community is on the cost/benefit analysis and practical application of the mentioned concept, one often overlooked aspect is its security. The following paper presents a comprehensive systematic literature review for the Industrial Internet of Things security. It contains a review of the most common types of attacks committed within the Industrial Internet of Things and a consequential analysis of the weaknesses those attacks exposed*.

Key words: Industrial Internet of Things, IIoT, security, systemati literature review, SLR, secondary research, Internet of things, IoT

1. INTRODUCTION

In the not-too-distant past, most people would never have thought that by pressing a few bu. ons on their smartphone, they could command their household appliances to do their work without any human interventi n. Even more inconvenient was the idea of a factory being run by machines and robots with absolutely minimal human oversight and control. This would, of course, as we know, change with the advent of one of the most important technologies to date, the Internet.

The meteoric rise of the internet at the turn of this century has led to the creati n of new ways of communica. on, thinking, collabora on, connectio , work, and generally - living. Consequenti lly, new opportunitie and obstacles have appeared in our lives and workplaces. Furthermore, some of these opportunities would present themselves in places for which the Internet was not intenti nally developed. For example, the Internet enables governments to provide crucial services for its citi ens - e-government (Stefanović, 2021), the Internet allows educati nal insti uĀons to share and teach academic subjects via the concept known as e-learning (Stefanović, 2020). Yet, in the context of industrial systems and manufacturing, new concepts have begun to emerge and gain momentum in the academic literature (Spasojević, 2021), these being the Internet of Things (IoT) and Industry 4.0.

The IoT is considered the next dawn of technology aĀer the innovatio that was the Internet. The IoT term was suggested, for the fi st ti e, by Kevin Ashton in 1999, it refers to a network within which informatio from all connected devices can be gathered, processed, and modifi d to o er new services (Litoussi, 2020).

The Internet of Things enables a large-scale of technological innovatio s and value-added services that personalize users' interac ons with various "things" (Čolaković, 2018).

Yet the IoT does not come without fl ws. Whereas IoT technologies bring convenience to people's lives, some security concerns also appear. Security is of the highest priority when enterprises consider deploying IoT systems, and most of them temporarily shelve their plans to deploy IoT because of these security concerns, which hinderd the rising trend of IoT and which have greatly aĀected the populariza on and development of IoT. (Ma, 2022).

The Industrial Internet of Things (IIoT) refers to the use of smart sensors, actuators, fast communica on protocols, and e cient cybersecurity mechanisms to improve industrial processes and applicati ns (Lati , 2021).

Even though IIoT represents the implementatio of IoT within industrial facilitie , there are considerable di erences between the two as stated by MarĀn Serror (Serror, 2021), these include criti ality, number of devices, lifeti e of devices, hardware complexity, data volume, data periodicity, etc.
These fundamental di erences alongside specific requirements of IIoT, for example, a need for constant availability and data integrity (Serror, 2021) make aĀacks against these systems highly consequenti l and potenti lly devasta ng.
Thus, the development of large-scale IIoT systems faces various security challenges, which result in many large-scale cybera acks, including fraudulent transac ons or damage to cri cal infrastructure (Pal, 2021).
This paper represents secondary research conducted over the currently available reviews which regard the security within IIoT, with the main focus being frequency and the types of aĀacks that are conducted against systems that implement the aforementio ed concept of IIoT. The main goal of this paper is to provide a high-level overview of the current representati n of the a ack types previously menti ned and security risks within IIoT in the literature.
This paper was wri en in accordance with Kitchenham's (Kitchenham, 2007) guidelines for conduc ng a systemati literature review.
The reviewed papers that were used for the wri ng of this systema c literature review provided informa on on various aĀack types, IIoT architecture weaknesses, potenti l countermeasures, etc. Yet, no paper was found that exclusively focused on providing the researchers with a high-level statisĀ al overview of the appearance frequency and research intensity of these aĀacks, within the available literature. Thus no paper presents the researchers with the ability to immediately grasp which types of a acks are the main focus of the available literature in the Āeld of IIoT.
The study is organized as follows. Sec on 2 contains a detailed methodology which was conducted for the purpose of creati g this paper; Sectio 3 discusses the data collected during the conduc on of the process of Systemati literature review. Finally, Sec on 4 presents the author's Ānal thoughts and conclusion.

2. METHODOLOGY

Systemati literature review method proposed by B. Kitchenham (Kitchenham, 2007) can be summarized into three main phases: Planning the Review, Conducting the Review, and Reporting the Review. The literature review is focused on a set of research questi ns, as well as the inclusion and exclusion criteria.

2.1. Planning the review

In the planning phase of the literature review, it is necessary to identif the needs for the review itself. The need for a systema c literature review can be established by reviewing existing literature reviews in that research area, following the guidelines proposed by Kitchenham (Kitchenham, 2007). During the planning phase several reviews on the subject of IIoT security have been discovered, and yet none of them dealt with the subject of quan fying and analyzing the frequency of occurrences of the various types of aĀacks within the literature itself. For this reason, this crucial and disregarded aspect represents the moti e for writing this paper.
According to the aim and the research framework, the authors propose the following three research ques ons:

RQ1: Which types of aĀacks are mentio ed in the literature reviews regarding IIoT security?
RQ2: Which types of aĀacks are most prevalent in the literature?
RQ3: Which part of the IIoT architecture is most suscepĀble to aĀacks according to the existing l terature?

For this literature review, the following databases were searched:

- Scopus
- Web of science

Scopus uniquely combines a comprehensive, expertly curated abstract and cita on database with enriched data and linked scholarly literature across a wide variety of disciplines (Elsevier, Accessed 21 July 2023). The Web of Science (WoS) database is a selecti e citati n index of scientifi and scholarly publishing covering journals, proceedings, books, and data compila ons. It is the oldest cita on index for the sciences, having been introduced commercially by the ISI in 1964 (Birkle, 2020).

Search terms de ned for search in these databases are presented below:

(“Industrial internet of things” OR “IIoT” OR “Industrial IoT”) AND (“Security” OR “Securing” OR “Safety”) AND (“Challenges” OR “Opportuni es”) AND Language = “English” AND Doctype = “re”

The inclusion criteria defin d for this review are:

IC1: The paper must contain a men on and/or detailed explanati n of the types of aĀacks that occur in the context of IIoT.

IC2: Papers that contain explana ons of architectural framework or layers of IIoT alongside their security downsides are to be included.

IC3: The publica ons must be published in the previous six years.

The exclusion criteria defi ed for the review are:

EC1: If the paper men ons security risks, concerns or a acks only in the context of IoT without any kind of prac cal transla on or reference to the IIoT.

EC2: If the paper is not open access, it should be removed.

EC3: Duplicate papers found in di erent databases should be removed.

For each paper, the following features will be extracted to answer the research ques ons:

1. Publicati n year;
2. Mentio ed/referenced/explained the type of aĀack;
3. Corresponding architectural layers which are targeted by the menti ned a acks;

2.2. Conducting and reporting the review

The reviews that met the inclusion and exclusion criteria in the literature review phase are presented in Table 1.

Table 1: Results of the exclusion and inclusion process

Resource	Ini al search results	Number of duplicates removed	Results a er removal of non-open access papers	Final selecĀon results
Scopus	30	/	23	8
Web of science	49	16	12	5

The previous chapter defin d the inclusion and exclusion criteria, as well as the database search string. A er applying the previously defin d sequence, a total of 79 results were obtained. Of those 30 were obtained from Scopus and 49 were obtained from Web of Science. To implement exclusion criteria 3 Scopus was selected as a reference database when determining duplicates, in other words, all of the obtained research papers from Scopus were considered unique and the papers found and obtained on Web of Science were considered duplicated. Consequently, 16 duplicates were found and removed. Following this, the exclusion criteria 2 was applied on the remaining papers, resul ng in 23 open-access reviews from Scopus and 12 from Web of Science. Furthermore, inclusion criteria 1 and 2, along with exclusion criteria 1 were implemented by reviewing the ti le, abstract, and content of remaining works, which resulted in the fina selecti n of results regarding the 8 reviews obtained from Scopus and 5 reviews from the Web of Science.

2.3. Data extraction and compression

Using data extracti n, the studies selected in the previous stages of a systema c review of the literature were summarized and then presented in the next secti n. The tables and graphs provide a visual representa on of the papers which were selected based on the criteria for data extracti n. The bracketed numbers in the tables

reference corresponding literature as follows: [1] (Abosata, 2021), [2] (Astorga, 2022.), [5] (Dhirani, 2021.), [7] (Fun, 2021), [8] (Jayalaxmi, 2021), [11] (Lati , 2021), [13] (Ma, 2022.), [14] (Mansour, 2023.), [15] (Mirani, 2022.), [16] (Pal, 2021.), [17] (Prinsloo, 2019), [18] (Raimundo, 2022.), [19](Sengupta, 2020.). As shown in Table 2, the most common types of aĀacks appearing in the literature are Denial of Service (DoS) a acks and their advanced version – Distributed Denial of Service (DDoS), appearing in some form in roughly 77% of reviews.

Table 2: Display of attacks and percentage of reviews in which they appear

Type of the a ack	Review in which a ack is men oned/explained	%
A ack on industrial devices	[5],[14],[16],[19]	30
Jamming	[1],[7],[16],[19]	30
InjecĀon a ack	[1],[5],[7],[15],[17],[19]	46
Node capture a ack	[1],[8]	15
Sleep depriva on a ack	[1],[19]	15
Roughly de ned network a ack	[2],[8],[13],[15]	30
Blackhole	[1], [16]	15
Wormhole	[1], [8], [16], [19]	30
Sinkhole	[1], [16],[19]	23
Sybil a ack	[1],[7],[16],[19]	30
Pharming a ack	[7], [16]	15
RouĀng a ack	[19]	7
Man in the middle a ack	[1], [7], [8], [15] , [16], [19]	46
Eavesdropping	[1], [5], [8], [14], [15],[16], [17]	54
Dos/DDoS	[1], [5], [7], [8], [11], [14],[15] , [17], [18], [19]	77
SelecĀve forwarding a ack	[1], [19]	15
SYN	[7], [16]	15
Replay a ack	[1],[8],[17],[19]	30
Spoofin	[5],[7],[14],[16],[19]	38
Data theĀ and breaches	[5],[7], [11],[13] ,[19]	38
Data distorĀon/inconsistency a ack	[1],[5],[19]	23
A acks targeted against ICS	[1],[5],[8], [15] ,[18],[19]	46
Malware a acks	[1],[5],[8], [11] ,[15] ,[17],[19]	54
Phishing a acks	[5],[7],[8],[16],[17]	38
Modern botnets	[14]	7
Advanced persistent threat	[7], [15]	15
Outdated devices	[5],[8],[13],[19]	30
A acks by malicious insiders	[17]	7

According to Abosata (Abosata, 2021) and Pal (Pal, 2021) the IIoT's system architecture can be divided into 4 layers: The PercepĀon layer, The Network layer, The Processing or Support layer, and The Applicatio layer. Addi onally, aĀack types from table 2 can be sorted by the layer which is ussually their main target. Thus rows starting at aĀack on industrial devices all the way to the sleep depriva on a ack can be classifie as aĀacks targeted against percepĀon layer, network layer a acks include rows from roughly defin d network aĀacks to spoo ng. Data theĀ and breaches, data distorĀon a acks and ICS a acks ussually target support layer while malware a acks, phishing aĀacks and modern botnets target applica on layer. Based on this division, the types of a acks men oned in Table 2 were sorted into the appropriate layers as shown in Table 3. Some of the a acks from Table 2 can't be exclusively placed into one of the four mentio ed layers due to their complex nature, these include:

- Advanced persistent threat – this represents the threats from individuals or organiza ons aĀ liated with organized cybercrimes;

- Outdated devices – while not being representati e of the type of a ack *per se*, outdated devices can be considered a security concern that could present themselves as an ideal entry point for future a acks and a severe security weakness;
- A acks by malicious insiders – Due to their unhindered access and knowledge of the system, these individuals can cause severe damage that would otherwise be impossible or less severe if the individuals were conduc ng the same a ack from the outside of the system;

These 3 special types were sorted into "Other security threats" in Table 3.

Table 3: Percentage of reviews which mention attacks that happen on corresponding architectural layers

Architectural layer	Review	%
PercepĀon layer	[1],[5],[7],[8], [15] ,[16],[17],[19]	62
Network layer	[1],[2],[5],[7],[8], [11], [13], [14] ,[15] ,[16],[17],[18],[19]	100
Support layer	[1],[5],[7],[8], [11], [13], [15] ,[18],[19]	69
Applica on layer	[1],[5],[7],[8], [11], [15] ,[16],[17],[19]	69
Other security threats	[5],[7],[8], [13] ,[15] ,[17],[19]	54

As shown by Table 3, 100% of reviews mentio or explain the a acks which happen on the Network layer, while only 62% of reviews deal with a acks that are related to the Percepti n layer. Table 4 shows the publicati n year of the researched reviews. Most of the reviews- 6, were published during 2021, followed by fi e publicati ns in 2022.

Table 4: Publication year of reviews

Publica on year	Review
2023	[14]
2022	[2],[13],[15],[18]
2021	[1,[5],[7],[8],[11],[16]
2020	[19]
2019	[17]

A combina on of data from Tables 3 and 4 is presented in Figure 1. Figure 1 shows the publica on year of the review and the number of reviews that menti n or explain the types of aĀacks belonging to one of the corresponding architectural layers. As Table 3 shows, all reviews menti n a acks that correspond to the Network layer. Figure 1 clearly presents this reality by showing that all reviews used for the purpose of writin this paper menti ned the Network layer, in other words, a acks corresponding to the Network layer were mentio ed in reviews published from 2019 to 2023.

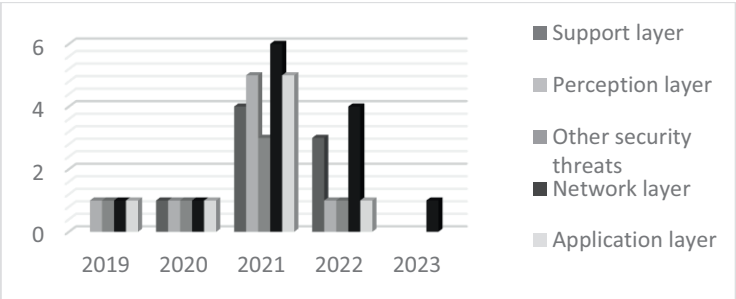

Figure 1: Distribution of reviews mentioning attacks within shown layers over five years

3. DISCUSSION

In this sec on, the obtained results of a systemati review of the literature will be presented and analyzed. The mentio ed types of a acks in reviewed literature are presented in Table 2. By examining the results shown in Table 2, it can be deduced that 25 distin t types of a acks emerge in the reviewed literature. A er adjustin the taxonomy model provided by Kaur (Kaur, 2023) these aĀacks can be sorted into groups based on their working mechanisms, the layers they target or the general concept that they are based on. Consequently, following groups emerge Physical a acks, Node aĀacks, Flooding aĀacks, Eavesdropping a acks, Spoofing a acks, and Data a acks.

The most prevalent types of aĀacks recorded in reviewed literature are Denial of Service (DoS) and Distributed Denial of Service (DDoS), appearing in a total of 77% of all reviewed literature. When combined with SYN and Selecti e forwarding aĀacks they consti ute a group called the Flooding a acks which are described in detail by Pal (Pal, 2021), these types of a acks appear in 85% of all reviewed literature. Potenti l reason why this is so is because the majority of devices, when damaged, are unable to provide their intended services and essen ally this is what DoS represents. With the majority of aĀacks causing some sort of a damage on the hardware or the softw re of the device it is plausible that DoS also represents a consequence of the other types of a acks thus infl ting ts occurrences within various reviews.

Based on the data shown in Table 3 and Figure 1, it can be concluded that all reviewed literature more or fewer deals with a acks that are related to the Network layer, thus it can be argued that the Network layer of IIoT architecture is the one that is most suscepĀble to aĀacks.

According to these insights several plausible conclusions can be assumed, these conclusions are listed as follows:

1. DoS and DDoS aĀacks are the most common occurring types of aĀacks in the context of IIoT systems.
2. DoS, DDoS and generally Flooding a acks are the most researched and menti ned group of a acks in the reviewed literature.
3. Previously menti ned a acks are given highest priority and a enti n in research circles regarding the subject of IIoT security. Potentia ly, these kinds of a acks are best understood and researched.
4. Overall, aĀacks which correspond to the Network layer are most commonly occurring a acks and the Network layer itself presents the most common target for malicious aĀacks.
5. Due to the previous statement, majority of aĀacks targeted against IIoT systems have the goal of causing industrial damage, system stoppage and sabotage, because the a acks against Internet layer prevent func onal and adequate communica on between industrial devices, thus causing miscommunicati n and reducti n of system availability and responsiveness.
6. Less common goals of a acks against IIoT systems appear to be data theft and data distortio as advocated by the fact that Support and Applicati n layers are next in line as the most common targets in IIoT architecture. Consequently, a ackers are potentia ly seeking to conduct industrial espionage or pave the way for a acks against the Internet or Perceptio layers.
7. A acks against the PercepĀon layer seem to be least frequent. Possible reasons for this might include the fact that conducting aĀacks against percepĀon layer usually requires aĀacker's physical presence near the industrial devices.

4. CONCLUSION

Based on the results presented in sectio s 2 and 3, the following conclusions are proposed:

The most frequently menti ned group of a acks within the reviewed literature are the Flooding aĀacks, specifi ally DoS/DDoS aĀacks. This group is closely followed by Eavesdropping, Man-in-the-Middle, and Malware aĀacks. If the propensity for a acks was determined only based on how many ti es a certain a ack corresponding to a certain layer was men oned in the literature, we could say that the Internet layer is the one that is most prone to aĀacks followed, in equal measure, by Support and Applica on layers.

In response to RQ1, it can be concluded that 25 disti ct types of a acks were identi ed in the reviewed literature.

In response to RQ2, it can be concluded that the most prevalent types of aĀacks recorded in reviewed literature are Denial of Service (DoS) and Distributed Denial of Service (DdoS).

In response to RQ3, it can be concluded that all reviewed literature more or less deals with aĀacks that are related to the Network layer, thus it can be argued that the Network layer of IIoT architecture is the one that is most suscepĀble to aĀacks.

As the industrial producti n paradigm slowly begins to shift enterprises will likely seek to gain compeĀti e advantage over their commercial rivals by accommodating newly emerging concepts of Industry 4.0. One of the potenti l cornerstone's of this implementa on will be IIoT, the success of its implementa on might highly depend on uti iza on of its strengths and eliminatio of its weaknesses, amongst which security is a major one.

To successfully navigate this process, enterprises will have to rely on academia and scientiĀ community for insights, theoreĀcal and prac cal soluĀons to the issues present in IIoT. Consequently, researchers themselves will have to rely on existing literature to grasp the extent of current research on the subject.

Thus, the goal of this Systemati Literature Review was to give researchers a concise high-level overview of the literary coverage of various types of aĀacks within the IIoT.

Based on the publica on years of reviewed literature, it can be argued that research in the area of IIoT security is sti l in its nascent stages and further research is encouraged.

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AUTOMATIC COLOR SEGMENTATION FOR HYBRID SUNFLOWER RAY FLORETS

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Abstract: *As an aesthetic trait, ray floret color has high importance in the development of new sunflower genotypes and their market value. The standard methodology for the evaluation of sunflower ray florets is based on the International Union for the Protection of New Varieties of Plants (UPOV) guidelines for sunflowers. Applying it, however, requires expert evaluators and results in evaluations that are still highly subjective. In this study, we focus on hybrid sunflower ray florets which are bi-colored, for which we propose a new methodology for automatic segmentation of the regions inheriting the dominant color of each of the parents in digital images, which can objectively quantify the contribution of each parent color to the offspring. To achieve this, we use a deep-learning model to extract the ray floret (the Segment Anything model), followed by a traditional automatic thresholding approach. We test our approach on a dataset comprised of 53 digital images, including parent variety images of "Pacino gold" and "Neoplanta", as well as images of hybrid offspring resulting from the crossing of these varieties. Our results show that the proposed approach can objectively quantify the contribution of each parent.*

Key words: *sunflower, ray floret, Segment Anything model, segmentation, Otsu thresholding, deep learning, computer vision*

1. INTRODUCTION

Commonly cultivated as an oil crop, sunflower (Helianthus annuus L.) also encompasses several varieties that are classified as ornamental (Mladenović et al. 2020). Ornamental sunflowers could be grown as cut flowers, in gardens, and as potted plants (Kaya et al. 2012). Their primary appeal lies in the beauty of their flowers, therefore flower traits, such as the color, size, and shape of florets, are primary targets in breeding programs. The sunflower inflorescence, referred to as a flower, is composed of ray and disc florets. The sterile ray florets are located on the outer part of the sunflower flower. Ray florets are usually yellow but may appear in different shades of red, orange, lemon-yellow, white, or a combination of these colors, thus making sunflowers desirable as an ornamental crop (Cvejić et al. 2016).

A comprehensive understanding of the hereditary factors influencing flower color inheritance and the generation of new color combinations is essential for enhancing genetic diversity and achieving success in the breeding of ornamental sunflowers (Kaya et al. 2012). This knowledge is also crucial for improving pollination success and yield in modern elite sunflower hybrids (Dowell et al. 2019). When two parent plants with different colors of ray flowers are crossed, the red color of ray florets in the F1 generation is partially dominant over yellow colors, resulting in a "gaillardia" pattern, meaning two colored ray florets. This trait is typically governed by one or two dominant genes in subsequent generations, as confirmed by various studies on sunflower germplasm. These studies indicate that floral pigmentation traits are controlled by a few loci with significant effects (Fick 1976, Yue et al. 2008, Cvejić et al. 2016). The expression of red color in ray florets requires the presence of two dominant genes, while the most common coloration, yellow, is controlled by the complementary interaction of dominant alleles from different genes (Fick 1976). Researchers are now exploring more objective methods, such as image analysis, to replace the subjective and laborious manual methods in agricultural applications (Sunoj et al. 2018). In that sense, ornamental sunflower breeding requires a detailed description of phenotype to avoid inconsistencies between variety descriptions and actual plants in the field. In order to reduce costs, prevent product damage, and improve the efficiency and quality of products offered to consumers, the ornamental sunflower market is expected to adopt automatic classification methods (Lino et al. 2011), (Dawod et al. 2022).

To address this issue, Zorić et al. (2020) developed a new, objective methodology for sunflower ray floret color evaluation based on digital image classification into the UPOV color groups. The Flower Color Image Analysis (FloCIA) software enables visualizations of segmentation of the sunflower images, the percentages of pixels belonging to each UPOV color category with graphical representation, and the position of the examined sunflower mean vector in Lab color space in relation to the mean vectors of the UPOV category. The precision of FloCIA was greater between UPOV-based expert color evaluation and software evaluation than between two UPOV-based evaluations performed by the same expert. With an accuracy of 91.50% in color category matching, the FloCIA software can serve as a guideline for evaluators to determine the dominant color and to identify multiple significant colors in the examined genotype. The current breeding, production, and sales of ornamental sunflowers face challenges under current guidelines and methodologies, particularly in defining new genotype colors, especially if they are multi-colored.

Color does have a strong influence on human perception and is commonly used to convey aesthetic information. It can affect people on an emotional level and determine the preferences, interpretation, memorization, and reactions of people to visual stimuli (Sartori et al 2015). However, mapping regions in digital images to what humans perceive as a single color is not a trivial task (Van de Weijer 2009).

In this paper, we propose a new methodology for ornamental sunflower ray floret color quantification that focuses on sunflowers with the "gaillardia" pattern but makes no assumption as to what the two colors exhibited by these flowers are. The approach uses a state-of-the-art image segmentation model (Segment Anything model proposed by Kirillov et al. 2023), to determine the area of the image corresponding to the ray floret of a sunflower. Once this is done, we employ automatic thresholding (Otsu 1979), (model to determine the relative ratio of each of the two colors. Such a descriptor is invariant to the colors themselves and the variance in the pixel values stemming from different illumination and image acquisition conditions and is applicable whenever the ray floret is bicolored.

2. PROPOSED APPROACH

Our approach is a two-step procedure. We first need to determine the pixels within an image that correspond to the ray floret. Then we need to find an adaptive way of quantifying the distribution of the two colors in this area. The whole process is illustrated in Figure 1.

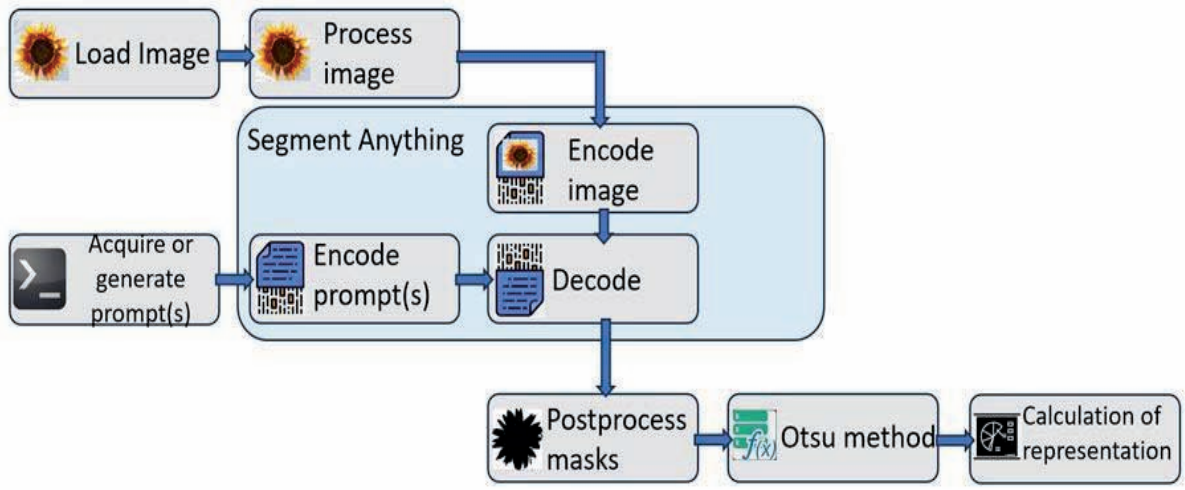

Figure 1: Data flow chart of sunflower image processing based on SAM

For the first step, we opted to employ the recently proposed Segment Anything model (SAM), which is a foundational model trained on the largest image segmentation dataset proposed this far. The model can often generalize to classes previously not seen without any training (so-called zero-shot performance), better than models designed for specific purposes.

The SAM builds on the success of large language models and can be prompted in different ways, including prompting it with a bounding box and the coordinates of a specific point located on the object we want to extract. In the work presented here, two prompts were used: the first is a bounding box that encompasses the entire sunflower, and the second is a point located in the central part of the sunflower that we want to remove, leaving only the petals. Prompted in this way, we were able to correctly identify the region of the

input images corresponding to the ray floret. Sample results are shown in Figure 2. The results are obtained in the “native’ R, G, B color space. We opted not to employ the LAB color space used in Zorić et al. 2020. Figure 2 shows the application of the "Segment anything" model on three different sunflower images. The model is prompted with a bounding box encompassing the entire sunflower and the coordinates of a point indicating the location of the seeds. This point marks the area within the bounding box that we want to remove.

Figure 2: Original images of sunflowers, and images processed with SAM model.

While SAM can correctly identify the region of interest to us, the pixel values within it vary significantly, as shown in Figure 3.

As Figure 3 illustrates, the red and blue channels seem to contribute little information when it comes to the distribution of the colors of interest to this study, so we opted to carry out subsequent analysis using the green channel. To separate the pixels corresponding to the two colors we used the classical method for determining the threshold separating them automatically proposed by Otsu (Otsu 1979). The dashed vertical lines in Figure 3 show the location of the threshold thus determined for each of the channels of the image. In the masks shown above the pixel-value distributions for each channel indicate in white pixels with values above the threshold.

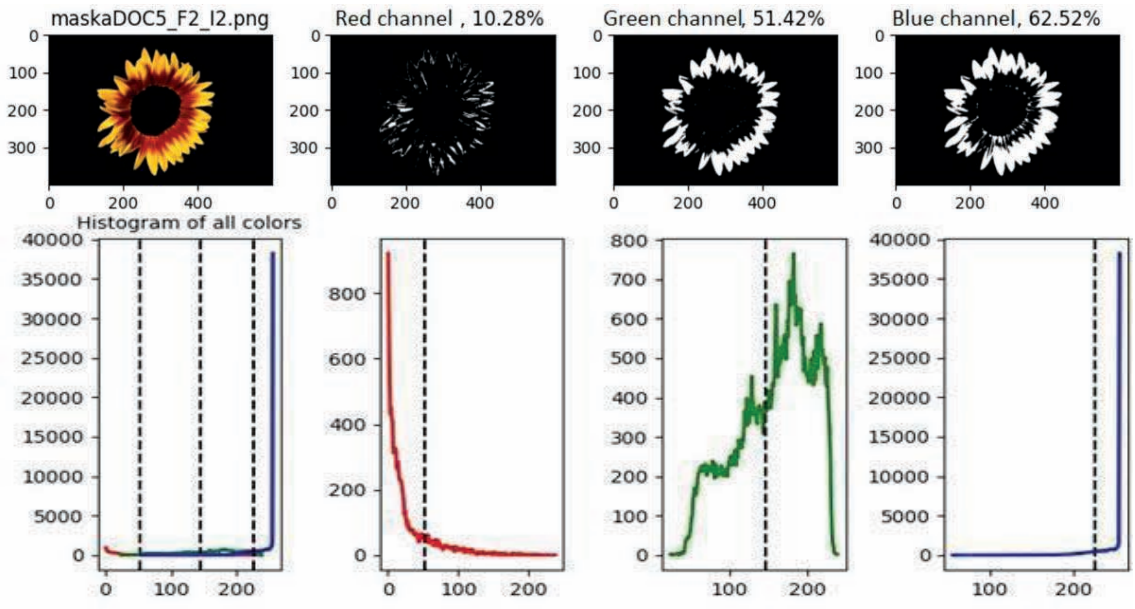

Figure 3: The application of the Otsu algorithm.

3. EXPERIMENTS AND RESULTS

To evaluate the proposed approach, we used a data set collected by the researchers of the Institute of Field and Vegetable Crops of Serbia. The dataset consists of 51 images of the hybrid offspring of two varieties, called “Pacino gold” and “Neoplanta”, shown in Figure 4.

Figure 4: The parent varieties “Neoplanta” (left) and “Pacino gold” (right)

When run on an image of a bicolored offspring, our method can automatically determine the percent of each of the colors in the ray floret, providing a descriptor that would be too labor-intensive to calculate manually. Figure 5 shows the distribution of this descriptor when evaluated for all images in our dataset, showing that the majority of the offspring flowers inherit more color from the darker parent.

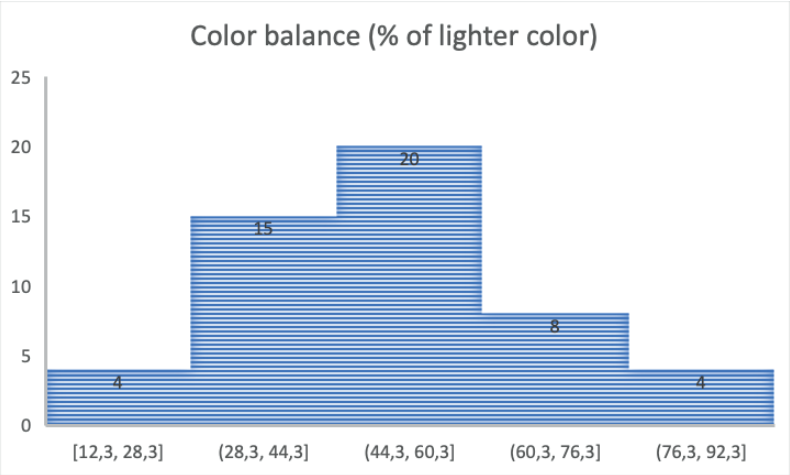

Figure 5: Portion of the color inherited from "Pacino gold" for hybrids in our data set

4. CONCLUSIONS

We proposed a new methodology for quantifying the appearance of "gaillardia"-patterned sunflower hybrids. The proposed approach can be applied to other flower varieties as we have based it on a zero-shot method for segmenting the region of interest and an adaptive thresholding method to extract our descriptor. Further study is needed to evaluate if the descriptor can be effectively used to help enhance genetic diversity and achieve success in the breeding of ornamental sunflowers. In the near future, we will extend the method to enable the automatic detection of flowers that are bicolored and for which we can reliably apply the methodology.

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UTILIZING THE 'SEGMENT ANYTHING MODEL' FOR MAMMOGRAPHY IMAGE ANALYSIS

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Abstract: *Mammography, considered the "gold standard" for breast mass detection, boasts approximately 90% sensitivity. However, the process of mammography reading and interpretation is time-consuming and susceptible to a significant number of false negatives and false positives. Compounding these issues is a notable shortage of radiologists specializing in breast imaging, highlighting a need for innovative solutions. This paper proposes the use of an artificial intelligence (AI) system, the Segment Anything Model (SAM), to address these challenges. SAM, a versatile image segmentation model, can generate segmentation masks in response to various prompts such as points, bounding boxes, masks, or textual descriptions. It employs a transformer-based architecture and utilizes a large-scale dataset for training. Within mammography, SAM could be deployed to automatically segment suspicious areas in the breast, thereby providing invaluable support to radiologists during diagnostic decision-making. Furthermore, SAM can be fine-tuned and trained on specific medical image datasets to enhance its performance. Our results underscore SAM's efficacy in producing accurate segmentation masks, demonstrating its potential for integration into human-in-the-loop systems for annotation and decision support in medical image analysis. Nevertheless, further research and training are essential before implementing SAM in real-world medical scenarios.*

Key words: image segmentation, semantic segmentation, computer vision, mammography

1. INTRODUCTION

Mammography, widely recognized as the "gold standard" for breast mass detection, offers an approximate sensitivity of 90% (Boot and Irshad, 2020; Jha et al., 2023) Each mammography examination generates X-ray images from two distinct angles for each breast, which are then carefully evaluated by a radiologist. This powerful diagnostic tool aids in the early detection of breast abnormalities by facilitating the identification of micro and macro calcifications, architectural distortions, as well as benign and malignant lesions (Liu et al., 2021; Singh et al., 2020). These diagnostic images and their subsequent interpretation are further guided by the Breast Imaging Reporting and Data System (BI-RADS). This classification system, proposed by the American College of Radiology, is a valuable tool utilized in interpreting and categorizing findings from mammograms, as well as breast ultrasounds and MRIs. With six categories that range from normal or benign to highly suspicious of malignancy, BI-RADS streamlines the decision-making process and directs subsequent follow-up recommendations (Magny et al., 2023). Despite the effectiveness of mammography, the interpretation process is time-consuming and lengthy, with a propensity for a significant number of false negatives and false positives. Compounding this issue is the shortage of radiologists specializing in breast imaging, underscoring the need for innovative solutions. The development of deep learning-based Computer-Aided Detection (CAD) systems has brought about considerable improvements in the detection, classification, and segmentation of Regions of Interest (ROI) within mammograms, and their use is highly recommended to support radiologists (Chanda and Sarkar, 2020; Jha et al., 2023; Kumar and Ramadevi, 2022; Salama and Aly, 2021).

The process of segmentation in mammogram images involves the division of these images into separate components, aiding in the identification of masses and facilitating the extraction of the ROI (Ali et al., 2019). It's important to remove pectoral muscles and artifacts before segmentation to avoid misguiding classification algorithms (Michael et al., 2021). One solution to these challenges is the application of artificial intelligence, particularly the Segment Anything Model (SAM) (Kirillov et al., 2023). SAM is capable

of autonomously determining suspicious tissue regions through segmentation, or it can do so with minimal expert intervention. Additionally, SAM can function within an active learning loop for annotation, potentially enhancing the accuracy and efficiency of mammographic diagnostics.
Building on the aforementioned challenges and potential solutions, this paper aims to illustrate the effectiveness of incorporating a contemporary artificial intelligence model, such as SAM, to establish a framework that enhances the field of mammography. We explore the possibility of augmenting radiologists' expertise with an automated system capable of segmenting and identifying areas of concern, thereby potentially improving diagnostic accuracy and efficiency. The integration of such a model offers the prospect of an active learning loop for annotation, which may advance the overall quality of mammographic diagnostics.

2. METHODS

To concretize the theory and test the effectiveness of SAM in a practical setting, we have employed specific mammography datasets in our research. To ensure the scientific robustness of our approach, we have made use of open mammography datasets from RSNA and CBIS-DDSM. Given that these datasets provide ground truth masks for some images, we can objectively evaluate the quality of segmentation achieved by the SAM model. This approach is designed to replicate real-world scenarios, where images would typically be loaded through communication with a Picture Archiving and Communication System (PACS) or from historical data kept in Digital Imaging and Communications in Medicine (DICOM) formats, as in our case. Our focus remains on the extensive preprocessing techniques necessary to adapt images to model-expected input, including normalization techniques, Contrast Limited Adaptive Histogram Equalization (CLAHE), image resizing, artifacts removal, boundaries cropping, panning, and replicating grayscale through all three RGB channels (Punitha and Perumal, 2019). These steps are critical to accurately and effectively utilizing AI models like SAM in real-world medical imaging.

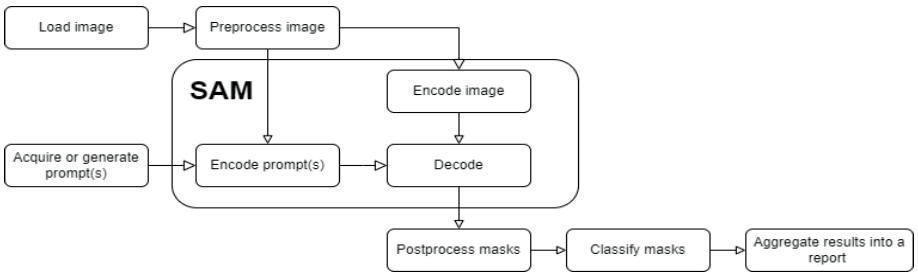

Figure 1 - Data flow chart of mammography image processing based on SAM

The Segment Anything model itself is a foundational model for image segmentation. The version used in this paper is an out-of-the-box one, intending to use it in a zero-shot regime and explore its efficacy in such a constellation. SAM introduces three novelties new task, segmentation model, and dataset (with segmentation annotations). The defined task is to create a segmentation mask based on an image as input and a specific prompt. Prompts can be point, bounding box, mask, and textual. In addition, there are three levels for mask generation, which the authors call object, part, and subpart, so if the user, for example, clicks on a suspicious mass on a mammogram, the model could theoretically generate three levels of segmentation - suspicious mass mask, suspicious mass mask with surrounding tissue and a mask of the whole breast, and the user chooses which mask corresponds to what he imagined.
In addition to the multi-mask mode, the model can also work in a single-mask mode if the user still wants to let the model generate only one mask, the one in which the model is most confident. There is also a multi-input mode, where the user can enter several different types of prompts, such as defining a bounding box around the breast on the mammogram and a point located in the suspicious mass but label the point as negative. In that case, the model should segment the entire breast except for the suspicious mass. As for the model itself, it contains three components: an image encoder, a prompt encoder, and a decoder. They are built on transformer models for computer vision with specific modifications such that the model can work in real-time.
A version of the Vision Transformer (ViT) model minimally adapted so that it can process high-resolution inputs in real-time is used as the image encoder. It runs once per image and can be run in advance before

the prompt is established. This part is usually frozen when fine-tuning, which is shown in the medical image processing example (Bagchi et al., 2020; Ma and Wang, 2023). The prompt encoder handles sparse and dense prompts differently. Sparse prompts include dots, frames, and text, and dense prompts include masks. Dots and frames are encoded by positional encoding and learned encoding, as well as off-the-shelf text encoder, and masks by convolution and summation with the input image, as shown in Figure 1. The decoder uses a transformer architecture to map the co-encoded image and prompt to a segmentation map. The dataset it was trained on consists of about 11 million images with about 1.1 billion segmentations. In the case of mammograms, a mask generator was used, which in the background performs the segmentation for the grid of input points as prompts to the model. The segmentation in which the model is the most certain is selected with its post-processing, i.e., for which the IoU metric is large enough. Another possibility of applying this model to this problem is the following: use the SAM model in prompt mode.

Depending on the type of prompt that would be used, there are several options for how to exploit this, so, for example, theoretically the text prompt "malignant tumor" or "benign calcification" should work on such images and find exactly what it is searching for. This certainly, even if we ignore the fact that the text mode of operation is not yet available, we could not expect it to work out-of-the-box if the model is not already trained on medical images of that type. It would be particularly challenging to extract a BI-RADS (Breast Imaging-Reporting and Data System) classification (Spak et al., 2017) through such a constellation because "BI-RADS 3" or "BI-RADS 4" is certainly not a textual prompt that a universally trained model would expect. What, however, exists as a possibility is to use this mode of operation in the future when it becomes available by performing fine-tuning on the model whereby some of the model's awareness of classes of interest from initial training could be used, but the model could additionally learn to accurately distinguish malignant and benign tumors, as well as benign and malignant calcifications from healthy tissue. Another type of prompt, as a representative of dense prompts, are masks. A mask of the breast itself could be used as a prompt mask. The breast mask can be automatically extracted through a series of steps - image binarization, contour finding, and keeping the inside of the largest contour as a binary mask corresponding to the breast. Such a mask found fully automatically, could be directly used as a model prompt. Additionally, for use in the human-in-the-loop systems, active learning (Ilić and Tadić, 2021), and help with annotation, which is certainly as interesting as the complete automation of decision-making (whether the subject is the system which will remain in this mode where it is left partly dependent on expert expertise or only on a temporary solution that will be useful in the stage of data set preparation - in the annotation), usage of an initial mask provided by an expert - radiologist could be exploited. An expert could mark the parts of the tissue that he considers suspicious, and the model would refine his masks into a more accurate segmentation. Boxes and points as prompts are also an option. Boxes can be manually created, or this coarse-level localization could also be automatized (Liu et al., 2020). Properly placed points labeled as 1 (foreground – suspicious mass) and 0 (background – healthy tissue) may be sufficient for the model to determine correct segmentations. This can be seen from the example with the generation of masks automatically, because in that example, in the background, nothing but multiple inference was performed on the model with prompts in the form of points.

It is also interesting to mention that prompts can be combined, so you can, for example, frame a certain group of calcifications and thus provide a box prompt, and additionally mark a certain number of points that are, and a certain number of points that are not, within the calcifications. This is how you get a complex prompt that will result in the model finding calcifications within the given region and correctly labeling them as foreground.

Masks acquired from a model could be further processed to filter out masks by size, shape, etc. As the SAM is a foundation model which is not particularly intended only for one type of segmentation, the type of masks differ according to the type of used prompts. If the pipeline is configured in such a way for the model to return instance masks of individual suspicious parts of the tissue, each mask could be further classified by severity, e.g., in a standard BI-RADS manner using an image classifier.

3. RESULTS

Figures 2 and 3 show the application of automatic mask generation using a grid of point prompts where parameters were refined to get from the segmentation on the left to the one on the right.

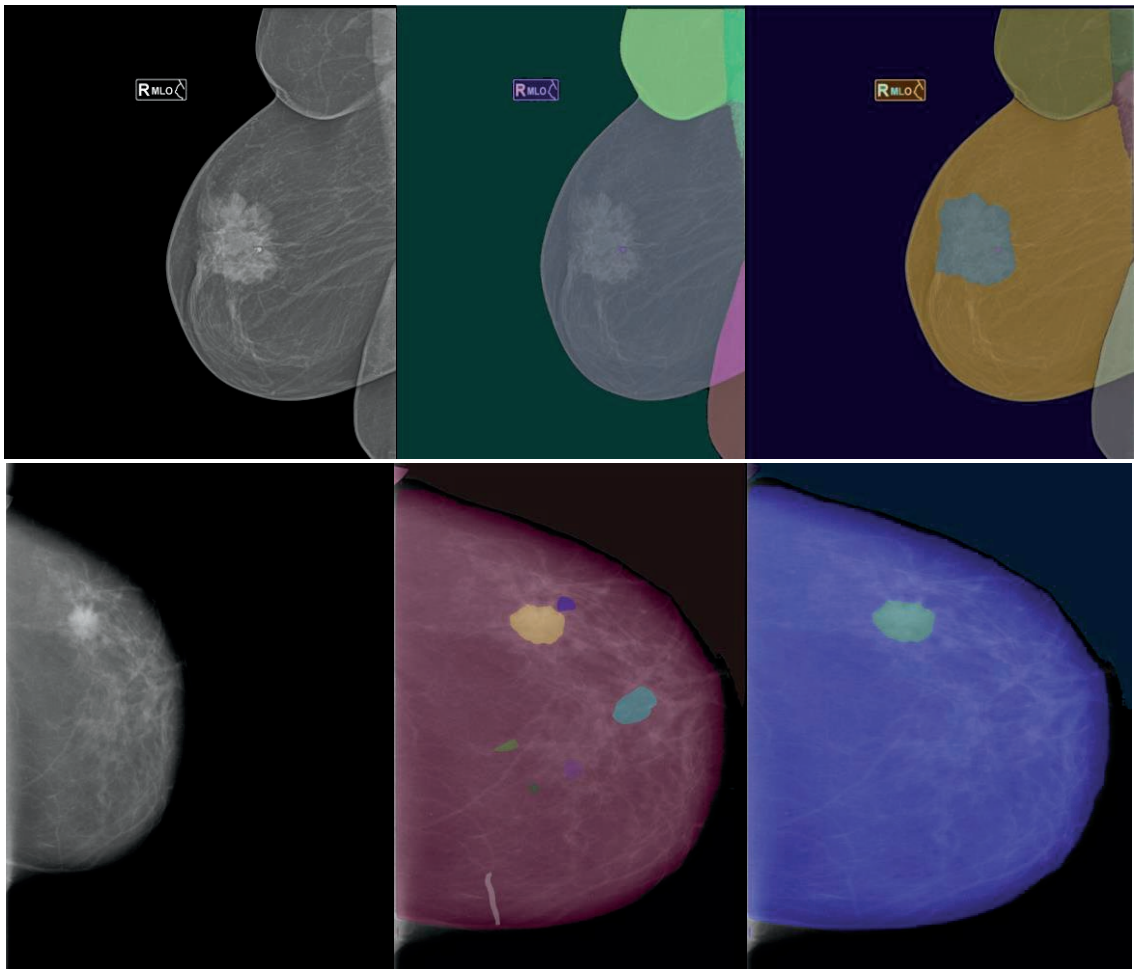

Figure 2 - Mammogram images processed with the SAM model with different settings, parameters tuned to accurately find the lesion

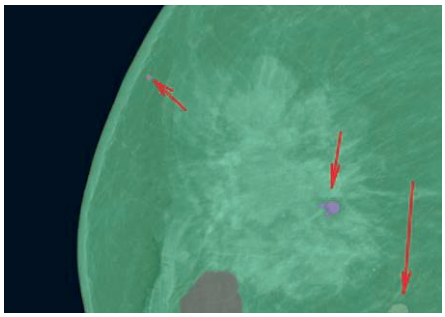

Figure 3 - Mammogram images processed with the SAM model with parameters tuned for finding calcifications

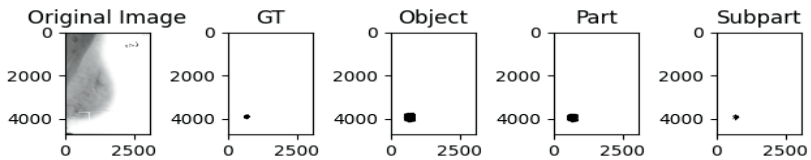

Figure 4 - The original mammogram image, the ground truth mask, the detected object and the part of the detected object and its subpart

Figure 4 shows the application of the SAM with a bounding box prompt artificially generated as an annotation frame. In this form, this has no practical application, but it serves to simulate a human-in-the-

loop usage and demonstrate the general awareness of this model about the objects on the mammogram, and examine how capable it is, given the approximate location of what it is looking for, to segment it. The fact that the division into object-part-subpart in the case of finding suspicious masses on a mammographic image does not have clear semantics for a human, it can be expected that it exists in some way for the model. Thus, for prompts from the figure it can be seen that the subpart category best matches the ground truth mask - it is clear that the IoU (intersection over union) metric is the best in the case of the subpart mask and reaches values of the above 70% on this particular dataset *(CBIS-DDSM)*.

4. DISCUSSION

The greatest significance of the usage of SAM in any type of segmentation, therefore also in mammography, is its ability to produce very high-quality masks in a zero-shot state. Traditional segmentation methods like otsu thresholding (Fazilov et al., 2022) are not able to produce such high-quality masks. Usual segmentation methods in medical image processing like U-net (Baccouche et al., 2021; Ronneberger et al., 2015) are able to learn to make high-quality masks, but require a vast amount of data to be trained on and lack a foundation model. The results seen from the usage of SAM are comparable to those methods even in its zero-shot state, and for the fatty breast images where mass boundaries are easier to identify, this multi-purpose model performs even better than specifically trained models. In addition, multiple interfaces offer help in adapting the model to a wider range of usages, so users are not limited only to one type of segmentation, one type of prompt etc.

5. CONCLUSIONS

As shown, SAM could certainly be used in some form in processing mammography images. It could be used for human-in-the-loop systems for providing help in segmentation or help in the annotation phase in its prompt mode or could even be used in the automatic mask-generating mode in some cases, even in zero-shot. Further training of the model would, however, be highly recommended if any type of medical image analysis were to be seriously considered.

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ROUGHNESS MEASUREMENT OPTIMIZATION OF REFLECTIVE SURFACES BY FOCUS VARIATION METHOD

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Abstract: *The quality of the treated surface is one of the key characteristics of each product. The functionality of the workpiece during its exploitation directly depends on the size of the surface roughness. Determining the quality of the machined surface comes down to measuring the roughness amplitude parameters, which can be linear (2D) parameters or surface (3D) parameters. According to the method of collecting data from the examined surface, roughness measurement techniques can be classified into contact (tactile profilometry) and non-contact methods. An example of a non-contact roughness measurement is the focus variation method. In this paper, a device based on focus variation, InfiniteFocus SL, was used to measure the roughness on the workpiece, which has an arithmetic mean roughness Ra less than 260 nanometers. Surfaces that have small micro-geometric irregularities are an issue when sampling with optical methods, due to the appearance of surface reflectivity. Using the L9 Taguchi design of the experiment, the optimal brightness, contrast, and vertical resolution parameters were determined for measuring the Ra, Rz, and Rt roughness parameters. The levels of the factors included in the study were optimized concerning the reference values of the roughness amplitude parameters obtained on the tactile profilometer.*

Key words: Roughness measurement, focus variation, Taguchi design of experiment

1. INTRODUCTION

The quality of the machined surface ensures the functionality of the product during exploitation. In the manufacturing industry, this fact is of particular importance when it comes to responsible components that ensure the relative movement of elements or the correct clearance tolerance of other system elements (Hadžistević et al., 2015; Runje et al., 2019). For example, in medicine, determining the relationship between the quality of the machined surface and its tribological behavior ensures a long working life of the implant (Orošnjak et al., 2016). The quality of the machined surface is defined based on the measured values of the surface roughness. Surface roughness is a set of micro-geometrical irregularities on the surface. These irregularities occur during the processing of the workpiece or may be caused by other influences, e.g. corrosion. Different roughness parameters are used to quantify surfaces. Given the importance of measuring micro-geometrical irregularities, various methods of data collection from the examined surface have been developed. The most commonly used methods for measuring surface roughness are tactile profilometry and optical measuring systems. In tactile profilometry, during data acquisition, the probe makes physical contact with the machined surface, and by swiping it, records a profile of a certain length. The use of profilometers is associated with a long data acquisition time and the possibility of scratching the examined surface, but with these methods, there is no issue when measuring reflective and/or transparent workpieces (Leach, 2011).

Measurement systems based on focus variation are devices that have precise lens systems, which enable measurements with different resolutions. The semitransparent mirror directs the beam of light from the source through the optical path of the system, and the lenses focus it on the surface of the workpiece. Depending on the topography of the surface, light rays are reflected differently. All reflected light rays that reach the lens are registered by the sensor. Due to the shallow depth of field of the optical system, only a small part of the surface is sharpened. To map the entire surface, the optical system must move relatively along the vertical *Z* axis concerning the workpiece (Grochalski et al., 2020; Jotić et al., 2023).

During this movement, a constant acquisition of sharpened images of the observed surface is performed, which means that the complete geometry is collected in a satisfactory resolution and sharpness. After that, the algorithm converts the collected data from the sensors into three-dimensional information, point cloud (Runje et al., 2019).

According to Leksycki (2021) trends in metrological analysis of surfaces are focused on the development of optical measuring devices, based on different measuring techniques. Such approaches allow for obtaining a vast amount of information from the examined surface during the measurement. However, devices based on focus variation have difficulties in measuring surfaces with low values of surface roughness like polished workpieces (Giusca et al., 2014) and transparent workpieces.

Also, many factors can affect the accuracy of data acquisition. Some of those factors are brightness and contrast. If the exposure time is too short, a dark image is obtained, conversely, if it is too long, the image is too bright. In such conditions, the device will not collect the data. Along with illumination settings, it is possible to use a polarizer that filters the reflected light from the workpiece. A polarizer can help collect the data from highly reflective surfaces. The intensity of the light in combination with the "ring light" can also affect the final result. The ring light is a hardware piece that can switch on or off segments that emit light. Vertical resolution defines the smallest height difference that can be measured. The values of the vertical resolution depend on the selection of the apparatus (lenses of a certain magnification). If the surface roughness of the workpiece is less than the minimum vertical resolution value for a particular lens, then data acquisition will be difficult or impossible. Data can be collected in Single mode, where roughness parameters are estimated based on one recorded image, or in ImageField mode, where sensor movement in the *XY* plane and a certain range along the vertical *Z* axis are defined. Other factors, which were not considered in this paper, are lateral resolution and data collection in ImageField mode.

In this work, by applying the *L9* Taguchi design of the experiment, the optimization of the influencing factors on data collection was carried out using focus variation. Factors that were included in the study were brightness, contrast, and vertical resolution. Each of the factors was varied on three levels. Reference values for all three measurement locations were obtained on a tactile profilometer. Analysis of variance, ie. by fitting a general linear model for all three outputs from the study, statistically significant factors with a confidence interval of 95% were determined. The study aimed to determine those factor levels that will give the least deviation of the roughness parameters *Ra*, *Rz*, and *Rt* from the reference values.

2. EXPERIMENTAL RESEARCH

The measuring device used in the study is the InfiniteFocus SL, from Alicona Bruker. The working volume of the device is 50 × 50 × 155 mm, and the load capacity of the work table is 4 kg. It can change lenses with different magnification values. Based on the manufacturer's recommended values and the measured reference values of the roughness parameters from the tactile profilometer, a lens with 50x magnification was used in the study. The minimum height of deviations that a lens with that magnification can measure is 20 nanometers. Also, the minimum value of the roughness parameter *Ra* that can be measured with the 50× objective is 0.08 µm. According to the ISO 10360-8:2013 standard, the extended measurement uncertainty of the device when measuring the arithmetic mean roughness of 0.5 µm is U=0.04 µm, with a standard deviation of σ=0.002 µm. Reference values were measured with a Hommeltester T2000 tactile profilometer, using a probe with a tip radius of 5 µm, 0.375 µm lateral resolution, and 0.01 µm vertical resolution. Reference values for roughness parameters were measured at three measuring points on the workpiece. The mean value, in µm, of the obtained results was used as a reference, in Table 1.

Table 1: Reference values of roughness parameters Ra, Rz, and Rt

Ra	*Rz*	*Rt*
0.2527	1.4447	1.593

The Taguchi design of the experiment involved three factors, Table 2. The level of the vertical resolution factor was chosen based on the manufacturer's recommendation and the objective's capabilities. The manufacturer recommends that the vertical resolution value be calculated by dividing the roughness parameter *Rz* by a coefficient from 15 to 30.

Table 2: Factors and Levels in L9 Taguchi Design of Experiment

	Levels		
Brightness [ms]	5.87	7.5	12.7
Contrast	0.4	0.6	0.8
Vertical resolution [nm]	50	70	100

Figure 1 shows the hardware setup of the experiment on the InfiniteFocus SL non-contact measurement system.

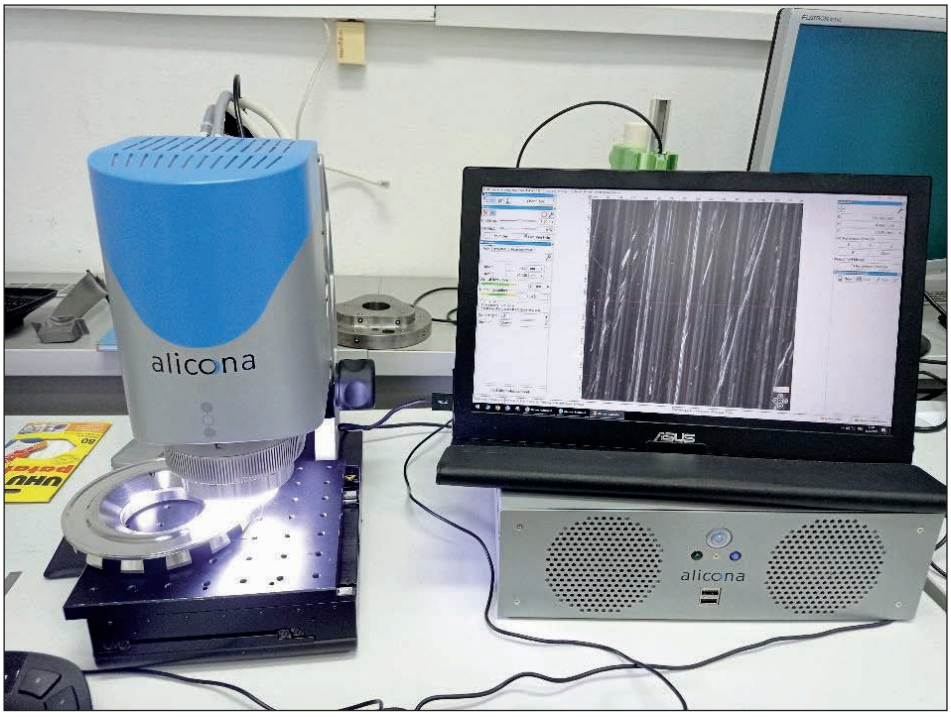

Figure 1: Measurement of workpiece roughness parameters on the InfiniteFocus SL system

3. RESULTS AND DISCUSSION

The data were analyzed using the statistical software Minitab 17. The method used to check the statistical significance of the considered factors is the Analysis of Variance (*ANOVA*). Each value obtained by non-contact measurement was subtracted from the reference value (Table 1), and the residuals were analyzed. The analysis of variance showed that for all three responses, there is not enough data to sufficiently conclude statistical significance at 95% confidence, for chosen factors. It is interesting that the model error for all three parameters is not statistically significant, but that the adequacy of the model is unsatisfactory for all three parameters. The reason for this phenomenon may be the presence of outliers in the collected data, which was determined by the later analysis of the box-plot diagram.

When analyzing the Taguchi design of the experiment, the optimization condition "smaller is better" was chosen, because the residuals of the measured values from the non-contact system were analyzed. The most influential factor for the signal-to-noise ratio is the brightness, followed by the vertical resolution factor, and the least influential factor is contrast. The most influential factor for the Means is brightness, followed by contrast, and the least influential factor is vertical resolution. The main effects plot for mean values and signal-to-noise ratio is shown in Figure 2.

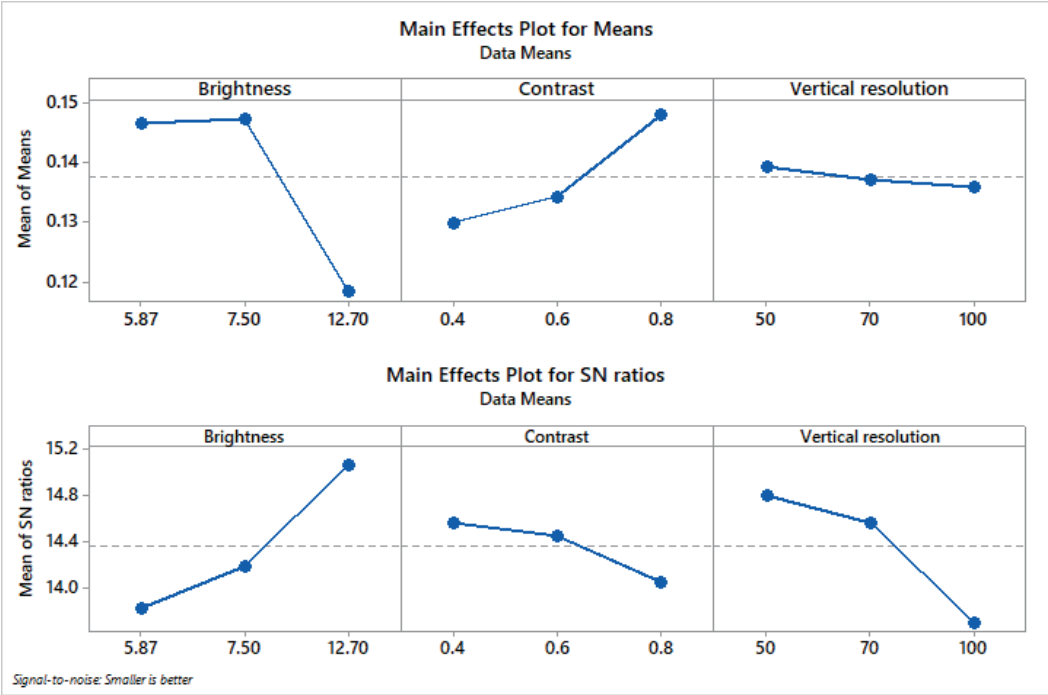

Figure 2: Main effects plot for mean values and signal-to-noise ratio

According to the diagram of the main effects, the optimal combination of factor levels for the S/N ratio is: for brightness choose the highest level (12.7), for contrast choose the lowest level (0.4), for the vertical resolution value choose 50 nm. The optimal combination of factor levels for mean values is as follows: for brightness, choose the highest level (12.7), for contrast, choose the lowest level (0.4), for the vertical resolution value, choose 100 nm.

Factors such as brightness and contrast are highly dependent, and an interaction is expected. This is also confirmed by the interaction diagram, where for all three observed roughness parameters *Ra*, *Rz* and *Rt*, i.e. their residuals appear as intersecting lines on the diagram. Due to limited space, Figure 3 shows the interaction diagram for the *Ra* and *Rz* parameter.

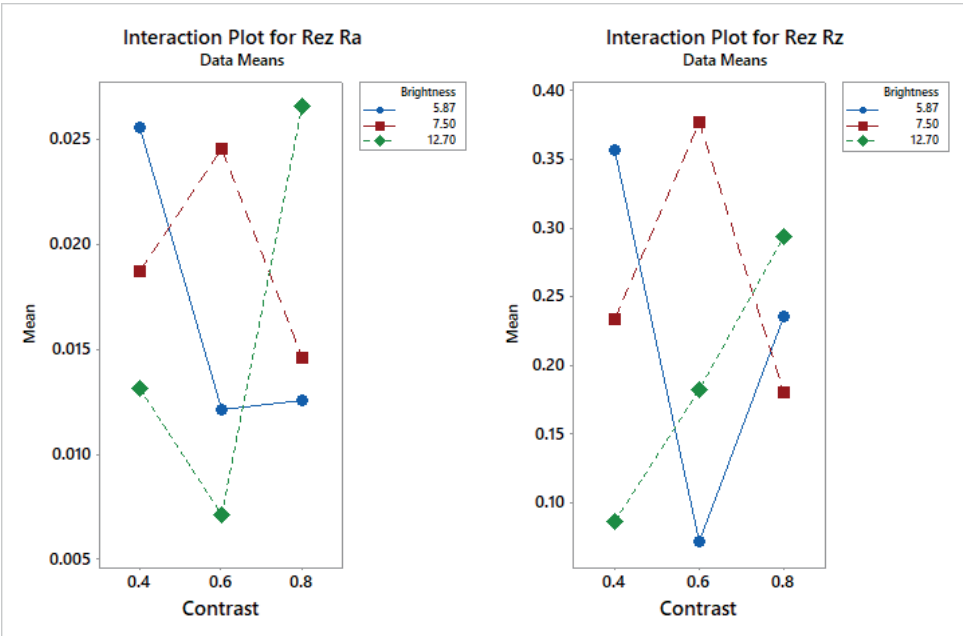

Figure 3: Diagram of interactions of brightness and contrast factors on the roughness parameter Ra and Rz

4. CONCLUSION

In addition to meeting the requirements for dimensional accuracy and geometric tolerances, satisfactory values of roughness parameters are an essential factor for the correct functioning of each product. The focus variation method with the possibility of measuring macro and micro geometrical irregularities on workpieces proved to be an excellent choice when measuring surfaces with submicron values of roughness parameters, with certain advantages over tactile profilometry such as the speed and amount of collected data. In the paper, the Taguchi design of the experiment was carried out, and through the analysis of variance, the main influence diagram, and the interaction diagram, the effects of certain factors on the quality characteristics were shown. For certain values of surface roughness, optimal levels of brightness, contrast, and vertical resolution are given.
Currently, in the industry, the standard for finding optimal parameters is the trial-and-error method (Gauder et al., 2021). This approach is not optimal, and we should strive for the formulation of a global optimization model. Through the possibility of including more factors such as the influence of different ring light settings, polarization, and lateral resolution, it is possible to provide a more comprehensive optimization model, which will be the direction of future research.

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METHODOLOGY FOR PREVENTION THROUGH DESIGN IN OCCUPATIONAL SAFETY

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Abstract: *Prevention by Design (PtD) is a concept of methodologies that can be applied during the design phase of work processes and products, ensuring the reduction of risks to the safety and health of individuals exposed to the design in all its forms. The purpose of this master's thesis is to assess the current methods of identifying and preventing work injuries among companies with the potential to implement Prevention through Design. Additionally, it aims to gauge the interest of designers, planners, and technical-engineering staff in its application. The analysis is conducted through literature research and a survey questionnaire distributed to companies directly or indirectly involved in design processes and products. This article provides an initial research analysis and sets the stage for further research on the methods and practices of implementing this ideology in the Republic of North Macedonia. The paper concludes with a summary of the data analysis and offers recommendations for future research.*

Key words: Prevention through design, occupational safety and health, design for safety.

1. INTRODUCTION

Prevention through Design (PtD) is regularly practiced in various industry sectors worldwide, indicating a clear interest in implementing this methodology throughout the industry. However, until its benefits are recognized and enabled, inhibitors of PtD implementation restrict its widespread diffusion across the industry. Efforts are being made, through various tools, to promote its use, overcome barriers, and educate industrial professionals/designers on this subject.
In the analysis of the occupational injuries in the Republic of North Macedonia, according to the Institute of Public Health, a total of 1,121 work-related injuries were recorded in 2019, and 599 work-related injuries in 2020. The rate of work-related injuries in 2019 in the Republic of North Macedonia was 141.0/100,000. This means that for every 100,000 workers, 141 workers were injured throughout the year. In 2020, the rate of work-related injuries was 75.3/100,000, indicating that for every 100,000 workers, 75 workers were injured. These statistical indicators demonstrate the relevance and the need for a comprehensive preventive approach that can contribute to reducing the number of work-related injuries and identifying workplace hazards and risks.

Table 1. Rate of work injuries per 100,000 employees in the period from 2019-2020 in the Republic of North Macedonia; Source - Work Injury Information 2019-2020, Institute of Public Health of the Republic of North Macedonia.

Injury Rate	*2019*	*2020*
Total work-related injuries	*1.121*	*599*
Number of employees	*797.651*	*794.909*
Injury rate per 100.000 employees	*141*	*75,3*

These alarming figures provide clear evidence that work-related accidents are a serious global problem and highlight the need for additional measures to enhance worker safety. This study primarily focuses on the implementation of the Prevention through Design (PtD) methodology and its impact on improving the safety of employees directly involved in carrying out work tasks. It addresses practical implementation and answers questions such as "Does design-based prevention increase worker safety?" and "What methods are available for incorporating PtD in the design phases?"
The introduction provides an overview of PtD, a brief historical review of its development, its merits, and general implementation-related issues. The subsequent sections review existing literature and research to

confirm the influence of design-based prevention on employee safety and the reduction of work-related injuries. This chapter includes a hypothesis, research methodology, and expected outcomes. Based on research from existing scientific literature, the elements and principles of design are defined, along with practical examples of successful PtD implementation that have contributed to risk reduction in the workplace. The obtained results from the study, along with the analysis of existing literature and research, supplemented by empirical research, will demonstrate the significance of PtD in reducing losses during work execution in the context of occupational safety and health. The information and findings from this study will contribute scientifically and provide practical insights relevant to organizations from a design/engineering perspective on their occupational safety and health systems.

2. LITERATURE REVIEW

In the eld of mechanical engineering, design decisions have a signifi ant impact on safety outcomes in various industrial seĀ ngs. To prioriti e safety, laws and regula ons have been implemented in many countries, requiring mechanical engineering companies to integrate safety measures during the design phase. Despite these e orts, there is a need to increase awareness among mechanical engineers about the importance of incorporating safety into design. Existing literature suggests that Preventi n through Design (PtD) principles can eĀecti ely enhance safety in mechanical engineering. Handbooks and recommendations developed for mechanical installa ons oĀer valuable insights applicable across industries. Overall, integrating safety into the design phase is crucial for protecting workers and preventin accidents in mechanical engineering, and ongoing awareness and educati n e orts are essentia for opti al results.

3. METHODOLOGY

This methodology focuses on incorporating safety and preventi e measures during the design phase of projects, products, and processes. It aims to identif and miti ate poten al risks and hazards to ensure a safer working environment and improve the overall safety and health of employees. The survey results indicate that there is a need for greater awareness and educati n among professionals regarding the implementa on and benefi s of this methodology.

Table 2. Description of different levels of hierarchy, from most effective to least effective

Phase	Activity
Conceptual Design	Setting goals for safety and health at work and identifying occupational hazards
Preliminary Design	Eliminating hazards, if possible; replacing them with less hazardous agents/processes; establishing goals to minimize the risk for remaining hazards; risk assessment; developing alternative control options. Writing project specifications.
Detailed Design	Selection of controls; conducting a process hazard review.
Procurement	Developing equipment specifications and incorporating them into procurement; developing "checks and tests" for factory acceptance, testing, and commissioning.
Execution	Ensuring safety on the construction site and safety for the contractor.
Commissioning	Performing "checks and tests"; safety reviews before startup; development of standard operating procedures; risk/exposure assessment; and management of residual risks.
Start-up and Management Education	Change management; modification of standard operating procedures.

The Key phases for implementing Design for Prevention:

- Hazard Identi cati n: Identif ing all hazards associated with the project, considering the full range of intended uses as well as foreseeable misuse.
- Risk Assessment: Assessing the risk of harm occurring and evaluating xisting controls.
- Design Review: Elimina ng hazards and controlling risks (If identiĀ d risks cannot be eliminated through feasible design modi ca ons, the focus of the designer shi s to reducing the risk to the extent reasonably prac cable. The designer must consider what is known or should reasonably be known about the risk and all possible means of reducing it).
- Implementa on: Addressing residual risks and hazards.
- Learning: Monitoring and reviewing the risk assessment throughout the project, including key design phases.

Each phase involves a set of tasks to be performed by one or more of the following stakeholders: Architect; Civil engineer; Mechanical engineer; Design engineer (safety specialist/supervisor); General contractor; Investor/Maintenance personnel.
It should be noted that the Design for Preven on process is a sequentia and cyclical process. A er the implementa on of design for preventi n, the mechanical installa on contractor documents the lessons learned within their company and shares them with other stakeholders in future projects. Through the conducted research and questio naire, a modified form adapted to the exis ng methodology will be proposed, resulting in recommenda ons and checklists for the design process to reduce risks in later stages of executi n.

4. CONCLUSION

The study revealed challenges and opportunities in implementing Design for Safety among designers and workers. Awareness and prac cal applicati n of safety considerati ns during the design phase were lacking. However, parti ipants expressed interest in learning and integrating Design for Safety. Accessible educati nal resources and standardized practi es are needed. Early integra on of safety measures is crucial, and regulatory requirements and industry-speci c standards are necessary for consistent implementa on. Clear guidance and a safety-focused culture are essentia . Comprehensive ini ati es should raise awareness, provide educati n and training, and establish standardized prac ces. Collabora on among stakeholders is vital for developing industry-specific standards. By enhancing awareness, educa on, and standardiza on, Design for Safety can improve safety outcomes and project e ciency. The research objecti es include a comprehensive understanding of this methodology and its specifi characteris cs represented in existing scientiĀ research literature, as well as recommenda ons for implementi g the methodology in companies involved in designing mechanical installati ns and products.
Demographics: The majority of respondents (64.8%) were in the age group of 25-34 years, indica ng a dominance of this age bracket in the survey. Furthermore, 49.6% of the par cipants had completed postgraduate studies, and the years of work experience varied. The industries and job posi ons represented in the survey were predominantly focused on designers, project managers, technical personnel, engineers, and professors from the Faculty of Mechanical Engineering in Skopje.
Training in Safety and Health: Only 8.4% of respondents were trained speci cally in safety and security, while 70.7% had a ended training related to safety and health in the workplace. This suggests a signifi ant proportio of par cipants were educated and aware of the importance of worker safety. However, the frequency of training varied, with some individuals a ending training only once and others undergoing multip e training sessions at speci c intervals.
Familiarity with Design for Preventio Methodology: When asked about their familiarity with the Design for Preven on methodology, the survey revealed that only 10.3% of parti ipants were familiar with the methodology, 24.1% had par al knowledge, and the remaining respondents had never heard of it. Notably, 65.5% of parti ipants indicated no knowledge of the methodology, highlighting the need for greater educati n and awareness about its significa ce and advantages.
Importance of Designing for Safety: A positi e response was received from 96.6% of respondents when asked about the potentia improvement of working conditi ns and employee safety by incorpora ng preventive safety measures during the design phase of processes and products. This demonstrates a strong interest in implemen ng the methodology across various industries and job posi ons. Additi nally, 54.4%

of parti ipants stated that their company identifie and considers all risks related to worker safety during the design of projects, processes, and products.
Overall, the survey results emphasize the importance of promoti g educati n and awareness about the Design for Preventi n methodology among professionals. It also highlights the potenti l for implementi g preventi e safety measures during the design phase to create a safer working environment and improve the overall well-being of employees.

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USING NEURAL NETWORK WITH CONVOLUTION LAYER FOR AUTOMATIC QUALITY INSPECTION

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Abstract: *At traditional assembly workstations product inspection is performed manually by operators and that takes a lot of time and represents a production bottleneck. Also, due to the appearance of mental fatigue, a drop in concentration in some situations, it is almost impossible for workers to notice the appearance of defects and irregularities. Therefore, in modern assembly systems, the implementation of advanced quality control through quality inspection, visually detect the quality of a product and recognition of irregularities has a crucial role.*

The main aim of this study is to research the possibility of involving neural networks for defects' detection of parts in the production process. The research includes using images of two classes (part with defect and well done part) and training the neural network with convolution layer for automatic classification produced part. The success of applied algorithms using this methodology in automatic detection of defects and non-conformity and on this way reducing cost is 96 %. One benefit of the proposed method is the relatively small number of input data set images which enables fast implement method with new production elements.

Key words: *automatic detection of defects, Industry 4.0, neural networks, Quality 4.0, zero defects manufacturing*

1. INTRODUCTION

It is of essential importance that organizations improve product quality and on this way remain competitive and meet the changing needs and expectations of customers. Improving quality products can help organizations achieve several benefits, such as increasing customer satisfaction, improving efficiency and productivity, reducing costs, and increasing market share. The integration of quality management with the technologies of the fourth industrial revolution (Industry 4.0) enables organizations to adequately respond to the conditions in the modern dynamic business environment (globalization, turbulent market conditions, and the development of information and communication technologies). The digitalization of business processes and the development of new technologies such as artificial intelligence and machine learning have opened up new opportunities for quality improvement. These technologies can help organizations collect and analyze data, identify patterns and trends, and predict potential irregularities and non-compliance before they occur.

At traditional assembly workstations, operators perform monotonous, repetitive and tiring activities of assembling parts and components into the final product by long-term. Also, inspection of these parts is performed manually by operators and that takes a lot of time and represents a production bottleneck. Traditional quality control methods, such as sampling a single component from a lot for inspection, can lead to inconsistencies in quality and potentially result in at one side the acceptance of defective parts or on the other hand the rejection of an entire batch. This can be a costly and time-consuming process that requires allocation of financial resources and hiring additional workers with specialized skills. In addition, traditional quality management systems often rely on paper-based documentation. During the inspection, workers must pay attention to detail, which can be difficult to maintain over time. This can lead to bottlenecks in the process and delays in getting products to market.

Improving the visual quality control of products is receiving increasing attention in both industry and academia (Cabral, de Araujo, 2015). Quality 4.0 encourages a culture of continuous improvement in assembly workstations. By leveraging real-time data and insights, organizations can identify areas for improvement, implement corrective actions, and optimize their assembly processes over time. This

iterative approach fosters ongoing quality enhancements and drives organizations closer to the goal of zero defects.
The full automation drastically reduces the burden on people by providing automatic control and monitoring of processes throughout the entire product life cycle (Castagnoli et al., 2021). Visual quality control systems during last years have been used to assess the quality of finished products, the quality of components and parts as well as to assess the correct functioning of workstations and production lines.
The main goal of the research paper is application of convolutional neural networks in quality inspection for detection of defects parts in the assembly process. The research includes using images of two classes (part with defect and well done part) and training the neural network with convolution layer for automatic classification produced part. Neural networks are a powerful tool in improving quality control processes by automating inspections, reducing human error, and increasing efficiency. Convolutional neural networks (CNNs) are a special type of neural networks with one or more convolution layers. The convolutional layers are responsible for extracting relevant features from the input data, while the pooling layers reduce the spatial dimensions of the feature maps, thus providing spatial invariance to small variations. CNNs are widely used in quality control. However, it is important to properly train and validate convolutional neural networks to ensure their accuracy and reliability.

2. MATERIALS AND METHODS

Real time data acquisition about product quality not only contributes to prevent products with defects but can also contributes to continuous improvement of assembly processes. This is of particular importance in the medical or automobile industry, the aim is often to realize a 100% quality inspection.
Industry 4.0 has brought about significant changes in quality inspection, what is known as Quality 4.0. Quality 4.0 refers to the use of digital technologies to improve quality management, inspection, and control in quality inspection processes.
The process of digitalization and improvements in industry has the tendency to automatize the whole process from beginning to end. The activities with this aim cannot be performed simultaneously for all parts of the system. This should only be done in stages and in a one by one basis, regarding the parts of the system part of system. According to (Rojko, 2017) costs in production and quality management can be reduced by 10-30% by implementing new Industry 4.0 technologies.
A good candidate for automatization is quality control (Schumacher, Nemeth & Sihn, 2018; Tortoella & Fettermann, 2017) on assembly workstation. The reason for this is availability of tools which are enough in visual perception recognition which include using cameras and AI system for classification. The most promising are artificial intelligence algorithms, including in particular deep machine learning algorithms based on neural networks, like in paper (Żabiński et al., 2019).
In the context of Industry 4.0, quality inspection is no longer limited to manual inspection and control by humans. Instead, it involves the use of digital technologies (Internet of Things, big data analytics, machine learning, and artificial intelligence) to collect, analyze, and interpret data in real-time. This enables manufacturers to identify defects and anomalies early in the production process and make necessary adjustments to improve product quality. Machine vision algorithms can be used in a wide range of application such as vision inspection, quality control and process monitoring (Bahaghighat, Motamedi, 2018; Pithadiya et al., 2010).
The focus of the paper (Weimer et al., 2016) is the proposal of a novel deep CNN architecture to detect defects, which takes all types of defects free and defective samples together as the input. In paper (Hoo-Chang et al., 2016.) CNN architectures within a deep learning framework that solve the shortcomings of the existing machine learning approaches were presented. Also, CNNs have recently been successfully applied to industrial surface inspection (Masci et al., 2012; Soukup, Huber-Mörk, 2014). In some research papers convolutional neural networks were used for analysis of measurement results in an intelligent condition monitoring system.
In this research paper convolutional neural networks were used in quality inspection for detection of defects parts in the assembly process. In this research the algorithms with CNNs for image classification process are presented. For training of neural network two database of 200 images. Half of the images were of well-done parts, while the other half were of parts with defects. It's important to note that the images were captured under the same conditions, which is crucial for the success of algorithms when dealing with a relatively small number of input images.

The process of collecting and grouping the images into two classes (well-done parts and parts with defects) was done manually. This manual classification ensured that the network received labeled training data, where each image was associated with the correct class label.
In the Figure 1 and 2 are shown the part with and without mistake respectively.

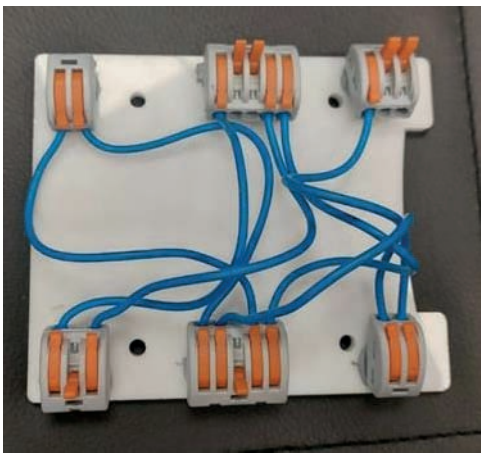

Figure 1: Correct part

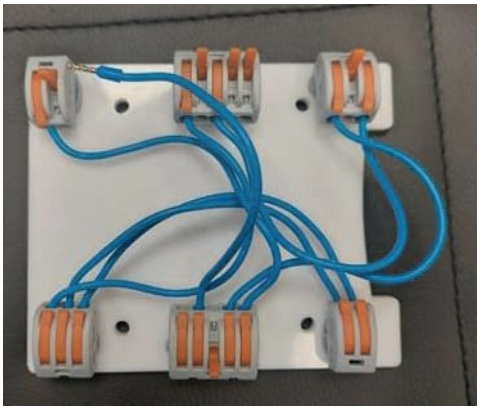

Figure 2: Part with mistake

The images were recorded in the same conditions; environmental brightness, background color, camera position and specimen orientation. All these conditions are necessary to provide well recognition quality with less number of training images. For this purpose, we used 100 images per both classes. The data set is divided into part for training, testing and validating of algorithms.
By training the CNNs on this labeled dataset, the network learns to identify patterns and features in the images that distinguish between well-done parts and defective parts. The trained CNN can then be used to classify new, unseen images and identify whether they belong to the well-done or defective class, providing a means for automated quality inspection in the assembly process.
Key benefits of using CNNs for defect detection are:

- CNNs excel at learning hierarchical representations of images, allowing them to automatically extract relevant features from raw visual data. This ability makes CNNs well-suited for recognizing patterns, shapes, and textures that are indicative of defects in assembly parts.
- CNNs leverage convolutional layers that use filters to detect local patterns in images. By applying these filters across the image, CNNs can capture local features that are crucial for identifying defects. This property is especially useful when defects are characterized by specific local irregularities or variations.
- CNNs can handle variations in lighting conditions, orientations, and scales, which are common challenges in quality inspection. Through the learning process, CNNs can generalize and recognize defects even in instances where there are slight variations in appearance.

In the Figure 3. the neural network architecture is presented.

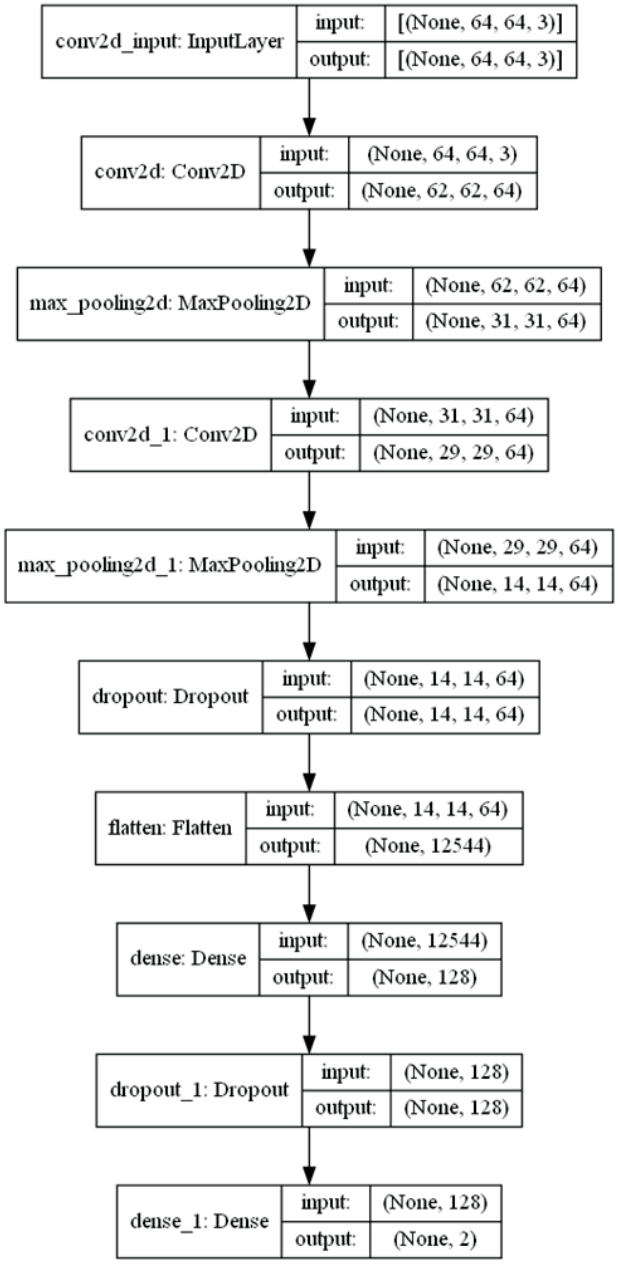

Figure 3: Structure of neural network used in research

3. RESULTS AND DISCUSSION

The neural network consists of a number of convolution layers. The first input layer accepts images whose size is resized at 64x64 pixels. During data propagatione the data dimensions are reduced. At the end, the result layer has only two outputs. This output values are connected with results classes. According to this, value image is assigned to the corresponding class in a way in which a greater value means that the image belongs to corresponding class.
The accuracy of the presented architecture with given data set is 96 % and training is performed relatively fast, around 15 minutes using standard laptop with Intel i3 with 2.3 GHz and 8 GB of RAM.

4. CONCLUSIONS

Poor product quality has a negative impact on the operational and financial performance of the organization (Kumar et al., 2018). Furthermore, it can negatively affect the company's reputation (Jun et al., 2020).

Achieving zero defects in assembly workstations is a key goal of many manufacturing organizations. The concept of Quality 4.0 has emerged as a way to optimize quality control and improve the efficiency of assembly processes. Quality 4.0 incorporates the principles of Industry 4.0, which refers to the integration of digital technologies and data-driven approaches into manufacturing. The use of Industry 4.0 technologies (such as computer vision, machine learning, and augmented reality) in assembly workstations has the potential to reduce defects and improve overall product quality. By using that advanced technologies, inconsistencies and irregularities can be identified and corrected early in the assembly process.

During the manual inspection of parts, components and the final product, errors often appear, and in some situations (eg, when production rates are high) manual inspection is impractical. So, it is necessary to apply new methods of monitoring and controlling product quality, which would be based on AI algorithms. Convolutional neural networks can help improve quality control processes by automating inspections and thus contribute to reducing human error and increasing control efficiency through identifying product defects through image analysis. However, it is important to properly train and validate neural networks to ensure their accuracy and reliability.

In this study the algorithms with CNN for image classification process are presented. The CNN has a relatively simple architecture with a number of convolution layers. For training of neural network two database of 200 images were used with half of images with well-done part and with other half parts with damages. The images were taken at the same condition, which is important for the success of algorithms with a relatively small number of input images. This causes relatively fast performing training. The study shows the ability to apply this type of algorithms in assembly process.

The improvements of the method could be in using a different architecture of CNN and with a larger database of images. Future research directions are related to the integration of this method with some robot systems for mechanical classification.

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DEVELOPMENT OF THE QUALITY CONCEPT IN THE TRANSITION FROM INDUSTRY 4.0 TO INDUSTRY 5.0

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Abstract: *Industry 4.0 has become a global research trend in the last few years. Even though Industry 4.0 has not reached its full development and the main achievements can be expected in the coming years, the development of Industry 5.0 is already visible. Thus, the world is currently on the threshold of the Fifth Industrial Revolution. Industry 5.0 complements the existing Industry 4.0, with an orientation towards man, who has a vital role in the production process and his maximum engagement in all economic spheres. The technologies that marked the 21st century impacted all production activities, forcing them to change and adapt to the modern form of production. Each industrial revolution has influenced the concept of quality, improving and advancing it. Quality concepts have been modified by technological trends and innovations that have permanently accelerated and facilitated the production process. Therefore, the importance of quality management due to technological changes is becoming increasingly pronounced. This research will emphasize Quality 4.0 and Quality 5.0, whose concepts were formed under the influence of modern technologies. This research aims to present the development and changes in the idea of quality in the transition from Industry 4.0 to Industry 5.0 through a critical literature analysis.*

Keywords: Industry 4.0, Industry 5.0, Quality management, Quality 4.0, Quality 5.0.

1. INTRODUCTION

1.1 From Industry 4.0 to Industry 5.0

Industry 4.0 represents an advanced level of automation to enhance productivity and efficiency within industries by connecting virtual and physical worlds (Akundi *et al.*, 2022). Industry 4.0 is centered around a smart factory, where smart products, machines, and data together form a cyber-physical production system (Zizic *et al.*, 2022).

Industry 4.0 marked a significant shift in the manufacturing industry by integrating advanced technologies such as automation, artificial intelligence, and the Internet of Things (Wolniak, 2023). From a technical perspective, Industry 4.0 has enhanced the human–machine interaction. However, in the socially sustainable aspect, technological transformations of Industry 4.0 should prioritize the central role of humans. Consequently, the concept of Industry 5.0 emerged as the extension to Industry 4.0, encompassing the social and environmental dimensions and the technological aspect (Zizic *et al.*, 2022). Industry 5.0 marks a revolution in industry and society (Maroof and Kapate, n.d.). Industry 5.0 builds on technologies of Industry 4.0, emphasizing the integration of human creativity and intuition into manufacturing processes, thus making a collaborative and adaptable manufacturing environment (Wolniak, 2023).

Industry 4.0 paradigm is understood to create a "smart factory", yet Industry 5.0 is conceptualized to design a "super smart society" for the world, making a critical difference about Industry 4.0“ (Gladden, 2019). Industry 5.0 does not involve a radical technological advancement, instead, it builds upon the principles of Industry 4.0 within a more comprehensive framework and purposeful perspective. It is characterized by a regenerative purpose and clear direction, directing the technological transformation of industrial production to prioritize the well-being of people, the planet, and overall prosperity (Zizic et al., 2022).

The European Commission's document (Breque *et al.*, n.d.) on Industry 5.0 identifies three key drivers to be the core of the new industrial paradigm: Human-centric approach; Sustainability and Resilience. The document states that Industry 5.0 aims beyond pure technological advancements and considers industrial development's broader societal and environmental implications. Industry 5.0 aims to create a manufacturing ecosystem that

goes beyond technological advancements, prioritizing human well-being, sustainability, and social responsibility (Wolniak, 2023).

1.2 Quality Management in Industry 4.0

In Industry 4.0, the focus on quality aims to digitize all business processes using advanced technologies. Quality management systems, enabled by Industry 4.0 technologies, ensure that all processes are traceable, controllable, and sustainable, thus helping businesses maintain the required level of quality to keep their operations running uninterrupted and effectively (Baran and Polat, 2022).
Regarding Industry 4.0, quality management shifts the focus from a technology-centric approach to a customer-centric one, ensuring that the quality of products and processes aligns with customer needs and preferences. Quality 4.0 perceives technology as an enabler rather than the primary driver. Advanced technologies serve to improve the quality management process and enhance customer satisfaction. The main benefit of Quality 4.0 is increased productivity. Companies can produce products that meet customer expectations by focusing on customer needs, leading to higher customer satisfaction**.** Data is the critical enabler in Quality 4.0. Organizations collect and analyze data from various sources, including customer feedback, to gain insights into customer preferences and identify areas for quality improvement. The evolution of Quality 4.0 is from a process-oriented approach to a customer-oriented one. Quality management is not just about ensuring the production process meets specific standards but also about delivering products that meet customer desires and expectations (Rowlands and Milligan, 2020) (Sony *et al.*, 2020) (Sader *et al.*, 2022).

1.3 Quality Management in Industry 5.0: Aligning with the Pillars of Human-Centricity, Sustainability, and Resilience

The Human-centric approach emphasizes placing human needs and well-being at the forefront of the production process. It focuses on understanding how technology can serve workers and benefit them, rather than solely prioritizing automation and efficiency. Sustainability as a second driver highlights the importance of environmental responsibility and resource efficiency, supporting practices such as reusing, repurposing, and recycling natural resources to reduce waste and minimize the industry's overall environmental impact—resilience centers around building robustness into industrial production processes. By incorporating flexibility and adaptability, industries can better withstand and respond to crises or unexpected challenges (Zizic *et al.*, 2022).
In Industry 5.0, the quality control process recognizes the significant role of human factors. Although machines provide valuable data and insights into product quality, human expertise, intuition, and experience are equally important (Wolniak, 2023). A belief in human potential in the context of quality management aims to reinforce the system around people, creating an environment that empowers people.
Connecting sustainability and quality has gained significant attention due to the growing societal demands, particularly in quality-based management for future-ready corporations that prioritize serving society and the planet (Fundin *et al.*, 2020). Quality management practices in Industry 5.0 could align with sustainability by prioritizing environmentally friendly approaches. This involves selecting materials and production methods with lower ecological impacts (Wolniak, 2023). Aiming quality management practices at achieving robustness involves enabling understanding of variation by incorporating statistical analysis and reliability principles, identifying sources of variation, evaluating their impact on product quality, and making informed decisions to enhance robustness (Fundin *et al.*, 2020).

2. METHODS

In this paper, we conducted a literature review to explore the topic of quality management in Industry 5.0. Through an extensive search of Google Scholar and Scopus, we gathered valuable insights from scholarly content, journals, and conference proceedings. The paper summarizes the topic's current state and aims to critically assess the relevant literature.

3. RESULTS & DISCUSSION

As the author (Akundi *et al.*, 2022) states, the limitation of Industry 4.0 to address the growing demand for personalization led to the emergence of Industry 5.0, a concept focused on personalized manufacturing empowering humans within the manufacturing processes. The author (Coelho *et al.*, 2023) states that while Industry 4.0 emphasizes process efficiency, it overlooks the importance of the human factor. Industry 5.0 aims to correct this by fostering a harmonious synergy between humans and autonomous machines. According to the work of (Tornjanski *et al.*, 2020) and (Ćoćkalo *et al.*, n.d.), the combination of Industry 5.0 pillars emphasizes the collaboration between humans and machines, leveraging their strengths for a more efficient and socially responsible manufacturing environment. Embracing these pillars will be crucial in meeting the growing demands of consumers, enhancing product excellence, and positively impacting society and the planet, thus shaping a more sustainable future for the manufacturing industry. The pillars of Industry 5.0 hold the highest significance in shaping the future of manufacturing and quality management. The author concludes that Industry 5.0 diverges from all previous industrial revolutions, presenting a "stakeholder-pulled socio-technological phenomenon" (Ghobakhloo *et al.*, 2022).

4. DISCUSSION

According to (Wolniak, 2023) in Industry 5.0, the quality control process recognizes the crucial role of human factors. In quality management, the collaboration between humans and machines allows for a more comprehensive and accurate product quality assessment. Quality control involves using data-driven analytics from machines to identify trends, patterns, and potential defects. Simultaneously, the expertise of human workers enables them to apply critical thinking and intuition to spot issues that might not be evident in the data.

The author (Maddikunta *et al.*, 2022) states that unlike Industry 4.0, which relies on automation and technological efficiency on a great scale, Industry 5.0 places greater importance on integrating human creativity throughout the production process. This approach supports creative thinking to generate new ideas and designs that optimize productivity and product quality.

According to (Majerník *et al.*, 2022), in Industry 5.0, sustainability is vital, emphasizing responsible resource utilization and minimizing the impact of manufacturing processes on the environment. This new production era places significant importance on eco-conscious practices and their integration into quality management. Quality management practices in Industry 5.0 align with sustainability by prioritizing environmentally friendly approaches. This involves selecting materials and production methods that have lower ecological impacts. Additionally, quality control focus should be on ensuring that products meet performance standards and eco-friendly criteria.

According to (Fundin *et al.*, 2020), quality management practices that aim to achieve robustness involve a comprehensive understanding of variation. This is accomplished by incorporating statistical analysis and reliability principles, which play a crucial role in identifying sources of variation and evaluating their impact on product quality. Robustness in quality management refers to the ability of a system or process to maintain consistent performance and product quality despite variations in inputs. Emphasizing adaptability and quick response to changing conditions can help maintain product quality and customer trust in times of crisis.

5. CONCLUSIONS

This paper delved into the transformative evolution of the manufacturing industry from Industry 4.0 to Industry 5.0. Industry 4.0, characterized by automation and technology-driven efficiency, paved the way for the emergence of Industry 5.0, where a human-centric approach, sustainability, and resilience form the core pillars of the paradigm.

The transition from Industry 4.0 to Industry 5.0 signifies a profound shift in the manufacturing landscape. The pillars of new industrial paradigm underscore the importance of not only technological advancements but also the well-being of individuals, the environment, and prosperity. By incorporating these pillars into quality management practices, Industry 5.0 can achieve a harmonious blend of innovation, sustainability, and superior

product quality.
Considering all the above, we can acknowledge the importance of Industry 5.0 and the need for organizations to devote themselves to achieving this level in the future. Furthermore, future research is essential and may provide more detailed studies on the subject.

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FUZZY FAILURE MODES AND EFFECTS ANALYSIS (FMEA) FOR HYDROSTATIC TRANSMISSION SYSTEM (HTS)

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Abstract: *Hydrostatic transmission system (HTS) is a crucial part of mobile working machines, which uses pressurized fluid to transmit power from the engine to the wheels or tracks and provides precise and efficient control over the machine's speed, torque, and direction. When the transmission system works improperly, productivity and/or safety can be highly impacted. This paper focuses on the identification, risk assessment, and prioritization of potential failure modes for the HTS with split configuration, to serve as a foundation for maintenance strategy to minimize or eliminate adverse effects and ensure safety. To analyze and rank all improper HTS working modes, a fuzzy Failure Modes and Effects Analysis (FMEA) method is applied. There are determined 11 HTS failure modes with their causes-effects, and Occurrence (O), Severity (S), and Detectability (D) scores were assigned with the help of experts. Using a base of 125 rules and a fuzzy FMEA model, the failure modes were prioritized based on calculated Risk Priority Numbers (RPN).*

Key words: Failure modes and effect analysis, fuzzy FMEA, maintenance, hydrostatic transmission system (HTS), closed hydraulic circuit

1. INTRODUCTION

The transmission system is used to transfer power from the engine to the wheels or tracks, enabling the machine to perform various tasks efficiently by transmitting the necessary torque and controlling the speed and direction of movement (Chen, 2020). This makes the transmission system one of the most important parts of any vehicle or moving machine. The design, durability, reliability, and performance of the transmission system can significantly impact the overall machine operation efficiency, safety, and productivity, which is why there is continuous development of transmission systems between manufacturers. There are several transmission types such as manual, automated, continuously variable, dual-clutch, automated manual, hydrostatic, electric, and hybrid transmissions (Chen, 2020). Each type of transmission has its own specifics, which makes it suitable for certain applications.

Hydrostatic transmission systems (HTS) have a compact design and well-proven performances, which suits them well for propulsion control of heavy-duty off-road machinery such as agricultural, mining, quarry, forestry, and earth moving (Singh et al, 2013), (Guo and Vacca, 2021.). Basically, the HTS is a closed hydraulic circuit system consisting of an axial-piston pump directly connected to a hydraulic motor, which greatly simplifies transmission system design and contributes to higher system reliability.

In order to justify the high installation costs, and ensure safety, and a long operational life, it is necessary to regularly carry out adequate maintenance. Failure causes and their effects can be identified meticulously using Failure Modes and Effects Analysis (FMEA) method, well-proven reliability tool.

This paper presents a comprehensive attempt to analyse possible HTS failure modes and prioritize them in order to propose adequate preventive maintenance actions which should be taken to avoid expensive shutdowns and repairs.

2. MATERIAL AND METHOD

2.1 HTS design

There are two basic configurations of the HTS:

- Integrated (or close-coupled) which physically can be connected in the form of an In-line, U-shaped, or S-shaped configuration;
- Split (non-integral) configuration.

Integrated HTS solutions, in general, are suited for light-duty applications (such as garden tractors, logistics, transportation vehicles, etc.), while split HTS configuration is mainly intended for heavy-duty off-road machinery (Zarotti, 2003). This paper will focus solely on split systems, which can typically be implemented in four configurations, of which the configurations with a variable displacement axial-piston pump and a variable or fixed displacement motor are the most commonly used. A typical HTS hydraulic circuit is shown in Figure 1.

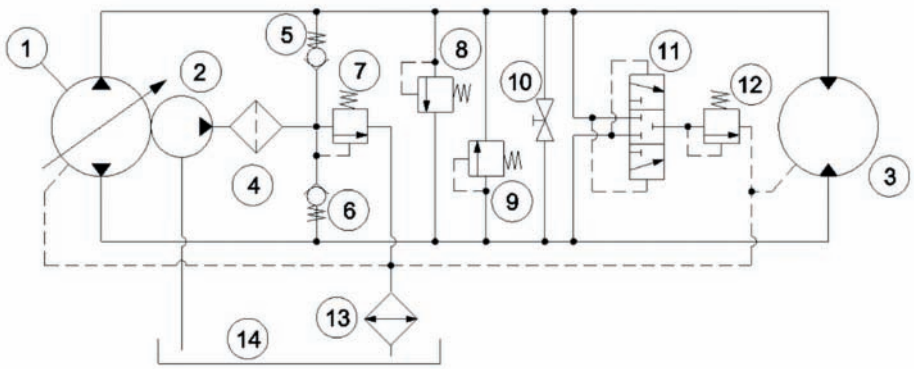

Figure 1: The basic design of the HTS hydraulic system

Basically, the HTS consists of an axial-piston pump (1) which is mechanically connected to the prime mover (IC engine), axial-piston motor (3) which is connected to the wheel shaft(s), filter (4), makeup check valves (5, 6), charge pump relief valve (7), cross port pressure relief valve (8, 9) for pressure overload protection, towing (bypass) valve (10), hot oil flush (shuttle valve) valve (11), flushing relief valve (12), oil cooler (13), and a reservoir (14). Unlike the open-circuit axial-piston pump, the closed-circuit pump (1) is the one that must have a charge pump (2). The charge pump is the vital component of the closed hydraulic circuit system and it has several functions: fluid replenishment, sufficient fluid supply on the low-pressure side of the pump in order to prevent cavitation, fluid filtration, to enable activation of pump servo controls, and in some cases to enable auxiliary functions (such as parking brakes control) with providing pressurized fluid. All valves shown in Fig. 1, are usually integrated into the pump or the motor housing which contributes to the compactness of the HTS.

2.2 Expert profiles

In FMEA experts play a crucial role in identifying potential failure modes, their causes, effects, and the effectiveness of existing or proposed mitigation measures. The experts' insights and experience are valuable in evaluating the severity, occurrence, and detection ratings for each failure mode, which are key factors used to prioritize and determine the level of risk associated with different failure modes. The experts who took part in this study have 5+ years of working in the field experience, in different companies (construction, agricultural company, and academy), and all of them have mechanical engineering degrees. Regardless of the type of machine (excavator, loader, tractor, self-propelled mobile working platform, etc.), all engaged professionals worked with a split configuration HTS, featuring a variable swash-plate axial pump and a fixed swash-plate axial motor. Thus, no weight was assigned to them during the rule-based fuzzy FMEA calculation.

2.3 FMEA

One of the most used methods for the identification and analysis of failures, in order to propose measures to prevent them, is FMEA. It provides a systematic approach to identifying, analysing, and prioritizing failure modes to develop preventive maintenance actions (Liu et al, 2016). FMEA is widely used in industries such as automotive, aerospace, manufacturing, healthcare, and many others to improve product reliability, quality, and safety. In order to prioritize which failures should be managed first, FMEA uses Risk Priority Number (RPN) which is obtained by multiplying Occurrence (O), Severity (S), and Detectability (D) scores, previously determined by experts.

2.4 Fuzzy FMEA

Although FMEA is a popular risk assessment method, it also has its drawbacks and limitations and has been criticized by researchers:

- The assumption that the three failure mode indexes (O, S, and D) are all equally important (Franceschini and Galetto, 2001);
- Different combinations of S, O, and D levels can yield the same RPN, but the associated risk implications might vary significantly, potentially leading to critical failures being overlooked (Liu et al, 2014);
- The RPN scale exhibits non-intuitive statistical characteristics. While it is commonly assumed that the scale starts at 1 and ends at 1000, this often results in erroneous assumptions about the middle of the scale (Seyed-Hosseini et al, 2006);
- The Risk Priority Number (RPN) is solely determined by multiplying the input elements, neglecting any indirect correlations between these components (Yazdi et al, 2017).
- Subjective input data and results (Liu et al, 2016).

In the literature (Ceylan, 2023), (Ahmed and Gu, 2020), (Balaraju et al, 2019), a fuzzy FMEA is employed to address the aforementioned limitations. Generally speaking, fuzzy logic is introduced to enhance decision-making systems, particularly in situations where traditional binary logic or deterministic models may fall short due to uncertainties and imprecise data. It finds applications in various fields, such as control systems, artificial intelligence, data analysis, and decision support systems.

Fuzzy logic had an algorithm that contains the following steps: 1) Define input and output variables; 2) Linguistic variable definition; 3) Membership function design; 4) Rule base construction with AND, OR, NOT operators; 5) Fuzzification; 6) Rule evaluation and aggregation; 7) Defuzzification.

The study is structured around four primary steps (Figure 2). The first step contains the detection of failure modes, and possible causes and consequences. The second step includes the selection of the inference engine, input-output membership functions, and the construction of the study's rule base. The third step implies O, S, and D ranking by experts and fuzzy RPN calculation, and finally, the fourth step is the prioritization of failure modes.

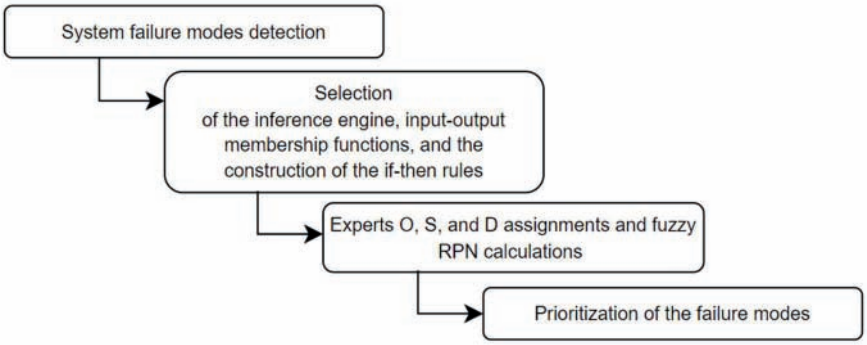

Figure 2: The methodical approach of the study

3. HTS FAILURE MODES AND EFFECTS ANALYSIS

This section presents, the implementation of the systematic approach to the HTS. As a result, fuzzy RPN values for every HTS failure scenario are calculated, and a ranking of failure modes was performed.

3.1 Failure modes

The HTS is the subsystem responsible for delivering engine power to the wheels of mobile machinery. Accordingly, any malfunction of this subsystem affects the safety and productivity of the machine. Therefore, this section defines potential failure modes, factors that can cause them, and their consequences, with the help of experts. HTS failure modes, causes, and effects are shown in Table 1.

Table 1: HTS failure modes, possible causes, and effects

Code	Failure mode	Possible cause	Effect
FM01	Insufficient system pressure	Problem with crossport relief valve (8, 9); Excessive internal or external fluid leaking; Open towing valve (10); Improper swash plate angle regulation, …	Inability to develop the proper torque and move the mobile machine
FM02	Excessive peak pressure	Crossport relief valve not functioning properly; Defective pump/motor compensator; Servo pressure too low to maintain firm control; Excessive decompression energy rates (improper hoses size), …	Heating of hydraulic oil, noisy working of the HTS

FM03	Insufficient pump outlet flow	Excessive internal or external fluid leaking; Open towing valve (10); Improper swash plate angle regulation (1); Problem with a hot oil shuttle valve (11); Defective hoses and/or connections; Problem with charge pump (2); Pump cavitation, …	Inability to achieve operational wheels speed
FM04	No system power, no pressure or flow	Damaged drive shaft; Damaged coupling; Prime mover doesn't work; Wrong direction of rotation; Charge pump (2) suction line clogged or disconnected; Low fluid level in the reservoir, …	No operation
FM05	The system works only in one direction	Problem with crossport relief valve (8,9); Problem with swash plate control valve; Problem with makeup check valve (5,6); Control input malfunction (hydraulic, mechanical, or electrical); Problem with a hot oil shuttle valve (11), …	Inability to safely and properly operate with mobile machine
FM06	System starts prematurely	Mechanical neutral position not set correctly; Hydraulic neutral position not set correctly; Control input malfunction (hydraulic, mechanical, or electrical), …	Extremely high safety risk
FM07	Excessive noise and/or vibrations	Air/foam in fluid; Low fluid level in the reservoir; Obstruction present in suction line; Pump cavitation; Improper fluid viscosity; Excessive wear or damage of the charge pump; Bearing damage; Piston ball is loose in piston shoe socket; Excessive wear on Fulcrum ball and socket of shoe retainer…	Stressed components with higher failure rates, heating of hydraulic oil, and unpleasant noisy working of the HTS
FM08	System is overheating	Excessive loads; Low fluid level in the reservoir; Problem with heat exchanger-clogged; Clogged inline pressure filters (4); Crossport relief valve (8,9) leaking or regulating continuously; Excessive pump and motor case drain; Open towing valve (10); External heat source too close to pump; Flushing flow too low…	Inadequate lubrication, increased wear, excessive leakage, underrated motor speed
FM09	Unresponsive or sluggish (or erratic) system control	Problem with charge pump (2); Problem with charge pump relief valve (7); Problem with hot oil shuttle relief valve (11); Control input malfunction (hydraulic, mechanical, or electrical); Swash block and/or saddle bearings worn or damaged; Partially activated towing valve (10); Contaminated, degraded or unsuitable fluid…	Unstable control
FM10	Irregular or unsteady operation	Problem with charge pump (excessive wear or damage…); The suction line is not sealed properly; Obstruction present in suction line; Worn swash block; Control input malfunction (hydraulic, mechanical, or electrical); Crossport relief valve (8,9) not regulating properly; Faulty output circuit components (cylinder, motor) …	Significantly lower productivity, and compromised safety
FM11	Leakage from the shaft seal	Case drain pressure is too high; Seal is worn or damaged; Improper shaft alignment	Loss of system fluid

3.2 Failure modes

After identifying the failure modes, causes, and consequences of the HTS, the experts allocated scores for O, S, and D as documented in Table 2. Ratings for O, S, and D range from 1 to 10.

Table 2: Rankings provided by experts for O (Occurrence), S (Severity), and D (Detectability)

Code	Failure mode	Expert 1			Expert 2			Expert 3		
		O	S	D	O	S	D	O	S	D
FM01	Insufficient system pressure	3	3	1	5	6	1	2	2	2
FM02	Excessive peak pressure	2	10	3	3	8	5	3	8	3
FM03	Insufficient pump outlet flow	4	5	4	5	5	6	4	3	4
FM04	No system power, no pressure or flow	4	4	1	1	5	1	1	3	1
FM05	The system works only in one direction	3	5	1	1	4	1	1	3	1
FM06	System starts prematurely	5	10	1	2	8	1	1	10	1
FM07	Excessive noise and/or vibrations	7	8	2	2	10	4	3	9	1
FM08	System is overheating	6	10	5	7	10	6	3	9	2
FM09	Unresponsive or sluggish system control	4	5	1	2	2	2	2	3	1

FM10	Irregular or unsteady operation	3	10	2	1	6	3	2	10	1
FM11	Leakage from the shaft seal	8	2	7	3	2	9	2	1	6

**For O a rating of 1 indicates a very low likelihood of occurrence, and 10 signifies an unavoidable event; for S a rating of 1 signifies negligible impact, while a rating of 10 implies catastrophic consequences; for D, a rating of 1 means the event is easily detectable, while a rating of 10 indicates that the event is very difficult to detect.*

3.3 Input-output membership function, inference engine selection, and rule base

The study's fuzzy model comprises three input variables (O, S, and D) and one output (fuzzy RPN). The fuzzy logic system utilizes various membership functions, such as triangular, trapezoidal, and Gaussian membership function. While the triangular membership function is frequently chosen in fuzzy logic due to its simplicity, interpretability, and versatility, the Gaussian membership function enables higher smoothness of the transition. For the study, a 5-level Gaussian input and output membership function was employed which comprises very low, low, medium, high, and very high levels.

In fuzzy logic, an inference engine is a crucial component of a fuzzy system that processes the fuzzy rules and input data to generate meaningful output. In order to establish the fuzzy model, the Mamdani inference engine was utilized in this study. It is widely adopted across various applications due to its intuitive and linguistic approach to handling uncertainty and imprecision and allows easy integration of human expertise and knowledge into the fuzzy system's decision-making process.

Rules are of utmost importance in fuzzy logic modeling as they form the foundation for making decisions in systems that deal with uncertainty and imprecision. The rule base has 125 rules, defined by experts involved. Each rule is an "if-then" statement that describes a condition based on the input variables and specifies the corresponding output action.

3.4 Fuzzy RPN results

Based on the scores provided by the experts for O, S, and D, the mean values were calculated, which were input into the fuzzy model to compute the fuzzy RPN values given in Table 3.

Table 3: Average O, S, and D values, and calculated RPN and fuzzy RPN values

Code	Average values			RPN	Fuzzy RPN
	O	S	D		
FM01	3,33	3,67	1,33	16,30	3,08
FM02	2,67	8,67	3,67	84,74	4,85
FM03	4,33	4,33	4,67	87,63	4,45
FM04	2,00	4,00	1,00	8,00	2,39
FM05	1,67	4,00	1,00	6,67	2,36
FM06	2,67	9,33	1,00	24,89	4,36
FM07	4,00	9,00	2,33	84,00	4,18
FM08	5,33	9,67	4,33	223,41	6,82
FM09	2,67	3,33	1,33	11,85	2,54
FM10	2,00	8,67	2,00	34,67	3,71
FM11	4,33	1,67	7,33	52,96	2,57

3.5 Prioritization of failure modes

The last step in the methodological approach of this study is the prioritization of failure modes based on calculated fuzzy RPN values. In Figures 3 and 4, the prioritization of failure modes is presented graphically. The top failure mode according to traditional FMEA and fuzzy FMEA is FM08 – overheating. Due to the operating conditions with heavy-duty off-road machines, it often happens that this phenomenon is not detected in time, and it is ranked high because the consequences can be catastrophic for the hydraulic system of the HTS. Failure modes FM02 and FM03 have switched positions, but using the logic of the defined fuzzy model, it has been concluded that the high severity rating (S factor) for FM02 takes precedence over the product of OSD factors for FM03. Therefore, FM02 is ranked second on the fuzzy FMEA list. A similar situation applies to failure modes FM06 and FM07, where the fuzzy model, due to greater consequences (despite the infrequent occurrence of this failure), ranked FM06 failure in fourth place. Furthermore, it can be observed that failures FM06 and FM11 have different positions, while the positions of the others remain the same on both diagrams.

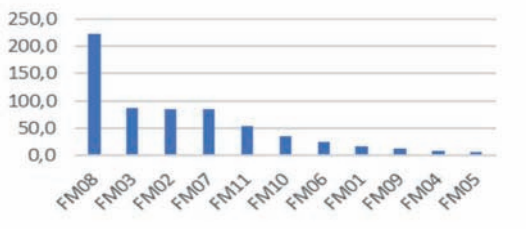

Figure 3: Failure mode prioritization by RPN

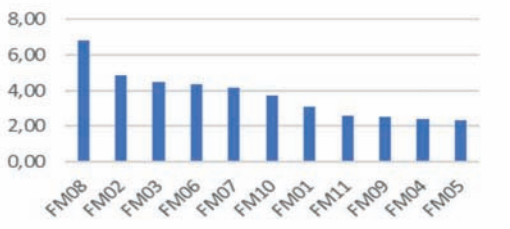

Figure 4: Failure mode prioritization by fuzzy RPN

4. CONCLUSION

The paper deals with the hydrostatic transmission system failure modes identification and prioritization by using the fuzzy FMEA method. The results obtained using the fuzzy FMEA method slightly deviate from the results obtained through the implementation of the traditional FMEA method. However, this approach has minimized subjectivity in assessing failure modes and reduced the disparity in calculated RPN values. According to the results top failure is system overheating (FM08), so analysis of failure causes is the next step which should be conducted by maintenance personnel in order to eliminate or minimize the risk of failure. Also, this study can be extended by using the same approach on other critical parts of heavy-duty off-road machines.

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IDENTIFICATION OF THE INTERDEPENDENT INFLUENCES OF MOTIVATORS FOR ENVIRONMENTAL PROTECTION IN REVERSE LOGISTICS IN THE CONDITIONS OF A DEVELOPING ECONOMY

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Abstract: *This research paper aims to investigate the interdependent influences of the motivators for environmental protection in reverse logistics in a wide spectrum of processing activities in the conditions of a developing economy. An effort was made to approach these motivators based on the relevant literature, predominant attitudes and experts' opinions, thus contributing to the body of knowledge in this domain. Determining the intensity of interdependent influences and the importance of motivators for environmental protection in reverse logistics was done to determine the most important (key) motivators, which can be practically applied as guidelines for decision-making. The DEMATEL method was used to assess the intensity of these influences on a representative sample of manufacturing companies in the Republic of Serbia.*

Keywords: Reverse Logistics, Environmental Protection, Manufacturing Industry, DEMATEL

1. INTRODUCTION

This research paper aims to investigate the presence and intensity of interdependent influences of motivators for Environmental Protection (EP) in Reverse Logistics (RL) in the conditions of a developing economy, such as the economy of Serbia. The need for this research arises from the fact that despite there is growing number of scientific publications dealing with RL and especially the application of multicriteria decision-making methods in this field, the domain is still not explored well enough so research efforts need to be intensified and expanded.

Previous studies have often been limited by the fact that they primarily focus on distinct industries (such as the electronics or automotive industry) and consider only cases of developed economies (such as USA, UK, China, India, Australia, and Brazil) (Bouzon et al. 2016; Lau and Wang, 2009; Abdulrahman et al. 2014), which makes the results difficult to generalize. This has led some researchers to express their concern about the absence of similar studies focusing on developing countries, as they might not be able to fully utilize findings from the aforementioned studies (Sarkis et al. 2011; Zhang et al. 2011).

Coupled with the rising awareness of the importance of RL and its slowly gaining a foothold in developing countries as well, in order to maximize chances of implementing it successfully critical motivators for EP have to be identified first so that they can be appropriately addressed. This paper makes a contribution in this regard, as it is one of the nascent empirical efforts of this kind to be carried out on the territory of the Republic of Serbia. This research was part of a broader research, with a larger number of examined elements in the field of motivators and barriers for the implementation of RL in organizations and their impact on organizational performance, and represents one of its segments (Brkljač, 2017).

The study, will present first a systematization of key motivators for EP in RL based on relevant literature sources, as well as on the prevailing views and opinions in this scientific field. After that, they will be defined the primary and secondary goals of the research, which is to identify their interdependent influences and to determine the significance of these motivators respectively. Finally, will be highlighted and briefly discuss those that are of key importance according to our results. Besides having academic value, we also believe that our findings will be useful to professionals in this domain since they can serve as guidelines in the decision-making process when implementing RL in organizations operating in similar conditions.

2. MOTIVATORS FOR ENVIRONMENTAL PROTECTION IN REVERSE LOGISTICS

By reviewing the literature, in order to determine and classify the most frequently cited motivators for the implementation of RL in organizations, it was found that they are most often grouped according to the criterion of their essential impact - economic, social and impact on EP, but for the purposes of this research, the focus is on EP. Shaik and Abdul-Kader (2014) point out that due to trends and incentives for the development of social responsibility of organizations, as well as legislation in the field of the environment, organizations must constantly take into account their context of expectations of interested parties, in order to achieve balanced development from the aspect of EP, social and economic aspect.

Corporate social responsibility refers to a set of values or principles that make the organization socially responsible towards the community in which it operates. It refers to the organization's responsibility for the impacts of its decisions and activities on society and the environment, through transparent and ethical behaviour (ISS, 2011). For this reason, RL activities can lead to gaining competitive advantages in the market (Carter and Ellram, 1998), improving the corporate image (Chan et al., 2012) and generally creating the image of a "green organization" (Mangla et al., 2016; Chileshe et al., 2016; Akdoğan and Coşkun, 2012; Ravi and Shankar, 2005; Walker et al., 2008; Kapetanopoulou and Tagaras, 2011; Chinda, 2017).

Various pressures from supplier chain partners, such as reducing supply chain waste, reducing pollution and sources of waste, suppliers rating based on sustainable practices and products, with reduced environmental, and social impacts, reduced harmful waste or materials, holistic approach for sustainable performance improvement and proactive sustainable supply chain management, are improving competitive advantage and drive the organization for the sustainable manufacturing (Hariyani et al., 2023).

The extended responsibility of producers, i.e. the right or obligation to return their products, after the expiration date or the end of the product's life, generate and intensify the collection and reuse of products (Akdoğan and Coşkun, 2012), the use of recycled materials (Ravi and Shankar, 2005), lowering the costs of waste management, reducing the amount of generated waste and reducing the necessary capacity for waste disposal (Govindan and Bouzon, 2018; Ravi and Shankar, 2015). Questions related to waste management also include suggestions that used products do not necessarily need to be disposed of in landfills, but can be reused or recycled by applying the "cradle to cradle" concept, through repair, reuse, "refurbishing", reproduction or recycling of usable and valuable products or materials (Chan et al., 2012), highlighting the importance of establishing a circular economy. In the context of the circular economy, RL management assists in closing supply chain loops and building partnerships to promote practices such as recycling and remanufacturing (Barros et al., 2021).

The availability of raw materials due to the use of already used ones, with renewed use value and the reduction of the need for new, often non-renewable resources, become one of the primary goals of organizations that strive to respect the principles of sustainability in their business and decision-making (Akdoğan and Coşkun, 2012; Rahman and Subramanian, 2012; F. T. S. Chan and Chan, 2008; Ravi and Shankar, 2005; Chinda, 2017; Mangla et al., 2016; Lau and Wang, 2009). The need to rationalize the use of resources in production processes and supply chains represents a trend in the modern way of doing business while numerous scientific papers support the importance of effective supply chain management (González-Sánchez et al., 2020). The need for competitiveness and elimination of negative effects of business activities and decisions requires organizations to explore ways of reusing the materials or products' components and restore the value of the material and energy inputs for a longer period of time (Rajput et al., 2019).

For the purposes of this research, a systematization and grouping of EP motivators (factors) was carried out. These factors were defined based on a review of the literature and their semantic analysis, where adjustments were made in order to eliminate redundancy in the statement and adequate understanding by the respondents. Accordingly, motivators for EP can be divided into:

- reducing the level of environmental pollution, due to the reduction of the amount of waste (C13),
- reducing the space required for waste disposal (C14),
- preserving natural resources and reducing the use of new raw materials (C15) and
- creating the image of a "green organization" (C16).

3. RESEARCH METHODOLOGY

In order to efficiently manage the process of RL implementation in an organization, it is necessary to comprehensively study the factors that may affect that process. There are several different motivators for EP in RL and they have an interdependent influence. In this case, management has to define priorities in providing resources and intensifying their positive impact on the implementation of RL in organizations. This is a classic example of Multiple Criteria Decision Making (MCDM), so it is necessary to determine the intensity of mutual influences of motivators in order to provide a solid foundation for effective decision-making. The DEMATEL method (Decision Making Trial and Evaluation Laboratory) is often used for this purpose as it represents a comprehensive method for analysing and solving complex and interdependent problems. It is intensively applied in the field of RL and supply chains, especially when determining the interdependent influences of RL implementation factors (Wang et al., 2016; Bouzon et al., 2018; Jalalifar and Kiamars, 2013; Xia et al., 2015; Shaik and Abdul-Kader, 2014; Gandhi et al., 2015; Mangla et al., 2016; Rahman and Subramanian, 2012; Wu et al. 2015a).

The DEMATEL method is based on graph theory and enables visual planning and problem-solving in such a way that relevant factors can be divided into causal and consequential so as to better understand their interrelationships. The resulting graph shows the contextual relationship between the elements of a system in which the number represents the strength of the influence of a factor. The procedure for calculating the intensity of the mutual influences of these factors comprises five steps (Wang et al., 2016; Bouzon et al., 2018; Xia et al., 2015; Gandhi et al., 2015; Mangla et al., 2016; Rahman and Subramanian, 2012; Wu et al. 2015a; Li and Tzeng, 2009).

Step 1: Generating matrices of scores (attitudes) of experts - $x_1, x_2 .... x_e$. Suppose it is assumed that there are e experts in a study and n factors to be considered. In that case, each expert indicates (evaluates) the degree of influence that factor *i* exercises on factor *j*. The value of each pair x_{ijk} is an integer, where the following integer scale is used: 0 - no influence; 1 - very low influence; 2 - low influence; 3 - high influence; 4 - very high influence.

Step 2: Calculating the matrix of average values of experts' scores (Average Matrix) - A.

Step 3: Calculating the normalized influence matrix (Initial Direct-Relation Matrix) - D.

Step 4: Computing the matrix of total influences - T.

The value ri represents the sum of the i-th row of the matrix T and shows the total effect, both direct and indirect, which factor *i* has on other factors. The notation c_j represents the sum of the *j*-th column of the matrix T and shows the total direct and indirect effects, which factor *j* received from the other factors. The expression (r_i+c_j) represents the importance of the factor, i.e., the degree of influence a particular factor has on the observed problem. The expression (r_i-c_j) denotes the intensity of the influence of the effects of a factor, in relation to other factors. If the expression (r_i-c_j) is positive, factor *i* exerts influence on other factors, i.e., the change conditioned by the action on factor i causes the change of other factors. If the observed expression is negative, factor i receives influence which comes from the effects of other factors.

Step 5: Determining the limit value of the importance of factor influence (Threshold Value) - p and constructing diagrams of mutual influences of the observed factors. Based on the opinion of the respondents (experts) or researchers, the lowest value of the importance of the influence of the factor - *p* is determined. This value is used to filter low values of the intensity of the influence among the factors of the matrix T, i.e., the values that are lower than the defined threshold value. Filtering is performed on all elements of the matrix T so that the values that are lower than the determined value of *p* get a value of 0 while the other elements of the matrix T, which are higher than the value of *p*, retain the existing value. If the defined value of *p* is too low, the presentation of the system structure will be inadequate, complex and difficult to understand for the decision-makers. The value of *p* which is set too high makes the structure of the system simplified, but it can lead to neglect and oversight of important influences in the system. Based on the determined value of *p* and filtered values in the matrix T, a diagram of mutual influences of the observed factors is constructed, which enables an easier understanding of factor relations in the observed system and facilitates the decision-making process based on results obtained by applying this method.

The research instrument used in this study was a questionnaire, which was devised based on the key elements in terms of motivators for EP in RL, as described in Section 2. There were two groups of respondents, who were selected from the ranks of experts in the field of logistics. The first group comprised respondents from the academic community (three university professors who specialize in the field of logistics) who also served as validators for the devised questionnaire. After a consensus among

them was reached on the suitability of the questionnaire, it was sent to the second group of respondents. This group consisted of 23 respondents who were recruited for the study from companies in the Republic of Serbia which belonged to the processing sector. All the respondents who participated in the research worked and / or managed logistics in their organizations for a considerably long time and were familiar with the concept of RL and its importance in the functioning of the logistics function and supply chains of these organizations. After being provided with the guidelines, the respondents completed the questionnaire.

Overall, 26 questionnaires of this type were collected and the received answers were converted to a set of matrices, which were subsequently used as input to the DEMATEL method. Based on the description of samples and the recommendations from the literature (Bouzon et al., 2018; Gandhi et al., 2015; Wu et al. 2015a; Wu et al., 2010; He and Cheng, 2012; Wu et al. 2015b), it can be said that the sample used is representative of the research population, i.e., the processing sector of the Republic of Serbia.

4. RESULTS

On the basis of the completed questionnaires, matrices with scores (evaluations) of the experts who participated in the research were formed. After the matrices of evaluation scores were formed, the matrix of average values of the experts' scores - matrix A was calculated, which represents the mean value of the scores of all the experts included in the study and is presented in Table 1, as an excerpt (with sums of the columns and sums of the rows).

The next step involved calculating the normalized influence matrix - *D*, using the formula *D=A/s*. The value of *s* represents the maximum value of the sum of all rows and columns, and is 10,077, as shown in Table 1. After calculating the normalized impact matrix (Table 2), the total impact matrix – *T* was calculated. Table 3 shows the matrix of total influences for the observed motivators (with sums of the columns and sums of the rows). It can be observed, as shown in Table 4, that the motivators C15 and C16, are factors whose effects influence (EI) other factors. The motivators C13 are factors that are influenced (receives influence - RI) by the effects of other factors. From the aspect of the significance of RL implementation for in organizations, the most significant motivators for EP in RL are C13, C16 and C15.

For the purpose of constructing a diagram of interdependent influences of the observed factors, the threshold value of the importance of the influence of factors (Threshold Value) - *p* is defined. According to some authors, this value can be defined on the basis of expert opinion or on the basis of calculations. In the present study, it is defined according to the recommendations in the literature (Gandhi et al., 2015; Mangla et al., 2016; Rahman and Subramanian, 2012; Wu et al. 2015a; Wu et al., 2010; Hsu et al. 2007) as the average value of the T matrix and is 5,485. Based on that, a filtered matrix of total interdependent influences was formed (Table 5). Figure 1 shows a diagram of the interdependent influences of motivators for EP in RL, formed on the basis of the values from Table 4 (the position of points in the diagram coordinate system) and on the basis of the values from the filtered matrix of total interdependent influences (connection of points based on *p* values of the importance of factor influence). The diagram enables a graphical display of data to facilitate the observation and understanding of the relationship of factors in the observed system. Each link line indicates the influence between the two variables, and the arrowhead indicates which variable is influenced by the other in the relationship shown. In the case of a connection, the arrowheads located on both sides indicate the mutual influence of the observed variables.

Table 1: The matrix of average values of the experts' scores - A

	C13	C14	C15	C16	∑
C13	0	3,231	3,231	3,231	9,692
C14	2,846	0	2,923	2,462	8,231
C15	3,154	2,846	0	3,615	9,615
C16	3,846	2,846	3,385	0	10,077
∑	9,846	8,923	9,538	9,308	

Table 2: Normalized impact matrix

	C13	C14	C15	C16
C13	0	0,328	0,328	0,328
C14	0,289	0	0,297	0,250
C15	0,320	0,289	0	0,367

C16	0,391	0,289	0,344	0

Table 3: Total impact matrix – T

	C13	C14	C15	C16	∑
C13	5,611	5,453	5,725	5,634	22,423
C14	5,168	4,588	5,056	4,949	19,761
C15	5,846	5,421	5,470	5,649	22,386
C16	6,086	5,609	5,922	5,573	23,190
∑	22,711	21,071	22,172	21,806	

Table 4: Importance and intensity of influence – motivators

importance	1	4	3	2
(r_i+c_j)	45,133	40,831	44,558	44,996
factor	C13	C14	C15	C16
(r_i-c_j)	-0,288	-1,310	0,214	1,384
contribution	*reciever*	*reciever*	*cause*	*cause*

Table 5: Filtered matrix of total interdependent influences

	C13	C14	C15	C16
C13	5,611	0,000	5,725	5,634
C14	0,000	0,000	0,000	0,000
C15	5,846	0,000	0,000	5,649
C16	6,086	5,609	5,922	5,573

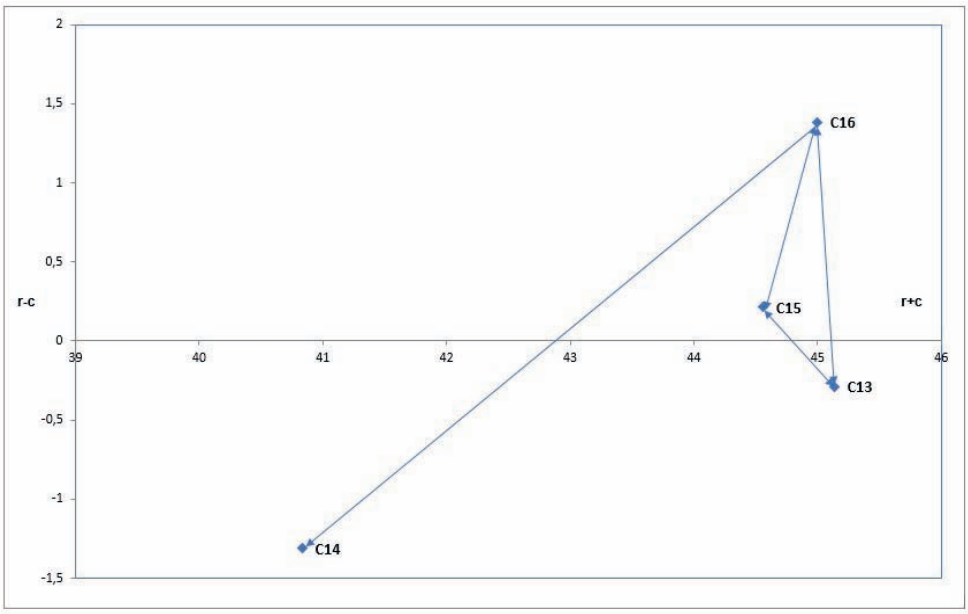

Figure 1: Diagram of the interdependent influences of motivators for environmental protection in reverse logistics

After analyzing the interdependent influence of motivators for EP in RL it can be concluded that, according to the level of importance for RL implementation, the most important motivators for EP are a reduction in the level of environmental pollution, due to a reduction in the amount of waste (C13), creating the image of a "green organization" (C16), as well as preserving natural resources and reducing the use of new raw materials (C15), while reducing the space required for waste disposal (C14) has the lowest level of significance of the observed factors. Viewed from the aspect of influence on other factors, motivators C16 and C15 influence the other mentioned motivators with their presence and encourage their persistence. For this reason, it can be said that C16, C15 and C13 are the key motivators for making a decision on the implementation of RL, from the aspect of sustainability in terms of EP, which is in agreement with the views of literary sources and the views of the authors, stated in chapter 2. It is obvious that the respondents believe that the motivation for the implementation of RL, from the aspect of EP, relies on creating the image of a "green organization", through a higher degree of utilization of materials from reverse flows and a reduction in the amount of generated and disposed waste.

5. CONCLUSIONS

The primary goal of this research was to identify the interdependent influences of motivators for EP in RL. In order to achieve this goal, the views of the academic community were reviewed and, based on relevant literature sources, motivators were identified and grouped. The secondary goal was to determine the significance of these motivators and highlight those that are of key importance so that they can be prioritized and appropriately addressed. At the same time, this study contributes to the growing body of knowledge in the domain and is particularly relevant for practitioners and academics coming from or operating in developing economies – as it indicates that expectations, conclusions and phenomena observed in the conditions of developed and stable economies may not necessarily translate well to developing countries. In practical terms, the results obtained from the present research can be especially useful for organizations operating in similar market conditions to those of the Republic of Serbia, as they can serve as guidelines for their management to direct resources more efficiently in the decision-making process.

The comparison of the results of this research with the theoretical considerations also suggests that there is an awareness of the importance of applying RL in the processing sector of the Republic of Serbia, in order to achieve the competitive advantages of organizations, but also to preserve the environment and natural resources. The lack of awareness about this has often been identified and especially expressed as a barrier to the application of RL in developing countries. Also, it appears to be necessary to define mechanisms and regulatory frameworks to encourage organizations to implement this concept, primarily through the cooperation of organizations and experts in the field of logistics with scientific and government institutions. The goal of this cooperation should be the exchange of information and joint action in the development of legislation that regulates this area and provides the conditions for its sustainability.

Based on the results of this study, we have identified several promising avenues for future research which may contribute to the implementation of RL in organizations, such as:

- Determining employees' competencies and experiences that are necessary to overcome barriers and formally expressing the way in which they contribute to the efficient and effective implementation and functioning of RL;
- Understanding the effects of deeper involvement of government departments on devising a more holistic view of the strategies for sustainability;
- Investigation of the connection between individual RL activities and criteria for selecting adequate implementation options and influences of individual RL activities on improving organizational performance;
- Comparison and better understanding of experts' attitudes and opinions between developing and developed economies, when it comes to overcoming RL implementation barriers.

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STANDARDISATION OF WORK AS PART OF THE IMPLEMENTATION OF THE LEAN STRATEGY IN SERVICES

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Abstract: *The application of Lean in various systems for the production of hardware, process, software, and other services and products is increasingly present. Considering the available research and literature on the application of Lean in the service sector, it can be noted that there needs to be more available professional material in the field of operations of public institutions. The Lean system is designed to eliminate waste, variability, and inflexibility.*

Standardisation in the service industry refers to the process of creating a consistent and unique experience for customers across different locations and service providers. This can be achieved by developing standardised processes, procedures, and protocols that ensure every customer is treated the same, regardless of where they are located or who serves them. Standardisation in the service industry is essential as it helps to improve efficiency, reduce costs and improve the quality of service delivery. By standardising processes, operations can be streamlined, errors minimized, and productivity improved. This paper will present the problems that have been identified in a public institution - the Cultural Center "Lukijan Mušicki" from Temerin, and then show how to solve them using lean tools.

Key words: Lean, service, standardisation, improve, process

1. INTRODUCTION

Contemporary trends require all service providers to continuously adapt, innovate and change the business environment. Some authors claim that competition is one of the critical reasons for resorting to the highest quality offer and that developing different standards for improving and maintaining the quality of services is an essential prerequisite for successful business and survival on the market. Standards ensure that goods or services produced in a particular industry are of consistent quality and equivalent to comparable products or services in the same industry. Standardisation also helps ensure manufactured goods safety, interoperability, and compatibility (Corporate finance institute, 2023). Standardisation aims to ensure uniformity of certain practices within the industry. Standardisation focuses on the process of product creation, business operations, the technology used, and how specific mandatory processes are established or implemented. Every organisation strives for quality, consistency, efficiency, and best practice. Service standards can help an organisation achieve its best results and show how to improve (Corporate finance institute, 2023). They also demonstrate that there are processes to monitor and improve quality and performance in the company's service. Service standards range from the basic level to sophisticated, externally assessed systems. If the company notices that clients regularly complain about the quality of the service received or the staff makes many mistakes in their work, there is a good chance that the problem may result from undefined or non-existent service standards (Schuh, G.,2007). Such an environment leaves staff figuring out what to do or where to draw the line regarding service level or quality. Standards enable greater efficiency in development and processing by individual suppliers. Growth is achieved when service quality can be reproduced over time and across locations (Schlesinger. I and J, Heskett., 1992). Technical know-how and innovation can be distributed more quickly when standards are set. An additional increase in efficiency is contributed by unique evaluation standards that increase effectiveness, which can primarily be explained by the rise in the degree of use by customers (clients) and the accompanying acceptance by increasing the price (Gudergan, G./Hoeck, H., 2002). Creating service sector standards strengthens individual service companies innovative and competitive ability. Standards encourage economic growth and competition, protect consumers, and create fair and accessible trade conditions. Service companies that apply company-specific and sector-specific standards have a competitive advantage. These companies reduce their transaction costs and are perceived as businesses that actively promote the security of their customers. For customers, standardised services represent

structured offers with low risk because they are comparable (Mörschel, 2002). By choosing the right point of standardisation during the development process, the service can be offered to interconnected markets; standardisation fosters competitiveness (Schauerte, 2007).

In 2015, the Cultural Center of the Municipality of Temerin was created by separating the cultural activity from the "Lukijan Mušicki" Cultural and Information Center. In 2018, at the initiative of the institution's founder - the Municipality of Temerin, the institution was transformed, and the name changed to the Cultural Center "Lukijan Mušicki" Temerin. For the implementation of cultural programs of various kinds, the Cultural Center disposes of an area of about 600m², which consists of a gallery space, a theatre, and a cinema hall with 320 seats, as well as business premises (administrative buildings), (Cultural Center "Lukijan Mušicki", 2023). The work of the Cultural Center is reflected in the organisation of numerous theatre performances (for adults and children), cinema screenings, art exhibitions, art colonies, literary evenings, book promotion, debates on various current topics, etc. The paper will present some of the problems in the current way of working of the institution, as well as appropriate solutions in the context of improving the operation of certain parts of the business process through standardisation.

2. METHODS

The current situation in the work and functioning of the Cultural Center indicates the need to introduce significant changes in the current way of working. Through the process of detailed analysis of the functioning of the Cultural Center, many problems were observed that must be solved and improved, such as inefficiency and dissatisfaction of employees, organisational confusion, lack of knowledge of responsibilities, conflicts between employees, inability to adequately monitor the work performance of employees, too much dependence on the execution of specific tasks by individuals, poor resolution of problems that arise in daily operations, low level of motivation of employees, poorly developed delegation, reduced level of communication between employees and superiors, complete mess on the desk as well as the cables of electrical devices on the desk (computer, printer...), etc. At the beginning of the work, it was known that there were specific problems in the process of selling tickets for screenings. A data collection plan is being prepared to collect the necessary data. This plan includes what type of data should be collected, the data sources, etc. This paper focuses on the functioning of the ticket sales procedure for theatre and cinema shows. The licensed Microsoft Excel program was used to standardise data entry and manipulation. The workbook layout is designed in which the necessary data is entered, as well as the required reporting. The problem in the analysis of this ticket sales procedure was that the employee who works directly on ticket sales complains that, in many cases, errors occur; this situation creates an environment of uncertainty for employees and the organisation. The existing environment limits employees to work better and with better quality. In the paper, the focus is on one segment in the business of the Cultural Center "Lukijan Mušicki" Temerin, which is the process of selling tickets for theatre and cinema shows. As stated earlier, the process is done manually, slowly, and with a high possibility of error. The employee who sells tickets has in front of him a theatre/cinema seating plan (printed A4 paper) on which he marks the sold seats. The seating arrangement is shown in Figure 1. After marking the seats sold, the employee prints the ticket. The ticket (front and back) is shown in Figure 2. After that, he collects the entrance fee.

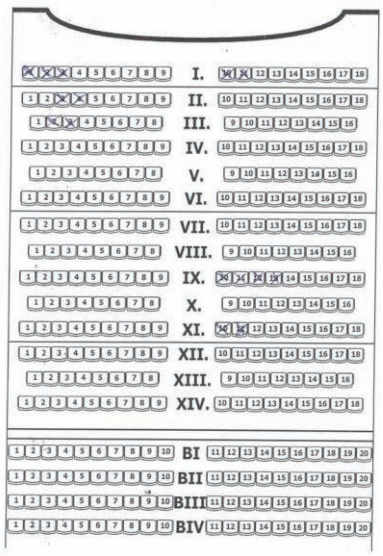


Figure 1: Theater/cinema seating plan (printed A4 paper)

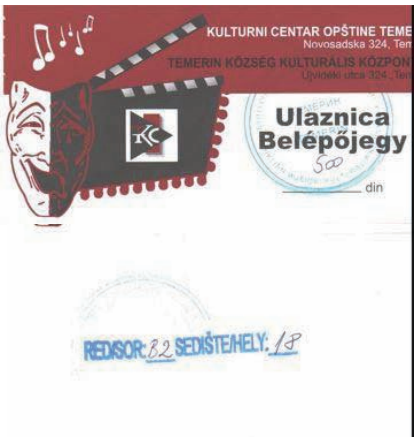


Figure 2: Ticket (front and back)

A block diagram was made for a more accessible analysis and graphic presentation of the process. A detailed examination of the created chart revealed certain process bottlenecks, marked on the diagram with the letters A, B, and C. In the case of bottleneck A, slow communication was observed due to additional administrative activities; also, an increased possibility of error is evident. In the case of bottleneck B, more activities were observed that deter and reduce the quality of the provided service. In the case of bottleneck C, the impossibility of data analysis on a more significant number of performances was observed, as well as an increased possibility of error regarding internal records of sold tickets. The block diagram of the process is shown in Figure 3.

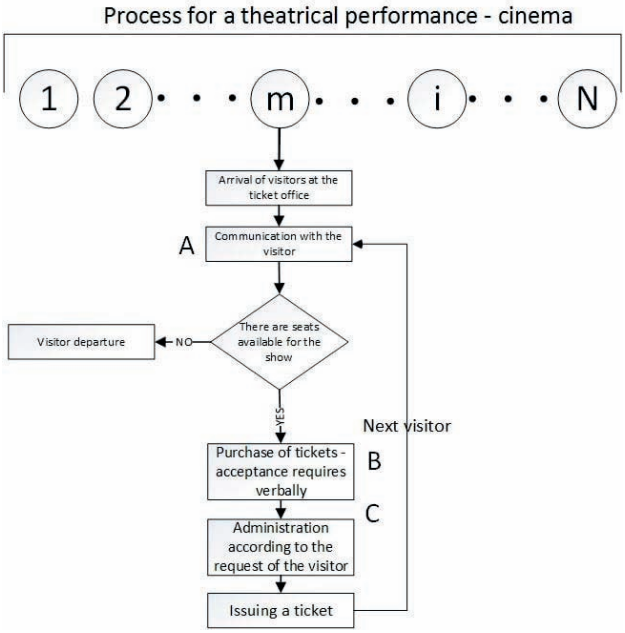


Figure 3: Block diagram (before)

The goal of the work is to establish work standardisation that would provide the opportunity to perform the job better and faster, clearly define how the service will be provided (thus minimizing errors), and increase customer satisfaction with the service provided.

3. RESULTS

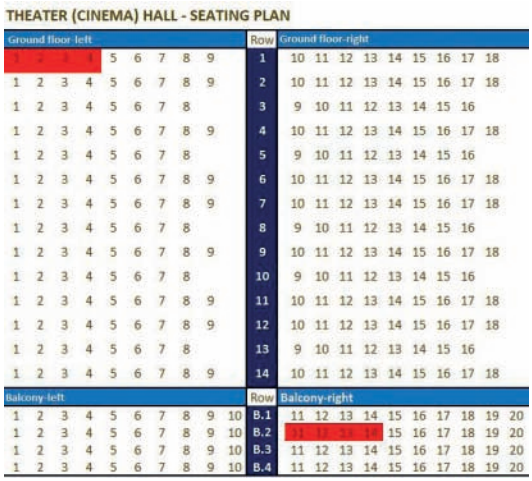
To perform the relevant measurements in real time, the first customer waited to start the ticketing process. Immediately after entering the client, the measurement with a stopwatch was started until the sales process was completed. To obtain the highest quality data, this procedure was repeated five times. The procedure was repeated for three days with three different employees. After collecting the initial data, they were systematically arranged in an Excel table, and the necessary analysis was performed. The analysis showed that some workers are more efficient than others (faster) and that they need less time to sell tickets. The average time required to perform the sales service was determined by systematizing the data in the table. It was found that the average time needed to complete the service is 4.24 minutes.
First, the layout of the Excel workbook was designed, as well as what data should be entered into it. In the workbook, the employee enters primary data, namely: ticket price for adults, the ticket price for children, then, if the prerequisites are met, the ticket price with a discount (persons with disabilities, people from vulnerable social groups, etc.). Also, entries (according to a free estimate, the expected number of visitors to the play/cinema screening). Furthermore, in the section provided for this, the employee enters information about the name of the play/film, the name of the person to whom the ticket is issued, the number of adults, the number of children, the number of discounted tickets, the location of the seat (ground floor of the hall or balcony- a predefined text is specified in the cell to reduce the error), the row and the number of desired seats. The initial data entry screen is shown in Figure 4.

Ticket sales		Theatrical performances/films	
Ticket price - adults:	400,00 RSD	Total tickets sold:	8
Ticket price - children:	100,00 RSD	Total income:	2.100,00 RSD
Ticket with discount:	200,00 RSD		
Expected visitors:	250	Name of the play/film	The Summer 2023

Name/card holder	Numb.Adults	Numb.children	Ticket with discount	Seat location	Row	Seat number
XX	2	2	0	Ground floor-left	1	1,2,3,4
YY	2	1	1	Balcony-right	2	11,12,13,14

Figure 4: Data entry screen

This completes the process of entering the required data. The workbook further provides the necessary data based on automatic procedures. It should be noted that the client can follow the entire process on the additional LCD screen in front of him. After entering the initial data, the seating plan appears before the client. Seating plan - occupied seats (sold) are automatically generated based on previously entered data and marked in red. The seating plan is shown in Figure 5.



THEATER (CINEMA) HALL - SEATING PLAN

Ground floor-left										Row	Ground floor-right								
1	2	3	4	5	6	7	8	9		1	10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8	9		2	10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8			3	9	10	11	12	13	14	15	16	
1	2	3	4	5	6	7	8	9		4	10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8			5	9	10	11	12	13	14	15	16	
1	2	3	4	5	6	7	8	9		6	10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8	9		7	10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8			8	9	10	11	12	13	14	15	16	
1	2	3	4	5	6	7	8	9		9	10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8			10	9	10	11	12	13	14	15	16	
1	2	3	4	5	6	7	8	9		11	10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8	9		12	10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8			13	9	10	11	12	13	14	15	16	
1	2	3	4	5	6	7	8	9		14	10	11	12	13	14	15	16	17	18

Balcony-left										Row	Balcony-right									
1	2	3	4	5	6	7	8	9	10	B.1	11	12	13	14	15	16	17	18	19	20
1	2	3	4	5	6	7	8	9	10	B.2	11	12	13	14	15	16	17	18	19	20
1	2	3	4	5	6	7	8	9	10	B.3	11	12	13	14	15	16	17	18	19	20
1	2	3	4	5	6	7	8	9	10	B.4	11	12	13	14	15	16	17	18	19	20

Figure 5: Seating plan (Automatically generated)

Empty seats remain unmarked with colour. At the same time, this gives the worker a much faster visual representation of the free places, so he can react quickly and possibly recommend a seat to the client. In this way, one of the problems that often occurs is manual entry. Namely, the duplication of sold places was eliminated. After entering the necessary data and defining the seat, the workbook automatically switches to a new tab sheet where the ticket is given to the client as proof of purchase (all required data is already generated on the ticket). The appearance of the ticket with all the data is shown in Figure 6. Also, according to pre-defined criteria, the ticket is printed in two copies - one that is given to the client (visitor) and the other that remains for internal records. In this way, there is no possibility that the institution does not have a copy of the ticket. When the ticket is printed, the ticketing process is complete.

Figure 6: Theater/cinema show ticket (Automatically generated)

As seen in Figure 7, the theatre/movie ticket sales process has been redesigned to provide the fastest and highest quality service to the customer and, to the greatest extent possible, for the employee to complete the process more easily and quickly. Bottlenecks that appeared in the process before the redesign are now resolved. The possibility of making a mistake during the process is minimised. After the entire process was redesigned and new solutions were implemented, relevant measurements were made, and it was established that the process was faster, safer (in terms of the possibility of error), and more efficient.

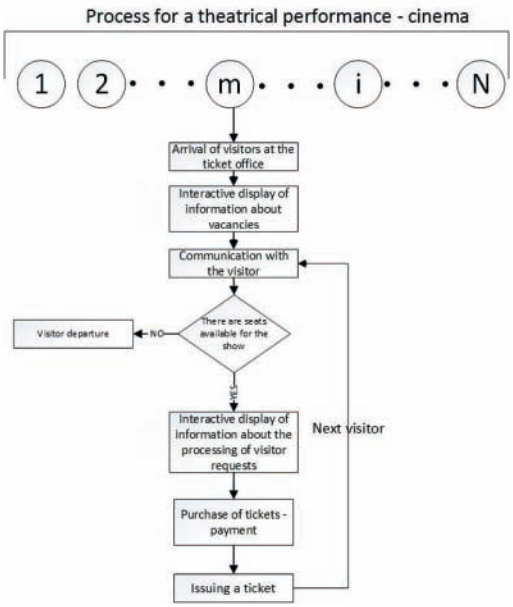


Figure 7: Block diagram (After)

4. DISCUSSION

After the implemented changes in the realisation of the operation of selling tickets in the process of showing a cinema show, there is a noticeable increase in the efficiency of work. Workers now carry out work in a relaxed manner without pressure. Training workers for the job is elementary. Errors during the first research of the developed solution have been eliminated. This does not mean it is impossible to make them and that the current solution is perfect. Precisely the opposite happened. Immediately after implementing the presented solution, new ideas and possibilities for improving the existing system were developed. Compared to the previous way of working, data that is "alive" and can be further performed is obtained. Based on the data collected, the statistics of each performance in all periods of duration can be seen very quickly. Clear key performance indicators (KPI) parameters are obtained. There was no interest in statistical data processing in the previous situation because it took much work to collect them in the first place. Also, their accuracy could have been more debatable.

5. CONCLUSIONS

As can be seen from the above results, the goal outlined at the beginning of the work has been achieved, which is to redesign, improve and simplify the process of ticket sales in the Cultural Center "Lukijan Musicki" Temerin and at the same time eliminate the possibility of loss/error. Significant improvements can be observed by comparing the way of working before and after the implemented changes. Previously, the entire process was done manually, it took a long time, and without clear instructions on how to do it, there was a high possibility of making a mistake during work. By designing and creating software (custom Excel workbook), the whole process becomes faster and, cleaner, more efficient while reducing the possibility of error. The entire procedure of ticket sales is standardised and automated. After this initial process improvement, the plan is to connect the custom Excel workbook to a relational database such as Microsoft Access.

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USING MULTISENSOR DATA FUSION FOR ALLOCATING SYSTEMIC FAULTS OF THE HYDRAULIC CONTROL SUBSYSTEM OF A RUBBER MIXING MACHINE

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Abstract: The rise of machine and deep learning algorithms in predictive maintenance has led to the influx of multidimensional data analysis studies. However, although studies dedicate towards increasing the accuracy of regression and classification models, many commit to resolving the issues by addressing a single fault mechanism, neglecting the latent degradation of other fault mechanisms. In this paper, we dedicate our efforts in understanding multiple and systemic faults through multidimensional data analysis. Using Knowledge Graph via Network Analysis we allocate markers of fault mechanisms that are used as features for fault classification. The features are extracted from discretised hydraulic power signal, hydraulic fluid physical and chemical data, and system response data. Using feature extraction we were able to observe latent degradation mechanisms that are used for multi label classification using machine learning algorithms. The results obtained show that neural network had highest, i.e., 85% accuracy (AUC = 0.88) among classification algorithms in allocating systemic faults within the hydraulic power system.

Keywords: predictive maintenance, multidimensional data, machine learning, network analysis, knowledge graph, systemic failures, hydraulic system

1. INTRODUCTION

Existing body-of-knowledge concerning failure mechanisms show conficting opinions regarding FPS (Fluid Power System). Many argue that particle (Jocanović et al., 2014) and air/water contamination (NORIA, n.d.) are the leading causes of stoppages, while some argue that overload and leakage are the most common causes of stoppage (Orošnjak et al., 2022). Furthermore, studies dedicated to analysing and understanding failure mechanisms show a lack of research related to multiple and systemic failures. Namely, most of the research performed dedicates to resolving the underlying mechanisms leading to a particular failure cause while neglecting the effects of latent degradation leading to a failure of other components within the system.

In such instances, many components within the system are left in an imperfect state with latent detrimental effects on the long run. For instance, in the case of a hydraulic pump, controlling and reducing the contamination by filter replacement will not reduce the risk of stoppage caused by pump-generated particle contamination that cause wear of valves and actuators down the return line of the system before the filter. Also, focusing simply on the contamination-induced wear will ommit degradation caused by poor operator manipulation of machine or system. Hence, it becomes a question whether the studies should still dedicate towards the uniform analysis of root causes or should studies turn towards resolving simultaneous and multivariate analysis of systemic failures and faults without production stoppages.

In this paper, we address the problem of systemic failures observed within the subsystem of the rubber mixing machines, specifically the hydraulic power system. As the system operates within an energy-intensive regime (Ragab et al., 2022), including around-the-clock production, there is higher theoretical probability that simultaneous and latent degradation will occur in different parts of the system. Hence, instead of monitoring the system and pinpointing a specific failure while performing diagnostics, we use multi-rate data fusion (Huang et al., 2021) for CM (Condition Monitoring) by allocating multiple deteriorating mechanisms.

The rest of the paper is structured as follows. The second section includes an in-detail description of the experimental installation, data acquisition and CM of the system. In addition, the section also presents descriptions of parameters and hyperparameters of used machine learning (ML) and Network Analysis (NA). The third section presents the results and discusses the obtained results. Finally, the last section includes contributions to the literature, limitations, and future research.

2. METHODOLOGY

2.1 Experimental Installation and Data Acquisition

The experiment is performed on a hydraulic control system of a rubber mixing machine that performs movement for opening and closing the chamber. The hydraulic control system performs a hydraulic cycle for unloading the bulk material in three regimes: Opening Saddle, Idle Saddle and Closing Saddle. Data acquisition is performed through non-destructive measurements (Horvatic et al., 2016), including (1) inline lubricant condition monitoring (automatic particle counter, aqua sensor and turbine flow meter); (2) online system monitoring (SCADA) for measuring hydraulic cycles, idle time, and actuators' movement; (3) offline fluid condition monitoring (ICP-OES – Inductively Coupled Plasma Optical Emission Spectrometry and laboratory analysis) for elemental and physio-chemical analysis of contaminants present in the oil. Offline oil analysis and online lubricant condition monitoring include measurements of physio-chemical characteristics of oil: oil density, viscosity (at 40°C and 100°C), viscosity index, flame point, flow point, total acid number, water (ppm), water saturation (%), ISO4406 contamination level, and elemental analysis using ICP-OES. The hydraulic power signal is discretised at 0.1 seconds (f = 10 Hz) from the HYDROTECHNIK MultiHandy 2045 with measurements from 15.10.2021-12.12.2021.

2.2 Data processing and feature extraction

From discretised hydraulic power signal, the signal is split into opening saddle, idle saddle and closing saddle regime. From the discretised signal, each part is used for feature generation (Table 1), after which features are used for machine learning classification based on quasi-faults generated by the deviations in the signal. Although the system (excluding total failures) was performing in order, the anomalies noticed in the signal are classified as „quasi-faults". Quasi-faults are labelled via the concept of functional-productiveness (see (Orošnjak et al., 2023)). The signal sample contains 980 performed cycles (15.10.2021-12.12.2021). Hence, the sample contains n = 980 cycles and designated 52 features used for machine learning classification. The interpolation of offline measurements is performed with polynomial regression for at least $R^2 > 0.95$ to eliminate missing data the sample used for machine learning classification.

Table 1: Feature generation from discretised hydraulic signal

Time-domain feature	Feature notation[1]	Formula for feature generation
Mean (average) value	N_Mean_*XS*	$MEAN = \frac{1}{n}\sum_{i=1}^{n} N_i$
Standard deviation	N_StDev_ *XS*	$StDev = \sqrt{\frac{(x_i-\bar{x})^2}{n-1}}$
Root Mean Square	N_RMS_ *XS*	$RMS = \sqrt{\frac{1}{n}\sum_i x_i^2}$
Quartile ranges (Q1,Q3)	N_nQ_ *XS*	$nQ_{1;3} = x_{(k)} + a\left(x_{(k+1)} - x_{(k)}\right)$
Interquartile Range	N_IQR_ *XS*	$\mathrm{IQR} = \mathrm{N_3Q}_XS - \mathrm{N_1Q}_XS$
Peak-to-peak	N_P-P_ *XS*	$P_P = \lvert \mathrm{N_MIN}_XS - \mathrm{N_MAX}_XS \rvert$
Skewness	N_Skew_ *XS*	$Skew = \tilde{\mu}_3 = \frac{\sum_i^n (x_i-\bar{x})^3}{(n-1)\cdot\sigma^3}$
Kurtosis	N_Kurt_ *XS*	$Kurt = \tilde{\mu}_4 = \frac{\sum_i^n (x_i-\bar{x})^4}{(n-1)\cdot\sigma^4}$

[1]*XS* can represent: **OS** for Opening Saddle regime; **IS** for Idle Saddle Regime; **CS** for Closing Saddle Regime.

2.3 Machine learning algorithms and parameters settings

The algorithms used for classification are Random Forest (RF), Decision Tree (DT), Gradient Boosting Classification (GBC), Support Vector Machine (SVM), Linear Discriminant Analysis (LDA) and Multilayer Perceptron (MLP) Neural Network. All algorithms are trained with 60% of data, using the holdout data of 20% tested, and for validation, 20% of data is used, splitting the data into 60/20/20. The following gives settings for the parameters and hyperparameters for all algorithms. The RF parameters are set: training data is used per tree at 60%, features are scaled, and splits are optimised with a maximum of 100 trees. The DT algorithm parameters are set: minimum observations per split are set at 20, minimum observations in the terminal are 7, maximum interaction depth is 30 and complexity penalty is set at 0.01 with scaled features. The GBC boosting parameters are set as follows: Shrinkage = 0.1, Interaction depth = 1, Minimum observations in node = 10, training data used per tree 50% with scaled features and optimised with a maximum of 100 trees. For the SVM, the settings are set as: weights = linear, cost of constraints violation

= 1.0, tolerance of termination 0.001, epsilon parameter ξ = 0.01 with scaled features. The LDA parameters include scaled features, and for the relationships estimation MLE (Maximum Likelihood Estimation) method is used. For the MLP-NN, the activation function is a logistic sigmoid function with a backpropagation algorithm with a learning rate set at 0.05. The stopping criteria for loss function is set to 1 with 100000 maximum training repetitions. The network optimisation used is a Genetic Algorithm (GA) with a population size of 20 and 10 generations. Parent selection is a roulette wheel with reset mutations (10% probability), a uniform crossover method, and a fitness-based survival method with elitism set at 10%. Given parameters and obtained results can be replicated via open-source JASP.

2.4 Network Analysis for multivariate data visualisation

For the NA the FR (Fruchterman-Reingold) is the common algorithm used in network analysis (Leme et al., 2020), however, the *huge* network we used relies on Meinshausen-Buhlmann graph or the graphical lasso since they are building the *huge* network (Zhao et al., 2012). The network analysis allows a user to research data relationship and data complexity between features of interest. In our case, we extend the ML classification results with insights about features and data used for classification. As it is most often the case, especially with Random Forest, Decision Trees and Ensemble aglorithms such as the case with Gradient Boosting, some feature can be used for reaching >99% accuracy, even though the feature would not lead to meaningful conclusions about the case. Therefore, we use NA for gaining inisights about the system behavior and degradations that can lead up to systemic failures. It is also useful to emphasise that NA can sometimes be referred to as KG (Knowledge Graph) in literature (Xia et al., 2022), if it relies on multi-source data. The *huge* package in R (Zhao et al., 2012) is used for NA while the estimation criterion the EBIC (Extended Bayes Information Criterion) (Foygel & Drton, 2010) with tunning parameter of 0.5.

3. RESULTS & DISCUSSION

Using quasi-events for binary classification as „None“ and „Quasi-fault“, i.e., [0, 1], the results show high accuracy. However, even though classification performed well, suggesting the possibility of upcoming fault or stoppage, there is a lack of information regarding the part of the system that has degraded. However, from the observed discriminative learning algorithms (GCB, DT, RF), the feature importance suggests that only a few features are used to classify 100% (e.g., Flame point, N_1Q_OS, Viscosity). At the same time, the rest of them are excluded. In particular, the GCB algorithm suggests that only Flame point, N_Stdev_CS, N_1Q_OS and T3 are features used for classification, which is a misconception and can be misleading. The underlying reasons is that different features suggest different changes as percentage of degradation that require maintenance action. For instance, degradation of 10% of viscosity and density of oil would require preventive actions and suggest replacement of the oil. In other instances, rise of *Fe* or *Cr* particles with elemental analysis would sometimes require 10-fold changes (i.e., from 5 to 50 ppm) that would indicate changes in surface texture (Alar et al., 2010) leading to a wear. For that instance, it further requires pre-set maintenance plan that would indicate changes needing maintenance actions. For that instance, we use NA that would suggest changes in nodes and edges and indicate potential degradation of the system.

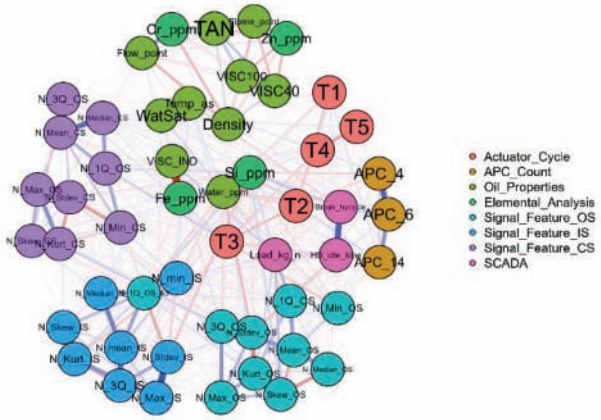

Figure 1. Network analysis of the system in the initial state with labels

Performing network analysis, we observe changes in the weight between the initial state (Figure 1) and in quasi-fault state (Figure 2), including clustering and labelling properties of the network.

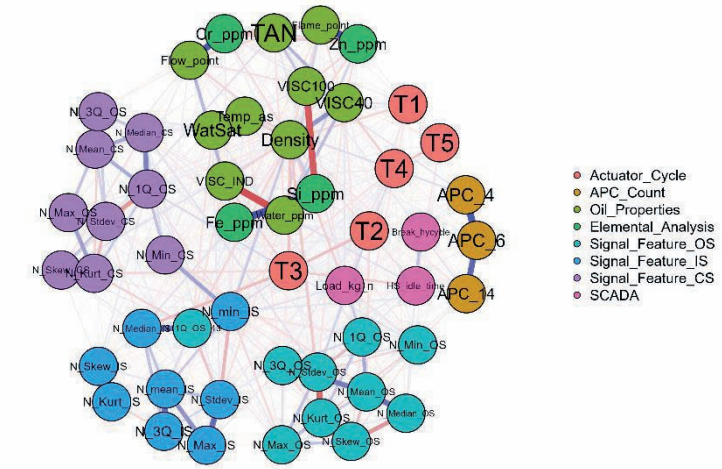

Figure 2. Network analysis of the system in the quasi-fault state with labels

Some nodes show high association with higher-order clusters such as oil and elemental analysis that cluster together. This can suggest that changes in oil physio-chemical properties cluster with elements rise within the fluid, which can indicate changes in not only fluid condition but the presence of wear, since aside from *Zn* and *Si*, rise in *Fe* and *Cr* particles can suggest starting wear of hydraulic pump. Following the statement, it is reasonable to assume that differentation between the states does not necessarily lead to wear. This is because different component degrade differently, and changes in percentage rise suggest different outcomes and not necessarily failure of a component. However, instead of using ML algorithms, such as discriminative ones, where for instance GCB or RF show perfect classification properties just by using 3% of the features extracted and neglect latent changes in other features, we use NA to gain insight about the changes in feature properties (Figure 3).

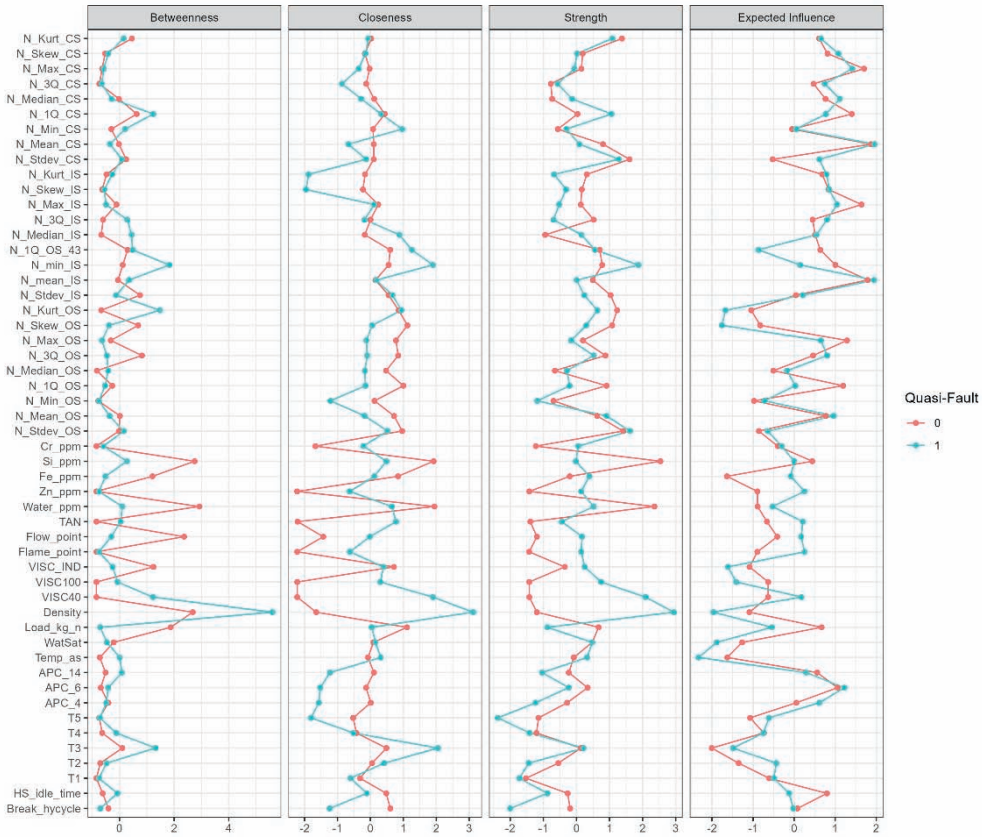

Figure 3. Centrality plot of conditions without and with quasi-faults

The strength and expected influence of the NA is important since it provides information about the sum of the weights of all edges connected to the particular node (strength), while expected influence provides

information about local and global influence. For instance, we can see that density significantly changes between quasi-events suggesting high strength, i.e., weighted sum of the edges to a particular node. In the case of expected influence, the N_Mean_CS, N_Mean_IS, N_Max_CS have the highest influence, followed by N_Max_IS, N_1Q_CS, N_Max_OS, and N_1Q_OS, and APC_6. From a practical standpoint this was confirmed since significant variations in the hydraulic power signal is noticed that would indicate degradation and potential wear. However, since other parameters, like Fe, Cr, oil density, that would indicate presence of wear were not noticed (e.g., filtering, filter replacement, oil refilling) and left unoticed, the changes in signal helped improve diagnostic and decision-making.

Instead of using features for binary classification, the expert opinion for multiclass labels provided helped determine the degradation of components. Hence, using binary classification as quasi-events, we labelled quasi-faults as follows: y_i = C, where C = {None, Closing saddle, Saddle position, Sensor response, Total failure, Wear component}. The recorded total and sensor failures are used for classification from the experiment; the rest are added as labels. For the classification, we use a neural network with the following parameters. The rprop+ (Riedmiller & Braun, 1993) with logistic sigmoid activation functions are used. Stopping criteria loss function 1 with 100000 max training repetitions. Features are scaled and seed is set at 1234. Topology of the network uses GA (Hajnayeb et al., 2011) with 20 population size and 10 generations with roulette wheel parent selection and uniform crossover method. Reset mutations with probability of 10% and Survival method with elitism of 10% are used. The obtained results show good prediction properties with overall prediction of potential failures of 84% and 87.9% AUC (Area Under Curve) metrics (table 2).

Table 2. Prediction accuracy of neural network for systemic failures

Evaluation metrics	None	Closing saddle	Saddle position	Sensor response	Total failure	Wear component	Average
Accuracy	0.561	0.561	0.985	0.959	0.995	0.980	0.841
AUC	0.955	0.977	0.997	0.857	0.500	0.988	0.879

Based on the obtained classification we see that combinations of different changes in nodes and edges, can lead to different types of failure mechanisms. For instance, changes in system response and idle position of the saddle, can suggest slow response of the sensor. However, the biggest issues encountered were degradations of mechanisms that are not classified accurately. Namely, anomalies and spikes in the signal (presumably due to sensor disturbances) were classified as “None”. The underlying reasons include not statistically significant degradation of used features, which can lead to innacurate classifications. Hence, since there are numerous failure mechanisms that are left undetected or can be associated with different proposed failure mechanisms, the poor accuracy suggests that more background knowledge and associated underlying mechanisms need to be provided in order to increase the accuracy of the model.

4. CONCLUSIONS

The paper investigates the use of NA for allocating latent degradational mechanisms that can be used for labelling and condition monitoring. Namely, since ML models can indeed predict the outcomes with “perfect” classification results, this often leads to missclassification and misinterpretation of the results. This is often the case with discriminative learning (e.g., RF, SVM, DT). In such instances, latent degradation of different components go by unnoticed since they are not captured as important features used for classifications. Therefore, we turn towards NA for observing changes in network structures, edge weights and centrality indices in understanding and observing potential systemic failure mechanisms that can go by unnoticed. The results obtained are used for gaining insights about the system behavior and from the observed distances metrics we generate multiclass features that would indicate existance of systemic failure mechanisms within practical hydraulic control system of a rubber mixing machine. The obtained results show classification accuracy and AUC metrics >80%, suggesting good results.

There are several limitations of the study. Namely, the NA is still in the infancy and interpretation centrality indices is not fully understood, especially considering the weighted undirected NA, such as this case. Also, the interpretation of expected influence and strength centrality measures have different mathematical estimation since in some cases the expected influence can be calculated using both betweenness and strength centrality measures suggesting overlap in the interpretation. Next, since huge package is used with multidimensional data it is usually applied in high-dimensional statistics with sparse data, where there is higher features than sample sizes. Also, the partial correlation metric is used for estimating the edge

weights to provide information how each pair of variables are related when the influence of all other variables are removed, which can be misleading in this case. Finally, there is only a handful of labels used, which is far from the actual potential failure mechanisms that potentially exist in the system.
The future studies will include expanding features and dataset with maintenance activity logs as qualitative data that can be used in generating high-dimensional knowledge graphs and gain deeper understanding about insights and system behavior that will initially increase classification accuracy and maintenance decision-making. The author will also in the future engage in graphical neural networks based on the expanded sample of the same system.

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EXPLORING THE QUALITATIVE DIMENSIONS OF INDIVIDUAL MOTIVATION OF EMPLOYEES IN SELECTED MACEDONIAN MANUFACTURING COMPANIES FOR OCCUPATIONAL HEALTH AND SAFETY TRAININGS: A SELF-DETERMINATION THEORY PERSPECTIVE

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Abstract: *Individual motivation plays a fundamental role in shaping human behavior, and this holds true for employees within the realm of occupational health and safety (OHS). Consequently, comprehending employee motivation from various levels and perspectives within organizations assumes paramount importance. Among the crucial components of Occupational Health and Safety Management Systems (OHSMS) within organizations, as well as OHS more broadly, are the OHS trainings provided to employees. This research aims to characterize the qualitative dimension of employee motivation, drawing upon the framework of the Self-Determination Theory (SDT), in manufacturing organizations located in the Republic of Macedonia. The findings of this study aim to contribute to a deeper understanding of employee motivation and aid in the enhancement of organizational approaches to the design of OHS trainings. The identification of qualitative dimensions of employee motivation, as per the principles of SDT, is grounded in the analysis of existing scientific and research literature, supplemented by a survey conducted among a sample of 70 employees.*

Key words: employee OHS trainings, motivation, Self-Determination Theory, qualitative dimensions of motivation, manufactory industry, work accidents

1. INTRODUCTION

Employee occupational health and safety trainings (e-OHS-t) are crucial for creating a safe and healthy work environment. These trainings provide employees with the knowledge, skills, and awareness necessary to prevent work accidents and promote a safety-conscious culture within organizations. Research has shown that well-designed and comprehensive e-OHS-t programs lead to improved safety outcomes, including lower injury rates and higher compliance with safety protocols (Clarke, Ward and Saksvik, 2012), (Deci and Ryan, 2000).

To enhance the effectiveness of e-OHS-t, incorporating principles from Self-Determination Theory (SDT) presents promising opportunities. SDT focuses on intrinsic motivation and fulfilling basic psychological needs, such as autonomy, competence, and relatedness (Gagné and Deci, 2005). By integrating SDT principles into e-OHS-t, organizations can tap into employees' intrinsic motivation and create a more engaging learning experience. This involves providing choices to employees, supporting their sense of competence, and fostering a sense of connection and belongingness. Research has shown that incorporating SDT principles in training contexts leads to positive outcomes, including increased motivation, engagement, and skill development (Fleming and Scott, 2012), (Mariani, Soldà and Curcuruto, 2015). By aligning e-OHS-t with these principles, organizations can optimize the influence of the programs and promote a culture of safety. To improve e-OHS-t using SDT principles, organizations can consider strategies that satisfy employees' basic psychological needs. This includes offering autonomy by involving employees in the training program's design and allowing them to choose relevant learning methods or topics. Fostering competence can be achieved through clear instructions, feedback, and opportunities for skill development. Additionally, promoting relatedness and belongingness within the training environment is crucial, encouraging collaboration and creating a supportive atmosphere. By leveraging SDT principles, organizations have the potential to significantly enhance e-OHS-t. The integration of autonomy,

competence, and relatedness into the training design and delivery enhances motivation, engagement, and the application of learned skills. Ultimately, this contributes to a safer work environment and improved organizational outcomes.
Determining the qualitative nature of motivation (types of motivation, internalized extrinsic motivation and SDT continuum, Figure 1. (Fleming and Scott, 2012), (Mučenski,2018) for e-OHS-t presents an opportunity to assess employees' motivation and satisfaction of fundamental Self-Determination Theory (SDT) needs. This understanding can be leveraged to enhance the design of e-OHS-t, ensuring that employees possess the desired qualitative characteristics of motivation for engaging in these trainings effectively in self-determined manner.

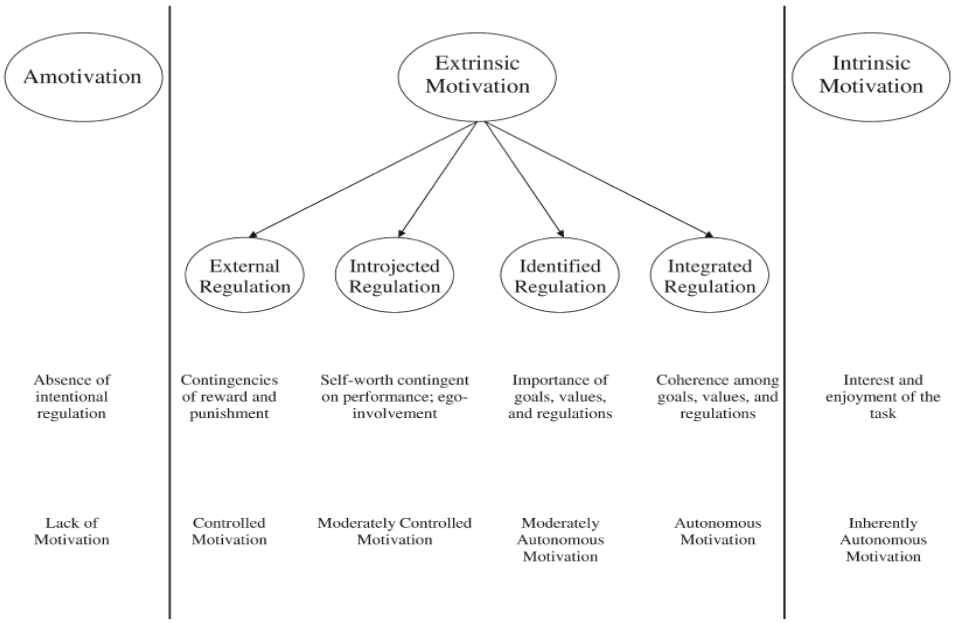


Figure 1. The SDT Continuum

By examining the current motivation types and assessing the fulfilment of SDT needs within the context of e-OHS-t, organizations can identify areas for improvement. This knowledge allows for targeted interventions and adjustments to the training programs, aligning them more closely with employees' intrinsic motivation, internalized extrinsic motivation and promoting greater engagement. Taking into account the qualitative nature of motivation for e-OHS-t enables organizations to create training experiences that are meaningful, empowering, and relevant to employees' needs. By satisfying the fundamental SDT needs of autonomy, competence, and relatedness, organizations can optimize employees' motivation, leading to increased participation, knowledge retention, and application of learned skills in the workplace. Ultimately, by incorporating a deeper understanding of employees' qualitative characteristics of motivation for e-OHS-t into the design and implementation of training programs, organizations can foster a culture of safety, enhance employee well-being, and achieve better outcomes in occupational health and safety (Gagné and Deci, 2005).

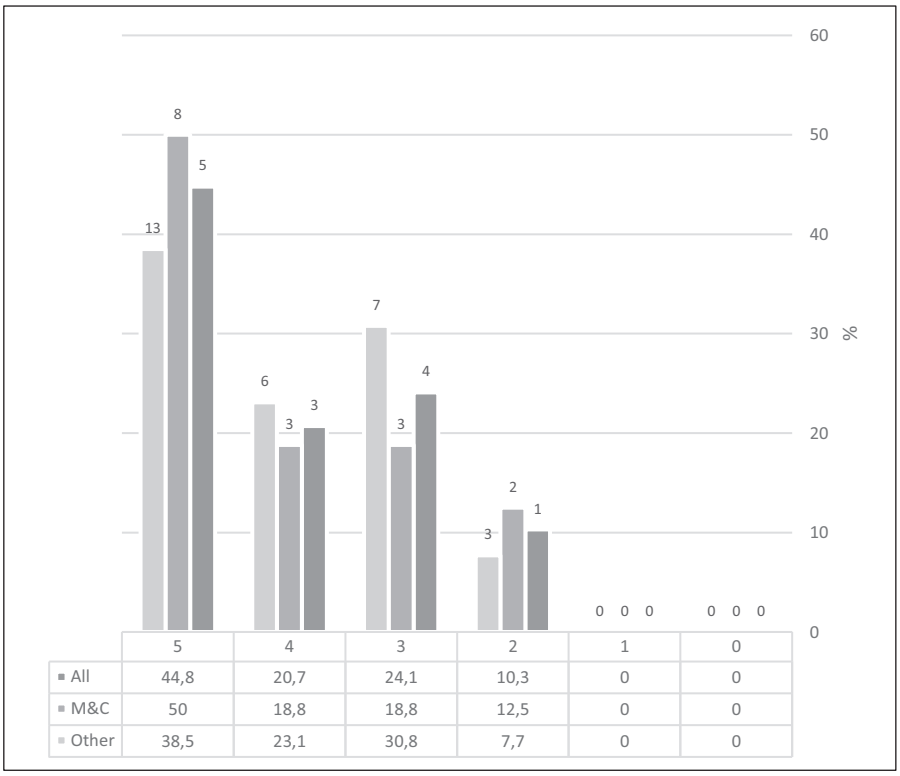
2. METHODOLOGY

The employed methodology encompasses a combination of qualitative and quantitative scientific research methods to collect, organize, and analyse the requisite data. The sequential stages of this methodology are depicted in Figure 1, with specific details provided in the ensuing text. The methodology is comprised of four distinct stages: 1) gathering and scrutinizing relevant literature, 2) assessing the significance of employee Occupational Health and Safety trainings (e-OHS-t) in relation to work accident prevention, 3) identifying motivation types with respect to e-OHS-t, and 4) processing and analysing the data, followed by a discussion of the findings.
To address the scientific research challenges at hand, an initial examination of the existing literature regarding the importance of e-OHS-t and the qualitative aspects of individual employee motivation based

on Self-Determination Theory (SDT) was conducted in Stage 1. This analysis forms the foundation for subsequent stages of the research methodology. In Stage 2, e-OHS-t was analysed within the context of work accident prevention, encompassing both theoretical aspects and practical applications within Macedonian manufacturing companies. This analysis took place in three steps. Firstly, an exploration of the theoretical approaches to understanding work accident causation (TAUWACs) involved the collection, identification, and analysis of the relative occurrence frequency (f_o) of various TAUWACs. From a pool of 142 identified TAUWACs, 22 (Heinrich's Domino Theory, Swiss cheese model, Systems-theoretic accident model and process, Bird and Loftus' Domino Theory, Human factors analysis and classification system, The Rasmussen (socio-technical) framework, The Functional resonance accident method, Normal Accidents Theory, Cognitive reliability and error analysis method, Accident proneness theory, Energy release and transfer model, Skill-rule-knowledge framework, High Reliability Organization Theory, Drift Into Failure model, Epidemiologic Theory of Accidents, Tripod delta, Haddon's ten countermeasure strategies, Multiple Causation Model, Human Factor Theory, The Petersen accident-incident causation theory, Systems Theory of Causation: Theory of Accident Causation, Goals Freedom Alertness Theory: Dr. Willard Kerr's theory of accident causation) were selected based on their cumulative occurrence frequency, which accounted for 70% of the total identified TAUWACs or TAUWACs with an occurrence frequency (f_o) equal to or greater than 0.9% ($f_o \geq 0{,}9\%$.). Secondly, the relevance of e-OHS-t as a mitigating factor for employees in work accidents was analysed and confirmed based on the postulates of the selected TAUWACs. Finally, an online expert survey was conducted among Macedonian OHS professionals to evaluate the influence of e-OHS-t on prevention of work accidents, employing a scale of 0 to 5 (0|This factor is not used., 1|Has no influence., 2|Has a negligible influence ., 3|Has an influence., 4|Has a significant influence., 5|Has a great influence.), as well as to determine the priority of e-OHS-t in comparison to other identified group factors, such as communication, feedback, information and OSH guidelines, workplace risk assessment, accident and injury investigations, internal acts and OSH objectives, continuous improvement of the OHS system, trainings and practical exercises, and selection of work equipment, employing a scale of 1 to 7 (1|highest priority and 7|lowest priority). The survey included 44 OHS professionals, with 29 providing complete responses, rendering them eligible for inclusion in the research. All surveyed OHS professionals possessed relevant experience in the field of OHS (6,9% have less than one year, 10,3% have from 1 to 5 years, 27,6% have from 6 to 10 years and 55,2% have more than 10 years' work experience; while regarding the work field, 51,7% have work experience in manufacturing industry [M], 13,8% as OHS consultancy [C] and 34,5% in other OHS field), and 96.6% of them had passed the OHS state exam in accordance with Macedonian law. Stage 3 involved a survey of 70 frontline employees employed in four large Macedonian manufacturing companies in the metal processing industry. These companies had implemented the ISO45001:2018 standard and employed at least one OHS professional. The objective of this stage was to identify the qualitative dimensions, based on SDT, of individual employee motivation towards e-OHS-t. To achieve this, a questionnaire consisting of 16 statements was adapted from a previously established scale, as described in the (Neal and Griffin, 2006), (Ryan and Deci, 2000). The respondents were asked to rate their agreement with each statement using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Lastly, Stage 4 encompassed the presentation and discussion of the results, contextualizing the understanding of employees' qualitative individual motivation, based on SDT, towards e-OHS-t. This knowledge contributes to the development of more effective e-OHS-t designs.

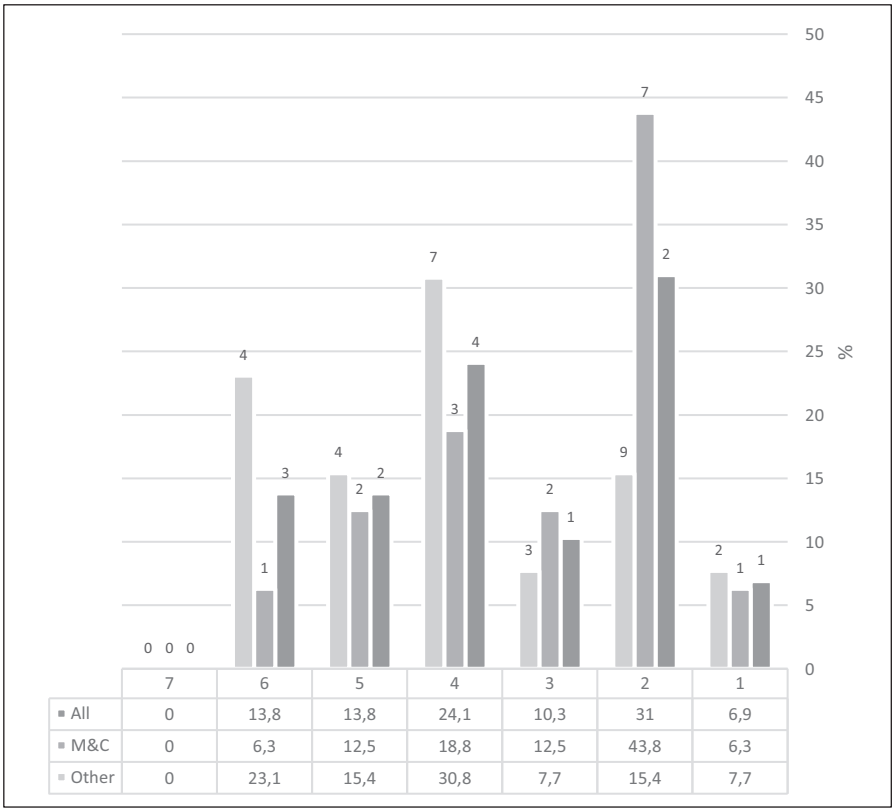
3. RESULTS

The analysis conducted on the relevance of e-OHS-t as a mitigating factor for employee influence on work accidents, whether as a cause or contributor, yielded a 96% correlation with the postulates of the selected 22 TAUWACs (21 TAUWACs). Figure 2 and Figure 3 present the processed data obtained from the expert survey, illustrating the evaluation of the influence and priority of e-OHS-t as mitigation factors by surveyed OHS professionals. Median values for the influence and priority are provided in Table 1 to offer a general summary. Table 2 displays the median values (from M_a to M_e) derived from the direct employee survey, specifically focusing on the type of motivation and internalised extrinsic motivation for e-OHS-t. The degree of agreement with identifying statements related to the type of motivation and internalised extrinsic motivation for e-OHS-t is captured in the survey, and Figure 4 showcases the distribution of answers regarding this agreement. Figure 5 presents a heatmap that represents the median values and values corresponding to the type and internalised extrinsic motivation per respondent. This visualization allows for a comprehensive understanding of the patterns and trends within the data set.



	5	4	3	2	1	0
All	44,8	20,7	24,1	10,3	0	0
M&C	50	18,8	18,8	12,5	0	0
Other	38,5	23,1	30,8	7,7	0	0

Figure 2: Influence of e-OHS-t as a mitigating factor on work accidents according surveyed OHS professionals



	7	6	5	4	3	2	1
All	0	13,8	13,8	24,1	10,3	31	6,9
M&C	0	6,3	12,5	18,8	12,5	43,8	6,3
Other	0	23,1	15,4	30,8	7,7	15,4	7,7

Figure 3: Priority given to e-OHS-t in relation to other groups of factors by surveyed OHS professionals

Table 1: Median values of the influence and priority of e-OHS-t according the surveyed OHS professionals

	All	M & C	Other
Median value of the influence of e-OHS-t on work accidents	4 (Has a significant influence .)	4 (Has a significant influence .)	4 (Has a significant influence .)
Median value of priority	3 1 (max) – 7(min)	3 1 (max) – 7(min)	4 1 (max) – 7(min)

Table 2: Median values of degree of agreement with the statements for identifying type of motivation and type of internalized extrinsic motivation for e-OHS-t per statement and type of motivation and internalized extrinsic motivation

	INTRINSIC MOTIVATION (a)				IDENTIFIED MOTIVATION (b)				INTROJECTED MOTIVATION (c)				EXTRINSIC MOTIVATION (d)				AMOTIVATION (e)				
QQ	1	2	3	M_a	4	5	6	M_b	7	8	9	M_c	10	11	12	M_d	13	14	15	16	M_e
M_{QQ}	2	3	3	3	4	4	4	4	3	3	3	3	2	3	2	2	2	2	2	2	2

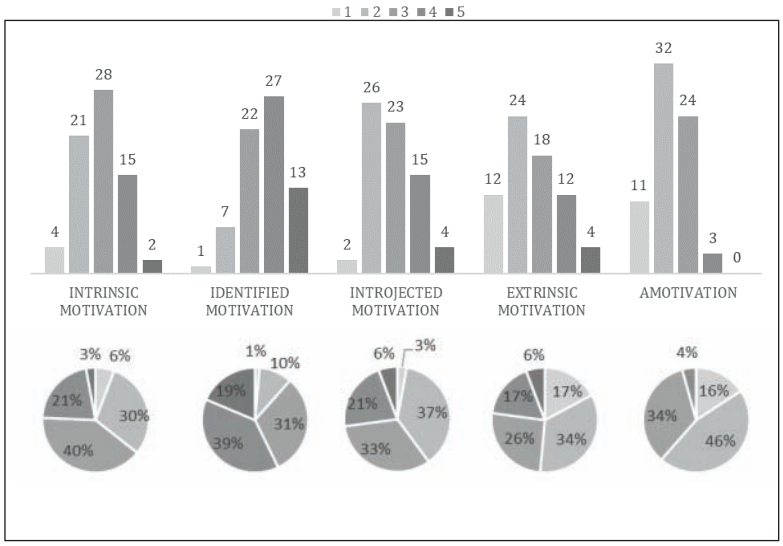


Figure 4: Distribution of answers regarding the degree of agreement with the statements for identifying type of motivation and type of internalized extrinsic motivation

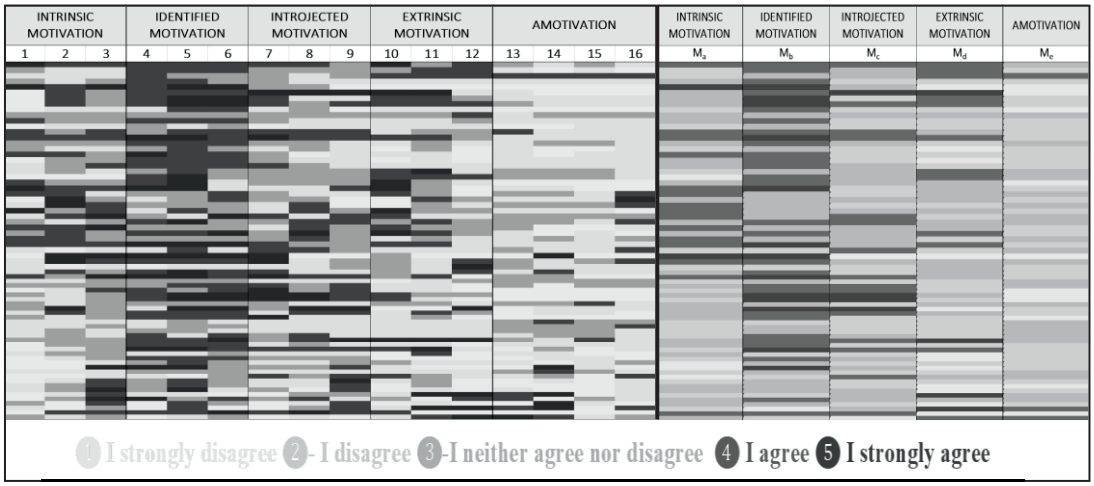


Figure 5: Heatmap of median values of degree of agreement with the statements for identifying type of motivation and type of internalized extrinsic motivation for e-OHS-t per respondent

4. DISCUSSION

This research aims to characterize the qualitative dimension of employee motivation, drawing upon the framework of the Self-Determination Theory (SDT), in manufacturing organizations located in the Republic of Macedonia. The findings of this study aim to contribute to a deeper understanding of employee motivation and aid in the enhancement of organizational approaches to the design of e-OHS-t. Considering that the design of e-OHS-t depends on various factors relevant to the organizational context in which they are implemented, including employee motivation to participate in training, it is essential to strengthen their effectiveness and efficiency. The activities performed mentally or physically within any microenvironment where individuals exist, including the role of employees/workers in the workplace microenvironment, depend on two general aspects of motivation: quantitative (level of motivation) and qualitative.

The first two stages of the research (Stage 1 and Stage 2) involved an analysis of the significance of e-OHS-t for organizations in the context of preventing workplace accidents. This analysis was conducted based on the postulates of selected theoretical approaches aimed at understanding the occurrence of workplace accidents. It was found that 96% of TAUWACs, specifically 21 out of 22, included ways in which employees influence or contribute to the occurrence of workplace accidents, making e-OHS-t one of the mitigating factors. The importance of e-OHS-t was further confirmed through evaluation of their influence and priority on work accidents.

Figure 2 illustrates the distribution of data regarding the evaluated influence as perceived by OHS professionals. The data is divided based on the professionals' work area in OHS (All, M&C, and Other) and the degree of influence on accident prevention. From the graph, it is evident that all groups of OHS professionals evaluated the influence of training on accident prevention *as great significance (5)*, with 50% of professionals from M&C, 38.5% from other OHS areas, and 44.8% of all respondents rating it as having a great influence.

Additionally, 18.8% of M&C professionals, 23.1% of professionals from other OHS areas, and 20.7% of all respondents rated it as *having a significant influence (4)*. Another 18.8% of M&C OHS professionals, 30.8% of professionals from other OHS areas, and 24.1% of all respondents rated it *as having an influence (3)*. The remaining percentages indicate no significant or no influence, with *none of the respondents considering that training has no influence on accident prevention*.

Furthermore, Figure 3 shows that the majority of M&C professionals (43.8%) prioritize e-OHS-t as the second most important factor in accident prevention, while 18.8% place it fourth. This is followed by third and fifth place with 12.5% each, and first and sixth place with 6.3% each, with none ranking it as the least important.

Considering the previous distributions, Table 1 provides the median values of all data from surveyed professionals. The median value for the influence of e-OHS-t on accident prevention as rated by M&C professionals is 4 (*Has a significant influence.*), the same as professionals from other OHS areas, and the overall median value for all respondents. Regarding the median value for priority based on the responses of M&C professionals, it is 3 of 7, while professionals from other OHS areas rated it as 4 of 7, and the median value for all responses is 4 of 7.

The third stage of the research aimed to identify relevant types of motivation and internalized extrinsic motivation for e-OHS-t. Table 2 presents the median values of responses indicating the level of agreement with statements (adapted from (Neal and Griffin, 2006), (Ryan and Deci, 2000)) related to different types of motivation and internalized extrinsic motivation.

The findings, presented in Table 2 (adapted from (Neal and Griffin, 2006), (Ryan and Deci, 2000)), indicate that all three statements related to the identified motivation received a median value of 4 (I agree.), indicating agreement. Statements 2, 3, 7, 8, 9, and 11 received a median value of 3 (I neither agree nor disagree.), indicating neutrality. Conversely, all other statements received a median value of 2 (I disagree.), indicating disagreement.

Figure 4 displays the distribution of median values for the types of motivation and internalized extrinsic motivation. The figure shows that for the identified motivation, 19% of employees strongly agree, 39% agree, 31% are neutral, 10% disagree, and 1% strongly disagree with the corresponding statements. Other types of motivation and internalized extrinsic motivation exhibit higher degrees of neutrality (intrinsic and introjected motivation) or disagreement (extrinsic motivation and amotivation).

Furthermore, Figure 5 visualizes individual results in a heatmap, highlighting the dominant agreement with statements concerning the identified motivation. While the individual results appear more scattered, they align more closely with the identified motivation when represented through median values.

5. CONCLUSIONS

In conclusion, this study emphasizes the crucial role of employee occupational health and safety trainings (e-OHS-t) in establishing and maintaining a safe work environment. However, it also recognizes that the mere provision of training is not sufficient to guarantee its effectiveness. To maximize the impact of e-OHS-t programs, it is essential to incorporate principles from Self-Determination Theory (SDT). By integrating SDT principles, organizations can tap into employees' intrinsic motivation and create a more engaging and empowering learning experience.

The research findings underscore the significance of e-OHS-t in preventing work accidents, as evidenced by the strong correlation with selected theoretical approaches to accident causation. OHS professionals acknowledge the substantial influence of e-OHS-t in mitigating workplace accidents. This recognition further reinforces the importance of prioritizing these trainings within organizations.

When assessing the qualitative dimensions of employee motivation, the survey of frontline employees revealed a higher agreement with intrinsic and identified motivation, as compared to extrinsic motivation and amotivation. This alignment with intrinsic motivation suggests that employees are more likely to engage in e-OHS-t when they perceive it as meaningful and enjoyable, driven by their own interests and values. By leveraging these findings, organizations can tailor their e-OHS-t programs to nurture intrinsic motivation, promoting active participation and sustained engagement.

By designing e-OHS-t programs that align with employees' intrinsic motivation, organizations can foster a culture of safety where individuals feel empowered and valued (Velkovski,2020). These programs are more likely to elicit positive outcomes, such as increased knowledge retention, skill application, and adherence to safety protocols. Ultimately, the integration of SDT principles into e-OHS-t programs contributes to a safer work environment, enhanced employee well-being, and improved organizational outcomes.

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PROFILING THE INDUSTRIAL ENGINEERING AND MANAGEMENT DISCIPLINE: KEY IMPLICATIONS AND PRELIMINARY EMPIRICAL EVIDENCE FROM AUSTRIA

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Abstract: *The industrial engineering and management (IEM) job profile includes working at the interface between engineering and management, for example, on the development of solutions for technical problems under economic premises. The processing and/or solution of these mostly interdisciplinary problems requires technical, managerial, and methodological competences, as well as interdisciplinary competences such as social and/or personal competences. The trend towards interdisciplinary competences can be justified by technological progress – keywords "Industry 4.0" and "Industry 5.0" - and by the advancing digitalization and sustainability debate that permeates all areas of life. Particularly in times of the twin transition, specialists and managers with interdisciplinary action competences are indispensable to be able to successfully master challenges in industry and society. This paper analyses the current trends regarding the IEM job profile based on the results of the Austrian IEM job profile study. It concludes with recommendations for a preliminary competence profile of IEM professionals.*

Keywords: Industrial Engineering and Management, Engineering Education, Competence Profile, Job Profile Study

1. INTRODUCTION

Industrial engineering and management professionals (IEM) operate at the intersection of technology and business, where they tackle technical problems while considering economic premises. Bauer (Bauer 2015) emphasizes that IEM professionals should address three key questions: whether the problem is technically solvable, if it makes economic sense, and whether it benefits or harms society. Resolving these interdisciplinary problems necessitates a combination of technical and business expertise, methodological, and social competences. IEM professionals today have a crucial role in addressing global challenges like climate change, resource scarcity, and energy transition while considering economic competitiveness, environmental protection, and social acceptance. Recent studies highlight the growing demand for qualified engineers in smart and sustainable operations management (OM). Operations Management (OM) encompasses a range of tasks, including organizing work, selecting processes, arranging layouts, locating facilities, designing jobs, measuring performance, controlling quality, scheduling work, managing inventory, and planning production. Operations Managers are versatile individuals who are known as the "improvement people" and are responsible for planning, coordinating, and negotiating. Due to the diverse nature of their role, operations managers require various competencies, including technical skills, conceptual skills, methodological competencies like presentation skills, and transversal competencies such as communication and negotiation skills. The field of OM has been shaped and evolved by technological, economic, environmental, and social revolutions, with the expectation that the Green Revolution will bring the next evolutionary step. Operations can be understood as a transformation process that converts inputs into outputs of greater value, spanning the entire supply chain and being relevant to all functions within an organization. Consequently, any manager should have some understanding of the principles and concepts of operations management. In this context, Slack et al. (Slack et al. 2009) distinguish between two meanings of "operations": as a function within an organization that produces products and services, and as the overall management of all processes across all corporate functions (Russell 2011).
According to research by the Institute of the German Economy, there is a projected need for 48,300 engineers and 68,800 STEM academics annually between 2023 and 2028 (iW Köln 2020). In Austria, IT and engineering are identified as the most significant areas for skilled labor demand in 2021 (Statista.de 2021).

Thus, flexibility, adaptability, resilience, and competences in the IEM area in the OM discipline are regarded as vital success factors to enhance long-term competitiveness, both nationally and internationally. In fact,, today´s IEM job profile requires a diverse set of skills, attitudes, and competences, which Klamert-Schmid et al. (Klamert-Schmid et al. 2021) define as a "colorful bouquet." These competences are necessary for IEM professionals to effectively navigate the intersection between technology and business. However, to the best of the author´s knowledge, profound empirical study regarding the composition of competences for IEM professionals are still missing.
This paper presents preliminary results of the Austrian IEM job profile study 2022. The second chapter provides an overview of the study procedure and chapter three is devoted to the descriptive results. In the final chapter, conclusions are derived in addition to a summary.

2. METHODS

The methods of this paper will be briefly described in the next paragraphs. In gerneal, a standardized research methodogly based on validated measurement instruments are most commonly used in quantitative social research to statistically examine samples that are as representative as possible. The epistemological interest of this paper follows Karl Popper´s critical rationalism as a scientific theoretical approach. In this regard, critical rationalism as an experiential theory builds on theories and follows a systematic research design for collecting and analyzing empirical data (Albert 2011). Therefore, Döring and Bortz (Döring und Bortz 2016) follow a commonly used nine-phase model for empirical quantitative research, which structures the research process in quantitative empirical studies (see also (Bryman 2008; Neumann 2003). The sequential process is shown in Figure 1. and briefly described below.

Figure 1: Research Process(Döring und Bortz 2016)

Steps 1 and 2 are already included in the introduction section of this paper. The results of this paper are based on the outcomes of the recent job profile study of the Austrian Association of Industrial Engineers (WING). WING conducts a job profile study every four years to analyze trends and advancements in the techno-economic field. The study aims to provide transparent information about educational content, training opportunities, and potential career paths in the industry. The study was conducted under the supervision of the Institute of Business Economics and Industrial Sociology at Graz University of Technology. To ensure comparability, previous studies from 2014 and 2018 were used as a framework, and contemporary theories and questions were incorporated into the questionnaire. Different questionnaires were designed for IEM students, professionals, and human resource managers, containing a total of 163 questions for students and professionals and 42 questions for HR managers. Feedback from 30 IEM students and professionals was collected during the pretest phase to refine the questionnaires. A second internal pretest was conducted at TU Graz. The final questionnaire aims to describe the characteristics of prospective and practicing industrial engineers.
In the process of operationalization, theoretical concepts were defined and developed before data collection, following a deductive approach. The scientific theory of critical rationalism guided this process,

which aimed to gather individual characteristics of social reality without claiming to be exhaustive. The questionnaire for students and graduates covered seven categories: demographic data, education, career entry and path, further education, IEM competences, digitalization, and services provided by the WING association.

The job profile study utilized a random sample survey methodology. The construction of the sample varied depending on the target group. For students, the sample was determined by analyzing secondary data on training programs at Austrian tertiary educational institutions. Alumni were recruited through alumni networks of educational institutions and the WING member network. Personal contact with university interfaces, such as alumni networks, institute secretariats, and professors, was used to reach out to alumni. Additionally, the study and survey invitation were actively promoted within the WING network and at networking events. In summary, the survey was sent to a total of 9,758 persons (N) (7,478 IEM students and 2,280 IEM professionals), while 1,219 persons (803 fully completed) completed the survey, so the response rate is 12.5%.

The fully structured study involved personal contact with the relevant multipliers, such as alumni networks or secretariats, before the survey. The questionnaire was programmed using the LimeSurvey tool and made available online for participants to complete. An initial invitation E-mail containing the survey links was sent out at the beginning of the study. The questionnaire remained active for four weeks. After two weeks, a reminder was sent to all recipients, requesting them to forward the questionnaire to others.

The LimeSurvey program used in the study provided various analysis options within the program itself. Additionally, the data sets could be directly exported as SPSS-compatible files. The questionnaire was programmed with careful consideration of answer scales and sub-questions, allowing for easy transfer of data into the statistical program IBM SPSS Statistics v.26. Data quality was ensured by addressing criteria such as completeness, uniformity, exclusion of duplicate values, proper treatment of missing values, and plausibility of response patterns, as outlined by Schendera (Schendera 2007). Data cleaning and recoding of reverse-coded items were performed in the final step of the analysis.

Exemplary descriptive results of the survey for the IEM students and professionals will be presented in more detail in the following chapter.

3. RESULTS

This section will briefly describe selected results of the IEM students and alumni job profile study. To begin, the demographic results of the survey will be described, followed by the results on IEM competences.

3.1 Demographic Data

Ratio IEM students and professionals and academic degree. Of the 803 completed questionnaires of IEM students and professionals, 340 questionnaires were completed by IEM students (42.34%) and 57.66% or 463 questionnaires were completed by IEM professionals. Figure 2 shows an overview of the academic degrees of the 463 IEM professionals. The majority, a total of 361, of the respondents have a master's degree or a diploma in engineering, which is equivalent to a master's degree. 56 people have a Ph.D. and 135 have a bachelor's degree.

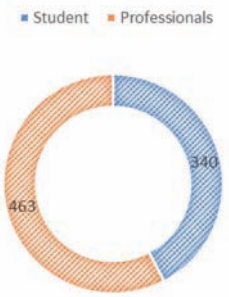

Figure 1: Ratio IEM students and professionals

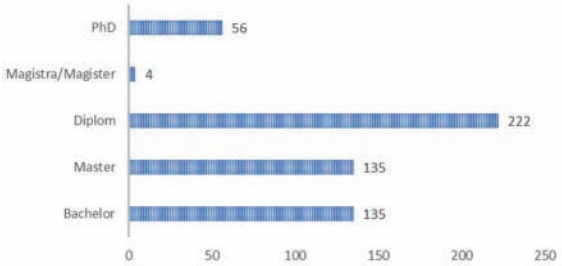

Figure 2: Academic degree

Age and years of experience. The age distribution of the completed questionnaires has a mean value of 33.29 years. The ages were divided into a total of six categories, with, for example, the first category comprising the age up to 30 years. A total of 488 people could be assigned to this first age category, followed by the second category up to 40 years with 112 responses. In addition, participants were asked

how many years of professional experience they had both in the IEM discipline and overall in their professional careers to date. The mean number of years of professional experience in the IEM discipline is 10.79. The mean total number of years of professional experience is 15.06, which could be attributed to the fact that survey participants did not work in any IEM industry-specific fields before or during their studies.

Industry Branch and Job Profile. Graphs 4 and 5 below show the distribution of industries and current job profiles from the target group. As already described in the introduction, the occupational field of an IEM is very diverse and by combining the teaching of technical and economic subjects, graduates have the opportunity to work in different industries and occupational positions. The definition of industries was taken from the nomenclature of the ÖNACE classification. However, as can be seen from the graphs, there are very clear trends in terms of industries. Most people, with a total of 109 responses, work in the manufacturing sector, followed by 39 or 11.47% in the education sector. 34 responses were in the construction sector. In each case, 0.29% (1 indication) were given for the areas "accomodation and food service activities", "arts, entertainment, and recreation", and "water supply/sewerage, waste management, and remediation activities". In terms of job profiles, there is a clear trend toward project management, with a total of 177 responses, followed by research and development/laboratory/Innovation with 155 responses.

Figure 3: Industry branch

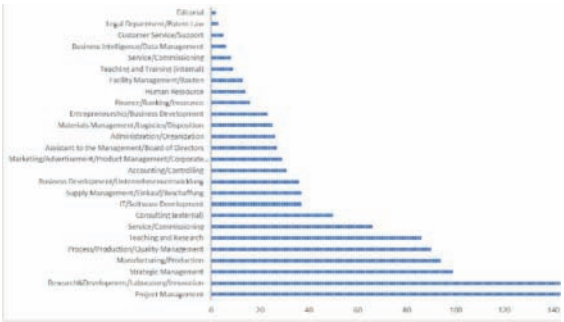

Figure 4: Job profile

3.2 IEM Competence

The survey participants were asked what the ideal ratio of professional, methodological, and social competence would be in their respective functional areas. Professional competence is the ability to combine, deepen and critically examine subject-related and interdisciplinary knowledge and to apply it in contexts of action (Erpenbeck et al. 2017). Methodological competence comprises the interdisciplinary ability to apply working techniques, procedures, analysis techniques, and learning strategies. The term social competence subsumes interpersonal and intrapersonal competence. Interpersonal competence is the ability to cope with tasks that arise when dealing with people. Intrapersonal competence includes knowledge about one's person, i.e. personality-related skills (Erpenbeck et al. 2017; Frey und Balzer 2017; wba 2019a, 2019b). Solving interdisciplinary problems successfully requires a combination of solid theoretical knowledge, methods, and personal skills. Both the Austrian and German competence profiles recognize the importance of technical, methodological, and social competences, although they may differ in their specific forms (Abawi 2019; Bauer et al. 2022). The results of the respective mean values of the three aspects of competence are shown below in Figure 6.

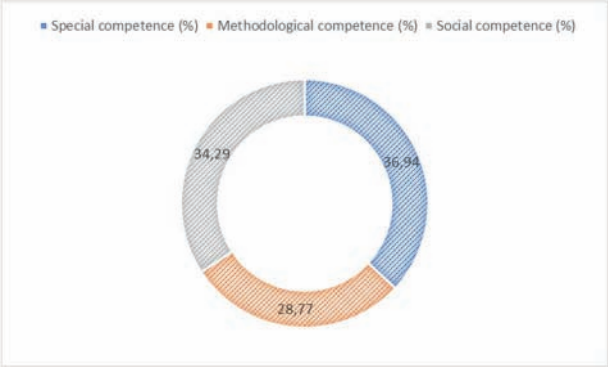

Figure 5: Overview of IEM competences

As the graph makes clear, the three areas of competence are similar in percentage terms, although a trend is discernible. Thus, professional competence seems to be most required for coping with professional demands at 36.94%, followed by social competence at 34.29%. With 28.77%, methodological competence is behind technical and social competence in percentage terms.

In addition to the question about the relationship between technical, social, and methodological competence, the most frequently required foreign language skills as defined as one of the key competences by the OECD (OECD 2005, 2007), were also queried based on a multiple selection. As can be seen in Figure 7, English is by far the most frequently required foreign language with a total of 324 mentions, followed by French with 28, Italian with 27, and Spanish with 24 mentions.

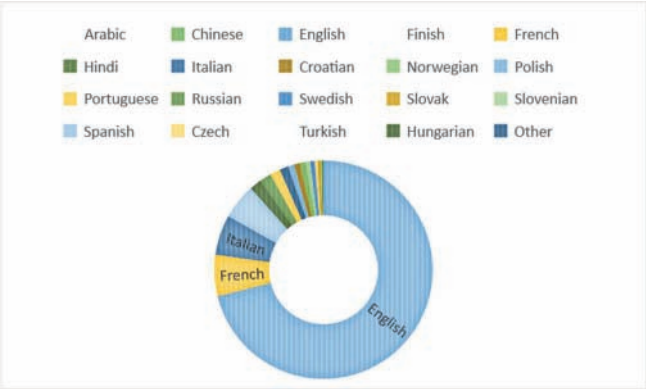

Figure 6: Foreign languages needed

4. SUMMARY AND CONCLUSIONS

The purpose of the 2022 job profile study is to survey current developments in the field on the one hand, and the needs and expectations of IEM students and IEM professionals on the other. This paper provided exemplary basic information on current and future conditions for IEM (future) professionals in the IEM fields and the current challenges faced by the OM discipline. Moreover, the results serve as a first baseline with implications for the realignment of an evidence-based competence framework for IEM and will help to prepare today the M-shaped engineers needed for tomorrow. Therefore, to ensure the quality, systematic growth, competitiveness, and employability of future engineers, it is crucial to establish universally applicable competences across the field of IEM. This requires collaborative efforts across disciplines to create evidence-based competence profiles (Rolf 2020). Based on the results of this study and other recent research achievements of the authors in this discipline, a complete competence profile of (future) IEM professionals will be developed. This competence profile is composed of the competence areas professional, digital, innovation competence, and transversal competences. The latter is in turn divided into interpersonal, intrapersonal, and methodological competences. The respective characteristics of the competence areas are to be a component of further investigations.

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FINTECH AND TRADITIONAL BANKS: FRIENDS OR FOES?

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Abstract: *Rapid development of technology is influencing all sectors of the economy. FinTech is a term that encompasses all technology used to enhance, hasten, and automate financial processes for all included. FinTech companies experienced twentyfold growth in the past 10 years, where two years topped above 200bn USD in yearly investments, being one of the fastest growing hybrid sectors in developed countries. The banking sector, on the other hand, is also experiencing growth, albeit at a much slower pace. Banks, however, are implementing FinTech solutions at an increased rate, using both internal sources and external FinTech solutions to propel their growth.*

With obvious differences between new FinTech companies and traditional banking sector, the question arises: does growth in FinTech inhibit growth of traditional banking sector, or are two sectors codependent?

Key words: FinTech, Banking

1. INTRODUCTION

Traditional banking has been stapled of humanity's progress since its inception in the Middle Ages. Banks have been leading financial intermediaries, especially for transferring financial resources from individuals to other individuals or businesses. For decades they went unchallenged, often being at the forefront of each financial revolution. Only regulators or certain market events could have a stronger negative influence on banks (of course, their own bad business mistakes as well). And up until now, their position in the hierarchy of financial institutions was never in doubt. However, in the past two decades, other, specialized companies started to emerge, which often tapped into one or more functions of a bank. Collectively, these companies are known as FinTech.

Broadly, FinTech is an umbrella term for innovative technology-enabled financial services and the business models that accompany those services. In simpler terms, FinTech can be used to describe any innovation that relates to how businesses seek to improve the process, delivery, and use of financial services (Mention, 2019). From the beginning in the '70s, traditional banks were the ones who were first to implement IT solutions in order to optimize their processes, most notably to improve operational efficiency through better data processing, introduction of ATMs and electronic processing of payments, and, at the end of the 20th century, the introduction of on-line banking. From the beginning of 21st century, different companies sprung up that started to compete with traditional banks, offering services that were directly competing with services offered by the traditional banks, or offering new services previously not offered by traditional banks. Today, innovations in FinTech can mostly be briefly summarized as "ABCD," a well-known acronym in which "A" stands for artificial intelligence (AI), "B" for blockchain, "C" for cloud computing, and "D" for Big Data (Chen, 2020). New technologies have potential to cause market disruptions, but competition is socially beneficial (Vives, 2019).

To keep their position as a staple of the financial sector, traditional banks are either collaborating with FinTech companies or making in-house solutions to answer new challenges that are put in front of them. The long-standing dominance of leading firms that are not able to figure out how to effectively hook up with the "Fintech Revolution" is at stake (Gomber et al, 2018). Different FinTech companies cover different aspects of financial businesses, such as, but not limited to: lending, transactions, personal finance and wealth management, regulations, accounting and corporate software etc. While some FinTech solutions could be disruptive to traditional banking, other solutions complement traditional banking processes and enhance them through better and/or faster execution, lower transaction costs and overall better user experience.

PayTech solutions encompasses a wide range of solutions that are both complementary and disruptive to traditional banking methods. Some of the PayTech technologies are:

- Mobile payments – use of mobile devices to initiate and complete transactions by using NFC or QR codes.
- Contactless Payments - similar to mobile payments. Payments without physical contact, using RFID or NFC technology.
- Peer-to-peer payments – money transfers between individuals without the involvement of traditional banking intermediaries, instead facilitated through online platforms or mobile apps.
- Blockchain based payments – transfers using distributed ledger technology to facilitate secure and transparent peer-to-peer transactions.
- Payment Gateways – systems that facilitate secure transfers of information between customers, financial institutions, and traders.
- Digital Wallets – Electronic platforms that store payment card information to allow users to make digital purchases.

PayTech is to some point involved in interest generated revenue, which is still the most important source of revenue for traditional banks. However, most PayTech companies either compete with traditional banks in the money-transfer segment or facilitate transactions from one bank account to another, boosting their revenues from transaction fees. We wanted to see does the change in revenue generated by largest PayTech companies somehow reflected on the non-interest revenue generated by the top US banks.

2. DATA AND METHODS

To test whether PayTech companies have positive or negative (or any) influence on the traditional banking sector, the authors compared growth rates of revenue in the past 5 years of four largest PayTech and money-transfer companies and growth of non-interest revenue of four largest banks based in the United States. Also, we tested for correlation by using Pearson's test, although we acknowledge the problems of small data-sample and possible non-normality. To somewhat mitigate those problems, we also used Spearman's rank coefficient to further test the correlation.

Traditional banks that we used in our research were JPMorgan&Co, Bank of America, Citibank and Wells Fargo. Their non-interest revenue from years 2018-2022 can be seen in Table 1, with Table 2. showing Year-over-Year revenue growth.

Table 1: Non-interest revenue for 4 largest US banks for 2018-2022 (in $ million)

	2018	2019	2020	2021	2022
JPMorgan&Co.	$ 53,724	$ 58,154	$ 65,388	$ 69,338	$ 61,985
Bank of America	$ 42,858	$ 42,353	$ 42,168	$ 46,179	$ 42,488
Citi Bank	$ 26,292	$ 26,939	$ 30,750	$ 29,390	$ 26,670
Wells Fargo	$ 36,413	$ 37,832	$ 34,308	$ 42,713	$ 28,835
Total	$ 159,287	$ 165,278	$ 172,614	$ 187,620	$ 159,978

Table 2: YoY revenue growth for 4 largest US banks for 2018-2022

	2019	2020	2021	2022
JPMorgan&Co.	8.25%	12.44%	6.04%	-10.60%
Bank of America	-1.18%	-0.44%	9.51%	-7.99%
Citi Bank	2.46%	14.15%	-4.42%	-9.25%
Wells Fargo	3.90%	-9.31%	24.50%	-32.49%
Total	3,76%	4,44%	8,69%	-14.73%

In total, it can be observed that there was growth in non-interest revenue in each year except 2022, where the whole sector experienced a sharp decline. Also, while some banks have quite small non-interest revenue changes from year to year, for other banks those changes were more severe, such in the case of Wells Fargo bank.

On the opposite side, we have the 4 most well-known PayTech companies that are mostly dealing with money transfer functions. Those companies are:

- PayPal – Largest PayTech company by revenue, based in the USA. It is one of the oldest FinTech companies, having been founded in 1998, it went public as early as 2002, being constituent of NASDAQ -100 as well as S&P 100 indices. In 2022, it was ranked as 143rd largest US corporation by revenue (Fortune, 2022).
- Stripe – Largest privately owned PayTech (beside other services) company by valuation, headquartered in USA and Ireland. Founded in 2009, with seed investors including Elon Musk and Peter Thiel, one of PayPal founders.
- Wise – One of the largest public FinTech companies in Europe and largest on-line money transfer company in Europe, founded in 2011 and listed on the London Stock Exchange.
- Payoneer – US money transfer and PayTech company founded in 2005, listed on NASDAQ and constituent of S&P 600 index.

Revenue for sample PayTech companies can be seen in Table 3.

Table 3: Revenue for 4 sample PayTech companies for 2018-2022 (in $ million)

	2018	2019	2020	2021	2022
PayPal	$ 15,451	$ 17,772	$ 21,454	$ 25,371	$ 27,518
Stripe	$ 1,500	$ 2,000	$ 7,400	$ 12,000	$ 14,000
Wise	$ 157	$ 228	$ 389	$ 584	$ 709
Payoneer	$ 260	$ 318	$ 346	$ 473	$ 628
Total	$ 17,368	$ 20,318	$ 29,589	$ 38,428	$ 42,855

Table 4: YoY revenue growth for 4 largest US banks for 2018-2022

	2019	2020	2021	2022
PayPal	15.02%	20.72%	18.26%	8.46%
Stripe	33.33%	270.00%	62.16%	16.67%
Wise	45.22%	70.61%	50.13%	21.40%
Payoneer	22.31%	8.81%	36.71%	32.77%
Total	16.99%	45.63%	23.00%	11.52%

From Table 4. can be seen that all sample PayTech companies posted revenue growth, even in year 2022, in contrast to traditional banks.

3. RESULTS

Figure 1. shows Year-over-Year revenue growth, showing, on average, constantly higher revenue growth than the non-interest revenue of the big 4 of US traditional banks. The only cases where single sample PayTech companies didn't post higher revenue growth compared to traditional banks were in 2020 (Payoneer revenue growth was lower than JPMorgan&Co. and Citibank) and 2021 (PayPal had lower revenue growth than JPMorgan&Co.)

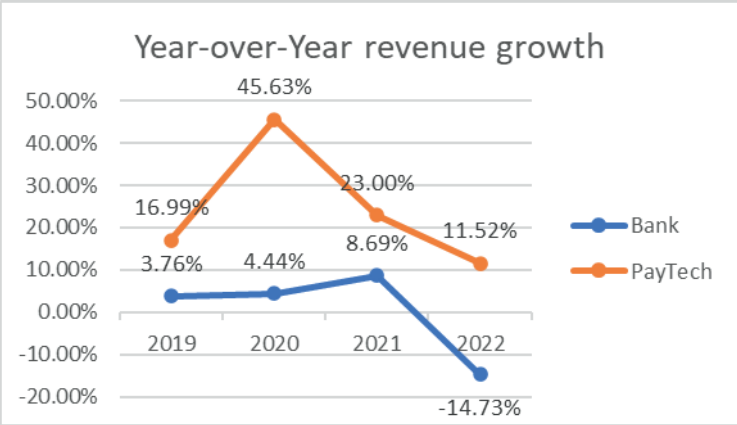

Figure 1: Year-over-Year revenue growth for Banks and PayTech companies

Pearson's r test returns the value of 0.522, which shows positive correlation between non-interest bank and PayTech revenue growth. However, due to the small sample size, it fails to prove significane at any meaningful level.
Spearman's rank coefficient shows even higher correlation of 0.8, with better *p*-statistics, however it is still not strong enough to verify the results.

4. DISCUSSION

Although both Pearson's r test and Spearman's rank coefficient test show strong correlation, the power of both test results are not significant. Those results show that it is possible that traditional banks profit from the PayTech emergence and that PayTech companies are not necessarily substitutes for traditional banks operations, but work in unison as well.
The YoY revenue growth shows prevalence of PayTech companies in previous years, but it is possible that some of their growth is coming from transactions in which traditional banks are also included. Considering current financial laws, traditional banks are still staple of financial sector, but it seems that they can keep their positions only if they aggressively follow current trends and work closely with FinTech institutions and companies in delivering better customer experience. On the other hand, although FinTech is growing faster than the traditional financial sector, it still relies on traditional banks. One reason for that could be the sense of security that traditional financial institutions offer, due to the regulations imposed on them by market regulators and the lawmakers. FinTech companies, although evermore present, and with increased scrutiny given to them by regulators, are still not perceived as safe as traditional banks, ushering in the need for cooperation between FinTech companies and traditional banks.

5. CONCLUSION

At the beginning, we gave a brief overview of FinTech influence on traditional banking and the course of development of FinTech. PayTech, as a part of FinTech industry, was thoroughly explained and given its role in the current financial industry, was prioritized in this research.
This paper showed that, although PayTech has significantly larger YoY revenue growth when compared to the non-interest growth of the traditional companies, the movement of and magnitude of that growth is correlated. Although the significance of both Pearson's and Spearman's rank test were lower than required, we can see that there is a strong possibility that PayTech and traditional banks do influence each other. We can't rule out the market influences on both banks and PayTech companies, however the current financial regulators work in favor of cooperation between two groups of financial companies. As the time goes, the correlation results will be stronger as PayTech companies, most of them new on the market, will gain enough track record for tests to have lower p-value and, thus, strong significance.

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SUSTAINABILITY EDUCATION IN THE FIELD OF INDUSTRIAL ENGINEERING AND MANAGEMENT: THEORETICAL CONCEPTS AND PRACTICAL APPLICATIONS

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Abstract: *Sustainability has become an increasingly critical consideration in the field of industrial engineers and management (IEM) professionals. As companies face growing pressure to balance profitability with environmental and social responsibility, the need for higher education institutions (HEIs) to incorporate sustainability principles into their curriculums has become evident. Teaching sustainability in business economics provides students with a comprehensive understanding of the environmental and social impacts of business activities. By emphasizing the interconnectedness between business decisions and sustainable outcomes, students gain a broader perspective on the long-term consequences of their actions. They become equipped with the knowledge and tools to make informed choices that promote environmental control, social equity, and economic prosperity. One of the main challenges in teaching sustainability lies in bridging the gap between theoretical concepts and practical application. To address this, educators can adopt experiential learning methods such as case studies, simulations, and real-world projects. These approaches enable students to analyze real-life business scenarios and devise sustainable strategies. By engaging in hands-on activities, students develop critical thinking skills, problem-solving abilities, and a deep appreciation for the complexities of sustainable business practices. Results will focus on following key approaches of teaching sustainability in the field of IEM: sustainable business models und sustainable finance*

Key words: Industrial Engineering and Management, Engineering Education, Competence Profile, Sustainability, Teaching Concepts

1. INTRODUCTION

In the past decade, sustainability has emerged as a central theme at higher education institutions (HEIs), accompanied by the belief that education could play a pivotal role in driving sustainable development (SD) strategies. As a result, the United Nations' decade of education for SD emphasized the integration of sustainable development theory and practices into educational frameworks. These initiatives have sparked a transformative shift in the education landscape, giving rise to the paradigm of education for SD (Stein, 2019; Yli-Panula et al., 2020; Buckler & Creech, 2014).

Most importantly, education for SD empowers students to gain direct experiences with sustainability through innovative learning approaches. By engaging with this framework, students can directly witness the impact of sustainable practices, fostering a deeper understanding of the importance of sustainability in their lives and broader society. Through education for SD, HEIs play a crucial role in nurturing environmentally conscious and socially responsible individuals who are equipped to address the pressing challenges of our time (Kishita et al., 2018; Bedawy, 2014).

Furthermore, there has been a notable surge in government policies, academic initiatives, corporate engagement, and public interest aimed at advancing the journey towards sustainability. This growing momentum underscores the collective recognition of the urgent need to preserve the environment, utilize resources prudently, and create value for society, all while ensuring long-term economic competitiveness. These focal points encapsulate the essence of sustainability as a well-defined concept, addressing the multifaceted challenges of our times (Lynch, 2019; Behnam et al., 2018).

Recognizing the urgency, it becomes crucial to comprehend the driving forces behind this necessary transformation. The transformation towards sustainability within higher education requires a multifaceted approach. A willingness to embrace sustainability among programme directors, coupled with supportive regulations, standards, and faculty commitment, will collectively drive change within HEIs. (Barth, 2015; Weiss & Barth, 2019).

Previous research highlighted the lack of integration of SD aspects into higher level operations management (OM) education (Fredriksson & Persson, 2011). Furthermore, OM is recognised as one of the fundamental fields in engineering education, especially for supporting SD, since it combines design, operation, improvement and transformation of input resources into output products and services (Fredriksson & Persson, 2011). Recently, a lack of studies focusing on the OM and SD integration in engineering education has been identified, especially in the context of didactic practices (Rampasso et al., 2019). It is necessary that SD fundamentals are integrated into engineering field, especially into engineering education (Frederiksson & Persson, 2011). For this reason, certain improvements in engineering education are needed, to motivate students to rethink their future professional roles and to recognise the necessity for creating value for all stakeholders, while providing a safe, healthy and quality workplace (Frederiksson & Persson, 2011). Necessary improvements in engineering education call for a variety of complex and transdisciplinary adaptations based on evidence-based competence profiles to contribute to the safety, health, and welfare of the public (Rampasso et al., 2020; European Commission, 2019). Integrating sustainability into the curriculum of IEM at HEIs is crucial in preparing future professionals to address the challenges of global environmental and social issues.
Based on the above statements this paper aims to narrow the scope and answer the following research question: What are theoretical concepts and practical implications to teach sustainability in the context of business economics at higher education institutions?

2. METHOD

According to Omazic et al. (2022), to tackle the complexities posed by contemporary challenges of sustainability education in the field of industrial engineering and management a pioneering initiative known as a "Sustainability Business Economics Lab" (SBEL) was implemented. The primary objective of this innovative lab is to cultivate sustainability competences among students specializing in the field of IEM. By integrating sustainability skills with their technical and economic expertise, the lab empowers students to approach problems in the area of techno-economics with a critical, analytical, and sustainable mindset. The SBEL is designed as a competence-based platform that goes beyond traditional classroom learning. It provides IEM students with hands-on experiences and practical scenarios to apply sustainability principles to real-world industrial challenges. By engaging in this dynamic learning environment, students gain the skills and knowledge needed to make informed and sustainable decisions in their future professional endeavors (Omazic et al., 2022).
Through the SBEL, students learn to analyze the socio-economic and environmental dimensions of complex industrial issues. They are encouraged to think holistically, considering the long-term impacts of their decisions on various stakeholders and the environment. By incorporating sustainability into their problem-solving approaches, students develop a heightened awareness of the interconnectedness between economic growth, technological advancement, and environmental stewardship. Furthermore, the lab fosters interdisciplinary collaboration, allowing students to work in teams with diverse backgrounds, sharing their expertise and insights to tackle multifaceted challenges. This collaborative spirit prepares students to thrive in a globalized world, where sustainability challenges often require a collective effort from professionals with different skill sets and perspectives (Omazic et al., 2022).
IEM students emerge as future change-makers and leaders, ready to shape industries in a way that aligns with sustainable development goals and brings about positive transformation in society. In conclusion, the SBEL represents a pioneering educational approach that synergizes sustainability competence with technical and economic skills, empowering IEM students to approach challenges critically, analytically, and sustainable. This transformative learning experience equips students with the tools they need to contribute meaningfully to the advancement of techno-economics while maintaining a steadfast commitment to environmental and social sustainability. As depicted in figure 1, the modules (phases) of the SBEL have been carefully crafted, drawing inspiration from the three commonly employed models of collaborative learning in engineering courses: classroom-based, laboratory-based, and project-based modules (Schnak, 1996; Rodriguez-Sanchez, 2020).

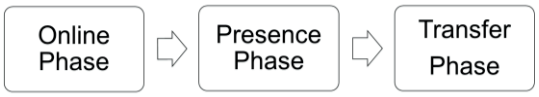

Figure 1: SBEL Methodology (Omazic et al., 2022)

The three phases of the SBEL of Omazic et al., 2022 are summarized and briefly described below.
The primary objective of the online phase is to equip students with a comprehensive understanding of sustainability within the context of business economics. This phase commences with a kick-off meeting, where the instructor outlines the learning and teaching concept, sets the goals, explains the assessment methods, establishes the sequence of events, and introduces useful tools to enhance the learning experience. As a crucial step in gauging students' current level of sustainability competence, a survey is conducted during the online phase. This survey draws upon the wealth of knowledge present in scientific literature concerning the cultivation of sustainability competence in education. Through this assessment, the online phase aims to gauge students' proficiency in specific sub-competencies related to sustainability (Omazic et al., 2022).
During the presence phase, students take on the roles of experts as they deliver their presentations on the generic introduction to sustainability in the context of business economics. This interactive phase allows for in-depth discussions and knowledge-sharing among peers, fostering a deeper understanding of sustainability concepts. Students are organized into small and homogeneous teams to collaboratively work on case studies provided by the instructor. This team-based approach encourages effective communication and collaborative problem-solving. (Omazic et al., 2022).
In the transfer phase, students review and update their initial survey on sustainability competence. They provide comments on changes and improvements experienced during the SBEL. This feedback helps observe individual learning pathways and refine the course content and teaching methods. An anonymous feedback session on the last day further ensures continuous quality assurance (Omazic et al., 2022).
The methodological approach of this paper is centered on competence-based education and training. It follows a modularized program architecture and utilizes digital teaching and learning formats within the area of sustainable business economics. Therefore, literature based theoretical concepts and practical implications will be introduced witch focus on the presence phase for the SBEL. For this purpose, different topics in the areas of sustainable education were evaluated in scientific publications. Care was taken to ensure that the subject areas can be used for the presence phase. The search query was performed in google scholar.

3. RESULTS

The results show a various sustainable practices and strategies in the design and optimization for sustainable education. In this context, the results will focus on following key approaches of teaching sustainability in the field of industrial engineering and management: sustainable business models und sustainable finance.

3.1 Sustainable business models

Teaching sustainable business models involves educating students about innovative and responsible approaches to conducting business that prioritize environmental, social, and economic sustainability. This type of education aims to equip future IEMs with the knowledge and skills needed to lead organizations towards a more sustainable future (Williamsson et al., 2022; Stadtlaender et al., 2021).
The first step is to provide students with a comprehensive understanding of sustainability principles and their significance in the business context. This includes exploring concepts like the triple bottom line, circular economy, social impact, and stakeholder engagement. A next step is Integrating real-world case studies and best practices to demonstrate the successful implementation of sustainable business models. By analyzing companies that have effectively integrated sustainability into their strategies, students can gain insights into practical applications and potential challenges. Teaching sustainable business models often involves adopting a systems thinking approach. Students learn to view businesses as part of a larger interconnected system, understanding the broader impacts of their decisions and actions on society and the environment (Karlusch et al., 2018; Williamsson et al., 2022; Stadtlaender et al., 2021; Geissdoerfer et al., 2018).
Encouraging collaborative learning fosters peer-to-peer discussions, idea sharing, and problem-solving. Group projects and activities allow students to work together to develop innovative and sustainable business solutions. Practical workshops and simulations allow students to engage in hands-on activities, such as designing sustainable business plans, conducting environmental impact assessments, or analyzing

sustainability reports. Teaching sustainable business models also involves exploring ethical considerations and responsible decision-making. Students learn to navigate complex ethical dilemmas and make choices that align with sustainability values. Encouraging students to explore and develop sustainable innovation ideas nurtures creativity and entrepreneurship thinking. This involves thinking outside the box to create products, services, and business models that contribute positively to society and the environment. As sustainability practices evolve, it is essential to emphasize the importance of continuous learning and adaptation. Teaching students to stay informed about the latest sustainability trends and practices ensures they remain effective and relevant in their careers. (Omazic et al., 2022; Stadtlaender et al., 2021; Geissdoerfer et al., 2018; Janker & Faber, 2019).

By incorporating these approaches, educators can effectively teach sustainable business models, inspiring the next generation of business leaders to prioritize sustainability and contribute to a more sustainable and resilient global economy.

3.2 Sustainable finance

Teaching sustainable finance in the context of business administration for IEM focuses on integrating environmental, social, and governance (ESG) factors into financial decision-making. Students can explore concepts like impact investing, green bonds, and socially responsible investing (SRI). They can learn how financial institutions can use their influence to direct capital towards sustainable projects and environmentally friendly initiatives. Following key aspects and approaches to teach sustainable finance should be considered (Poyser & Daugaard, 2023; Annand, 2015).

Educators introduce students to the concept of ESG integration, which involves assessing companies' environmental, social, and governance performance alongside financial data. Students learn to identify ESG risks and opportunities and understand how these factors can impact a company's financial performance and long-term sustainability. A next step is Impact investing. This is an essential aspect of sustainable finance, where investments are made in companies or projects that aim to generate positive social or environmental impacts while also achieving financial returns. Students explore different impact investing strategies and evaluate real-world impact investment opportunities (Belinga & Morsing, 2020; Ziolo, 2020).

Furthermore, sustainable finance involves exploring investment vehicles such as green bonds and sustainable funds. Students learn how green bonds raise funds for environmental projects, and how sustainable funds invest in companies with strong ESG performance. Teaching responsible investment strategies involves understanding various approaches like negative screening (excluding certain industries), positive screening (including sustainable industries), and best-in-class selection (investing in companies with leading sustainability practices) (Oulton, 2019; Annand, 2015).

Sustainable finance considers not only financial risks but also non-financial risks related to ESG factors. Students should learn how to incorporate sustainability risks into risk management practices and investment decision-making. A following aspect is corporate sustainability reporting. Understanding corporate sustainability reporting and the disclosure of ESG-related information is crucial for sustainable finance. Students analyze sustainability reports to evaluate a company's commitment to sustainability and its potential impact on investment decisions. Furthermore, sustainable finance involves engaging with various stakeholders, including investors, companies, regulators, and NGOs. Students explore the importance of stakeholder engagement in promoting sustainable finance practices and influencing corporate behavior. Sustainable finance also encompasses ethical considerations (Poyser & Daugaard, 2023; Annand, 2015; Oulton, 2019).

By offering a comprehensive curriculum that covers these aspects, educators can equip students with the knowledge and skills needed to navigate the evolving landscape of sustainable finance and contribute to building a more sustainable and socially responsible financial system.

4. CONCLUSIONS

This paper emphasizes the critical need for an educational offensive on sustainable development, given the growing legal regulations and resource demands that impact prosperity and peace. The Sustainable Business Economics Lab of Omazic et al., 2022 presented a showcases of an innovative teaching method and a modular program structure, offering a blueprint for future IEM education. Teaching sustainable business models involves instilling innovative and responsible practices prioritizing environmental, social, and economic sustainability. Equipping future IEMs with such knowledge and skills is essential for leading

organizations towards a more sustainable future. Similarly, teaching sustainable finance in business administration for IEMs integrates ESG factors into financial decision-making, exploring impact investing and environmentally friendly initiatives. This ensures students comprehend how finance can direct capital towards sustainable projects. Both approaches sustainable business models and sustainable finance contribute to fostering environmentally conscious and socially responsible professionals.

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SOURCES OF FUNDING ACADEMIC ENGAGEMENT: EMPIRICAL RESEARCH OF UNIVERSITY OF NOVI SAD AND UNIVERSITY OF BELGRADE

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Abstract: *The research paper analyzes the various funding sources available to support academic engagement activities among scholars in the Republic of Serbia. The study focused on the two largest and most influential universities, the University of Novi Sad (UNS) and the University of Belgrade (UB). A questionnaire was sent to 3,163 scholars, and 184 respondents' answers were analyzed to compare funding sources. These sources included government grants, foreign (EU) grants, university resources, own resources, private market capital, and venture capital. The study tested for statistically significant differences in funding sources between the two universities and found a significant difference in relation to two sources: own resources and venture capital. The University of Novi Sad had a significant advantage in attracting venture capital. Overall, the study shows that researchers at the two universities use slightly different funding sources to support academic engagement activities.*

Keywords: sources of funding academic engagement, government grants, foreign (EU) grants, university resources, own resources, private market capital, venture capital

1. INTRODUCTION

The knowledge economy emphasizes the importance of knowledge as a strategic resource in the global economy, and learning as a crucial competitive activity. While the terms knowledge economy and learning economy are often used interchangeably, the former is more commonly used by OECD countries and American authors, with traces of the latter found among Nordic authors. High-tech companies have been associated with innovative and knowledge-intensive activities, particularly in the information and communication sector. Research and development (R&D) activities are closely linked to knowledge acquisition and innovation, which provide a clear competitive advantage in the global economy. The approach to innovation depends on whether the economy is defined as knowledge-based or learning-based. The learning economy sees innovation as a socially and territorially embedded, culturally and institutionally shaped interactive learning process.(Lundvall and Borras, 1998).

Each university operates uniquely in accordance with its surrounding environment. In addition to their fundamental roles of educating and conducting research, universities also have a responsibility to enhance the progress of the economy, society, and culture of the region they are located in.(Cirella and Murphy, 2022). Modern universities have a multifaceted role.(Thomas and Pugh, 2020) and encompasses teaching, research, and entrepreneurship functions (Audretsch, 2014). Many universities are transforming by incorporating innovative activities and adopting practices that promote entrepreneurship (Siegel and Wright, 2015). Establishing strong external partnerships with key players in the ecosystem, such as entrepreneurs, universities, local and national governments, and private industries, is crucial for the successful commercialization of research.(Ács, Autio and Szerb, 2014).

The transfer of knowledge from universities and the financial compensation that follows are areas of interest for researchers and policymakers in both developed and developing economies. There is ongoing research being conducted on these mechanisms(Marozau and Guerrero, 2016).

Over the past two decades, there have been changes in the way higher education funding is allocated worldwide. The proportion of public funds has decreased significantly, while private sources such as businesses have increased their share. (Sengupta and Rossi, 2023). Universities have been compelled to rely more on private sources of income due to the decrease in public funding for academic research and education (Muscio, Quaglione and Vallanti, 2013), including income from knowledge exchange (Sengupta and Ray, 2017). Currently, policymakers in developed and emerging economies are urging universities to utilize their intellectual property and prioritize socioeconomic impact in all their pursuits. (Perkmann *et al.*, 2021). In light of external challenges, universities have strategically adapted their approach to research,

teaching, and knowledge exchange to make the most of their competitive advantages. The response has been thoughtful and deliberate (Horner *et al.*, 2019).

2. SOURCES OF FUNDING ACADEMIC ENGAGEMENT

In modern society, universities hold a unique position as key knowledge generators. With the addition of a third mission - technological transfer - it has become crucial to assess their contribution to economic growth. The investigation of transforming academic knowledge into commercial products - such as patenting, licensing inventions, and academic entrepreneurship - has become increasingly crucial for both academia and policymakers.(Di Gregorio and Shane, 2003; Lockett, Wright and Franklin, 2003). Generating academic impact can be exemplified by commercialization, which provides tangible market validation. The academic community's fundamental and crucial contribution to society and the economy is through academic engagement, that encompasses more than commercialization and refers to the transfer of university knowledge through scientific cooperation (Perkmann and Walsh, 2007).

Working together can be defined in various ways, such as conducting research, providing consulting services, or simply connecting with colleagues. Once a collaborative relationship has been established, there may be opportunities for academic entrepreneurship to develop. This can involve commercializing a patent, invention, or area of expertise that is not yet protected (Würmseher, 2017). Commercialization is defined as the pursuit of financial gain through academic engagement. This definition highlights the narrow and precise nature of the term (Petrov, 2022).

The issue with academic engagement is that it is driven primarily by the individual motives of scientists. To establish entrepreneurially oriented universities that can easily collaborate with the economy and innovation systems, it's crucial to motivate university researchers to work on commercializing scientific research.

Many obstacles hinder the commercialization of scientific research, including excessive teaching and administrative duties that leave little time for pursuing commercialization. Additionally, researchers and teachers often perceive commercialization as unimportant to their academic careers and consider it a burdensome waste of time. This mindset reflects a lack of understanding regarding the potential market applications of research and its potential value for society. Furthermore, many fear active involvement in commercialization may impede their academic progress(Van Looy *et al.*, 2004).

The level of engagement in academic activities is influenced by a multitude of factors, including personal preferences, individual attributes, as well as organizational and institutional factors. The presence of a proficient technology transfer office can greatly facilitate the commercialization of university research. Moreover, the organizational culture, accessibility of successful academic startup models, and proximity of business incubators, technology parks, and other supportive institutions all contribute to academic engagement. It is important to note that academic engagement has a significant impact not only on scientific research but also on the teaching outcomes of researchers (Petrov, 2022). As we move into the 21st century, student characteristics and motivations are evolving. Therefore, it is essential to showcase the practicality of the knowledge being imparted. By fostering academic engagement, educators can make their teaching more captivating and relatable, ultimately increasing interest in their subjects, modules, and profiles.

Successful scientists with strong connections and social capital often engage in academic activities at higher levels. These individuals typically hold higher scientific and teaching positions, have many approved grants, and publish numerous scientific papers, making them experts in their fields. This level of engagement has been shown to positively correlate with grant funding and scientific production, demonstrating that academic progress and engagement go hand in hand(Perkmann *et al.*, 2013).

Cities in Serbia that have universities and a strong industrial foundation, namely Belgrade, Novi Sad, and Niš, exhibit a notable presence of academic involvement. Nevertheless, this involvement lacks consistency and primarily relies on personal networks and individual initiatives. Presently, there is no established and organized collaboration between state scientific research institutions and private sectors in the Republic of Serbia. The historical partnership between industries and universities has resulted in a regional clustering of researchers. Studies indicate that the research sector lacks a significant pool of human resources, with the exception of Belgrade and Novi Sad (*Industrial Policy Strategy Of The Republic Of Serbia From 2021 To 2030.*, 2020).

The output of university research can vary depending on the funding source and its priorities. Historically, governments have been the largest funders of such research in most economies. They usually disburse public funds through project grants or contracts with government bodies. Governments also use

competitive mechanisms to allocate funds to institutions, evaluating project proposals and considering the expertise and past performance of researchers during the selection process. Expected performance is a crucial factor in funding decisions. (Jongbloed and Vossensteyn, 2001; Hooi and Wang, 2020).

The purpose of this study is to investigate the funding resources that are available for academic engagement activities for scholars at two esteemed universities in the Republic of Serbia: the University of Belgrade and the University of Novi Sad. The potential for commercialization of these activities can vary, as scientific paper publications typically lack a direct economic connection. Conversely, participation in conferences and lectures may or may not offer compensation (Petrov *et al.*, 2023). The practice of consulting entails leveraging research expertise in a manner that is financially sustainable, thus representing a more sophisticated approach to commercialization. The closest academic engagement activities to commercialization involve selling research products, patent licensing, and creating a spin-off business.

The purpose of this paper is to examine the significant diferences in funding sources for academic activities between respondents from the University of Novi Sad (UNS) and the University of Belgrade (UB).

3. RESEARCH METHODOLOGY

We conducted research using a survey instrument (Belitski, Aginskaja and Marozau, 2019) that had been previously utilized in transitional economies such as Belarus, Kazakhstan, and Azerbaijan. This same instrument was also used in a study conducted in the Republic of Serbia(Petrov *et al.*, 2022).

The instrument is comprised of three sections. The initial section includes essential information about the participants, such as their age, work experience, job title, research area, faculty, and university. The second section consists of inquiries concerning academic progress, particularly the quantity of papers published in both Serbian and international journals during the preceding five years, as well as the level of involvement in academic research (Petrov *et al.*, 2023). Finally, the third section focuses on the sources of funding for academic research activities (Belitski, Aginskaja and Marozau, 2019):

- Government grants;
- Foreign (EU) grants;
- University resources;
- Own resources;
- Private market capital;
- Venture capital business.

The empirical analysis is based on a dataset collected via online survey over the four months from September 2018 to January 2019 in the Republic of Serbia.

3.1 Sample

Our initial focus was on gathering contact information of scholars from the two most prominent universities in the Republic of Serbia. Through their official websites, we discovered 3,163 established scholars. From this pool, we sent out 956 questionnaires and received 266 responses, resulting in a response rate of 27.82%. Unfortunately, we had to reject 41 responses due to incomplete information as the respondents did not mention their university affiliation.

Out of 225 responses that were deemed valid, 115 participants hailed from the University of Novi Sad, while the remaining 110 were from the University of Belgrade. Among the 115 respondents from the University of Novi Sad, 17 individuals (14.78% of UNS respondents) did not disclose any engagement in academic activities. Similarly, 24 respondents (21.82% of UB respondents) from the University of Belgrade also reported the same.

We were left with a subsample of 184 individuals who reported engaging in academic entrepreneurial activity. Figure 1 provides an overview of the respondents' demographic characteristics.

Out of the total number of respondents, the age range of 30 to 39 years had the highest representation with 64 individuals (34.78%). This was followed by 51 respondents (27.79%) between the ages of 50 to 59 years, and 38 individuals (20.65%) aged between 40 to 49 years old. The percentage of the youngest and oldest scholars is lower, with 9.78% and 7.07% respectively.

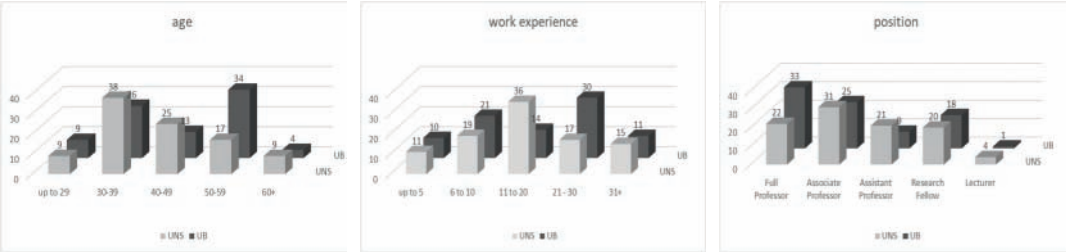

Figure 1: Demographic characteristics of survey respondents from UNS and UB
Source: Authors

Regarding work experience, the majority of respondents had between 11 and 30 years of experience, with 27.17% having between 11 and 20 years and 25.54% having between 21 and 30 years. The remaining groups with 6-10 years, 31+ years, and up to 5 years of work experience were less represented, with 21.74%, 11.41%, and 14.13% respectively.

In our sample, the most common academic title was PhD, with 79.89% of respondents holding this degree. MS and MSc were held by 16.3% and 3.8% of respondents respectively. The majority of respondents held teaching positions, with 29.89% as full professors, 30.43% as associate professors, and 16.30% as assistant professors. Research fellows represented 20.65% of the sample, while lecturers made up 2.72%. You can find a detailed overview of the sample in Figure 1.

4. RESULTS AND DISCUSSION

In this study, we examined the funding sources of academic engagement among employees at the two most important universities in the Republic of Serbia, as well as any potential differences in the types of engagement. To determine whether the sample data had equal variances, we used Levene's test. Table 1 displays the results of the t-test.

Table 1: Results of independent t-test for two samples

Sources of funding academic engagement	t statistics	df	p
Government grants;	-1.382	181.812	.169
Foreign (EU) grants;	.262	182	.794
University resources;	.080	182	.936
Own resources;	2.730	173.118	.007
Private market capital;	-.152	182	.879
Venture capital	2.516	96.000	.014

Source: Authors

It was discovered that there were significant differences between the respondents from the University of Novi Sad and the University of Belgrade regarding the mean values computed for three kinds of academic engagement activities:

- Own resources (t=2.730, df=173.118, p<0.01), and
- Venture capital (t=2.516, df=96.000, p<0.5).

For these two types of sources of funding academic engagement, the variance homogeneity test indicated that equal variance was not assumed (F=21.468, p=0.000 and F=26.013, p=0.000 rrespectively).

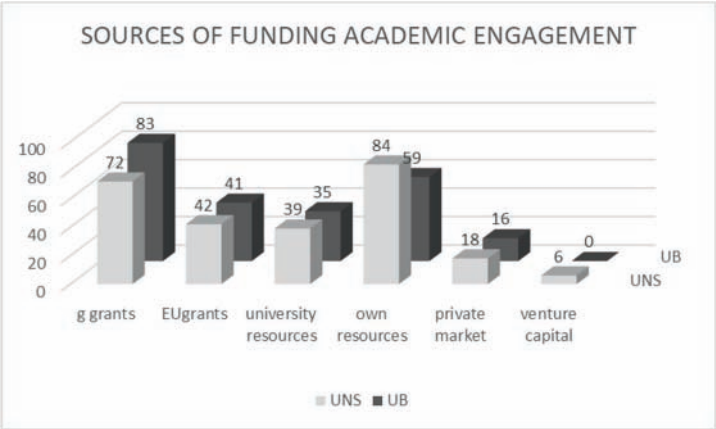

Figure 2: Reported sources of funding academic engagement at UNS and UB (Source: Authors)

Figure 2 presents distribution of frequencies for sources of funding academic engagement activities at University of Novi Sad and University of Belgrade. Government grants and own resources are the most represented sources of funding activities at both universities. For the University of Novi Sad own resources are more commonly used compared to government grants, as opposed to University of Belgrade were opposite holds. Almost evenly represented are foreign (EU) grants and university resources at both universities. From the responses it is evident that money from the private market and venture funds is rarely used, or hardly at all.

5. CONCLUSIONS

The research was conducted at two of the largest and most important universities in Serbia. According to the Academic Ranking of World Universities, the University of Belgrade achieved a ranking within the range of 401-500, while the University of Novi Sad ranked between 901 and 1000.

According to a survey conducted among individuals who engaged in academic activities and studied at the University of Novi Sad, the majority of respondents were Associate Professors aged between 30 and 39, with 11 to 20 years of work experience. Meanwhile, respondents from the University of Belgrade who participated in academic engagement activities were typically Full Professors aged between 50 and 59, with 30 to 39 years of work experience, as depicted in Figure 1.

Based on Table 1, it was discovered that there is a statistically significant difference at the 95% confidence level between the survey participants from the University of Novi Sad and the University of Belgrade in terms of variables: Own resources, and Venture capital. For the variable Own resources, in total 143 respondents reported using own resources, of which 84 were from the University of Novi Sad, while 59 were from the University of Belgrade. For the variable Venture capital in total only 6 respondents from the University of Novi Sad reported using Venture capital, while none of the participants from the University of Belgrade did so.

Apart from the significant statistical differences between the University of Novi Sad and the University of Belgrade, there is also a noticeable dissimilarity concerning the variable of Government grants, as depicted in Figure 2. Though not statistically significant, the disparity implies that researchers from Belgrade's universities tend to rely more on financial aid from the budget of the Republic of Serbia to support their academic initiatives.

As a helpful suggestion for policymakers, we recommend that scientific research is funded to achieve sustainable growth. It is important to balance funding strategies between stimulating innovations in higher education and industry (Le *et al.*, 2022). Additionally, funding schemes should closely link academic research directions with emerging industry and societal issues. For researchers at universities and firms, proactive collaborations for research, technological transfer, and academic knowledge diffusion have proven to be beneficial for research outputs in both types of organizations.

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AN OVERVIEW OF RISK MODELING AND REPRESENTATION IN BUSINESS PROCESS MODELING LANGUAGES

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Abstract: *Business process modeling is important because it allows us to clearly and unambiguously define business processes, to identify the company's operations. It provides formal knowledge about work performance, work standardization, process analysis, and risk detection, leading to process improvement and automation possibilities. This paper focuses on the BPMN (Business Process Modeling Notation) modeling language, which aims to facilitate understanding and usability for all business users, participants, analysts, and software engineers. Before creating the model, it is crucial to determine the modeling goal, as companies encounter unforeseen events that can impact business objectives. Timely identification and assessment of risks, along with consideration of their consequences, are essential to prevent adverse effects. BPMN allows comprehensive process mapping and real-time monitoring to aid in risk identification. By integrating risk management into the process model, proactive identification and mitigation of risks can be achieved, reducing the likelihood of risk occurrence. While BPMN 2.0 lacks risk management constructs, various authors offer suggestions that will be presented in this paper.*

Key words: BPMN, risk, risk management

1. INTRODUCTION

Small errors in business process modeling can have significant consequences. This is because many employees may not be aware of or adequately consider all the potential risks that could lead to major consequences later in the process. Michael zur Muehlen and Michael Rosemann (2005) provide an example in their work where a typographical error in the entry of a date in payroll lists resulted in a series of problems, including unpaid salaries and unmet obligations to employees. The cause was a simple data entry error made by employees, which went unnoticed by other employees working on the same tasks. This happened despite clearly defined salary payment processes and accuracy assurance based on double signatures. No one had recognized the risk of a possible data entry error, leading to errors cascading throughout the entire business process. If the company had been aware of this risk and had managed it properly, these issues could have been avoided.

Identifying process risks, such as data entry errors, is crucial for ensuring business continuity and complying with regulatory requirements, particularly those related to data protection and financial transactions. Compliance with legal standards depends on analyzing the business processes where sensitive information is generated, accessed, or modified.

This paper addresses the importance of business risk management, emphasizing that companies need to be aware of the risks associated with their business processes. Awareness alone is insufficient; companies must develop methodologies for risk management. This can involve minimizing risks or understanding the consequences of risks that cannot be managed differently. One risk management methodology includes collaborating with other companies to reduce shared risks. The paper focuses on developing techniques for process modeling that incorporate the risks associated with the process. In the realm of business process management, risk is a factor that significantly influences process management. While there are many works in the literature on this topic, it's essential to highlight the case study of the Little Rock Music and Arts Festival by Ballou et al. (2000). This study considers risk at the business process level, but it remains at a high level of abstraction, primarily focusing on financial and general business risks while neglecting operational risks. The paper's objective is to present techniques for modeling risk inclusion in business process models, both at the overall process level and at the level of individual activities.

Reijswoud and Hommes (2000) have provided frameworks for defining business process modeling techniques. According to them, each model consists of four essential elements: notation, meaning, connection concept, and modeling concept. Modeling methods inform us about the models used for specific techniques, while working methods describe the procedures employed to build these models. There are three fundamental formats for modeling: horizontal, vertical, and cascade.

Before creating the model itself, it is crucial to determine the modeling goal. When modeling business processes, it is important to choose appropriate techniques and tools, as the modeling process is complex and involves numerous modeling languages, some of which lack detailed instructions. Process maps, which are graphical representations of business processes describing step-by-step procedures, are used for modeling. While these maps provide an overview of the process flow, they are not sufficient for a comprehensive representation. To obtain a detailed view, business process modeling tools are utilized, enabling statistical evaluation of process performance in different scenarios and facilitating design optimizations. These modeling tools also allow resources to be represented, providing insights into potential risks. Analyzing and measuring business processes are essential prerequisites for effective business process modeling. During the analysis, the flow of the process itself, elements, participants, and technological systems are examined to identify and document all processes.

2. RISKS AND BUSINESS PROCESS MODELING LANGUAGES

To discuss risk in the context of a process, it's essential to have a good understanding of the term "business process". Risk management is a highly complex process and presents a significant challenge for organizations in mitigating risks. The process of risk identification enables us to take appropriate mitigation measures when potential risks arise. Risk assessment involves evaluating the impact of risks and their probability of occurrence (Schechtman, 2002). Enterprise Risk Management (ERM) is a form of management that addresses uncertainties in an organization's operations. ERM aims to move away from managing individual risks in isolation and instead adopts a holistic view of risk management (Akram & Pilbeam, 2015; Mensah & Gottwald, 2016). It is important to note that many risks are interconnected, and standard risk management approaches often fail to establish the relationships and correlations between risks.

Business Process Management (BPM) combines a managerial approach with appropriate technology to enhance company performance (Benedict et al., 2013). BPM focuses on the business-oriented aspect of change management to achieve improved business processes and align them with overall business goals.

The need to incorporate risk into business process models has driven the development of risk-aware business process management (R-BPM) (Suriadi et al., 2014). The integration of BPM and ERM has resulted in R-BPM (Thabet, 2018), which aims to effectively identify, detect, and manage process-related risks (Jakoubi et al., 2010). Modeling business processes with risk awareness is a crucial task in the R-BPM life cycle, necessitating the inclusion of risk-related information in business process models.

Various languages exist for modeling business processes, including Event Driven Process Chains (EPC), UML Activity Diagrams, Business Process Model and Notation (BPMN), Petri Nets, among others. Although some of these languages cover different aspects comprehensively, none of them adequately integrate risk and business processes. Efforts are underway to incorporate risk into process models to enable a holistic evaluation of process performance. However, research and practice in risk-aware business process modeling remain limited and require further investigation.

Business process modeling is significant as it allows clear and unambiguous definition of business processes to identify company operations. It provides formalized knowledge about work performance, standardizes work, enables process analysis, facilitates risk detection, and supports process improvement and automation. In a study by Favera et al. (2020), experts expressed the desire for risk management information to be represented in business process models, viewing them as additional means of communication to guide stakeholders in their risk management activities. Experts only care about the complexity of the model, which should be taken into account when integrating risks into modeling languages.

The EPC modeling language partially supports risk modeling, allowing for the identification and linkage of risks to specific process activities within a detailed business process model [Anton 2016]. Additionally, within the same methodology as EPC modeling, it is possible to create separate formal models solely focused on risk, resembling the organizational structure model [Anton, 2016]. In the case of UML activity diagrams, direct support for risk modeling is not provided. However, as UML is not limited to activity diagrams alone, integrations have been developed between UML methodologies and corresponding standards covering information security (Fabien, 2022), as well as software solutions for risk management (Gorecki, 2021).

Business Process Modeling Notation (BPMN) was developed by the Object Management Group (OMG) as a visual representation language for processes in the IT industry. BPMN utilizes elements to construct

business process models. While BPMN underwent significant changes in its 2.0 version released in 2011, it still does not include specific elements related to risk management. The primary objective during the development of BPMN was to ensure its comprehensibility to all business users. Unlike EPC, BPMN does not incorporate graphical symbols or elements explicitly designed for risk expression within process modeling (Dalla Favera et al., 2020).

EPC (Event-driven Process Chain) is a modeling language that represents various enterprise elements and their connections to business processes. EPC shares similarities with BPMN, including functions or activities, events, and exclusive, parallel, and inclusive connectors. However, unlike BPMN, EPC addresses organizational aspects, incorporates data, and includes groups of risk elements (Favera et al., 2020).

According to Sikavica and Hernaus (2011), key characteristics of a business process include having a specific goal, an owner, a defined start and end, inputs and outputs, customers, cross-functional activities, complexity, dynamics, repetitiveness, automation potential, measurability of success, and room for improvement. Notably, each process having its owner is crucial from a risk management perspective, as the process owner is responsible for implementing measures to mitigate risks. In cases where multiple functions are involved, introducing a new role of process owner and process manager becomes necessary to maintain a balance between the process and the functional organization. In risk management, it is essential to assign a responsible person, often referred to as the risk owner, for each identified risk.

In the context of this paper, with its focus on risks, two aspects are significant. First, the close relationship between processes and goals illustrates that processes can have various goals, and these goals are supported by activities within the process. As risks are clearly linked to activities, they must also be interpreted in the context of objectives. A risk that could potentially cause a one-day delay in the entire process is relevant in a process aiming for a quick turnaround but may be less important in a process focused on ensuring high quality. Second, a process encompasses much more than a mere sequence of activities. Therefore, there are numerous other sources where risks can potentially become relevant. Risks can be associated with incoming business items, data, information technology resources, and so on.

3. ANALYSIS OF RISK INTEGRATION INTO MODELING LANGUAGES

The previous sections of the paper have highlighted the complex nature of processes and risks. Conceptual modeling is a well-established approach for comprehending various forms of complexity, including those related to data, processes, organizational structures, and more (Gupta and Sikes, 2001). However, traditional information system modeling techniques such as EPC, UML, Petri Nets, or IDEF do not explicitly incorporate risk-related information at this stage. We propose the use of conceptual risk modeling to ensure that risk is integrated into process management projects.

Michael zur Muehlen and Michael Rosemann (2005) suggest three interconnected types of models to effectively incorporate risk into the context of business processes. They employed the widely accepted architecture of integrated information systems (ARIS) and extensions of the embedded event-driven process chain (EPC) notation to illustrate their concepts (Scheer, 2000). Two of the three model types pertain to the structural and behavioral aspects of risks, while the third acts as an integration model that connects risks to process goals and the overall process structure.

The three proposed model types are as follows:

- Risk structure model,
- Risk target model,
- Risk state model.

In this section of the paper, we focus on the analysis of risk integration in various modeling languages, with particular emphasis on the BPMN language for business process modeling. BPMN is widely used in modeling business processes due to its comprehensive coverage of the BPM life cycle phases and its ability to construct process models (Panagacos, 2012).

Meland and Gjære (2012) conducted a study on the use of BPMN 2.0 in the security community. They highlighted the benefits of BPMN 2.0 in designing and executing complex services with dynamic behavior by incorporating threats as part of the process model. These threats can cause deviations from normal business processes. The authors provided examples of how threats can be represented using symbolic constructs and diagrams in BPMN 2.0, such as error events, escalation events, and text notes. Meland and Gjære (2012) proposed a BPMN meta-model for risk visualization, aiming to include more detailed information beyond just risk names. They acknowledged the limited support for BPMN 2.0 in existing tools but noted that BPMN 2.0 provides a wide range of constructs and diagrams suitable for threat

modeling. The authors concluded that extending the notation or meta-model is unnecessary since escalation events adequately describe threats, and further additions would only create confusion among modelers and the public. However, Anton et al. (2016) criticized this approach, pointing out that exclusively presenting risks through events disregards other aspects of the risk phenomenon.

In their scientific paper, Marcinkovski and Kuciapski (2012) aimed to enhance BPMN for risk management by utilizing error events. They noted that the textual annotations in BPMN for risk identification were not sufficiently clear and precise. To address this, they introduced risk factors that provide a comprehensive characterization of potential risks based on their type, probability, and impact on the overall business process. They emphasized that one risk factor can be associated with multiple types of risks, but at least one type of risk must be specified. Furthermore, for each identified risk, an appropriate solution should be assigned. To assess the severity of a given risk, Marcinkovski and Kuciapski (2012) assigned a score ranging from 1 to 5 for both the probability and impact factors. As is widely known, the total risk is calculated by multiplying the probability and impact values.

Bernasconi et al. (2013) aimed to enhance the clarity and effectiveness of risk modeling, particularly for analysts involved in risk identification and assessment. They employed a data object to represent risks, which modeled activities and flow controls in business processes. The authors focused on the cause-and-effect relationship between risks and their patterns, utilizing Fuzzy Cognitive Maps (FCM) for clarification. FCM served as a valuable tool for visualizing and representing the interconnections among risks, including the causal links between individual risks and their causes, as well as relationships between different risks. To further improve clarity and precision, Bernasconi et al. (2013) introduced a new element in FCM: the specification of the difficulty in detecting the causes of risk. Additionally, they employed Fuzzy Logic as a formal method to address the challenges posed by incomplete and fuzzy data, thereby providing a more robust and reliable framework for risk assessment.

Radloff et al. (2015) focused on an extension that enables an integrated representation of business processes and control tools to support the implementation of process audits within EPC. They also mentioned the potential contribution of their extension to BPMN.

Anton et al. (2016) examined risk analysis in the modeling of business processes across various modeling languages. They found that none of the proposed extensions covered all relevant aspects of risk, and these extensions were not compatible with each other. They analyzed BPM languages as well as "generic" languages not based on BPM. They emphasized the cause-and-effect chain of risks and highlighted the importance of the business owner and external actors in risk-awareness during the modeling of business processes. Similar to Bernasconi et al. (2013), they underscored the significance of understanding the impact of risks on each other, rather than focusing solely on individual risks. Anton et al. (2016) also noted the importance of time sequence, recognizing that there is often a time gap between the occurrence of the cause of a risk and its subsequent consequence. They observed that existing approaches did not fully capture all aspects of the risk phenomenon and proposed an extension to BPMN to address these limitations. In their proposed extension, they integrated risk phenomena directly into existing BPMN diagrams, which can be toggled on and off without affecting the process structure. This integration allowed for the management of risk elements without impacting the overall process structure. They introduced additional risk-specific elements represented by an octagon shape and introduced the term "risk flows" to describe the relationships between risks. The risk owner was represented using a pool line, clarifying the responsibility for managing identified risks. Through these proposed improvements to BPMN, Anton et al. (2016) aimed to overcome the identified limitations and provide a more comprehensive framework for incorporating risk analysis into business process modeling.

Cardoso et al. (2021) emphasized the importance of risk assessment for business processes and its impact on their design and control. They presented their own extension, riskBPMN, which was developed using the native extension mechanisms offered by the BPMN meta-model. This extension aimed to facilitate quantitative risk assessment and built upon relyBPMN, an existing BPMN extension designed for reliability assessment. Due to the absence of an official methodological guideline for extending the BPMN 2.0 meta-model, the authors proposed a three-step methodology inspired by the approach presented by Stroppi et al. (2011). The first step involved defining a conceptual model of the extension domain using UML, establishing basic extension concepts and understanding domain-specific elements and relationships. The second step focused on defining the BPMN extension model, describing how the riskBPMN extension integrates with the existing BPMN 2.0 meta-model using the standard BPMN extension mechanism. This step specified additional elements, attributes, and relationships that comprised the riskBPMN extension, ensuring seamless integration within the BPMN framework. The third and final step of the proposed methodology involved defining the extension of the XML schema, creating an XML schema for validating

instances of the risk BPMN extension. This ensured compatibility with the existing BPMN 2.0 meta-model and proper integration into BPMN-compliant tools and systems. In quantifying risk in business processes, risk BPMN considered both the probability of failure associated with the process and the corresponding business loss. The probability of failure represented the reliability of the process, while the impact of failure referred to the business value at different levels of the process fragments. The authors also mentioned the consideration of quantitative risk acceptance criteria for risk assessment.

4. CONCLUSIONS

Process management and risk management are topics that are gaining increasing popularity. However, at this stage, there are no consolidated approaches that either apply the process paradigm to the discipline of risk management or consider risks as an integral part of business processes. Our work aims to take a step toward risk-aware process and modeling techniques. We propose three interconnected types of models, as explained in the previous sections of the paper, which collectively address risk-related requirements. These model types, particularly the target risk model, state risk model, and EPC, extend the widely adopted ARIS approach to risk visualization. Consequently, they hold potential significance for organizations that have an interest or urgency to model risk within the context of their business processes. These results also hold importance for modeling tool manufacturers who are facing demands to provide conceptual risk modeling solutions.

However, it's important to note that this work has several limitations. Firstly, we are still in the early stages of exploring risk assessment and its impact on business processes. In future research, we intend to delve into the management of business risks and their effects on business processes, with a focus on evaluating the effectiveness of internal controls, an aspect that has been relatively overlooked in risk research. Our current evaluation method largely relies on descriptive arguments aimed at addressing this issue, and we are actively seeking more comprehensive solutions.

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ACCELERATED DIGITALIZATION OF HUMAN RESOURCES IN THE POST-PANDEMIC ERA

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Abstract*: The main purpose of this paper is understanding the role of technology in managing Human Resources in the Digital age. The pandemic has been an accelerator for digitalization of workspace. Human Resources Department became more virtual and digital than ever before. Many organizations increased their usage of Video conference tools, Employee self-service (ESS), Electronic performance monitoring (EPM), Internet of Things, Robotics and Artificial Intelligence. Recruitment and selection processes became significantly more virtual and digital, since video interviews usage went from 22% to 58% in 2020. Artificial Intelligence can help in Talent Management, since managers can determine the key skills that need to be developed for different roles. Digital tools can be used for Performance Management, as well as Training and Development. It is argued that E-HR speeds up activities and contributes to more transparent and accurate transactions, and it makes HR data more available and disseminated in organizations. Human Resources practitioners will need to exploit the benefits of these technologies, in order to adjust to the Digital age, and maximize their performance. In addition, we can say that ICT and AI have significant positive impact in the development of sustainability.*

Key words: Human Resources, Digitaliza on, Pandemic, E-HR, Artifi al Intelligence

1. INTRODUCTION

Business world is facing changes, and the main source of these changes is the advancement of the technology. According to Divya and Gupta, a large number of "employees and labors will be displaced by the advanced technology". (Divya & Gupta, 2022).
The pandemic crisis had accelerated digitaliza on for many organiza ons, since many businesses couldn't operate in a usual way, and people have adapted to the new normal. Working remotely has accelerated the development of employees' digital skills, because they needed to master the new tools "overnight" (Babapour Chafi, ultberg, & Bozic Yams, 2021).
E-HR includes online based recruitment processes, self-service HR pla orms and online trainings (Kim, Wang and Boon, 2021). Corporati ns have digitalized the recruitment processes, performance management prac ces, onboarding, training and overall employee experience (Minbaeva, 2021). In addi on, other HR processes, like employee rela ons and compensati n will probably rely on *"big data, analytics and metrics",* as well as Roboti s and Artifi al Intelligence - AI (Mefi & Asoba, 2021). The digitaliza on has changed the talent strategies as well. For example, the promise of Machine learning (ML) and AI increased hiring of data scienti t (Minbaeva, 2021).
Today, increasing number of companies are already adopti g AI-based HR soluĀons (Kim, Wang and Boon, 2021). ML and AI could provide signi cant value for HR (Fernandez and Gallardo-Gallardo, 2020).
For enterprise systems, digitaliza on of work was a good soluĀon, and small and medium organizati ns needed more ti e to respond. Partia digitalizati n of business processes could be the soluti n, by introducing home office o remote work, and a endance system (Kmecova et al., 2021).
Some of the factors that can improve the digital innovati n of organizatio s are the digital organizatio al culture, integra on of the technological resources, and organiza onal readiness (Zhen et al., 2021).

2. INDUSTRY 4.0

The world has been transformed quickly due to the fast innova on of new technologies, and hence influe ced life and business worldwide. (Burrichter, Chen & Marco, 2022). Modern technologies enable machines to become sophisti ated. This means that most manual-control tasks can be automated (Burrichter, Chen & Marco, 2022).

HRM fi ld is changing rapidly, and it needs to digitally transform (Zhang & Chen, 2023). HRM professionals will need to learn the terms and applicati ns of technology related to Industry 4.0 – for instance the Internet of Things (IoT), Artifi al Intelligence, cloud compuĀng, big data and virtual reality (Da Silva et al, 2022). The workforce trends will need to be deepened, and they should focus on Training and Learning, Human-Robot Collabora on, Organizati nal Culture and Diversity and Inclusion (Da Silva et al, 2022).
In their systema c review, Vrontis et al. (2022) are explaining the role of IoT, Employee self-service (ESS), Electronic performance monitoring (EPM), and AI in HRM. They imply that technology-enabled HRM have some benefit , such as "cost savings, harmonizati n and integrati n of HR acti itie , e ciency, support of interna onal strategy", but also some barriers, like "more HR administrati n, work stress, disappointments with technological properti s" (Vron s et al. 2022). Some authors suggest that AI and Robo cs will "improve our work and general well-being more than the industrial and digital revoluĀons" (Dabica et al., 2023).

3. BENEFITS OF USING E-HR

According to Li (2021), The integrati n of HRM and new technologies is an "inevitable trend for the future development of enterprises" (Li, 2021). The areas of HRM that were performed manually before the digitaliza on include recruitment, training, and performance management. Today, big data can help create a larger database, and manage the full-cycle management (Da Silva et al, 2022).
According to Sengupta et al. (2021), digitalizati n is dominant in the following functio s of HR: Recruitment, Training & Development, Performance Management and Compensati n (Sengupta et al. 2021). The implementa on of modern technologies can relieve HRM professionals of repetiĀ e work; documentati n has been reduced by automatio ; and overall e ecti eness of HRM systems is improved (Burrichter, Chen & Marco, 2022). Machine learning can be used for the recogniti n of soft skills in and talent management as well as recruitment processes (Da Silva et al, 2022).
Research from France that questio ed the connec on between digitalizati n and autonomy implied that technology and HR practi es "work side by side in an organizatio ". This mean that if the HR policies and prac ces are supporĀng the employees, the technology will support them as well. On the other hand, if the HR practi es are threatening to employees, technology will be perceived as an instrument for these inten ons (Zeshan, Qureshi & Saleem, 2021). In their research, Heslina and Syahruni showed that organiza ons should provide trainings to employees, and management should pay a entio to competence of the staĀ, in order to assure benefi s of technology that is used (Heslina & Syahruni, 2021). AlHamad et al. (2022) suggest that E-HRM can help in achieving organizatio al cohesion, and have an impact on organiza onal health, reducing bias in performance appraisal and building communica on channels within the company (AlHamad et al., 2022).
The digitalizati n of work caused by the pandemic can have signi cant influe ce on the sustainability (Burrichter, Chen & Marco, 2022). The eĀects are reduced its CO2 emissions thanks to the introductio of remote and hybrid working models and recruitment process (Kuzior, KeĀler & Rab, 2021).

4. E-RECRUITMENT

Nguti and Mose (2021) de ne e-recruitment as "the process of identif ing and a racting potenti l employees" (Nguti & Mose, 2021). According to Baykal (2020), E-recruitment is reducing costs and increasing e ciency. It eliminates the need for HR middleman, hence lower working hours and fewer HR professionals are required. E-HR can increase the speed of transac ons, and lower the number of informati n errors (Baykal, 2020). By using E-HR systems in recruitment, companies could a ract the a en on of large number of quali ed candidates. (Baykal, 2020). Today, many organizati ns are using social media pla orms in recrui ng, such as LinkedIn, Facebook and Glassdoor, reaching out to more suitable candidates (Zhang & Chen, 2023). Organizati ns are also establishing functio s like talent sourcing experts, that are responsible for seeking and approaching talented individuals via social media. Many employers try to make a good impression on websites and plaĀorms like this, but it is also important to send a realisti message to candidates, in order to avoid early departures (Gilch & Sieweke, 2021).
Sourcing soft are supports recruiters to rapidly find new candidates, as well as provide "up" and "down" votes on candidates (Li et al., 2021). According to Kshetri (2021), ti e to hire candidates can be reduced

from 10 to 2 weeks (Kshetri, 2021). E-HRM also help companies a ract candidates from di erent geographical locati ns, which can result in organizatio al culture with diverse skills and knowledge (AlHamad et al., 2022).

The process of searching for potenti l candidates can be simplified with AI by assis ng recruiters and HR practi oners with sugges ons of keywords they can use to build complex search queries (Li et al., 2021). AI can also help by suggesting the most promising keywords in an ad (Laurim et al., 2021). Soft are "Textio that can predict the a racti eness of a job lis ng, by scanning the job ad for key phrases, as well as the overall tone of the ad, and make sugges ons for improving inclusiveness of the language (Hunkenschroer & Luetge, 2022). AI could be helpful in defect reductio ; it could detect fraudulent acti ities and increase e ciency (Kshetri, 2021), as well as improve job posts and minimize selecti n errors (Da Silva et al, 2022).

Intelligent algorithms can be used to iden fy and conduct the profi ing of candidates (Zhang & Chen, 2023). Tools like Applicant Tracking Systems (ATS) are used for analysis of applicatio s, and reduce the e ort for both recruiters and applicants (Laurim et al., 2021). NLP techniques can be used for parsing unstructured documents (for example, CVs and cover leĀers) and extract important informa on in order to complete applicati n forms (Hunkenschroer & Luetge, 2022). AI is used in the evalua on and selecti n of candidates as well, since it can analyze the en re career path of candidates, and fi ter out the results (Laurim et al., 2021). This technology can pre-screen candidates by checking parameters such as salary expectatio s, and specific skills (Laurim et al., 2021), and replace human interviewers by asking set of other predetermined ques ons (Hunkenschroer & Luetge, 2022).

Candidates are usually ranked by using a set of criteria, which are applied to all candidates. There are also some additio al applica ons in the system, like specialized selectio tests (i.e., knowledge tests and personality tests) and preliminary online procedures that could be applied through internet. If the evaluatio is negati e, the candidates are informed about the negati e feedback via the web-based portal. (Baykal, 2020). For example, the softw re "Pymetrics" which is ML based, can predict an applicant's fit for the role. Some other AI pla orms can analyze social media and other digital records in order to construct a psychological proĀle of candidates (Hunkenschroer & Luetge, 2022). By using AI, HR employees can conduct background checks, and assess applicants more objecti e than humans (Vrontis et al., 2022). The use of AI in the recruitment will result in increased e ciency, focusing on candidates with the required skills instead of primarily on quali ca ons (Baykal, 2020).

Some organiza ons are using chatbots, as the fi st point of contact between the company and candidates (Laurim et al., 2021). The assistance of chatbots can be benefic al for applicants, because it can help them find t e right job, and they are "inclined to associate positi e experiences with it" (Laurim et al., 2021).

Al-Zagheer and Barakat (2021) are listing seven bene ts of E-recruitment: Shorter ti e for hiring; Lower costs; Wider spread of companies; Wider spread of job seekers; Con den ality; Initi ti e – direct communica on with job seekers; Building a reference database for future use (Al-Zagheer & Barakat, 2021).

5. TECHNOLOGY IN OTHER HRM PROCESSES

In addi on to recruitin , modern technology is oĀen used in other HR processes. For example, by uti izing AI in training, organiza ons can create individual development programs. Employees could choose the suitable ti e for the training and access training materials from their loca on (Zhang & Chen, 2023). AI coaching is a "machine-assisted, systema c process to help clients set professional goals and construct solutio s to e ciently achieve them" (Graßmann & Schermuly, 2021). AI can be a helpful tool in coaching, but only if the client is aware of the problem and understand the goals. Therefore, it is unlikely that AI will take over the enti e process of coaching. However, HR professionals should capitalize on its advantages, and combine the benefi s of both human and AI approaches (Graßmann & Schermuly, 2021).

Emoti nal AI is a tool that can "recognize, learn about and interact" with emoti nal life (Walkowiak, 2023). Those pla orms could be used for monitoring of stress and anxiety. Current trends include increasing use of Virtual reality for supporĀng mental health of employees. The pandemic accelerated the adopti n of VR; thus, it became more aĀordable (Walkowiak, 2023).

Digital service centers can be used to cover the en re career cycle of employees fi st to last day at the company. There are many "Web portals, mobile apps, WeChat public numbers, self-service terminals, call

lines, smart robots and semanti analysis" that can provide bene ts to employees as well as organizati ns (Zhang & Chen, 2023).
Internet of Things – IoT can be used in various domains, such as personal, industrial and business (Almeida, Santos, & Monteiro, 2020). According to Li (2021), internet is "being extended to the physical world, forming Internet of Things" (Li, 2021). IoT has been used within organizatio s, especially when they are working remotely. It is facilitating knowledge management, changing business models, facilitati g HRM in general, and it can save money by preventin or fi ing problems (Gamede & Mtotywa, 2022).
Robotics are being used for completing complex tasks, and Industry 4.0 o ers a great potentia for its further growth and improvement (Almeida, Santos, & Monteiro, 2020). Robots are already able to learn and interact with people, and they will certainly become a useful tool in Human Resources Management.

6. DISADVANTAGES AND CHALLENGES

There are several challenges and potentia disadvantages of implementi g modern technology to HRM. Fernandez and Gallardo-Gallardo (2020) identiĀ d 4 categories of barriers for HR Analyti s adopti n: "data & models, soĀware & technology, people, and management" (Fernandez and Gallardo-Gallardo, 2020).
When it comes to recruitment, candidates could become anxious regarding their privacy, since they are sharing their personal informati n on the internet. Some people may avoid applying via internet if they are not familiar with technological tools (Baykal, 2020). Web based interviews are o en used today. However, there are certain disrupti ns, such as technical problems, verbal and non-verbal communicatio challenges and other environmental factors. They are more comfortable for people who are experienced in this type of communicatio (Wolf & Burrows, 2020). According to Al-Zagheer and Barakat (2021), employers and employees in India, sti l prefer face-to-face interac on over online communica on (Al-Zagheer & Barakat, 2021). Recruiters prefer an experts' recommendati ns over algorithms. (Oberst et al., 2021).
The use of digital technologies could have an impact on diversity and inclusion. For example, AI-based tool for evaluatio of candidates in Amazon showed discriminatory behaviours against women. AI that screens body language, verbal and non-verbal content in pre-recorded interviews may exclude some candidates from di erent cultural backgrounds, di erent body languages and accents, or auti ti candidates (Walkowiak, 2023). Contrary to that, some researchers showed that AI is more objecti e and less biased in evaluating candidates (Mirowska & Mesnet, 2021). According to Li et al. (2021), AI could help increase the diversity of the candidate pool (Li et al., 2021). Kshetri (2021) argue that AI can prevent some biases, but introduce new types of biases, such as gender biases (Kshetri, 2021).
Some authors argue that E-HR system could increase some costs. For example, it can be necessary to buy expensive devices for the sta , like high-tech cameras and computers (Baykal, 2020). AI could also be complex, which can impact companies' decision about AI adoptio . AI developers should try to deliver tools that are user friendly. Top management should launch strategies regarding AI initi ti es, provide trainings and speci c procedures (Pan et al., 2022).
Some other challenges of digital transformatio include disappearing of certain professions, as well as possible replacing of existing workforce (Nafchi & Mohelská, 2021).

7. CONCLUSION

Since HR is facing disrupĀons, HR professionals should rewrite the rules and prac ces in order to adjust to the new normal (Minbaeva, 2021). When exploring emerging technologies, previous ways of researching technologies could sti l provide fresh insights (Kim, Wang and Boon, 2021). Organiza ons need to change their mindset into a 'digital' one (Gilch & Sieweke, 2021). By uti izing AI in repeti ve acti itie , HR professionals can parti ipate only when it is necessary, and focus more on interpreĀng informatio , instead of administrati n (Kshetri, 2021). In order to remain competiĀ e, organiza ons are expected to become cyber-based (Mefi & Asoba, 2021). Today, many small and medium size enterprises have outdated systems. However, it is important to digitalize at least some of the HRM processes, and implement HRIS (Kmecova et al., 2021), since the use of technology in HRM is inevitable (Sengupta et al. 2021). Some future studies should focus on inves ga ng the actual digitaliza on paths (Strohmeier, 2020), in order to prepare for the future, as well as to respond to it (Li, Ghosh & Nachmias, 2020).

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SUSTAINABILITY THROUGH COMPETENCE DEVELOPMENT: CLOSING THE GAP FOR FUTURE CHALLENGES

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Abstract: *While the concept of sustainability is widely recognized, the practical implementation often demands specific skill sets, innovative thinking, and the ability to engage stakeholders effectively. Thus, the research question in this study is: Is there a gap between existing and required competencies in organizations of different characteristics? The research was conducted on 454 employees in managerial and non-managerial positions. The participants were employed in organizations of various characteristics, in terms of size, industry, and ownership. The instrument for assessing competency gaps was defined by competencies gap questionnaire (Duffy, 2015) and includes an evaluation of 12 competencies relevant for various industries in both managerial and non-managerial positions. Based on results of testing the significance between current and required competencies of employees in organizations with different characteristics, it is determined that there is a statistically significant difference – there is a gap between all perceived current and required competencies for successful job performance.*

Key words: competencies, gap, sustainability

1. INTRODUCTION

The development of competencies plays a vital role in ensuring the long-term sustainability of organizations. In today's rapidly changing business landscape, organizations must constantly adapt to new challenges, technological advancements, and market demands. A workforce with relevant and up-to-date competencies is essential to meet these evolving requirements and maintain a competitive edge. Investing in competency development fosters a culture of continuous learning within the organization. Employees actively engaging in education and skill-building are more adaptable and better equipped to handle unforeseen challenges. They become more open to innovation and change, making them valuable assets in driving organizational growth and development. Sustainable organizations recognize the importance of nurturing talent from within.

By providing opportunities for employees to enhance their competencies, organizations can groom a skilled and motivated workforce capable of taking on leadership roles in the future. This approach also promotes employee loyalty and retention, as individuals are more likely to stay with an organization that invests in their professional growth. The current business environment imposes continuous development of competencies for organizations, primarily aiming for survival in the market and then creating a competitive advantage (Assensoh-Kodua, 2020; Sitorus et al., 2020). Planning and developing human resources today represent a significant challenge for managers. Their long-term goal is to timely address the deficiencies in knowledge and skills of existing resources and ensure continuous development to enable the organization to survive and achieve better business results.

Highly trained personnel bring many benefits to the organization and the individual. The organization becomes stronger, more competitive (Singh et al., 2019), achieves higher profits (Al Karim, 2019), reduces turnover (Park et al., 2021), while individuals, by acquiring new knowledge, gain personal development (Stachová et al., 2019), efficiency in their work and increased work motivation (Ozkeser, 2019). Competencies are defined as abilities, skills, traits, and behaviors that contribute to the superiority or performance of an organization. Competencies encompass both technical and personal skills as well as observable behaviors. They also include behaviors through processes, skills, and traits that are not directly visible (Cripe et al., 2011). The skills gap is the distance between job demands and an individual's current skills (McKenney & Revees, 2020).

Sustainable development requires organizations to adopt environmentally friendly practices, promote social responsibility, and ensure economic viability. However, many organizations might lack the necessary competencies and expertise in sustainable practices. By identifying and addressing the competencies gap, organizations can equip their employees with the knowledge and skills required to

integrate sustainable practices into their operations effectively. In today's rapidly changing world, sustainable development has become an imperative for organizations to address environmental, social, and economic challenges responsibly. To achieve sustainable goals, organizations must adopt and integrate sustainable practices into their operations. However, a significant impediment lies in the competence gap - the disparity between the skills and knowledge possessed by employees and the competences required to effectively address future sustainability challenges. The research problem is related to question how organizations can bridge the competence gap to foster sustainability in the face of uncertain and evolving challenges. While the concept of sustainability is widely recognized, the practical implementation often demands specific skill sets, innovative thinking, and the ability to engage stakeholders effectively. Thus, the proposed research question of the study is:

RQ: Is there a gap between existing and required competencies in organizations of different characteristics?

2. METHODS

2.1 Sample

The research was conducted on 454 employees in managerial and non-managerial positions. The participants were employed in organizations of various characteristics, in terms of size, industry, and ownership.

Table 1: Sample structure

Variable	Category	N	%
Type of ownership	Private	266	58,6
	Public	188	41,4
Company activity	Service	320	70,5
	Mix	58	12,8
	Production	76	16,7
Company size	Micro	72	15,9
	Small	96	21,1
	Medium	108	23,8
	Large	178	39,2

2.2 Instrument

The instrument for assessing competency gaps was defined by modifying existing questionnaire (Duffy, 2015) and includes an evaluation of 12 competencies deemed relevant for various industries in both managerial and non-managerial positions. The instrument assesses the following competencies: Communication, Time Management, Problem-Solving, Critical Thinking, Setting Priorities, Interpersonal Skills, Team Management, Negotiation, Flexibility/Adaptability, Sales, Foreign Language Proficiency, and Technical Skills. Participants rated their current competencies and the desired - required competencies for their job on a scale from 1 to 5 (1 - low level - 5 - highest level). The difference between existing and required competencies represents the competency gap.

2.3 Research procedure and analysis

Data were collected through a survey conducted among employees in organizations with different characteristics. The survey was administered to the selected employees using an online data collection method. Clear instructions were provided to ensure consistent and accurate responses. Participants were informed about the purpose of the study, the voluntary nature of their participation, and the confidentiality of their responses. After data collection, the data were analyzed using the statistical analysis software SPSS. The following tests were conducted: descriptive statistics, frequency analysis, and paired t-test.

3. RESULTS

Table 1 provides the means and standard deviations obtained from the assessments of current and the level of required competencies for employees performing various types of jobs in different organizations.

The analysis includes 12 competencies: Communication, Time Management, Problem Solving - Critical Thinking, Setting Priorities, Interpersonal Skills, Team Management, Negotiation, Flexibility/Adaptability, Sales, Foreign Language Proficiency, and Technical Skills. The table below the text presents the comparative values obtained by determining the mean values of current and required competencies for job performance.

Table 1: Descriptive statistics of current and required competencies of employees

		M	SD
Pair 1	Communication (C)*	4,02	,927
	Communication (R)**	4,36	,973
Pair 2	Time Management (C)	3,86	1,010
	Time Management (R)	4,27	,987
Pair 3	Problem Solving - Critical Thinking (C)	3,90	,973
	Problem Solving - Critical Thinking (R)	4,14	,988
Pair 4	Prioritization (C)	4,06	1,021
	Prioritization (R)	4,35	1,003
Pair 5	Interpersonal Skills (C)	3,91	1,035
	Interpersonal Skills (R)	4,23	1,035
Pair 6	Organizational Skills (C)	3,86	,952
	Organizational Skills (R)	4,13	,999
Pair 7	Team Management (C)	3,49	1,062
	Team Management (R)	3,67	1,229
Pair 8	Negotiation (C)	3,38	1,069
	Negotiation (R)	3,64	1,172
Pair 9	Flexibility/Adaptability (C)	3,95	,943
	Flexibility/Adaptability (R)	4,19	1,019
Pair 10	Sales (C)	2,70	1,316
	Sales (R)	2,85	1,386
Pair 11	Knowledge of foreign languages (C)	3,63	1,105
	Knowledge of foreign languages (R)	3,89	1,273
Pair 12	Technical Skills (C)	3,83	,908
	Technical Skills (R)	4,10	1,042

*C – current; **R - required

Based on results of testing the significance between current and required competencies of employees in organizations with different characteristics, it is determined that there is a statistically significant difference – there is a gap between all current and required competencies for successful job performance. The results of the paired t-test are shown in Table 2 below the text.

Table 2: Significance of differences between current and required competencies

		M_{dif}	SD	t	p
Pair 1	Communication	-,334	,747	-9,417	,000
Pair 2	Time management	-,405	,810	-10,420	,000
Pair 3	Problem solving and critical thinking	-,231	,743	-6,545	,000
Pair 4	Determining priorities	-,287	,879	-6,848	,000
Pair 5	Interpersonal skills	-,321	,789	-8,494	,000
Pair 6	Organizational skills	-,266	,738	-7,524	,000
Pair 7	Team management	-,173	,935	-3,880	,000
Pair 8	Negotiation	-,255	,965	-5,543	,000
Pair 9	Flexibility and adaptability	-,222	,821	-5,624	,000
Pair 10	Sale	-,150	,887	-3,496	,001
Pair 11	Knowledge of foreign languages	-,264	,958	-5,784	,000
Pair 12	Technical skills	-,266	,738	-7,524	,000

4. DISCUSSION

The rapid pace of technological advancement in today's society presents a challenge for maintaining competencies in a contemporary labor market oriented towards sustainability. Many employees may struggle to keep up with the technical skills evolving in their respective fields. Recognizing that labor market demands are continuously evolving, it is imperative for organizations to stay competitive and adapt to the changing business environment by continuously identifying and developing the necessary competencies for successful job performance. Employees who fail to update their skills accordingly may experience a significant gap between their current competencies and the new demands, leading to various negative and counterproductive behaviors at the individual level, with potential negative effects on the organization as well. Within this research, an analysis of 12 competencies was included: Communication, Time Management, Problem Solving - Critical Thinking, Setting Priorities, Interpersonal Skills, Team Management, Negotiation, Flexibility/Adaptability, Sales, Foreign Language Proficiency, and Technical Skills. Based on testing the significance between current and required competencies of employees in organizations with various characteristics, it is determined that there is a statistically significant difference, or gap, between all current and required competencies for successful job performance. Identified gaps - discrepancies between the current level of competencies and the desired level of competencies included in the study necessary for quality job performance - represent areas for improvement and development within the organization. These gaps indicate disparities between the skills, knowledge, and abilities that employees currently possess compared to the ideal or desired level of expertise required for effective job performance and achieving high-quality results.

Essentially, when there is a gap between current and desired competencies, it implies that employees may lack certain skills or abilities necessary to meet the performance standards set by the organization. These gaps can arise due to various factors, such as changes in job requirements, technological advancements, evolving market demands, or the need to align with new organizational goals and strategies. Identifying these gaps is essential as it provides valuable insights into the areas on which training, development, and improvement initiatives should focus. It helps organizations understand their current strengths and weaknesses in terms of competencies, enabling them to bridge the gaps through targeted interventions. Closing these competency gaps allows organizations to enhance their overall performance, productivity, and competitiveness. Developing a comprehensive plan to bridge these gaps and providing targeted training and development opportunities enables employees to acquire the necessary skills and competencies to achieve the desired level of performance. This, in turn, contributes to improved job satisfaction, employee engagement, and organizational success. The identified gaps between current and desired competency levels highlight the areas in which organizations need to focus their efforts to improve the skills and knowledge of their employees.

5. CONCLUSIONS

The dynamic nature of the labor market and rapid technological changes contribute to the absence of a systematic approach to competency development. The skills required for success are constantly evolving, and organizations may struggle to keep pace with these changes. Inadequate awareness of new competencies and failure to adapt to technological advancements can hinder the establishment of a systematic process. The existing and required skills gap may be partially attributed to deficiencies in the developmental elements of education. While educational systems often prioritize knowledge acquisition, they may overlook the holistic development of an individual's personality and the necessary job-related competencies.

Education plays a crucial role in shaping individuals' cognitive abilities, but it should also focus on nurturing interpersonal skills, problem-solving abilities, critical thinking, and effective communication. Developmental elements such as experiential learning, practical applications, and hands-on experiences can enhance the integration of theoretical knowledge with practical competencies. Simultaneous personal and competency development are essential to bridge the gap between current and required skills in the labor market. Individuals should develop self-awareness, emotional intelligence, adaptability, and resilience to effectively apply their competencies in the real-world work environment. Nurturing these elements within the educational system can contribute to creating "well-rounded" individuals capable of responding to the challenges of the labor market and maintain the organizational sustainability.

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ANALYSIS OF KNOWLEDGE GAP IN STUDY PROGRAMS: A STRATEGY FOR SUCCESSFUL IMPLEMENTATION OF INDUSTRY 4.0

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Abstract: *The adoption and implementation of the Industry 4.0 concept, which essentially refers to the digitization of production and service systems, is heavily dependent on the knowledge and skills of the employees. For this reason, it is important for companies that their staff is trained to operate according to the principles of Industry 4.0. Adapting and improving the current study programs to match the market's evolving needs is one strategy to satisfy the demand for an adequate workforce. This paper will present the findings of the research indicating the expected demand and perceived gap for particular knowledge from the perspective of Industry 4.0 on the Master's academic study programs in the field of Industrial Engineering and Engineering Management from the perspective of professors, students, and former students of these study programs, as well as the points of view of employees in manufacturing and service companies on these issues. More specifically, the trends will be presented as a comparative analysis of the results obtained in the Southeast European (SE) countries compared to those gathered in several European Union (EU) countries. The study's findings indicate that there is a high degree of agreement between two analyzed groups. Furthermore, the research results show evidence about existence of the knowledge gap for specialized expertise relevant to the implementation of the Industry 4.0 concept. These findings show that Industry 4.0 is acknowledged as a concept that requires adaptation of the knowledge and skills of the employees, and that study programs need to be designed and developed with this understanding in mind.*

Key words: industrial engineering, engineering management, Industry 4.0, study program, knowledge gap, industrial systems

1. INTRODUCTION

In order to effectively address the problems provided by the adoption of digital technologies and the idea of Industry 4.0 in the business environment, companies require a new strategic approach to human resource management. A growing number of professionals with advanced degrees and specialized knowledge and abilities are required as the processes become increasingly complex (Erol et al., 2016). Having as many skilled workers as feasible is one of the most important requirements for achieving the greatest possible transition to new trends in production and service systems (Benešová & Tupa, 2017). The new market conditions have sparked the academic community's interest and involvement in developing solutions, including improvements to current study programs to create a new generation of employees who, in turn, could easily respond to various market needs caused on by the introduction of Industry 4.0 (Richert et al., 2016).

Given that skills in both engineering and social capabilities are needed for Industry 4.0, this topic is crucial for the discipline of industrial engineering and management, which integrates both (Shet & Pereira, 2021). In this light, it is essential to investigate the competencies that employees will require in the context of Industry 4.0, as well as how these competencies are currently represented in trainings organized by companies and study programs at institutions of higher education that offer programs in industrial engineering and management (Ivanov et al., 2021).

This paper will present the results of research indicating the anticipated demand and perceived knowledge gap for a specific area of expertise from the perspective of Industry 4.0 on master's academic study programs in the field of Industrial Engineering and Engineering Management from the perspectives of professors, students, and former students of these study programs, as well as the points of view of

employees in manufacturing and service companies on these issues. More precisely, the patterns will be shown through a comparison of data from various European Union (EU) countries with those from Southeast European (SE) countries.
The remainder of the paper is structured as follows. The process for acquiring data, the design of the instruments utilized, and a few straightforward sample descriptions are covered in the next section. Additionally, the methods used for the research purposes are briefly explained. The results and discussion section, which makes up the bulk and most crucial portion of the article, follows. The main results, the study's shortcomings, and suggestions for future research directions are all included in the concluding part of the paper.

2. METHODS AND DATA

Data was acquired for this research's purposes using a quantitative survey. More precisely, the questionnaires were created and delivered to stakeholder groups (i.e., companies, professors, alumni, and students). The questionnaires were coded in MS Forms to enable distribution and completion as simple as feasible. This made it possible to automatically gather responses and keep track of them daily to make necessary corrections and accumulate a considerable number of responses. The stakeholders received a questionnaire invitation that included a summary of the research's objectives and a link to the related questionnaire.
Each competency-related question in the questionnaire requested the respondent to evaluate the frequency of adoption (i.e., offer) and the frequency of predicted adoption (i.e., demand) (Anisic et al., 2022). The respondent might choose from one of five options for both the offer and the demand: not offered/required, low, medium, high, and don't know. The gap between offer and demand is then assessed using the responses. Each potential response was given a numerical value, as indicated in Table 1, to facilitate quantitative analysis.

Table 1: Numerical values adopted for each answer in the analysis of questionnaires' results

Answer	Values
"not offered/required"	0
"low"	1
"medium"	2
"high"	3
"don't know"	null

This paper's analysis is entirely supported by statistics. For the purposes of this research, we specifically employed comparative analysis and descriptive statistics. This involves grouping the data that each stakeholder provided as well as comparing the results obtained in the Southeast European (SE) countries compared to those gathered in several European Union (EU) countries. The comparison is performed for each of the stakeholder groups using the competencies that are evaluated as most important considering the demand and the gap between offer and demand.

3. RESULTS AND DISCUSSION

This section will present a comparison of the results of research conducted in EU countries with the results of research conducted in SE countries.
The comparison was performed for each of the categories of respondents (i.e., companies, academies, alumni, and students), trying to find similarities and differences in demand and gap trends for the most influential characteristics. The selected most influential samples were compared in terms of overlap between two groups of samples from different countries.

3.1 Comparison of responses and attitudes from the perspective of companies

Looking at the most important specialties from the group "Knowledge, skills and competencies" from the point of view of companies, we can conclude that there is a high degree of matching with identical three out of five most important specialties. EU companies notice that the lack of knowledge dominates in the field of Innovation and Communication skills, while SE companies consider that the lack of knowledge is in the field of Teamwork and Investment and Finance (see Table 2).

Table 2: Comparison of companies' responses from EU and SE countries in the group Knowledge, skills and competencies

Companies' perspective EU		Companies' perspective SE	
Knowledge, skills and competencies		Knowledge, skills and competencies	
Demand	Gap	Demand	Gap
Problem Solving and Decision Making	**Problem Solving and Decision Making**	**Team Working**	**Problem Solving and Decision Making**
Team Working	**Entrepreneurial Mindset and Skills**	**Problem Solving and Decision Making**	Team Working
Communication Skills	Innovation and Change Management	Quality Management	**Strategic Management**
Project Management	Communication Skills	Safety of Work	Investment and Finance
Innovation and Change Management	**Strategic Management**	**Communication Skills**	**Entrepreneurial Mindset and Skills**

Looking at the most important specialties from group "Operational tools" we can conclude that there is a certain match considering the demand, but some differences between the demand and offer of courses for certain operational tools. EU companies are dominated by the need to analyze large amounts of data, as well as the need for Machine learning, artificial intelligence and Big data analysis, while this is not the case in SE companies, where Management software tools and Cyber security competencies are the most lacking (see Table 3).

Table 3: Comparison of companies' responses from EU and SE countries in the group Operational tools

Companies' perspective EU		Companies' perspective SE	
Operational tools		Operational tools	
Demand	Gap	Demand	Gap
Management Software Tools	**Computer-based Statistic Competencies**	**Computer-based Statistic Competencies**	Management Software Tools
Computer-based Statistic Competencies	Big Data Analysis	**Management Software Tools**	**Computer-based Statistic Competencies**
Big Data Analysis	Machine Learning/AI Competencies	Cyber Security Competencies	Cyber Security Competencies

Regarding the methodology of knowledge transfer, there are no significant shortcomings, with a minor gap in the EU countries for the Web-based synchronous transfer method, while in the companies from SE countries there is a slight need for Web-based asynchronous transfer method.

3.2 Comparison of responses and attitudes from the perspective of academics

The next category of respondents is academics, who have interesting overlapping between EU and SE countries. Comparing the answers from belonging to the group "Knowledge, skills and competencies", we can notice a high degree of agreement from the point of view of demand with four identical skills, while this match considering the gap is slightly less with only two identical skills. The highest gap between offer and demand in EU companies goes in the direction of Communications, Leadership and Entrepreneurial thinking, while in the case of academics from the selected SE countries the difference is oriented towards Safety of work, Industrial Marketing and Operations Management. Generally, it can be concluded that the answers differ in nuances and that there are no essential differences (see Table 4).

Table 4: Comparison of academics' responses from EU and SE countries in the group Knowledge, skills and competencies

Academics' perspective EU		Academics' perspective SE	
Knowledge, skills and competencies		Knowledge, skills and competencies	
Demand	Gap	Demand	Gap
Project Management	Communication Skills	**Project Management**	**Problem Solving and Decision Making**
Operations Management	Leadership Issues	Quality Management	**Team Working**
Team Working	Entrepreneurial Mindset and Skills	**Operations Management**	Safety of Work
Problem Solving and Decision Making	**Team Working**	**Logistics**	Industrial Marketing
Logistics	**Problem Solving and Decision Making**	**Problem Solving and Decision Making**	Operations Management

Analyzing the differences in answers related to the use of "Operational tools" it should be noted that the differences are high, both for demand and gap. The impression is that in the EU countries more operational tools are needed to process large amount of data that already exist in companies, while in the SE countries the focus is on the field of sensor installation and connection of machines and equipment to start collecting data (see Table 5).

Table 5: Comparison of companies' responses from EU and SE countries in the group Operational tools

Academics' perspective EU		Academics' perspective SE	
Operational tools		Operational tools	
Demand	Gap	Demand	Gap
Big Data Analysis	Big Data Analysis	Machine Learning/AI Competencies	**Cyber Security Competencies**
Computer-based Statistic Competencies	**Cyber Security Competencies**	IoT Monitoring Competencies	Sensor-based Monitoring Competencies
Management Software Tools	Machine Learning/AI Competencies	Sensor-based Monitoring Competencies	Augmented/VR Competencies

In the last group of comparisons regarding "Knowledge Transfer Methodology", the technics used are almost identical, which leads us to the conclusion that academics from the EU and the SE countries use the same methods to transfer knowledge (see Table 6).

Table 6: Comparison of companies' responses from EU and SE countries in the group Knowledge Transfer Methodology

Academics' perspective EU		Academics' perspective SE	
Knowledge Transfer Methodology		Knowledge Transfer Methodology	
Demand	Gap	Demand	Gap
Seminars	**Field Trips**	Field Trips	**Field Trips**
Workshops	**Workshops**	**Traditional F2F Lectures**	**Workshops**
Traditional F2F Lectures	**Asynchronous web-based learning**	**Workshops**	**Asynchronous web-based learning**

3.3 Comparison of responses and attitudes from the perspective of alumni

Considering alumni' perspective related to "Knowledge, skills and competencies", the similarity of answers between the two observed groups is obvious (see Table 7).

Table 7: Comparison of alumni's responses from EU and SE countries in the group Knowledge, skills and competencies

Alumni's perspective EU		Alumni's perspective SE	
Knowledge, skills and competencies		Knowledge, skills and competencies	
Demand	Gap	Demand	Gap
Problem Solving and Decision Making	**Leadership Issues**	**Problem Solving and Decision Making**	**Problem Solving and Decision Making**
Team Working	**Communication Skills**	**Communication Skills**	**Entrepreneurial Mindset and Skills**
Communication Skills	**Entrepreneurial Mindset and Skills**	**Team Working**	**Leadership Issues**
Project Management	**Problem Solving and Decision Making**	Entrepreneurial Mindset and Skills	**Communication Skills**
Leadership Issues	Project Management	**Project Management**	Team Working

Analyzing the differences in answers related to the use of "Operational tools" it should be noted that Alumni from EU countries highlight the importance of Management Software Tools and Computer-based Statistic Competencies, while in the SE countries the focus is on the field of Augmented/VR, 3D Printing, and Cybersecurity competencies. Big Data and Machine Learning/AI Competencies are important for both observed groups (see Table 8).

Table 8: Comparison of alumni's responses from EU and SE countries in the group Operational tools

Alumni's perspective EU		Alumni's perspective SE	
Operational tools		Operational tools	
Demand	Gap	Demand	Gap
Big Data Analysis	**Big Data Analysis**	Augmented/VR Competencies	**Big Data Analysis**
Management Software Tools	**Machine Learning/AI Competencies**	3D Printing Competencies	Cyber Security Competencies
Computer-based Statistic Competencies	Management Software Tools	**Big Data Analysis**	**Machine Learning/AI Competencies**

As far as knowledge transfer methodologies are concerned, the impression is that there are requirements for Field trips in all categories, but that there is a lack of appropriate offer for them. There is also a gap between offer and demand for Synchronous web-based learning that is noticed from both observed groups (see Table 9).

Table 9: Comparison of alumni's responses from EU and SE countries in the group Knowledge Transfer Methodology

Alumni's perspective EU		Alumni's perspective SE	
Knowledge Transfer Methodology		Knowledge Transfer Methodology	
Demand	Gap	Demand	Gap
Workshops	**Field Trips**	Asynchronous web-based learning	**Field Trips**
Seminars	Asynchronous web-based learning	**Field Trips**	Workshops
Field Trips	**Synchronous web-based learning**	Traditional F2F Lectures	**Synchronous web-based learning**

3.4 Comparison of responses and attitudes from the perspective of students

In the last category of students, we also have a similar picture of mutual comparisons, as in the case of the previous three groups. In the group "Knowledge, skills and competencies" there is a high level of matching between the two groups of respondents. It is not easy to establish a clear pattern-

consequential relationship, and it can be considered that the answers mostly match without pronounced differences (see Table 10).

Table 10: Comparison of students' responses from EU and SE countries in the group Knowledge, skills and competencies

Students' perspective EU		Students' perspective SE	
Knowledge, skills and competencies		Knowledge, skills and competencies	
Demand	Gap	Demand	Gap
Problem Solving and Decision Making	Leadership Issues	**Team Working**	Safety of Work
Team Working	**Communication Skills**	**Communication Skills**	**Problem Solving and Decision Making**
Project Management	**Entrepreneurial Mindset and Skills**	**Problem Solving and Decision Making**	**Communication Skills**
Communication Skills	**Problem Solving and Decision Making**	Quality Management	Innovation and Change Management
Operations Management	Strategic Management	Logistics	**Entrepreneurial Mindset and Skills**

In the observed group "Operational tools" there are obvious differences in the given answers, which complies with previous categories of respondents. In the case of demand, there are two matches, while in the case of the gap, the answers are completely different. In this case, similar to the previous respondent categories, the demand for analysis and processing of large amounts of data dominates for a group of EU respondents, while among respondents from the SE countries, the demand for AR/VR competencies, artificial intelligence and cyber security are the most important (see Table 11).

Table 11: Comparison of students' responses from EU and SE countries in the group Operational tools

Students' perspective EU		Students' perspective SE	
Operational tools		Operational tools	
Demand	Gap	Demand	Gap
Big Data Analysis	Big Data Analysis	**Management Software Tools**	Augmented/VR Competencies
Computer-based Statistic Competencies	Management Software Tools	**Big Data Analysis**	Cyber Security Competencies
Management Software Tools	Computer-based Statistic Competencies	Augmented/VR Competencies	Machine Learning/AI Competencies

When it comes to knowledge transfer methodologies, we have an almost complete match comparing observed groups. In this group of respondents, there is a pronounced need for a field trip method of knowledge transfer (see Table 12).

Table 12: Comparison of students' responses from EU and SE countries in the group Knowledge Transfer Methodology

Students' perspective EU		Students' perspective SEC	
Knowledge Transfer Methodology		Knowledge Transfer Methodology	
Demand	Gap	Demand	Gap
Workshops	**Workshops**	**Workshops**	**Field Trips**
Field Trips	**Field Trips**	**Seminars**	**Workshops**
Seminars	**Asynchronous web-based learning**	Traditional F2F Lectures	**Asynchronous web-based learning**

3.5 Comparison summary

The differences in the answers between the respondents from the EU and the Balkan countries can be summarized as follows:

- In the category of “Knowledge, skills and competencies” we have a high degree of agreement in the answers with minimal differences
- A group of respondents from the SE countries has a need for Safety of Work, which has never been the case with EU respondents
- In the category “Operation tools” there were the most differences in the given answers. Among the respondents from the EU, the following dominated: Big Data Analysis and Computer-Based Statistic Competencies, while respondents from the SE countries had requests in the area Augmented/VR Competencies, Cyber Security Competences, and Machine Learning/AI Competences
- In the category of “Knowledge Transfer Methodology” there were no significant differences. Characteristically, there is a need for both groups of respondents for Field Trips.

4. CONCLUSIONS

The research presented in this paper shows the findings that indicate the expected demand and perceived gap for particular knowledge from the perspective of Industry 4.0 on the Master's academic study programs in the field of Industrial Engineering and Engineering Management from the perspective of companies, professors, alumni, and students on these issues. More specifically, the trends are presented as a comparative analysis of the results obtained in SE countries compared to those gathered in several EU countries.

The results indicate that the two groups that were analyzed have a lot of similarities with each other. Furthermore, the necessity for improvements of study programs is recognized in both regions in which the research is conducted. This is especially important for SE countries that should follow the path of more advanced partners from EU counties. The fact that the answers from both groups of respondents are similar is a good starting point for further improvements.

This study is limited to the use of simple statistical tools such as descriptive statistics with the main idea to check the status in different countries considering their development level. Further research could include some advanced statistical tools to perform in depth analysis of the data to get more detailed information on the samples, as well as their relationships. Furthermore, the findings presented in this paper could serve as a basis for the development of new and improved study programs in the field of Industrial Engineering and Engineering Management that can match the market's evolving needs for knowledge of their employees.

5. ACKNOWLEDGMENTS

The results presented in this paper are part of the research within the project "Implementation of the results of scientific research work in the field of Industrial Engineering and Management in DIIM teaching processes with the aim of their continuous improvement", at the Department of Industrial Engineering and Management, Faculty of Technical Sciences, University of Novi Sad, Republic of Serbia.

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USE OF BEAUTY APPLICATIONS AND AR BEAUTY FILTERS AMONG YOUNG PEOPLE: TRENDS AND CHALLENGES

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Abstract: *Beauty applications and augmented reality beauty filters are widely used on social media platforms. These filters detect and transform facial features by overlaying digital masks on moving faces. In addition to beauty applications that are used for retroactive photo editing, augmented reality beauty filters adapt to facial features in real-time, resulting in a unique digital beautifying process. This quantitative study explores how the use of beauty applications and the use of AR beauty filters impacts young people's perception of themselves, and whether their use affects the self-confidence and mental health of young people. It is based on an online survey that was conducted on a sample of 232 respondents from the category of young people (i.e. Millennials and Gen Z). For that purpose, this paper provides a relevant literature review on the attitude of young people toward trends that are imposed through social networks. The research results showed that more than 70% of respondents use ARB filters and applications to beautify their photos. Young people are largely satisfied with their appearance and more than half of them do not succumb to trends imposed by social networks. However, they notice that an increasing number of people strive for imposed ideals of beauty, which affects their self-confidence.*

Key words: augmented reality beauty filters, social media, young people

1. INTRODUCTION

The majority of augmented reality (AR) applications used by the general public today are found on smartphones. Social network apps enable the usage of numerous AR filters, including AR beauty filters, which alter users' surroundings as well as their own appearance (Fribourg, Peillard, & Mcdonnell, 2021). These AR filters are being utilized more and more frequently, and they have the potential to modify users' facial features in many ways.

There is a consensus among authors that research on using AR filters, beauty apps and the effects of the appearance caused by those filters, has been insufficiently investigated (Lavrence & Cambre, 2020; Fribourg, Peillard, & Mcdonnell, 2021; Javornik, et al., 2021; Newell, 2022). Some of the previous studies highlight that digital self-tracking devices and beauty apps articulate idealized facial images, body ideal internalization, and sociocultural pressures (Newell, 2022), and this trend can be observed especially among the younger generations.

Hence, this research aims to determine young people's attitude towards trends imposed through social networks, their attitude towards beauty applications and AR filters, as well as whether the use of beauty applications and AR filters affects their self-confidence. Therefore, the subject of this research are attitudes of young people in Serbia about the use of AR filters and beauty applications on social networks. According to the Law on Youth, young people in Serbia represent the category of persons from the age of 15 to the age of 30 (Official Gazette of RS, 2011). Data from the Serbian Republic Institute of Statistics from 2019, show that this category makes up one sixth of the total population of the country. Therefore, this research is essential as it addressing a critical gap in understanding the evolving dynamics of modern beauty standards in the digital age.

2. LITERATURE REVIEW

With the use of AR, businesses can now provide highly customized, interactive experiences, enabling entirely new levels of customer engagement. Although digital filters that change people's appearances might be very useful, they also come at a cost – according to recent research, AR apps that enable users digitally try on clothing, accessories, or makeup may have a significant, negative impact on psychological wellbeing (Javornik, et al., 2021). In addition, the impact can differ greatly depending on the user.

AR (Augmented Reality) technology is a digital technology that overlays computer-generated sensory information, such as images, videos, or 3D models, onto the real-world environment to enhance the user's perception and interaction with their surroundings (Javornik, et al., 2021). Different types of AR face filters are currently available on social media for a variety of applications and use cases (Riccio, et al., 2022), including marketing and commercials (Appel, et al, 2019), entertainment, and aesthetics (Fribourg, Peillard, & Mcdonnell, 2021). Users of social media platforms are able to create and share their own AR filters using off-the-shelf tools, establishing a new creative form of expression and a new artistic role: the filter creator (Riccio, et. al., 2022). Other users can utilize the filters to experience various versions of themselves, including ones with 3D makeup or beauty enhancement, hilarious deformations, horrific or surreal textures, future or sci-fi scenarios, or funny deformations. Since the capacity to experience these changes goes beyond the user's physical location and only requires a smartphone with an internet connection, AR face filters represent a form of post-internet art. (Riccio, et al., 2022). When it comes to the general public's acceptance of AR filters as a viable artistic medium, the COVID-19 pandemic was a watershed event (Herrington, 2022), endowing filter designers with a crucial role in determining the technology's cultural and societal effects.

For young people, applications such as SnapChat or Instagram have taken on a central role in personalized AR. Users of these apps are able to engage in real-time face figure distortion (e.g., making the eyes look bigger or in different color) and feature addition (e.g., adding dog ears or fashion accessories on top of a user's face) which are enabled by a variety of available filters (Fribourg, Peillard, & Mcdonnell, 2021). Filtered faces are some of the most predominant and heavily engaged photos on social media (Lavrence & Cambre, 2020) and not only users spend some time looking at themselves through these filters while taking selfies, they can as well use these filters on video calls or video conference with social networks apps. Such filters have received an increased interest in sociological studies, exploring for instance the long term impact of beauty filters on self-perception and self-esteem (e.g. Rajanala, Maymone, & Vashi, 2018). However, these studies tend to focus on the filters designed to increase users self-perception of attractiveness or cuteness and to study long term effects.

The quantitative study conducted by Newel (2022) advocates the attractiveness and insufficient research of this topic. The Web of Science, Scopus, and ProQuest databases were used by this author to perform a literature review using the following search terms: "beauty apps and filters in visual digital cultures" + "perceived sociocultural pressures," "self-rated emotional expressiveness," and "image processing algorithms". Studies were reviewed between 2017 and 2022 and only 166 met the eligibility criteria (Newel, 2022). While this topic is highly intriguing, it remains insufficiently researched.

3. METHODS

The research in this work was quantitative and the survey method was used for data collection. An electronic questionnaire, created through the Google Forms, was used as a research instrument. It contained 15 questions grouped into three units (socio-demographic characteristics; attitude towards social networks, AR filters and beauty apps; the influence of AR filters and beauty apps on self-confidence of young people), of which 11 questions were with offered response modalities, two questions contained a 5-point Likert scale, while two questions were open-ended. The questionnaire was distributed via e-mail addresses and Viber, using the snowball method, and the data were processed through a statistical program directly on Google Forms. The research was conducted from May 20 to June 3, 2023.

4. RESULTS

232 respondents from the territory of Vojvodina participated in the research, of which 81.9% were female and 18.1% were male. More than half of the research participants – 60.8% of them, were between the ages of 21 and 25, 19.8% were between the ages of 15 and 20, and 13.3% were between the ages of 26 and 30. Only 6% of respondents were over 30 years old. Among the research participants, there were mostly highly educated people, that is, those who completed four-year studies (39.7%), followed by those who completed high school (35.8%). Only 15.9% of the respondents had a master's diploma, 6.5% of them had a higher school, and 0.9% had a primary school diploma. Only 1.3% of the respondents obtained the title of Doctor of Science. Half of the research participants were students (50.4%), and the other half were respondents of the following employment status: permanent employees (20.7%), temporary employees (12.9%), students (8.6%), unemployed (5.2%) and freelancers (2.2 %).

4.1 Attitude towards social networks, AR filters and beauty applications

Instagram is the social network used by almost all research participants (91.4%), while the second, most used, was *YouTube* (59.5%). Popular social networks among young people were *TikTok* (39.2%), *Facebook* (29.7%), and somewhat less *Linkedin* (17.2%) and *Twitter* (13.8%). The largest number of young people who participated in the research spent between two and three hours (40.5%), that is, between three and four hours (24.6%), on social networks every day, and an almost equal percentage of them spent more than four hours (17.7%), that is, less than two hours (17.2%) per day.

Two thirds of the research participants use AR filters and beauty applications, but with different frequency: 5.2% use them regularly, 26.7% occasionally, and 36.2% rarely. AR filters and beauty applications are never used by 31.9% of respondents. Research participants who use them most often use the following apps: *Lightroom* (29.3%), *VSCO* (15.5%), *Snapseed* (13.8%), *FaceApp* (9.5%), *Facetune* (3.4%) and *Makeup Plus* (1.7%); while among the AR filters, the most dominant, are those for adjusting brightness and contrast (60.8%), for adjusting colours (51.3%), for removing various imperfections such as pimples, spots, scars, etc. (33.6%), to add effects to photos (24.1%), and often use filters to change skin colour (9.1%), to change face shape (6.9%), to change photo background (4.7%) and body shape (4.3%).

Evaluating the attitude towards AR filters and beauty applications, the largest number of research participants fully agreed with the following statements: "girls who use the most popular beauty applications start to look like each other and lose their identity" (55.17%), "they contribute to the creation of unrealistic standards beauty" (48.28%), "negatively affect the attitude towards natural appearance" (43.53%), and "impose new standards of beauty" (39.66%). With the claims "I always recognize when a filter or beautification application has been used on a photo" and "they completely change the physical appearance of those who use them" 42.67%, that is, 36.21% of respondents agreed. A third of the research participants did not agree at all with the statement that they "support the use of filters and beauty applications because they believe that they contribute to increasing self-confidence in real life" (36.64%), while 34.05% of them did not agree with the statement that they "support their use because then everyone more beautiful". Half of the respondents have between one and three apps for photo processing/beautification installed on their mobile phone (51.7%), and only 2.2% of them have between four and six. 45.7% of young people who participated in the research have not installed any applications from this category. As the most common reason for using filters and beauty apps, in a free answer, the respondents cited the correction of imperfections that exist on their faces.

4.2 The influence of filters and beauty applications on the self-confidence of young people

The research results showed that the participants had a high level of self-confidence, because more than two thirds of them either completely agreed or agreed with the statements that they are pretty, attractive, intelligent, confident in themselves and their decisions, that they are happy, that they do not succumb under the influence of others, that they are satisfied with themselves and that they already have a built image, as well as that they have a large number of friends with whom they spend time outside of social networks. At the same time, he most of them totally disagreed or disagreed with the assessments that they have bad thoughts and that they are depressed. Figure 1 shows the summary of results about the self-perception and self-confidence of the participants, shown in absolute values according to the number of respondents and their degree of agreement with the defined statements.

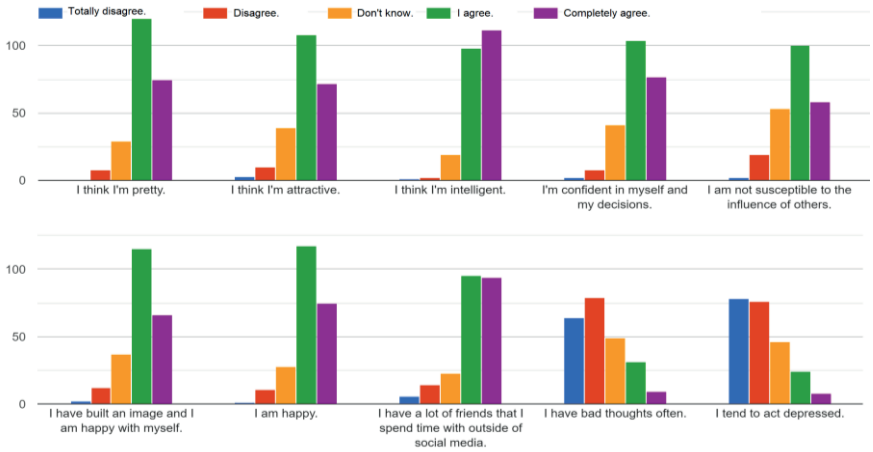

Figure 1: The results of self-confidence and mental health of young people

5. CONCLUSIONS

According to the study's findings, more than 70% of participants use AR beauty apps and filters to enhance and beautify their photos. Conducted research indicates that more than half of representatives of young people in Serbia said they are largely satisfied with how they look and do not follow social media trends. However, the research results demonstrate that young people in Serbia have noticed an increasing number of people strive for imposed so-called social media ideals of beauty, which affects their self-confidence. Noteworthy is that the majority of research participants do not succumb under the influence of others and that they are satisfied with themselves, based on which it is possible to infer that young people in Serbia have decent mental health.

However, the public in Serbia has a very different viewpoint about this subject, so the high likelihood of providing socially acceptable responses represents one of the major limitations of this research. By combining multiple research methods and including more respondents from various backgrounds, this study shortcoming can be overcome. Future studies could include a comparison of the findings about the situation among young people in region countries that share comparable cultural norms.

Some of the suggested strategies to address the challenges young people are facing, could include avoiding promoting unrealistic beauty standards by popular brands, celebrities and influencers, proactively educating customers about the possible risks of utilizing AR, as well as collaboration with regulators and business leaders to create an industry code of ethics for the future socio-economic development.

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TRENDS IN USE OF ADVANCED MANUFACTURING TECHNOLOGIES IN SLOVENIAN MANUFACTURING COMPANIES

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Abstract: *This paper deals with the use of advanced manufacturing technologies (AMT) and information technologies (IT) in Slovenian manufacturing companies in the light of Industry 4.0. The main objective of the paper is to determine the adoption of specific AMT and IT, such as digital factory technologies, 3D manufacturing technologies and use of specific types of robots. A special focus is on the use of artificial intelligence. Results are based on a sample of 141 Slovenian manufacturing companies, whose data were obtained through the latest 2022 European Manufacturing Survey edition. Additionally, we use data from previous research rounds. The results are presented with the use of descriptive statistics. Results show that the use of specific technologies in Slovenian manufacturing companies is quite diverse and that several technologies have obviously reached its peak.*

Key words: manufacturing company, advanced manufacturing technology, Industry 4.0, European manufacturing survey, Slovenia

1 INTRODUCTION

Industry 4.0 can be briefly defined as the digitalization of manufacturing and services. Commonly the general understanding of industry 4.0 concept is fully automated physical systems, but it should be considered as also automated and smart decision systems, not only automated physical systems (Elibal and Özceylan, 2021). Industry 4.0 is marked by highly developed automation and digitization processes and by the use of electronics and information technologies (IT) in manufacturing and services (Yang, 2017). Digitalization refers to "the manifold sociotechnical phenomena and processes of adopting and using (digital) technologies in broader individual, organizational, and societal contexts (Legner et al., 2017). The adoption of digital technologies influences almost all areas of modern firms, including manufacturing/production processes (Plekhanov et al., 2022).

In manufacturing companies besides IT, we must consider also other advanced manufacturing technologies (AMT), such as robots and additive manufacturing technologies. There are many representatives of AMT and IT and it is a fact that the dispersion of these technologies heavily depends on industry and company size. It is also true that technologies are very context related and are not suitable for all manufacturing companies. To determine the dispersion of different IT and AMT, we have analysed several technologies from the "digital factory" area as well as from "automation/robots" and "additive manufacturing technologies" area that have a potential and the need to find their way in all manufacturing environments. Therefore, our research presents the diffusion of 16 selected AMT and IT that are characteristic for the Industry 4.0 era in the Slovenian manufacturing industry. Besides analysing diffusion of AMT and IT this paper also presents a possible Industry 4.0 readiness index and assess Industry 4.0 readiness of Slovenian manufacturing companies.

This paper is organized as follows: first, we will introduce the concept of Industry 4.0 readiness and maturity models in general and later Industry 4.0 readiness index that we used in our research. The methodological section explains the characteristics of the European Manufacturing Survey (EMS). After that, we present the use of selected technologies in Slovenian manufacturing companies and the results, obtained with the use of Industry 4.0 readiness model. Finally, a concluding discussion is provided for the findings, where some managerial implications, research limitation and directions for future research are given.

2 INDUSTRY 4.0 READINESS & MATURITY MODELS

2.1 Industry 4.0 Readiness models in general

As the industry 4.0 concept came to the scene, both academics and practitioners are challenging to identify the current maturity and readiness of organizations for the industry 4.0 concepts (Elibal and Özceylan, 2021). In order to perform better, industry and academia have been making continuous attempts to

develop and re-develop self-assessment models that can evaluate the Industry 4.0 readiness of organizations (Hizam-Hanafiah et la., 2020). Identification of these Industry 4.0 readiness models is also significantly needed as it will enable companies to measure precedents and antecedents in the digital transformation process which can then lead to organizational transformation (Canetta et al., 2018).

Industry 4.0 readiness model tries to represent how ready an enterprise is to implement advanced technologies and concepts. Some authors define readiness model as "the degree to which organizations are able to take advantage of Industry 4.0 technologies" (Hizam-Hanafiah et la., 2020) while others define it as "an instrument to conceptualize and measure the starting point and allow for initializing the development process" (Schumacher et al., 2016). In order to successfully master Industry 4.0 readiness, academic and industry researchers have developed a variety of Industry 4.0 readiness models in the recent years.

Schumacher et al. (2016) have developed maturity model to assess the Industry 4.0 readiness and maturity of manufacturing companies. Their main goal was to extend the dominating technology focus by including organizational aspects. They defined 9 dimensions and assigned 62 items to them for assessing Industry 4.0 readiness and maturity. The dimensions "Products", "Customers", "Operations" and "Technology" have been created to assess the basic enablers. Additionally, the dimensions "Strategy", "Leadership", Governance, "Culture" and "People" allow for including organizational aspects into the assessment.

De Carolis et al. (DeCarolis et al., 2017) have developed maturity assessment method to measure the digital readiness of manufacturing firms. Different dimensions are used to assess 5 areas in which manufacturing key processes can be grouped: 1) design and engineering, 2) production management, 3) quality management, 4) maintenance management and 5) logistics management. Canetta et al. (2018) have proposed a digitalization readiness model to assess the state of a company journey towards Industry 4.0 considering five dimensions: "Strategy", "Processes", "Technologies", "Products & Services" and "People". Pachinni et al. (2019) proposed a model, that employs a structure based on the Society of Automotive Engineers (SAE) J4000 standard for measuring the implementation of lean manufacturing in a company; the model is duly modified to encompass Industry 4.0 principles and concepts. The proposed model comprises eight technology enablers that are the most relevant based on existing literatures: big data, 'Internet of Things' (IoT), cloud computing, autonomous robots, additive manufacturing, cyber physical systems, augmented reality, and artificial intelligence.

As we pointed out there are many different readiness (and maturity) Industry 4.0 assessment models that cover many different areas. In our research, we focus on "Technology" area. We include several representatives of IT technologies from the model proposed by Pachinni et al. (2019). We present an Industry 4.0 readiness index, developed by Fraunhofer Institute for Systems and Innovation Research – ISI (Lerch et al., 2016), who is a coordinator of the EMS project. The model was applied to Slovenian manufacturing industry.

2.2 Industry 4.0 Readiness Index

The proposed Industry 4.0 readiness index was developed by Fraunhofer ISI (Lerch et al., 2016) to analyse data collected within our research: EMS. The logic of the Fraunhofer Industry 4.0 readiness index is presented in Fig. 1 and it is based on the selected Industry 4.0 enabling technologies. Since the different technologies are highly process and operation-dependent and come from different technology fields, a simple counting of the technologies used is not sufficient for an Industry 4.0 readiness index. Therefore, these AMT are divided into three technology fields: Digital management systems, Wireless human-machine communication and Cyber-physical system (CPS)-related processes. While the first two technology fields cover IT-related processes (Industry 4.0 basic technologies) and still have a clear distance from Industry 4.0, technology field CPS already contains the first approaches to networked/digital production and can therefore be classified as Industry 4.0 closer than the other two technology fields (Lerch et al., 2016).

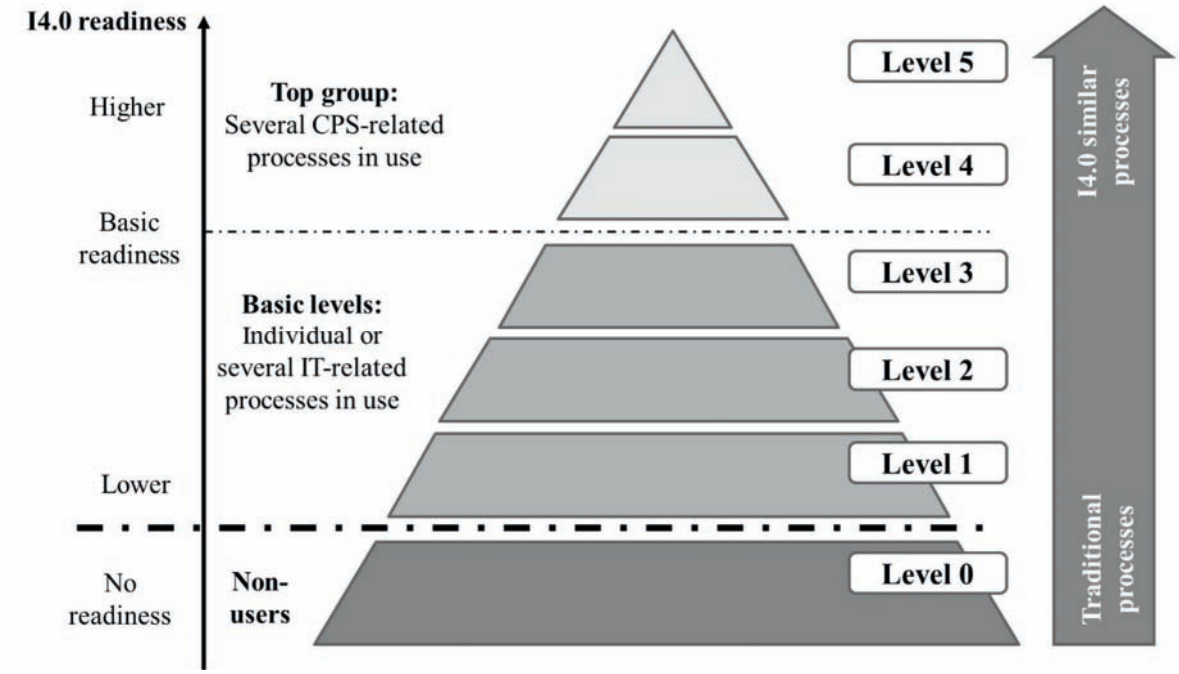

Figure 1: Industry 4.0 readiness index (Lerch et al., 2016)

Using this grouping, the companies can be classified as Industry 4.0-close companies, which, on the one hand, use and combine several technology fields in production and, on the other hand, use several of the CPS-related processes in their production. Accordingly, Industry 4.0 readiness index results with the following main groups and levels:

Non-users who are not (yet) ready for Industry 4.0:

- Level 0: Companies that do not use any of the Industry 4.0 enabling technologies and tend to still rely on traditional production processes.

Basic levels, as the basis on the way to Industry 4.0, with little readiness:

- Level 1 (beginners): Companies that use IT-related processes in one of the three technology fields.
- Level 2 (advanced beginners): Companies that use IT-related processes in two of the three technology fields.
- Level 3 (advanced users): Companies that are active in all three technology fields and use both IT-related processes and CPS-related processes.

Top group, as a pioneer on the way to Industry 4.0, with a slightly higher readiness:

- Level 4: Companies that are active in all technology fields and use at least two technologies of CPS-related processes.
- Level 5: Companies that are active in all technology fields and use at least three technologies of the CPS-related processes.

With each level, the Industry 4.0 readiness status increases or the distance to networked production decreases. While there is no readiness for Industry 4.0 in level 0, companies in levels 1 to 5 have a basic readiness. Companies that already use IT-related processes (levels 1 and 2), however, have a greater Industry 4.0 distance than companies in levels 3 to 5 that are already implementing the first elements of networked production. However, even at levels 4 and 5 it cannot be assumed that the threshold to Industry 4.0 has actually been breached. Rather, only the distance to networked production has narrowed. With the help of this Industry 4.0 readiness index, the change from traditional production to production close to Industry 4.0 can be mapped. Companies with a higher level have already made the transition more strongly than companies in the lower levels (Lerch et al., 2016).

Fig. 2 presents all three technology fields in Industry 4.0 readiness index and AMT from our research:

- Digital management systems: The first technology field is formed by software systems for production planning and scheduling (ERP) and the product lifecycle management systems. These are classified as the basic technologies of IT and digitization and are thus assigned to IT-related processes.
- Wireless human-machine communication: In the second technology field, the digital visualization is summarized with the mobile devices. This field is also assigned to the I4.0 basic technologies and thus to IT-related processes.

- Cyber-physical system (CPS)-related processes: The third technology field takes into account the near real-time production control system, the automation of logistics and the digital data exchange with suppliers and customers. These technologies already had production elements in cyber-physical systems and are therefore considered to be among the advanced I4.0 technologies.
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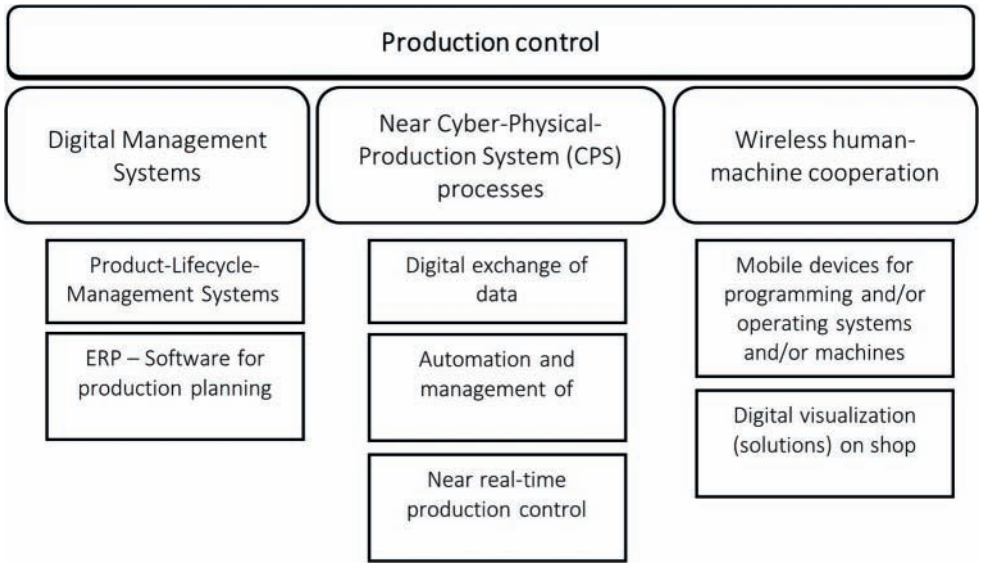

Figure 2: Industry 4.0 readiness index with selected AMT (Lerch et al., 2016)

3 EUROPEAN MANUFACTURING SURVEY

The research data was collected using the EMS, coordinated by the Fraunhofer Institute for Systems and Innovation Research – ISI, the largest European survey of manufacturing activities. The survey's questions deal with manufacturing strategies, application of innovative organizational and technological concepts in production, cooperation issues, production offshoring and backshoring, servitisation, and questions of personnel deployment and qualification. In addition, data on performance indicators such as productivity, flexibility, quality and returns is collected. In our last EMS research round we added questions on digital elements of products, new business models, artificial intelligence, circular economy etc. The survey takes place every three years. In most countries, EMS is organized as a paper-based survey at company level (the core questionnaire has six pages). The persons contacted to fill in the questionnaires are the production manager or the CEO of the manufacturing companies. The responding companies present a cross-section of the main manufacturing industries. Included are producers of rubber and plastics, metal works, mechanical engineering, electrical engineering, textile and others. The survey is conducted among manufacturing companies (NACE Revision 2 codes from 13 to 32) having at least 20 employees. The main objectives of the EMS project are to find out more about the use of production and information technologies, new organizational approaches in manufacturing and the implementation of best management practices.

Our research is based on EMS data from a Slovenian subsample from the year 2022 round. We sent 950 questionnaires and received 146 responses – a 15,4% response rate. For the purpose of our presented study, we have excluded companies from the textile industry (NACE 13, 14 and 15) and included 141 responses from other industries into the analysis. The response rate is almost 16%. In our 2022 subsample, manufacturing companies from NACE divisions 22, 25 and 28 are represented most widely with around 32% of companies from NACE 25, around 18% from NACE 28, and around 16% from the NACE 22 division. We classified manufacturing companies in three size classed based on the number of employees. The largest share of respondents is from medium sized companies (around 49%), followed by small companies (31%) and large companies (20%). We also classified manufacturing companies into suppliers (system supplier or supplier of parts or components) and Original Equipment Manufacturers (OEM): 52% were suppliers and 48% OEMs.

4 RESULTS AND DISCUSSION

4.1 Adoption of AMT in Slovenian manufacturing companies

In our last EMS 2022 research round, we have analysed the use of 21 AMT and ICT. Technologies were divided into six groups:

- Production control (7 technologies);
- Automation and robots (4 technologies);
- Additive Manufacturing Technologies (2 technologies);
- Simulation Tools and Data Analysis (3 technologies);
- Energy efficiency technologies (3 technologies);
- Waste recycling technologies (2 technologies).

In this paper, we are focusing on Industry 4.0 specific IT and AMT from the Production control, Automation and robots, Additive manufacturing technologies and Simulation Tools and Data Analysis (we are skipping energy efficient and waste recycling technologies). Fig. 3 presents a structural part of a question from EMS 2022 that deals with the diffusion of technologies and represents a core question for all our analysis.

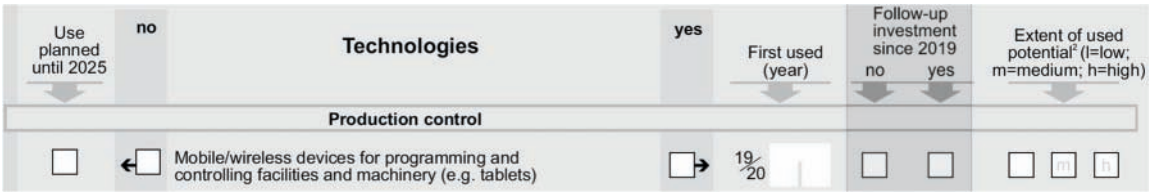

Figure 3: Question on the use of technologies in EMS 2022

Analysis shows (Table 1) that digital solutions to provide drawings, work schedules or work instructions directly on the shop floor and software for production planning and scheduling (e.g. the ERP or APS systems) are the most frequently used technologies, with instalment in around two thirds of Slovenian manufacturing companies. Mobile/wireless devices for programming and controlling machinery and/or facilities and Digital Exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI) from "Production control" group are also catching up with instalments in almost 50% of Slovenian manufacturing companies. From the IT we can also observe frequent use of software for product design simulation, while software for simulating production processes (e.g. digital twins) are still rarely implemented.

We observed 4 types of robots. Besides industrial robots for manufacturing and handling processes we included additional subgroup of robots, namely: mobile industrial robots (e.g. AGVs) and collaborating robots/cobots. The former two robot types have been a part of manufacturing companies for a long time, while the latter robot types are gaining in their importance. When we looked at the use of industrial robots for manufacturing and handling processes together, we found that at least one type of robots is present in 64% of companies, making industrial robots the most widely used technology from our list next to ERPs and digital solutions on the shop floors.

Additive technologies have been a part of our research for several rounds. We observe two types of these technologies: 3D printing technologies for prototyping and 3D printing technologies for manufacturing. If we combine both types of additive manufacturing technologies, we can observe that at least one of them is used in around 45% of companies.

Figure 4 presents the use of selected technologies in the period from 2015-2018-2022. Firstly, we can clearly observe that the adoption share of majority of selected IT and AMT has increased in the period from 2015 until 2018. The only exceptions are ERP systems and 3D technologies for manufacturing. The former already have a very high adoption frequency with around 65% through the whole observed period.

Table 1: AMT adoption in Slovenian manufacturing companies

AMT	Share [%]
Production Control	
Mobile/wireless devices for programming and controlling machinery and/or facilities	47,5%
Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor	64,5%
Software for production planning and scheduling (e.g. ERP or APS system)	63,8%
Techniques for automation and management of internal logistics (e.g. Warehouse management systems, RFID)	27,7%
Digital Exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI)	44,0%
Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management	17,7%
Near real-time production control system (e.g. Systems of centralized operating and machine data acquisition, MES)	33,3%
Automation and robots	
Industrial robots for manufacturing processes (e.g. welding, painting, cutting)	52,5%
Industrial robots for handling processes (e.g. depositing, inserting, sorting, packing processes)	38,3%
Mobile industrial robots (autonomously moving around the shopfloor)	5,7%
Collaborating robots/Cobots (free of fences)	9,9%
Additive manufacturing technologies	
3D printing technologies for prototyping (prototypes, demonstration models, 0 series)	39,0%
3D printing technologies for manufacturing of products, components and forms, tools, etc.	23,4%
Simulation Tools and Data Analysis	
Software for product design simulation (e.g., product performance or parts reliability)	44,0%
Software for simulating production processes e.g. on process, line, factory level, or for supply chain	14,9%

The increase of IT and AMT use in the period from 2018 until 2022 in general is not so evident as for the previous period. Some technologies are (at least) stagnating in their use, while some received a major boost, especially mobile/wireless devices for programming and controlling machinery and/or facilities. Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor are also showing a steady increase in use.

We can observe an increase in the use of industrial robots manufacturing and handling processes in the period from 2015 to 2018. But if look the last period from 2018 to 2022 it seems their use is stagnating. In 20 years since we follow the use of industrial robots in Slovenia, we observed that in the period from 2003 until 2009 the use of industrial robots has doubled, but after that there was only approximately 15% of additional growth (in terms of looking the percentage of manufacturing companies that use at least one type of industrial robot).

If we look at the 3D technologies and companies that use at least of two types, we can observe a substantial increase of use in the period from 2018 until 2022. According to EMS 2018 results these technologies were used in one third of the companies, in 2022 already in almost 45% of Slovenian manufacturing companies.

In the last 5 years we are witnessing a lot of conversation on the use of artificial intelligence (AI) in every aspect of our lives. The same applies for manufacturing companies, where the applications / software with self-learning functionality are already showing their potential. In our research we asked manufacturing companies if they use specific software solutions in different areas (Table 2). Additionally, we have asked if this software solutions already include self-learning algorithms / AI functionality. As we can see from Table 2 the share of companies that use software for specific areas quite differs (column 2). In general, around 20 to 30% of companies that use software solution for specific area also includes self-learning algorithms / AI functionality in these software solutions (column 3). The fourth column presents the general share of Slovenian manufacturing companies that use AI-supported software. It is seen that this percentage is from 5 to 12%.

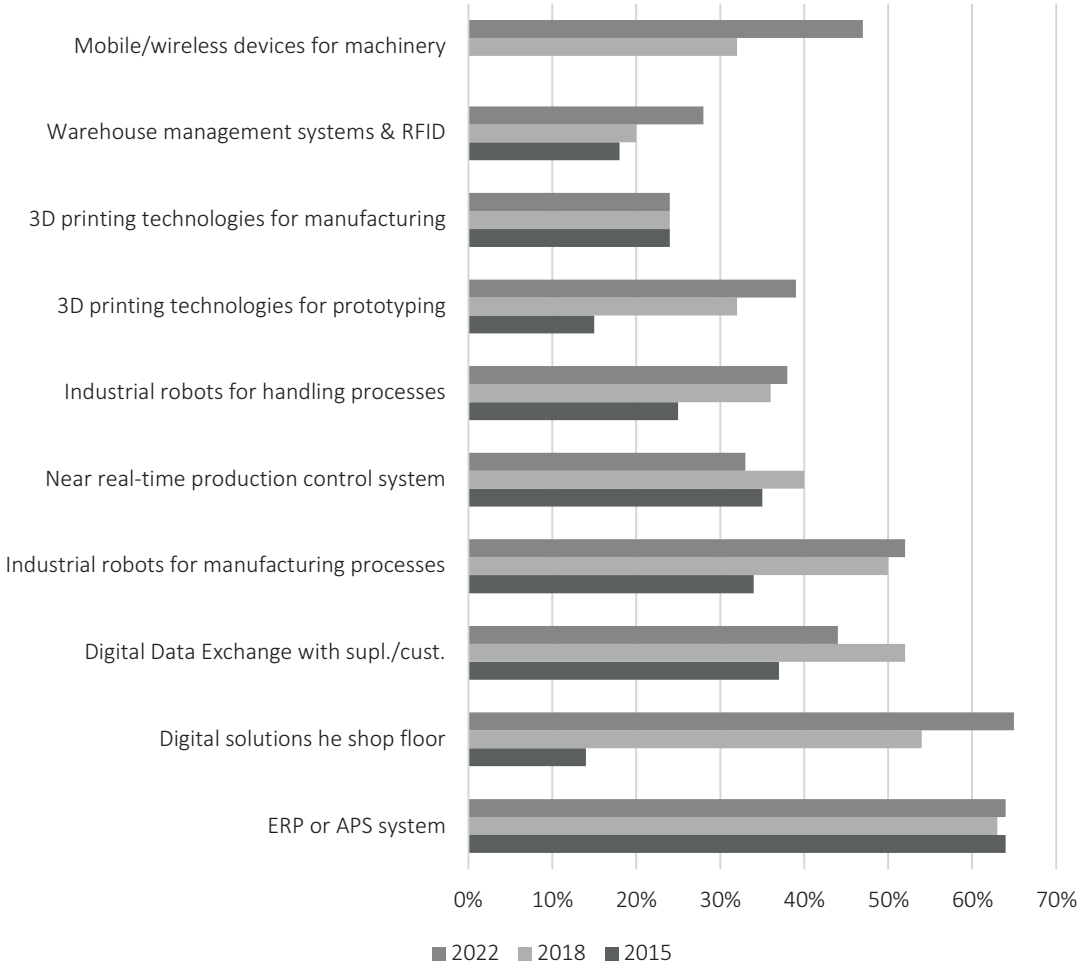

Figure 4: Trends in using AMT in Slovenian manufacturing companies

Table 2: Use of specific software solutions in Slovenian manufacturing companies

Using specific software solutions in the area of ...	Share [%]	Share with AI who use SW [%]	Share with AI in general [%]
Management of production processes (e.g. process monitoring)	61,7%	12,6%	7,8%
Quality control (e.g. defect detection)	43,3%	27,9%	12,1%
Maintenance of machinery and equipment (e.g. condition monitoring)	36,9%	21,2%	7,8%
Management of internal logistics (e.g. warehouse, transport)	30,5%	18,6%	5,7%
Energy management	23,4%	24,2%	5,7%
Improvement or innovation of production processes	26,2%	29,7%	7,8%

In EMS 2018 we added one general question on AI use and its first installations. Four years ago, only 5% of the observed population of manufacturing companies used AI in their processes. As we can see there was a substantial growth of share of manufacturing companies that use specific solutions based on self-learning algorithms / AI. If we combine all 6 possible AI-based software types, there is 20% of Slovenian manufacturing companies using at least one of these 6 types.

4.2 Industry 4.0 readiness index in Slovenian manufacturing companies

Fig. 5 depicts the distribution of all six described Industry 4.0 readiness levels for Slovenin manufacturing companies. Around 14% of all companies have so far not implemented any AMT or IT in production. Around 57% of all companies already have IT-related processes in their production and form the basic levels.

However, this group covers a big share of companies (nearly two thirds). This basic users group includes the group of beginners who only use technologies from one field (almost 18%; level 1), the advanced beginners who operate in two technology fields (almost 24%; level 2), but also the already advanced companies that are combining technologies from all three technology fields (over 16%; level 3). In the two highest levels 4 and 5, this top group consist of a total of 28,4% of all companies. About every fourth company is consequently active in all three technology fields, and not only uses IT-related processes, but also several CPS-related processes simultaneously. Levels 4 and 5 have very similar share of companies.

A look at Slovenian manufacturing sector shows that there is still a certain share of companies that heavily relies on traditional production processes (non-users). The main group of Slovenian manufacturing companies has slowly started to use IT-related processes, but there is a big difference between beginners and advanced users. The former are clearly closer to the non-users in terms of the type of production processes, the advanced companies are slowly preparing to enter the top group. The top group is not only active in each of the three technology fields, but also uses several CPS-related processes. There is a certain readiness to digitize their production, where the level 5 companies (14,9%) in particular seem to be preparing for Industry 4.0 related production or are already trying to implement it.

Fig. 6 presents comparison between Industry 4.0 readiness levels for Slovenian manufacturing companies based on data from EMS 2018 and EMS 2022 data. We can see a small shift of companies into higher levels (3, 4 and 5), and a small decline in lower level (0, 1, and 2), but the differences are rather small.

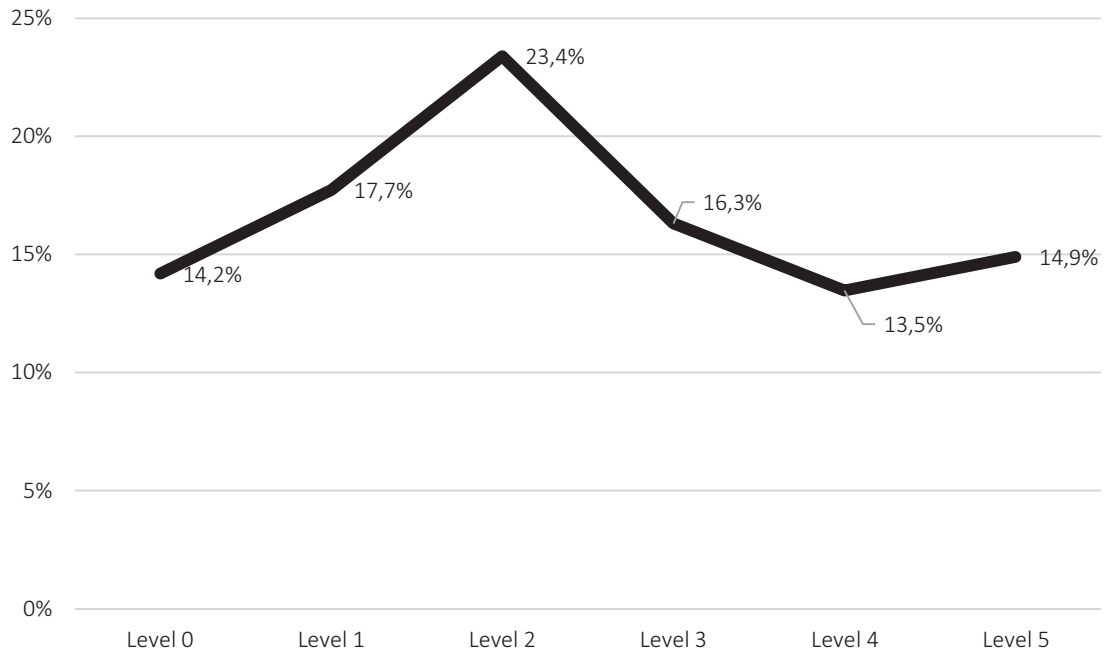

Figure 5: Industry 4.0 readiness index in Slovenian manufacturing companies (EMS 2022)

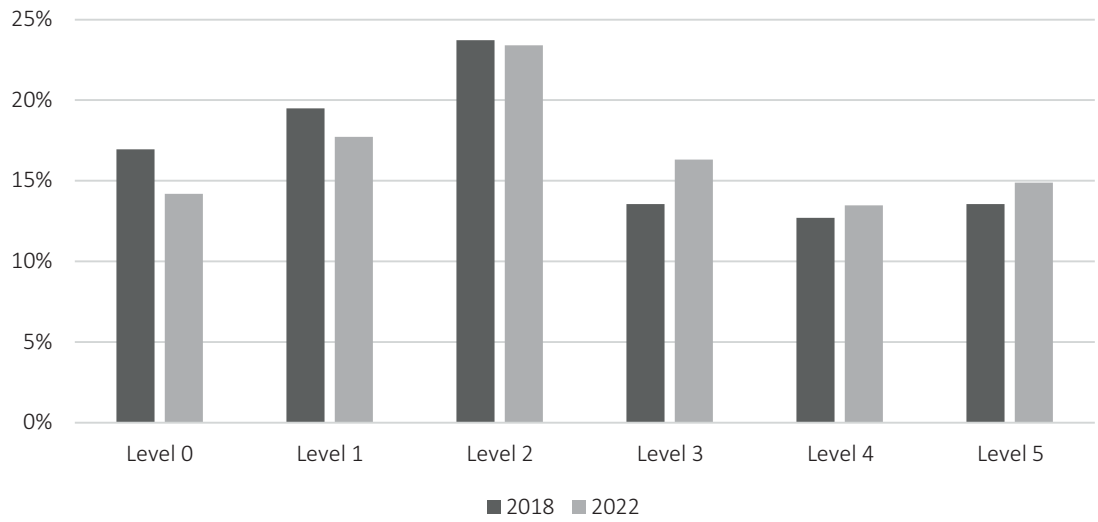

Figure 6: Comparison of Industry 4.0 readiness index in Slovenian manufacturing companies in EMS 2018 and EMS 2022

5 CONCLUSIONS

Our results show that the use of IT and AMT in Slovenian manufacturing companies is very diverse and context related. Our main goal of this paper was to compare the use of selected IT and AMT through the last 4 years. In general, we have observed a small increase in use of included technologies, but there are also technologies where their use obviously achieved its peak. The Industry 4.0 readiness levels for Slovenian manufacturing companies also points on the fact that the observed period did not bring a huge shift in using IT and AMT.

As is the case with all research, some issues must be taken into account when considering the reliability, significance, and general use of the obtained results. First, the data from Slovenia contains 141 companies in the EMS 2022 round. Although the sample is not small, further research should go towards the direction of a larger sample of more countries. We will also make more in depth analysis regarding the use of IT and AMT where we will consider company size, technological intensity of the industry they belong to, their status as the final producer for consumers or business customers (OEM) or supplier. We will also look into the relationship between introduced IT and AMT and specific characteristics, such as product complexity, production type and ability to introduce new products.

This research also has practical and managerial implications. Our results on the adoption of IT and AMT indicate the current state of technology implementation in Slovenian manufacturing companies, which can serve managers as a roadmap for future investments. Similar with Industry 4.0 readiness index managers can on one hand get familiar with one of the possible models to measure company readiness for Industry 4.0 and on the other hand compare their company to Slovenian average Industry 4.0 readiness.

6 ACKNOWLEDGMENTS

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INTERNET OF MEDICAL THINGS – BASED HEALTH RISK INSURANCE MODELING

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Abstract: *When concluding an insurance contract, data collections that convey information about an individual's measurable parameters are vital in assessing the insured's health state. Within the model that relies on data about potential insured, the technical and technological background of solving the health insurance modeling challenge should be found. The data is inherited (historical), previously acquired data, as well as data collected in real time. A body area network is a network of wearable computing devices or devices embedded in the body. These devices can be worn on the body or monitored by equipment in the local surroundings, whether wearable or stationary. The concept of the Internet of Medical Things on and around the human body, such as Wearable Sensors, is increasingly being used for not only monitoring an individual's health state, but also for collecting data that might be used for health risk assessment of insured.*

Key words: Body area network, Health insurance, IoT, Wearable Sensors

1. DIGITAL ECOSYSTEM IN INSURANCE

For a number of years, people have been carrying devices and sensor systems with them that are able to collect and transmit a large amount of data about the person wearing the device, his or her behaviors, and even their health. Such collections can be used for real-time analysis, automatic triggering of actions, or even defining business or operational models. Accurate and precise determination of risk is one of the basic activities of insurers. The more accurate the estimate, the greater the business success. IoT-based systems in insurance are often tasked with interacting with the user, retrieving the necessary information about the client or processing claims. No special explanation is needed for this traditional approach, they naturally occupied a business niche. However, increasingly, IoT systems are changing or completely defining new business logic.

Business models based on IoT are grouped into several current digital ecosystems (Behm et al., 2019):

1. Ecosystem of network-centric organized smart vehicles.
2. Smart housing and smart risk management ecosystem.
3. Smart treatment ecosystem in health management.
4. Ecosystem for business distribution with partners (B2B/B2C).

If it functions and operates in a single instance of the ecosystem, the organization of life and business in habitats created in this way extends to the horizon; if it functions and operates in multiple coexisting instances of the ecosystem, it extends within the intersection of several ecosystems of interest. This type of structure exists in both the physical and digital realms of existence. The commercial dynamics are best illustrated by two examples: the smart housing ecosystem, the most advanced of the four ecosystems, and the smart treatment ecosystem in health management. Ambient Assisted Living is one of the more successful concepts; it mixes smart homes and connected health services and enables corporate integration into the personalized insurance approach market.

1.1 The role of health management ecosystems in the development of health insurance models

The insurance market did not initially recognize smart housing and smart health management as important concepts. This was primarily due to technological but also sociological limitations. The potential new market was too limited for technical reasons and the solutions available on the market were slow to meet technical standards. Fortunately, it didn't stop there. After the big players in the field of IoT services like Google and Amazon, other providers have also offered their digital infrastructure services needed for smart health and treatment management. Such a technological breakthrough has enabled many insurers to launch collaborative models, selling integrated products through Google Nest or a similar service. In 2008, the

number of IoT devices exceeded the current population (Behm et al., 2019) and thus definitely enabled insurance companies to enter the field of personalized life and health insurance (Figure 1).
People who collaborate in an ecosystem based on the Internet of Medical Things idea and use IoT edge devices to monitor their essential functions are now eligible for personalized products and insurance bonus. In addition, insurers offer digital services such as health security and other services whose advantages correspond to consumers' interests based on the data gathered.

2. WEARABLE *DEVICES* IN THE HEALTHCARE ENVIRONMENT

As we've seen, and have known for some time, wearable technology and the related algorithms of the digital ecosystem of smart treatment in health management allow medical professionals to view the individual in a wider context and deliver effective health services. When examining the individual from the perspective of insurance, there aren't many differences. We are particularly interested in wearable devices that enable the collection of contextually organized data on possible insured. Therefore, wearable devices used in the healthcare environment to quantify the health status of the user are also devices of interest to the insurance industry. These devices can be divided and organized into several categories. For example, they can be divided according to the location on the body where they are worn or changes in medical records that device register. The following figure (Figure 2) illustrates wearable gadgets based on their location on the human body.

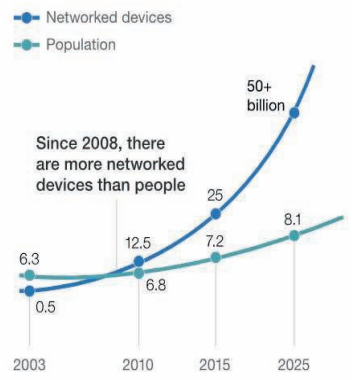

Figure 1: Time distribution of the number of IoT devices and population (Source: Behm et al., 2019)

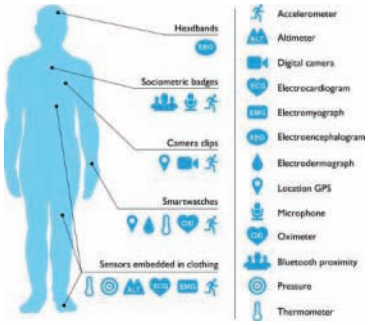

Figure 2: Wearable devices and their attached locations on the human body (Source: Piwek et al., 2016)

Regardless of the perspective, measurement or health condition that device record, we have identified a number of commercially available wearable devices that are used in the healthcare environment and are suitable for health insurance modeling based on the Internet of Medical Things (Table 1).

Table 1. Wearable devices that are used in the healthcare environment and could be used in health insurance modeling

Wearable Device	***Body Location***	***Typical Use Case/Disease Condition***	***Captured Movement***
Smartwatch with chest band (Vijayan et al., 2021)	Wrist and Chest	Multisport overal body condition	Movement, VO2Max, heart rate, oxygen saturation.
Smart Electro-Clothing Systems – SeCSs (Sayem et al., 2020)	Heart	Health Monitoring	Surface electromyography (sEMG); HR, heart rate variability.
Xsens DOT (Xsens, 2015)	All over the body	Healthcare, sports	Osteoarthritis
5DT data glove (Caeiro-Rodríguez et al., 2021)	Fingers and wrist	Robust Hand Motion Tracking	Fibre optic sensors measure flexion and extension of the Interphalangeal (IP), metacarpophalangeal (MCP) joints of the fingers and thumb, abduction and adduction, and the orientation (pitch and roll) of the user's hand.
Neofect Raphael data glove (Shin, 2016)	Fingers, wrist and forearm	Poststroke patients	Accelerometer and bending sensors measuring flexion and extension of finger and thumb.
Polysomnography sensors (Schätz et al., 2020)	Chest, hand, leg and head	Identify sleep apnoea	Breathing volume and heart rate.

Pulse oximetry (Liebling et al., 2018)	Finger	Pulmonary disease	Monitor oxygen saturation, respiratory rate, breathing pattern and air quality.
Eversense Glucose Monitoring, Guardian Connect System and Dexcom CGM (Kumar, 2019)	Hand	Diabetes	Glucose level monitoring.

Although recognized devices are widely distributed among patients with various medical conditions, the most interesting for insurers are those that are commercial and are most commonly worn by the healthy part of the population. Due to this, we will focus on the most commercially viable gadgets, smart watches.

3. SMART WATCHES AS PROVIDER OF PHYSICAL ACTIVITY METRICS IN HEALTH INSURANCE MODELING

The efficiency of physical activity as measured by wearable sensors in stratifying the mortality risk profile of a U.S. population-based dataset derived from a collection of clinical research studies was assessed by Munich Re. The dataset includes each participant's vital status (dead or alive) across a 20-year period, allowing for a comprehensive dive into the association between physical activity and mortality outcomes. The results of the study showed (Figure 3) that those with sedentary lifestyles and low daily step counts have considerably greater mortality risks, whereas people with moderate to high daily step counts have lower risks (Chefitz et al., 2022). The number of daily steps is particularly useful in identifying sedentary behavior that has a high mortality risk. Insurers who want to involve clients in the risk assessment process, improve the healthy lifestyle of policyholders may in the future want to consider the use of physical activity metrics obtained using wearable sensors such as smart watches throughout the insurance period and at different time points of life insurance.

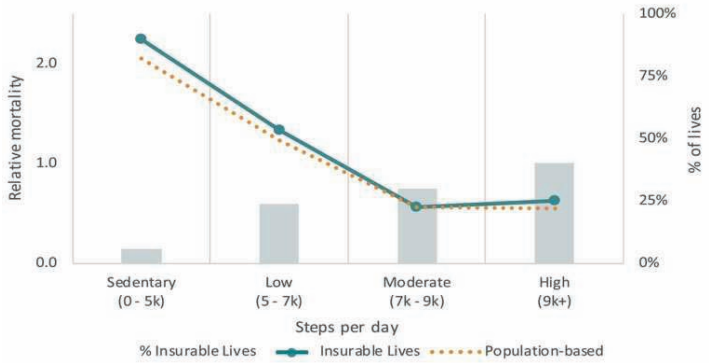

Figure 3: Relative mortality by average steps per day (Source: MunichRe, 2022)

3.1 Health monitoring and activity tracking features of smart watches

For the purpose of research, we have selected a multisport smart watch, the Garmin Fenix, as a representative example of a device for exploring the features of a fitness tracker that can be useful to insurers when determining and monitoring the health status of the insured.

Garmin Fenix, a multisport smart watch, from version 5 to the current version 7, is a device from the category of wearable medical devices that is widely used to monitor the state of training of athletes, their general condition, and critical health indicators. The reports generated by this device can be monitored live on the display of the watch itself, on the local application (bluetooth connected to the logger), and also remotely for the purposes of acquisition or monitoring by trainers and medical staff.

This device can only be used as a smart watch, with the use of a chest strap, or with the use of a logger. Regardless of which configuration is used, the time series of collected data are stored and used locally, both at the time of logging and in subsequent processing. Therefore, this device can be seen as an edge IoT device but also as an edge-to-fog system when it is completed with a logger. When the watch is used only in an isolated device configuration without a logger, data can be stored for 24 hours, after which it must be transferred to either the logger or a computer due to the limitations of the local memory on the watch. The chest strap does not expand the possibilities but serves to increase the precision and density of data sampling.

Data can be generated to examine the general status of training and vital functions, in addition to GPS, multisport capabilities and sensor data, to track the wearer's present health. Reports intended for

subsequent analysis are of particular interest to medical censors in insurance companies. Specifically, in the case of the mentioned smart device, the following reports that could be useful for health risk assessment are available (Figure 4): Activities; Activity Calories; Average Heart Rate; Average Pace; Average Speed; Calories Consumed; Calories Remaining; Functional Threshold Power; HRV Stress; Max Heart Rate; Total Activity Time; Total Distance; Training Status; VO_2 Max.

Figure 4. Health risk assessment reports

Of particular interest, for subsequent analysis, can be the monitoring of heart activity (Figure 5).

Figure 5: Heart rate report

In order to show potentially dangerous health conditions and situations that can be noticed in the reports and are therefore potentially useful to insurers, we will also list some specific examples. One of the particularly interesting monitored parameters is the Resting Heart Rate (Figure 6). In a healthy person, this parameter is in the range of 50 to 70 bpm (beats per minute). In the observed series of data, this value

deviated from the usual value in November last year. The change was registered and logged. It was subsequently determined that there were health impairments during that period, which were confirmed by laboratory analyses and medical examination later on. In other words, if this parameter had been monitored by a person or healthcare AI in charge of the client's health condition, the client could have been alerted immediately and not later, when the consequences had already occurred. In the following example of monitoring physical activities, a dangerous situation also occurred (Figure 7). During the activity, the heart rate was in the danger zone for twenty minutes.

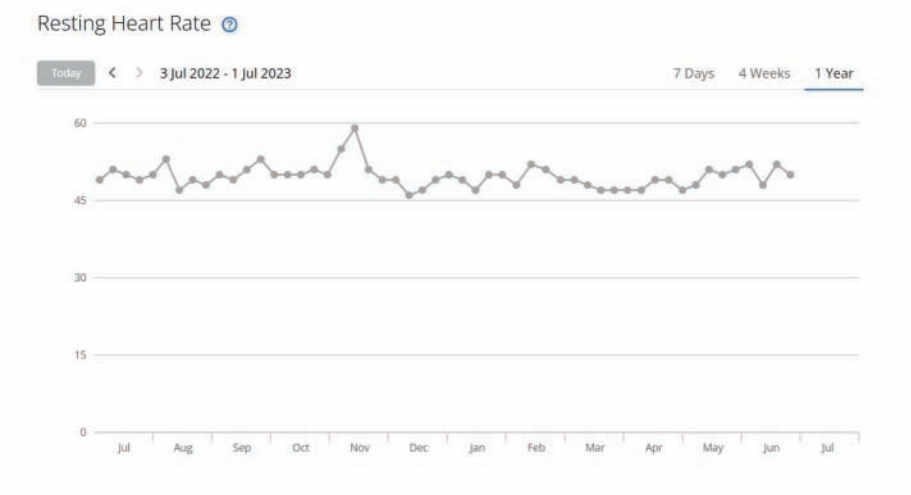

Figure 6: Resting Heart Rate

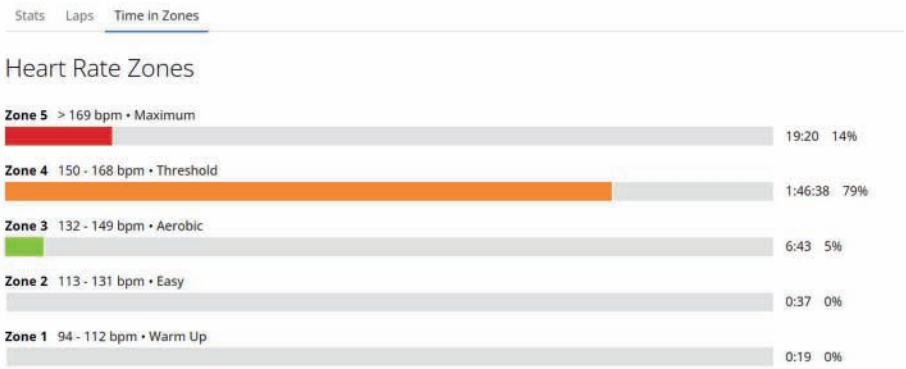

Figure 7: Heart Rate Zones

4. DISCUSSION AND CONCLUSION

Based on the presented case study of the Garmin Fenix multisport smart watch application, two roles for the person or AI who monitors and interprets the data are indicated. The first roll is related to incidental health conditions and potentially harmful events. In this type of data analysis, the monitoring person or AI recognizes unwanted conditions and informs the insured about the danger. The second roll is less noticeable but potentially more interesting for further insurance personalization. In this case, the person conducting health surveillance creates a kind of medical data model and projects desirable activities based on that model. Activities can be various, from suggestions for preventive examinations to recommendations on daily routines that can raise the quality of life of the insured. This increases health resilience and reduces the occurrence of potentially harmful health events. Ultimately, this reduces the insured's claims.

Modeling of health insurance based on the Internet of Medical Things is definitely an aspect of modern technology that brings novelty in the perception of business. Also, to a certain extent, it changes the perspective and the role of the insurance agent. Beside identifying sales opportunities for insurance plans and overseeing a portfolio of clients or tracking claims, the aspect of continuous monitoring of the health parameters of the insured is now being added. A trend that began in professional sports, where the coach

received real-time values of the variables of interest and could alter training or even the athlete's behavior during competition, is now spreading to the health insurance industry. Now the insurance agent assumes the role of a supervisor and monitors the client's vital parameters in real time. Based on currently measured values or on the basis of analysis of historically collected data series, a model of the insured's medical assessment is generated, and the agent is able to take pro-active steps and thus influence the insured's health condition and contract terms.

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THE INFLUENCE OF ORGANIZATIONAL CHANGE ON THE EMPLOYEE'S PERFORMANCE

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Abstract: *In order to survive in a global knowledge economy, all organizations that want to position themselves well in the market must initiate changes or adapt to the already occurring changes in the environment. The aim of this study is to explore the impact of organizational changes on performance of employees. The significance of this study is in determining how different types of organizational changes affect employees and their performance. It is extremely important to study changes from the perspective of employees. If employees do not see the change as a threat, they will more easily accept it and therefore take part in it, which in turn leads to improved performance and quality in the organization. Change produces a deep effect on an employee's attitude, so it will result in performance of employees. Achievement of an organization depends on how it enhances employee performance and encourages commitment to the organization. Today, knowledge and ideas quickly become outdated, and employees must acquire new knowledge throughout their entire lives in order to cope with changes. This main goal of present study is to expand the existing base of scientific knowledge, so it can be a useful base for researchers to develop further analysis.*

Key words: organizational changes, change management, employee performance, organizational learning

1. INTRODUCTION

Change is an essential characteristic of organizational, civic and personal life. Change is something we sometimes strive for and sometimes resist. It would not be an exaggeration to suggest that society is full of change and questions about how, when and in what ways change should occur. Achieving a goal, making progress, and even avoiding a crisis very often implies the implementation of planned changes. Change can serve as a means to address many important challenges such as those related to politics, governance, rule of law, philosophy and the distribution of information, rights and resources.

Changes represent the basis of survival and development of all organizations, social and business systems. Today there are many factors that generate constant changes that force organizations to change themselves in order to adapt to changed conditions and new challenges. The most important factors of change are scientific and technological development, competition, market, international relations, economic system, legal system, fiscal and monetary policy of the country, etc. Changes in the organization itself imply a change in its business and development strategy, production technology, organization, management, workers. To survive, an organization must manage change and use it for its own development. Responding quickly to changes and adapting to changes is the most important challenge for modern managers. Managers are the ones who must encourage and implement change. They must overcome the inertia and resistance to change that exist in every organization and create such a climate that people see changes as their own opportunities, not as threats to them. Therefore, instead of studying organizational stability, more and more organizational changes are being studied (Bogdanović, 2015).

In today's modern era of the knowledge economy, organizations gain a competitive advantage through employees and their knowledge. In human nature is to want things to remain unchanged. Even when organizational change results in a better work environment or process improvements, people will resist change. The main reason is that every change is a path into the unknown, which consequently means a path into uncertainty, which creates stress. Therefore, after examining and identifying the causes of changes, the main task of the manager is to implement changes, overcome resistance to changes, control the implementation of changes and their results.

Performance of employees defined as the degree of accomplishment and achievement of task of an individual (Kansal & Singh, 2016). In in today's modern learning organizations employees are required to show proactivity, initiative, creativity and motivation. Dulger (2009) indicated that the degree of tolerance and employee commitment toward change has important implications for employees' performance. The business success of depends not only on how the organization makes the most of the competences, but also how it makes better employee performance and stimulates commitment to the organization (Karanja,2015).

The main objective of this study was to investigate effects of organizational changes on the employee performance and thereby contribute to a better understanding of this relationship and expand the existing literature in the field.

2. ORGANIZATIONAL CHANGE

Organizational changes represent changes from the current state of the organization to the desired one in order to improve its efficiency. Sometimes organizations themselves initiate changes, and sometimes they are forced to adapt to changes that occur in the external environment. Taking this global approach into account, we are talking about two basic types of changes: developmental (internal) and adaptive (external) changes.

Internal causes of changes in the company are changes that lead to an internal imbalance, due to changes in one and the absence of other components. This requires changes to achieve an internal balance of the company's components.

External causes of changes are changes in the environment that lead to external imbalance, mismatch of the company with the requirements of the environment, which sets the demand for changes in the company.

Managers must be able to quickly notice changes in the environment, to analyze and interpret them, and to encourage and implement changes in their own company. Managers' abilities to overcome inertia and resistance to change, which exist in every company, and to create a positive atmosphere for change, so that people see changes as their own opportunities, and not as threats and threats to their position, are very important.

In modern theory, the organization is seen as a complex and open system: complex, because it consists of numerous subsystems (human, technical, resource, informational, etc.); open, because in order to survive, it must communicate with environment. All factors, which disrupt the balance, both between organizational subsystems, as well as the balance between the organization and the environment, represent cause of organizational changes. Imberman (2003) claimed that organizational changes are necessary in order to ensure organizational strategies realization.

Since change management is a modern discipline, in practice and theory much attention is paid to this discipline. This is how numerous definitions of the concept of organizational changes were created. In this paper we will mention a few:

- Organizational change represents the launching and adding a new series of action, belief and attitude among considerable segments of a population. Reason behind this is that opportunities arise at external and internal environment (Tichy, 1983)
- Organizational change can be defined as the process through which something becomes different (Pakdel, 2016)
- Organizational change is considered as an purposeful change design in the official structure of the organization, systems, processes or product market, which is trying to improve the achievement of one or more organizational goals (Lines, 2005)
- Change in the organization is the process of transformation which occurs in behavior, structures, policies, intentions or the output of organizational units (Hanson, 1996).

Every organizational learning is organizational change, but every organizational change is not organizational learning. This phrase, however, hides an important conclusion: organizational learning is only one of different types of organizational change

Organizational learning is most often defined as a change in the cognitive structures and behavior of the organization's members, which ensures an increase in the organization's ability to adapt to its environment. Learning is the process that underlies and creates change.

Change itself is one of the ways that organizations learn. The purpose of learning is to acquire new, necessary knowledge and to use it effectively in practice, so that the organization has a competitive advantage over other organizations.

3. EMPLOYEE PERFORMANCE

Performance can be defined as the ability of an organization to achieve its goals (Stainer, 2006). Performance indicators should be integrated and interdependent in order to provide an overall perspective on the company's goals, business strategies and specific objectives, as well as on the company performance (Tesic, Tomic, Gajic, Kuzmanovic, & Tomic, 2014).

Performance measurement is a concept that allows the coordination of component parts of complex organizations. The companies which are capable of using the frameworks and methods for measuring performance in the management of their strategies, systems and processes have the ability to achieve competitive advantages (Spitzer, 2007).

Ittner, Larcker, and Randall (2003) point out that measuring the company performance means easier access to the information needed to identify strategies and coordinated management processes such as goal-setting, decision-making and performance evaluation. An essential condition for the fulfillment of the objectives is the proper selection of key indicators for performance assessing (Lohman, Fortuin, & Wouters, 2004).

This research represents a further contribution to the idea, which was discussed by a number of authors, that employees' loyalty in service organizationshave a positive influence on the performance (Balkyte & Tvaronaviciene, 2010; Cavacoa & Machado, 2014).

The relevance of the topic for service companies is considerable, since employee loyalty is very important for company success. Service companies generate their income by providing services and they are based on human capital.

Loyalty signifies a person's devotion or sentiment of attachment to a particular object and employee loyalty can be defined as employees' commitment to the organizational success and thinking that working for that organization is their best opportunity (Iqbal, Tufail, & Lodhi, 2015). Loyal employees are faithful to the organization and do their best in service providing, which has a direct and significant influence on the service companies' performance.

A considerable body of theoretical and empirical research has been done on employees' influence on company performance. Sila (2007) researched employee performance or the effect of employee fulfillment on company performance and Fulmer, Gerhart, and Scott (2003) explored whether superior firm-level relations between employees can be associated with better financial and market performance relative to other firms.

Baptiste (2008) indicates that, whilst the issue of employee wellbeing at work has reached a new level of importance in the minds of managers, but a little attention was paid to the connection between performance and employee wellbeing.

Yee, Yeung, and Cheng (2008) indicated that the importance of employee attitudes, including employee loyalty, and their impact on operational performance has largely been neglected and that loyal employees are more capable and have a direct impact on delivering a higher level of service quality, which has an indirect impact on company performance.

Loyalty behaviors will generate both market share and profitability increases for the service company (Chi & Gursoy, 2009) and, if employees are committed to organization and performing at a higher level, this will have an indirect impact and a positive influence on organizational performance (Ali, Rehman, Ali, Yousaf, & Zia, 2010).

4. THE EFFECT OF ORGANIZATIONAL CHANGE ON EMPLOYEE'S PERFORMANCE

Today's organizations are faced with constant changes. It can be said that change is the only constant in modern times. Every organization that wants to achieve and maintain its competitiveness must implement change management as a priority discipline. The increasing frequency of changes in the working environment imposes the need for employees to adapt to the changes. However, almost every change is accompanied by certain changes. In these conditions, the primary task of the manager is to

consider not only how the change affects the performance of the organization, but also the employees themselves.

in learning organizations, employees are expected to show creativity, initiative, proactivity, motivation. The success of an organization depends not only on how well it uses human resources competencies, but also how well it manages to improve employee performance and commitment to the organization.

Feedback is one of the ways to improve employee performance, which is the goal of almost every organizational change. Feedback is a proposal for how employees can change their behavior and is a tool for organizational change.

Lewin's change management model (1951) consists of three distinct phases: unfreeze, change phase and refreeze. Unfreezing is the stage of preparing the organization for changes. It implies those activities in the organization that will enable changes to be made in the most efficient way possible. This phase includes process of explaining to employees the causes of changes and the necessity of making changes and inciting dissatisfaction among employees with the current situation in the organization and a sense of guilt for maintaining the current situation. The second phase - the phase of change is the most difficult to implement. It includes overcoming all resistance to change and changing employee behavior, as well as organizing learning and training to implement employee behavior. In the third phase, named refreezing, employees integrate new behaviors into their way of working.

There are many studies focused on influence of organizational change on employee' performance. Karanja (2015) found that organizational changes have positive influence on employee performance. Similar results were reached by Ahmed, Rehman, Asad, Hussain and Bilal (2013). According to the study conducted by Kansal and Singh (2016), a positive attitude leads to an improvement in employee performance, and the organizational change itself creates a greater impact on the attitude of employees, which results in increased performance. On the report of Wanza and Nkuraru (2016), structural changes and organizational leadership influenced university employees' performance positively. According to the authors, structural changes, leadership, technology and organizational culture affects the employee's performance positively.

5. CONCLUSIONS

Change is an essential characteristic of organizational, civic and personal life. Change is something we sometimes strive for and sometimes resist. It would not be an exaggeration to suggest that society is full of change and questions about how, when and in what ways change should occur.

People always support what they are involved in and then help make it happen. Support for change will be stronger if the change allows active participation of individuals in planning and implementation. The goal is to accept the change as something that is unique to the individual, that is, something that he wants and can live with. Acquaintance with changes leads to acceptance of changes, when the manager is prepared to listen and change his plans, if there is a clear message that they are not effective, or if they could be acceptable without jeopardizing the goals to be achieved.

Organizational change can affect all aspects of the operation and functioning of the organization. Therefore, management should implement regular training program, in order to enable changes at the level of the entire organization by improving them so that it reaches a higher, more qualitative level of functioning. These changes that apply to individuals include recruitment, selection, replacement and transfer, training and development of personnel, and supervision and counseling.

The first group of individual changes involves bringing in and placing the right people in the right places to help the process of introducing changes at the level of the entire organization.

The second group of changes aims to train and develop personnel for the changes that will be introduced at the organizational level. This process implies the existence of a good training program that will enable employees to better understand the changes and how to introduce them.

The third group of individual changes includes supervision and counseling with the aim of providing assistance to managers to manage changes as effectively as possible.

This study adds to the body of knowledge that organizational changes have significant effect on employee performance.

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THE YOUTH AND THEIR PERCEPTION OF ONLINE HATE SPEECH

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Abstract: *Young people, as the most sensitive category of society, are daily exposed to hate speech through numerous communication channels. Media content that promotes violence, content that clearly expresses intolerance towards differences, content that promotes wrong value systems and allows daily disparagement, insults and belittling, contribute to the creation of an inadequate society for growing up and educating young people. Precisely with the aim of determining the attitude of youth towards hate speech to which they are exposed in the online space, a survey was conducted on a sample of 108 respondents. The results of the survey showed that more than 90% of young people witnessed some form of hate speech, which was most often directed at political dissenters or members of the LGTB+ community. Also, in the largest percentage, they condemn every form of violence, including verbal violence, believing that hate speech on the Internet can affect mental health. However, young people are not sufficiently informed about hate speech and do not know how to react in situations where they are exposed to it. Additional education is necessary, as well as the reduction of content that propagates this type of communication.*

Key words: Media, internet, information, hate speech.

1. INTRODUCTION

The Internet provides access to an almost unlimited amount of information, facilitates work and speeds up communication between people. Internet has partly assumed the role of means of mass communication, which contributed to the increase and democratization of communication. On the other hand, the negative aspects of the Internet are the facilitated creation and spread of half-truths and unverified information, the expansion of cybercrime, hate speech and many other negative social phenomena (Veljanovski, 2012). Social networking sites are especially popular on the Internet, and they have become an almost indispensable part of everyday life, as a channel through which information is collected, communicated and further distributed (Krivokapić et al, 2021). Social networking sites represent the most widespread form of "social media", which implies the creation of user-generated content (Miladinović, 2015). The advantages of social networks are structural flexibility and fast communication flows that enable easier association and spontaneous organization of individuals based on common interests (Andrade & Pischetola, 2016).

However, internet media and social networks can become a suitable environment for the manifestation of negative social phenomena, among which hate speech stands out. Hate speech can be defined as “any kind of communication in speech, writing or behavior, that attacks or uses pejorative or discriminatory language with reference to a person or a group on the basis of who they are, in other words, based on their religion, ethnicity, nationality, race, colour, descent, gender or other identity factor” (United Nations, 2019). As the Internet and social media are characterized by physical distance and the virtual presence of users, the spread of hate speech is facilitated, especially due to the presumed anonymity as well as the relatively inexpensive and convenient place for wide communication (Daniels, 2008).

In discussions about the concept of hate speech in the media, two opposing positions are represented. On the one hand, hate speech is identified as a negative social phenomenon that should be banned, and on the other hand, it is considered that such a ban would threaten the freedom of expression. Many experts nevertheless agree that education is necessary to oppose hate speech, in order to eradicate prejudices, misconceptions and stereotypes that lead to it (Sikorskaya & Gafarova, 2014).

Since young people are daily users of the Internet, and especially of social networking sites, they are particularly susceptible to their negative influence. The fact that they feel more free online than in direct communication speaks in support of the understanding of the great popularity of the Internet among young people (Nikšić-Rebihić & Smajović, 2021). However, the World Health Organization pointed out the negative impact of the Internet on human health, especially young people, and that the excessive use of digital technology is a public health problem (WHO, 2014). What is more, research entitled "Communicative aggression in Serbia 2019" showed that in the period of one month, almost 20,000 texts

with elements of aggressive communication, hate speech and sensationalism were published in the most widely read print and online media in the country. These data indicate a high exposure of the population to hate speech through the media, which can lead to many negative consequences (CEPROM, 2019).

In this paper, the analysis is limited to the perception of youth[1] in relation to the hate speech they encounter on the Internet. The subject of the research was the attitudes and opinions of the research participants about hate speech in the online space. The goal of the research was to determine the general attitude of young people towards the use of hate speech, that is, whether they are familiar with the term "hate speech", whether they have been exposed to hate speech, whether they react to it (and in what way), as well as whether they are sufficiently informed about this phenomenon on the Internet and the ways in which they can best approach it.

In many countries, there are debates about the optimal way to balance seemingly opposing values – freedom of expression, on the one hand, and the imperative to ban certain types of communication that encourage violence, hatred and discrimination, on the other. Internationally, the right to freedom of speech is provided for by numerous international legal instruments, but certain limitations of this freedom are also prescribed. International law prohibits the incitement to hostility, violence and discrimination, rather than the hate speech as such. However, hate speech can be harmful, given that it promotes intolerance and discrimination, which can lead to serious crimes (United Nations, 2019).

Numerous media operate in the online space, whether they are just internet presentations of traditional media, with an editorial policy or the social media, among which the most numerous are social networking sites (such as Facebook, Instagram, Youtube, etc.), which lack a responsible editor. Regulations generally regulate hate speech found on traditional media websites, while the issue of regulating hate speech on social networks is still controversial and unclear. Thus, different countries approach the problem in different ways. For example, in the US, social media have wide freedom to adopt and enforce their own rules, while not being responsible for the actions of their users. On the other hand, under new social media rules in India, the government can order platforms to remove posts within twenty-four hours based on a wide range of violations, as well as identify the users who made the offence (Laub, 2019). In the European Union, a significant shift in legal regulation was achieved with the adoption of amendments to the Directive on Audiovisual Services (2018), which extended the original rules, that only applied to traditional media, to platforms for sharing video content (such as YouTube), as well as to audiovisual content shared on other social media platforms, in order to protect minors from harmful content, and all citizens from incitement to hatred, violence and terrorism. Although this represents a change in terms of legal regulation of social media, a large part of the activities of network users remains unregulated. The situation is further complicated on the sites of editorially designed Internet pages, which have the possibility of commenting by the user. At the international level, there is still a dilemma as to whether the media is responsible for the comments of its readers (Atanacković, 2020).

In the Republic of Serbia, there are several laws that are relevant to the field of combating hate speech: Law on Advertising (Article 8), Law on Public Information and Media (Article 75), Law on Prohibition of Discrimination (Article 11), Criminal Code (Articles 317, 387 and 138), Law on Electronic Media (Article 51), etc. (Ivanović & Stojanović, 2022). However, due to the disparity of regulations and the possibility of legal protection, individuals often find it difficult to navigate it and do not know who to turn to (Atanacković, 2020). That is why solutions are often found in self-regulation – adopting legally non-binding, but very significant documents, such as ethical codes and guidelines of behavior of certain social networking sites that prohibit socially unacceptable behavior of users.

Therefore, in order to reduce hate speech in public discourse, social engagement is necessary on several fronts – on the level of regulation, self-regulation, ethics and education. As the legal regulations cannot fully sanction hate speech on the Internet, it is considered that the key role in recognizing and reducing hate speech should be played by the education of young people through media literacy. Media literacy is defined as a set of viewpoints that we actively apply in media consumption to interpret the meaning of the messages we receive (Potter, 2011).

2. METHODS

The conducted research was of a quantitative type, while data collection was carried out based on the survey method. A specially structured electronic questionnaire was used as a research instrument,

[1] According to The Law on Youth ("RS Official Gazette", no. 50/2011 and 116/2022 – other law) of the Republic of Serbia, young people are persons from the age of 15 to the age of 30.

created through the Google Forms option, with open and closed answer modalities offered, and a set of questions formed according to the Likert scale. The online questionnaire contained 13 questions, grouped into two parts: socio-demographic characteristics of the research participants (four questions) and the attitude of the research participants towards hate speech on the Internet (nine questions). The online survey process was conducted via e-mail and Viber, with the limitation of "one address – one answer". In this way, potential misuse was prevented, i.e. it was impossible to reply multiple times from the same e-mail address. The obtained data were processed through a statistical program directly on Google Forms. Participation in the research was voluntary and anonymous for all respondents. The research was conducted in the period from May 5 to 19, 2023.

3. RESULTS

The research sample consisted of 108 respondents, of which 57.5% were female and 42.5% were male. Adult young people between the ages of 18 and 30 participated in the research, with the average age of the respondents being 24.8 years. Among the research participants, there were mostly highly educated people, that is, those who completed four-year studies (46%), followed by those who only completed high school (29.9%). An equal number of research participants had a master's degree and a higher education degree – 11.5% of them each. The largest number of respondents stated the city as their place of residence – 95.4%.

Almost all research participants were familiar with the term "hate speech", where 58.6% of them were fully familiar with the meaning of this term, and 36.8% were partially familiar with it. A negligible percentage of respondents – 3.4%, were not sure what the meaning of the mentioned term was, while only one (1.1%) respondent did not know what was meant by "hate speech". The largest number of research participants (77%) heard about this term via the Internet, an almost equal percentage of them via the media or in an educational institution such as school and college – 48.4% each, from their family members 16.1%, and from friends – 14.9% of respondents.

The results of the conducted research confirmed that more than 90% of the research participants witnessed some kind of "hate speech" on the Internet, but with different frequency (Graph 1). Thus, "hate speech" was witnessed daily by 23% of respondents, occasionally by 36.8%, and rarely by 31% of them. There were 5.7% of those who were not sure whether they had witnessed this type of internet violence, and only 3.4% of those who estimated that they had not witnessed it.

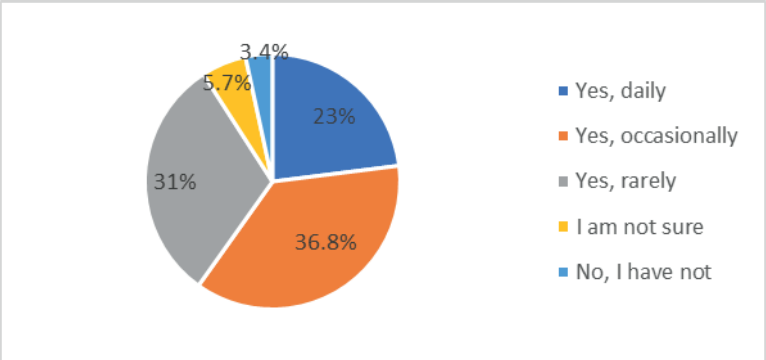

Figure 1: Exposure to "hate speech on the Internet"

The "hate speech" witnessed by research participants in the last three months was in most cases directed towards members of the LGBT+ population (62.1%), political dissidents (60.9%), members of another nation (47.1%) and other religions (41.4%), but also towards migrants (27.6%) and people with disabilities (8%).

Although they witnessed "hate speech" on the Internet, more than half of the respondents did not react to it in any way (51.7%). Nevertheless, there were those who reacted, most often in one of two ways: either they blocked the person who spread "hate speech" (20.7%), or they reported "hate speech" online, that is, the page where they noticed it (13.8%).

Research participants who did not react to "hate speech" on social networks but noticed it, were asked an additional question, i.e. what was the reason for their decision to do so. As the most common reason, they stated that "they don't like to publicly express their position on sensitive topics" (40%) and that they "didn't want to enter into discussions in the online space" (40%), and there were also those who "didn't

know how to react" (15.6%). Although a large number witnessed hate speech on the Internet, a small number of research participants – 6.9% of them were directly exposed to it, while 19.5% of respondents were not sure whether it was or not. Those who were directly exposed to it, as a form of this type of internet violence, stated that they were insulted and ridiculed because of the posts they posted, then because of a conflict of opinion on certain topics, or on a national basis.

Based on a five-point Likert scale, the degree of agreement with the respondents' statements regarding the use of "hate speech" on the Internet was assessed. Thus, the largest number of them, in different situations, never used "hate speech" (Figure 2). Constant and frequent use of "hate speech" by research participants was negligible, so in the online space, "hate speech" was rarely used in the context of "offensive and derogatory names" (11.49%), "to ridicule groups or individuals" (11.49%), and in the context of "expressing and/or spreading offensive stereotypes" (10.34%).

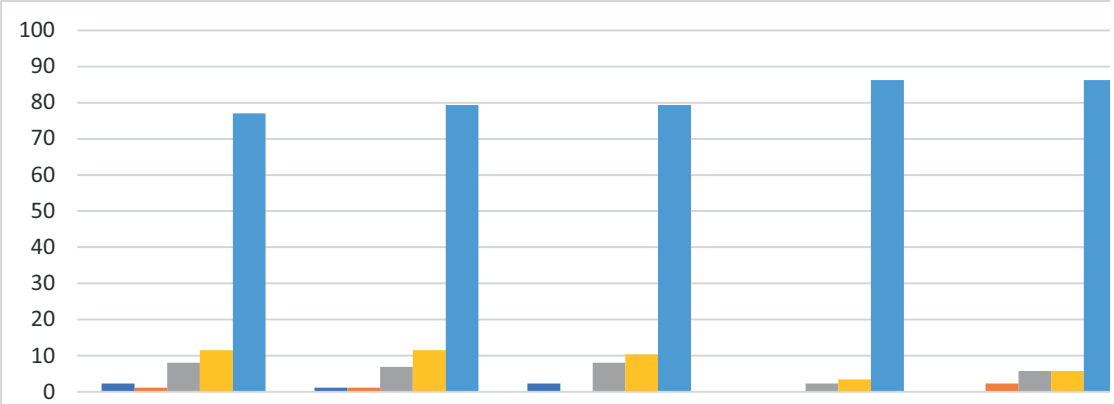

Figure 2: The use of "hate speech" in the online space

The largest number of research participants fully agreed with the assessments that they "condemn all forms of violence, including verbal violence" (73.56%), and that "hate speech can seriously affect an individual's mental health" (56.32%). Also, the largest number of them agreed with the statements that "hate speech contributes to the formation of a general negative attitude about an individual or group" (45.98%), that "hate speech on the Internet often leads to violence in a real environment" (43.68%), that "prejudice is most often behind hate speech" (40.23%), and that "it is expected that you will be attacked on social networks if you publicly speak about things that are not acceptable in society" (26.44%). On the other hand, respondents completely disagreed with the statements that "they do not see a problem in the use of hate speech in the online space" (68.97%), that "violence on social networks cannot seriously harm anyone" (48.28%), and that "some individuals or groups of people deserve to be ridiculed" (43.68%). These results clearly indicate a developed awareness of the negative consequences of the use and exposure to "hate speech", but also a direct condemnation of the use of this form of communication. However, the majority of research participants were of the dominant opinion that young people are not sufficiently informed about "hate speech" on the Internet (58.6%), stating that there should be more discussion about this topic in educational institutions (81.6%), that it is necessary to additionally educate parents on how to act in case of exposure to "hate speech" (63.2%), but also to launch a greater number of educational campaigns that will be advertised through social networks (60.9%) and traditional media (37.9%), including the launch of specialized websites (23%).

4. DISCUSSION AND CONCLUSION

Numerous studies (Ivanović & Stojanović, 2022; Al Serhan & Elareshi, 2019), including ours, confirm the knowledge of the concept of hate speech among Internet users. Some even indicate that it is the category of young people that is most affected by hate speech in the online space, especially if they are politically engaged or members of specific social minorities (Obermaier & Schmuck, 2022). In Germany, 40% of the population witnessed hate speech on the Internet, while 73% of young people aged 18 to 24 were exposed to hate speech victimization on social networking sites (Geschke et al., 2019).

Although more than 90% of the young people who participated in our research witnessed some form of hate speech, a smaller number of them were directly exposed to it. On the other hand, although they noticed it, they did not react to it. Data from the UK Safer Internet Center (2016) confirm that young people do not react to this type of incident in the online space most often due to a lack of appropriate

competences such as limited knowledge of what is meant by hate speech or due to insufficient knowledge about what actions they can take to oppose it.
As the young population is most sensitive to negative thoughts and comments, and is daily exposed to hate speech, especially in connection with sexism, offensive texts and religious differences, this can lead to various disorders, such as depression, learning difficulties, social discomfort (Sarfraz et al., 2022), but also a feeling of fear, insecurity and sleep disturbances (Obermaier & Schmuck, 2022). For the above reasons, dealing with this topic is extremely important.
It can be concluded that young people's awareness of the harmfulness of hate speech was at a high level, although they expressed concern about the level of media literacy, and they believe that additional education by formal and informal educational organizations is necessary.
Given the delicacy of the topic, the main limitation of this research is the sample size and potential bias in answering the questions, according to socially desirable behavior. The sample should be expanded to respondents of a younger age category, considering that teenagers spend the most time on the Internet, and grow up exposed to the influence of the virtual world, where there are still no clear legal restrictions regarding the spread and propagation of hatred. This can have unforeseeable consequences in terms of personality development and being in a real environment. Also, it is desirable to launch initiatives to limit and suppress the use of hate speech on the Internet, not only through the introduction of legal regulations, but also through various dedicated, educational content.

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LEVERAGING CHATGPT FOR CREATIVE COMMUNICATION STRATEGIES: EXPLORING PROS AND CONS

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Abstract: *In today's rapidly evolving digital landscape, effective communication strategies play a pivotal role in the success of any organization. As businesses strive to engage and captivate their target audiences, innovative technologies have emerged as powerful tools to enhance communication efforts. One such technology that has garnered significant attention is ChatGPT, an advanced language model developed by OpenAI. This paper aims to explore the pros and cons of utilizing ChatGPT for a creative communication strategy, focusing on its potential benefits and challenges. Moreover, this paper provides an analysis of the advantages and drawbacks of implementing ChatGPT in various communication channels, including social media, customer support, and content creation. To evaluate the pros and cons of using ChatGPT for creative communication strategies, a mixed-method research approach was employed. Firstly, a relevant literature review was conducted to gather insights and perspectives on the topic. Additionally, a number of use cases of implementing ChatGPT in communication strategies were analyzed. The research results provide valuable insights into the practical aspects of utilizing ChatGPT and allow a deeper understanding of its advantages and challenges.*

Key words: *ChatGPT, creative communication strategy, marketing communication*

1. INTRODUCTION

Artificial intelligence (AI) is becoming increasingly prevalent in the marketing sector (Dilmegani, 2023). However, using recently developed technologies, like generative AI and particularly ChatGPT in marketing is not widely known.

Launched on November 30, 2022, the ChatGPT platform has attracted global attention and interests. According to Statista (Buchholz, 2023), ChatGPT gained one million users just five days after launching compared to other popular online services that needed more time to reach the million-user mark.

Harnessing the power of such an emerging technology requires a new approach in businesses. Unlike traditional methods for innovation, such as design thinking, ChatGPT poses a fundamentally different challenge because there are no clear problems to address, user pain points to alleviate, or KPIs to achieve (Cromwell, et al., 2023). This AI chatbot can seemingly solve problems in almost any industry, domain, or context. Cromwell et al. (2023) therefore suggest that using this technology requires a different skill: emergent thinking, which involves generating ideas for innovation without fully understanding the problem that needs to be solved.

More companies are looking for creative ways to use ChatGPT to their benefit going forward as its generative AI capabilities garner media attention (Rupam, 2023). All data enthusiasts and marketing experts want to know how marketers and creative communicators can use ChatGPT. By reviewing the relevant literature and analyzing the use cases of ChatGPT in communication strategies, this paper highlights the possibilities of this tool, as well as the current shortcomings in order to put this technology in the function of professionals, and not vice versa.

2. THEORETICAL BACKGROUND

2.1 Creative corporate communication

As a management process and an important management function, corporate communications define a variety of communication strategies and activities in business. A mutually beneficial relationship is created and maintained between the organization and its internal and external environment through corporate communication (Lalić & Vlastelica, 2019). According to Lalić and Vlastelica (2019) corporate communication include deliberate, planned and continuous communication activities that are based on the business policy of the organization and its operation. Therefore, it is important to understand how to

use the available theoretical options to achieve the best effect with the audience and to develop creative messages (Blakeman, 2023).

The four key phases in the implementation of communication strategies include: research and analysis, planning of the communication process, execution of the communication plan, i.e. implementation, and finally, evaluation, more precisely measuring the results with identified indicators (Lalić & Vlastelica, 2019). The creative team uses the creative communication strategy to determine the approach and the appeal combination that will be use to determine the look and overall tone the creative message will take (Blakeman, 2023). Blakeman (2023) also states that short creative message is often more memorable, focuses on a single feature and benefit, directly addresses lifestyle and has all the focus one message needs to deliver and create the desired action. This work should answer the question of whether artificial intelligence technologies such as ChatGPT can help or hinder creative teams in this process or replace them completely, as is speculated in the public.

2.2 A use of ChatGPT in communication strategies

With the advent of ChatGPT technology, writing any type of text now requires only a specific written command in any language. ChatGPT (Generative Pre-trained Transformer) is a chatbot launched by OpenAI in November 2022 (Roose, 2022). On November 30, 2022, a prototype for ChatGPT was released and quickly gained attention for its detailed and articulate responses in many knowledge domains, but its uneven factual accuracy was identified as a significant shortcoming (Vincent, 2022). Also, ChatGPT is an intelligent artificial intelligence chatbot that has a wide range of applications, it can answer questions, write student essays, help with content creation, translate languages, debug, compose, reject inappropriate requests, program, play games and much more (Spajić, et al., 2023.).

What differentiates this model from previous chatbots is that it is capable of recalling past conversational statements made by the user, so it can conduct a continuous dialogue (Jiao, et al., 2023). In March 2023, OpenAI created GPT-4 and thus this robot was updated with even more powerful functions. In fact, now users can enter text and visual images in parallel, and thus more demanding multimodal tasks, such as image captions, graph explanations or paper summarization, can be performed (Jiao, et al., 2023).

In addition, according to (OpenAI, 2023) ChatGPT could be used to conduct market research and collect feedback from customers, both existing and potential. In this way, organizations would have a better insight into client preferences, market trends and would arrive at decisions in marketing and sales strategies more quickly. Given its ability to generate human text, ChatGPT helps improve content, its quality and efficiency. It contributes by writing high-quality content and a strategy of targeted content (Enterprise DNA, 2023a). Within organizations, ChatGPT can positively impact communication, thereby increasing efficiency, and potentially revenue, through creation, editing and proofreading of e-mails, personalized interaction with clients and content generation (Enterprise DNA, 2023b). New beliefs lead to the fact that artificial intelligence will influence the design and creation of content in the future. AI can greatly help social media content creators, copywriters as well as creative directors for marketing purposes (Persado, 2023). Therefore, a detailed summary of the use cases of ChatGPT technology is presented in the next section of this paper.

2.3 Artificial intelligence in marketing: Statistics and Facts

According to the Statista's report (Dencheva, 2023a), the global market revenues of artificial intelligence in marketing are expected to grow from 27.4 billion U.S. dollars in 2023 to 107.4 billion in 2028. With the expected fast-paced adoption of the technology, alongside the achievements of ChatGPT, many are left thrilled and simultaneously fearful of what is yet to come.

In the world of branding, AI is not all about robotics. Chatbots and other machine learning technologies are deployed for various purposes in the customer experience, such as tailored customization of content and product offerings. According to a survey conducted in 2022 worldwide among marketing leaders (Dencheva, 2023b), 60% of respondents stated that predicting consumer behavior and demands is the most prominent use of AI to enhance the customer experience. Another 47% of them said that they use AI in their marketing company in order to uncover frequent customer journeys.

Statista's research also indicates that in the U.S., the largest ad market worldwide, consumer attitudes towards AI fluctuate as much as those of marketing professionals (Dencheva, 2023a). While 35% of marketers are concerned about risk and governance issues in relation to AI usage in marketing, 45% of consumers say that they lack understanding of how these technologies work. In the context of social

media advertising, almost half of the consumers in the United States shared that neither Photoshop, nor generative AI should be used in posts with commercial purpose.
According to a survey conducted in February 2023 (Dencheva, 2023c), 34% of consumers in the U.S. trusted influencer content generated by AI the same amount as they trusted content generated by human influencers themselves. Another 22% of U.S. consumers distrusted the same type of content a little more than the human-generated one. These research results demonstrate that consumers appear to be both hopeful and skeptical when it comes to automatized CXs or AI-powered social media content.
In a context of public relation and content creation, according to a global survey about Generative AI use in newsrooms (Watson, 2023), 39% of newsroom executives believed that less than five percent of journalists in their newsroom were using ChatGPT or similar tools on a weekly basis. Just three percent of respondents said that they thought half the journalists in their newsroom were using Generative AI tools weekly, though this could change as the prevalence and potential of these tools continues to grow.
On May 19, 2023, the artificial intelligence and machine learning laboratory OpenAI launched ChatGPT as a mobile app on iOS first for the United States market. Announced on May 18, 2023, the app generated over 230 thousand downloads during its first day on the Apple App Store (Ceci, 2023). Figure 1 shows that on May 20, the mobile version of the conversational AI platform generated 280 thousand downloads.
In addition, ChatGPT represents the most tried AI tool and users are loyal to it (Richter, 2023). Ever since the emergence of this AI chatbot, other tools, for example Midjourney or DALL-E, have also gotten more attention, but so far none has come as close to mainstream adoption as ChatGPT has.

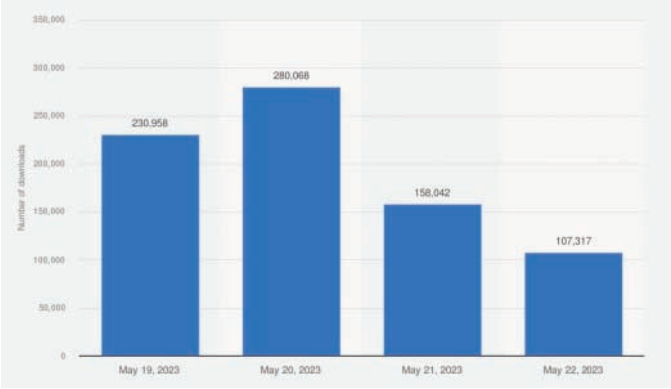

Figure 1: Number of ChatGPT daily app downloads worldwide as of May 22, 2023 (Ceci, 2023)

3. USE CASES OF CHATGPT IN CREATIVE COMMUNICATION STRATEGIES

Considering the process of creating a creative communication strategy (Lalić & Vlastelica, 2019) and good examples from practice (Dilmegani, 2023; Rupam, 2023; Entrepreneur, 2023), this section summarizes the use cases of implementation ChatGPT technology for the purpose of creating an effective marketing and creative communication strategies. The following use cases can help digital marketing creators to develop and accelerate the creation process of communication strategies:

- Research and content curation – ChatGPT has the ability to conduct internet research on any subject and choose pertinent material from a variety of sources. This kind of technology assistance can help companies in creating an organized and successful content marketing strategy.
- Getting a quick summary of information – To assist marketers in streamlining their promotional efforts and enhancing customer experiences, ChatGPT can search the Internet for certain user queries and offer a quick summary of pertinent data. Additionally, frequent conversations with ChatGPT can save customer support representatives time and effort allowing them to focus on more important and specialized tasks.
- Audience research – By capturing information about the intended audience to better understand their interests, preferences, habits, and needs, ChatGPT can be used to analyze consumer insights. From search queries, social media interactions and mast purchases information, ChatGPT can identify patterns and trends in customer behavior and provide valuable information for creating more effective marketing strategies, including content creation, ad targeting, and product development.

- SEO optimization – ChatGPT can generate interesting ideas for content marketing topics, conduct keyword research, come up with appropriate and appealing titles, categorize search intent, create content structure, generate meta descriptions and so on.
- Keyword targeting suggestions – By locating synonyms for root keywords, ChatGPT can assist marketers with keyword research, enabling them to incorporate these into landing pages, blog articles, and Pay Per Click (PPC) campaigns and boost their on-page SEO strategy.
- Content creation – specifically for text generation, ChatGPT can be a powerful tool for content marketing (e.g. generating personalized, attractive and persuasive emails, newsletters and copywriting, social media posts for various social media platforms, blog articles, script writing and storytelling for advertising goods and services). This kind of exciting and relevant content can be combined with other marketing tactics and distribution channels to boost online traffic to a business's website or social media pages.
- Attractive copywriting – ChatGPT makes creating unique and attractive ad copies more manageable. To increase the marketers' productivity, this most recent generative AI tool can provide suggestions for the copywriting and structure of an advertisement. ChatGPT may assist in developing enticing and informative product descriptions that appeal to the target audience since they enlighten potential customers about the characteristics, advantages, and value of a product. ChatGPT can generate catchy titles and apply them for naming blogs, podcasts, and webinars.
- Social media management – As well as many brands have turned to automation for social media, so the ChatGPT will complete scheduling, analysis, advertising and optimization.
- Lead generation – ChatGPT can carry on interactive text-based conversations to problem-solve with site visitors. During these conversations, this AI chatbot is gathering data that can be utilized for lead generating and lead nurturing in addition to assisting clients. Marketers can use ChatGPT to interact with website visitors and gather useful segmentation data.
- Personalized customer experience – ChatGPT with its NLP can generate personalized content for targeted customers based on their preferences, past behavior, and demographics. This can help organization to create targeted content that their audience finds appealing, which can lead to higher engagement and conversion rates.
- Inspire ideas for A/B Testing – A/B testing studies can be automated with ChatGPT to produce insightful campaign data. In order to evaluate the various iterations of a campaign and see which one performs better, marketers split their audience for this testing experiment. In this process, ChatGPT can help marketers select the best-suited version for a particular campaign.
- Customer service and support – ChatGPT can be included in a chatbot to offer prompt and individualized customer service, such as frequently asked questions, technical support and troubleshoot issues. In this manner, chatbots in marketing communication can improve customer satisfaction, reduce response times and decrease the workload of customer service representatives.
- Creating customer surveys – In order to stay in the loop with the audience and know their interests, ChatGPT may accelerate the market research procedure by conducting surveys and analyzing feedback.ChatGPT can help with question generation, organizing survey structure, making surveys multilingual and survey analysis. This evaluation aspect of the communication strategy is essential because it provides a means of obtaining consumer feedback and insights that can be used by marketers to enhance their goods, services, and marketing strategies.
- Analyzing feedback – ChatGPT may examine customer input, compare it to important trends, and produce a thorough report to help marketers better understand the preferences and perceptions of their target market.
- Onboarding and training – By integrating ChatGPT into the process of virtual training for example, future marketers will be able to respond right away to inquiries from participants during the onboarding procedure. Due to ChatGPT's flexible usage, they can even ask follow-up inquiries. ChatGPT can additionally be utilized for: customized learning pathways, interactive scenarios and marketing terminology and processes.

ChatGPT exhibits exceptional capabilities in generating human-like responses, enabling companies to engage with their customers in a more personalized and interactive way. By leveraging the model's natural language processing abilities, organizations can develop tailored messaging strategies that resonate with their target audiences, fostering stronger brand-consumer relationships. Moreover,

ChatGPT's versatility in multilingual communication opens doors to global market expansion, enabling businesses to reach and connect with diverse customer segments worldwide. The model's ability to comprehend and respond to a wide range of languages contributes to enhanced accessibility and inclusivity in communication strategies.

However, the implementation of ChatGPT is not without its challenges. Concerns around ethical usage, privacy, and potential bias need to be carefully considered. As an AI-driven system, ChatGPT may inadvertently generate responses that lack accuracy or exhibit unintended biases, posing reputational risks for businesses. Close monitoring, constant refinement, and human oversight are necessary to mitigate these risks and ensure responsible use of the technology. It can be concluded that ChatGPT is an unprecedented technology that has potential to unlock value for millions of customers across many industries (Cromwell, et al., 2023). However, pursuing these benefits also comes with considerable risks, as we're all as academicians or practitioners entering uncharted territory with AI, and we must learn how to use it effectively so it can be leveraged for positive rather than negative outcomes.

4. CONCLUSIONS

This research provides a comprehensive summary of the uses cases associated with incorporating ChatGPT into creative communication strategies. A several notable pros associated with using ChatGPT for creative communication strategies are revealed. Firstly, the model's ability to generate human-like responses facilitated more personalized and interactive customer interactions, leading to improved engagement and satisfaction. Secondly, ChatGPT's multilingual capabilities were highlighted as a significant advantage, enabling businesses to expand their reach to global audiences and overcome language barriers. However, the analysis of use cases suggests potential cons that need to be considered. Ethical concerns emerged as a prominent issue, as ChatGPT's responses can sometimes lack accuracy or unintentionally exhibit biases. Additionally, privacy concerns regarding the handling of user data and the transparency of AI-driven interactions were highlighted as challenges that organizations must address when implementing ChatGPT.

In conclusion, the research outcomes underscore the importance of carefully weighing the pros and cons of using ChatGPT for creative communication strategies. By leveraging the model's strengths while addressing its limitations through continuous monitoring, refinement, and human oversight, businesses can harness its potential to enhance customer engagement and communication effectiveness while ensuring responsible and ethical use. By intelligent use of this technology, organizations can unlock new dimensions of customer engagement and pave the way for more innovative and effective communication approaches.

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THE INFLUENCE OF THE PROJECT TEAM MEMBERS' PERFORMANCES ON THE PROJECT SUCCESS

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Abstract: *There is no specific, valid criteria that could define project success, due to the fact that it varies from project to project and also from organization to organization. Regarding to the available literature it can be concluded that the significant role plays project team. In addition to this, the aim of this paper is to bridge the gap between project team members' performances and project success, based on the literature review. Also, the paper determines which performances are considered as the most important for the success of the project. Future research could include empirical studies which will show the compatibility of theory and practice. The paper contributes to the literature by summarizing all the performances project team members should have while implementing the project in a desired way, leading it to a success.*

Key words: project, project success, project team, team's performances

1. INTRODUCTION

Although project management is a discipline that has been researched and improved for a relatively long period of time, project managers often encounter poor project execution, which often leads to their failure. Due to the aforementioned, it is of primary importance to precisely define the key factors that can influence the success or failure of the project, which directly depends on the type of project, the area in which it is implemented, etc. Different authors define the key performances of success differently. The "iron triangle" model was the first model to describe project management success. It was proven to be only part of general project success (de Wit 1988). Projects can be successful despite poor project management if they reach their higher, long term goals and vice versa. Extending the "iron triangle"model, shows that there are many opportunities to widen our perspective; as project managers and project team members are also responsible for integration, resource, scope, communication, risk management, within time, budget, and performance. The success in projects is something much more complex than just meeting cost, deadlines and specifications. Research has identified that people management drives project success more than technical issues do (Scott-Young and Samson 2008). Despite this finding, there exists only a small body of research that examines the so-called soft project management, i.e. the people side of project management (Kloppenborg and Opfer 2002) which could be defined as either a project manager or a project team member. This paper aims to present the basic characteristics, based on the literature review, related to project team members that can influence the success or failure of the project. In this regard, the subject of research is the examination and evaluation of the importance and performance of success factors, in accordance with the members of the project team.
This paper is organized into four parts. In the first section the concept of project and project success is defined in more detail. Second part deals with the literature review of the main performances that influence project success, based on team members. Conclusions and furure disquisitions are presented in the third part while the fourth section gives a list of literature used while writing the paper.

2. PROJECT AND PROJECT SUCCESS

Today's technologically accelerated development of society leads to the fact that most organizations are increasingly turning and organizing themselves as project-based organizations, that is, organizations are being created that base their processes and activities entirely on projects, which are a means of achieving business goals. The word project comes from the Latin word *proiectum*, which means "thrown in advance". In essence, a project implies something that is originally created or conceived, and then spatially or temporally directed towards it. Unlike everyday, routine processes in an organization, the need for projects arises as a result of an ever faster and more turbulent market, and as an organization's response to all these changes.

In the world, regulations related to product quality, requirements in terms of ecology and health safety are constantly changing. It is always something new and the company is forced to adapt to it, and it usually does so through projects. The development of new production and information technologies and new materials is getting faster and the company, for its own survival and development, has to introduce them, and most often it does this through projects, which are crucial for the future of a company, and it is certainly imperative to determine, select and the most efficient way to implement real projects.

A project is most often understood as an undertaking undertaken to achieve defined goals, within the stipulated time and with the stipulated costs. The intended realization of the project can only be achieved if all activities, resources and participants are rationally coordinated and all possible deviations are avoided, that is, eliminated, which is why it is necessary to manage the project (Jovanović Petar 2012).

In projects, unlike operational processes, which are continuously carried out in the company, the level of changes, unknowns and execution risks is high. A project, as a term, implies the realization of a new undertaking in conditions of risk and uncertainty, competition for the necessary resources, in a certain period of time, with a defined cost price and required quality (Avlijaš Radoslav and Avlijaš Goran 2011, (Dakovic et al. 2020).

Each project is special and unique, primarily because projects have different goals, scopes, deadlines, costs, etc. However, there are certain features that are common to all projects and these are (Jovanović Petar 2012):

- OBJECTIVE – all projects are established to fulfill some needs or requests of the management, and each project must achieve some special goal that has been set for it.
- DEADLINES - all projects have a defined specific goal that must be achieved within a specific time frame.
- COMPLEXITY - which is related to the technology used to achieve the project's goals. If the technology does not exist or is not available, either alternative solutions must be found to achieve the project's goals or deadlines must be extended in order to develop and realize the technology.
- SCOPE AND NATURE OF THE TASK - each project can achieve its goals within the established deadlines and costs, only if an appropriate implementation plan is made, which actually represents the project's strategy.
- RESOURCES - every project uses some resources (people, equipment, material, financial resources, etc.) to perform the assigned tasks. Given that resources are limited, the goal can be to provide the necessary resources in a timely manner and to use them rationally.
- ORGANIZATIONAL STRUCTURE - for the implementation of the project, it is necessary to determine the appropriate organizational structure and the project manager who will have the appropriate powers and be responsible for the project. He must ensure that the goals of the project are achieved, within the set limits. At the same time, it is very important whether it is possible to use the usual channels of information and decision-making in the existing organization for the realization of the project.
- INFORMATION AND CONTROL SYSTEM - the usual information and control systems used in organizations, usually based on functional lines of authority, are not sufficient for effective monitoring of project implementation.

Today, there are numerous ways and criteria for evaluating the development and success of a project. One of the oldest is based on the so-called the iron triangle, which contains the principles of cost, time and quality, that is, the three main aspects that must be achieved and that characterize projects are: scope, cost and time. In this regard, a project that would not deviate too far from the primary budget, fulfill the time frame and requirements set by the interested parties, would be considered as successful (Jovanović Petar 2012).

Success is quite a subjective thing and different people perceive the aforementioned concept differently, but it is generally considered that a successful project is one that meets the requirements of the client/project orderer and other interested parties, especially the quality dimension.

When talking about performances that are crucial for achieving project success, it is important to keep in mind the following (Gido and P. Clements 2012):

- Planning and communication are key to successful project management. They prevent problems from occurring or minimize their impact on project goal achievement when they do occur.
- Taking the time to develop a well-thought-out plan before starting a project is critical to the successful completion of any project.
- The project must have a clear goal of what needs to be achieved and defined in terms of the final product or deliverable, schedule and budget, which must be agreed upon by the customer.

- Involve the sponsor or customer as a partner in the successful outcome of the project through active participation during the project.
- Achieving customer satisfaction requires constant communication with the customer in order to inform the client and determine whether expectations have changed.
- The key to effective project control is the measurement of actual progress and its timely and regular comparison with planned progress and immediate taking of all necessary corrective actions.
- After the completion of the project, the performance of the project should be evaluated to find out what could be improved if a similar project were to be done in the future. Feedback should be obtained from the sponsor or customer and the project team.
- Learning and understanding the culture and customs of other project participants will show respect, help build trust and help develop an effective project team, and is critical to successfully managing global projects.

When we talk about project management, different project managers have different definitions of success, depending on their experience, knowledge, and the context in which they work. Some consider the number of projects completed on time and within the available budget to be the key project performance, which results in customer satisfaction, while others consider effective communication, successful cooperation, and the involvement of interested parties as success criteria. By researching the literature, it was concluded that the list of project performances is large, and some key performances are given below (Alvarenga et al. 2019), (Bryde 2005), (Ciric Lalic et al. 2022), (Girish et al. 2019), (ÖZDEMİR GÜNGÖR and GÖZLÜ 2016), (Anon 2017), (Taherdoost and Keshavarzsaleh 2015b), (Liu and Cross 2016), (Oh and Choi 2020), (Durmic 2020), (Tereso et al. 2019), (Ciric, Lalic, and Gracanin 2016), (Gruden and Stare 2018), (Ciric et al. 2020), (Stefanovic et al. 2020):

- costs,
- time,
- disadvantages,
- customer satisfaction with the product,
- client satisfaction with the service provided,
- profitability,
- productivity,
- human resources,
- sustainability,
- quality,
- involvement and cooperation of interested parties,
- clear goals,
- proper selection of resources for project execution.
- efficient use of material and human resources,
- use of new technologies,
- decision-making efficiency,
- risk management,
- innovation,
- successful communication, etc.

The key performances that influence the success of the project is an interesting and inexhaustible field of research, and the largest research area, that is, the lack of research coverage, is in the area of human resources, i.e. project manager and project team members. In this regard, below is a presentation of the basic key indicators related to the project team, which have a significant impact on the success of the project.

3. PROJECT PERFORMANCES BASED ON PROJECT TEAM MEMBERS

Traditionally, project management is understood to succeed with the right tool and technique, regardless of the project participation's personality or project type. This is contrary to the studies of the mentioned competency theories. Crawford et al. mentioned that not only project management procedures, but also the project manager's competence should be applied to project management (Crawford, Hobbs, and Turner 2004). In other literature, the correlation has been shown between the competence of managers and project success in different projects (Müller and Turner 2007). There are many empirical studies on leadership and project success using LDQ questionnaires, such as the financial

industry, construction industry, agile projects, and general projects (Dvir, Sadeh, and Malach-Pines 2006), (Rodney Turner, Müller, and Dulewicz 2009), (Geoghegan and Dulewicz 2008), (Raut et al. 2018).

Among the whole factors classification Spalek (2005) mentioned that one the most important factor which has substantial influence on project success is personal competence (Spalek 2005). In addition to this, Oh and Choi (2020) stated that the abilities or capabilities of human resources in an organization are described as value, vision, knowledge, career, role responsibility, and task needed to perform (Oh and Choi 2020). According to Taherdoost and Keshavarzsaleh (2015) clustered factors of the project success, defined as 5Ps are; Presiding, People, Pragmatic, Process, and Performance (Taherdoost and Keshavarzsaleh 2015b). Researching key factors through the project life cycle, Durmic (2020) prioritized personal issues, i.e. competences as significant for project success (Durmic 2020). When speaking about success dimensions related to individual stakeholder groups, Kate (2016) also defined personal competences of the project team member as crucial (Davis 2016).

Liu and Cross (2016) in their paper stated that project team members have major impact to project success and pointed out that many performances, related to them, are crucial: leadership, management support, rewards, skills, team diversity, clear defined goals, activities connected to education, efforts and commitments to the team (Liu and Cross 2016).

The fact that team members with high competence and expertise, i.e. skillful people, are significant factor who highly influence project success is conclusion by many authors (Chow and Cao 2008), (Belassi and Tukel 1996), (Taherdoost and Keshavarzsaleh 2015b), (Durmic 2020), (Heinz et al. 2006). In addition to this, previous research has shown that team members involved in the project need personal competencies, such as knowledge and technical skill. However, as more complex and dynamic projects increase, professional and multifunctional requirements are required to build a project team. Team members also need the skills and expertise that managers need, and they must have a high level of communication, management skill, and integration capabilities, as well as the ability to utilize and understand knowledge, tools, and techniques (Nguyen and Hadikusumo 2017), (Rota and Zanasi 2011), (Oh and Choi 2020), (Dakic et al. 2019).

Communication, an overarching theme in the literature, describes the effective and efficient information gathering and sharing; it comprises community involvement, clear communications channels, and frequent progress meeting. It is becoming more and more important today. Collecting and sharing of information are fundamental to communication, and therefore frequent meetings are inevitable. Project participants should share the project information in a sincere way and obtain different perspectives on the project, which lead to successful implementation (Belassi and Tukel 1996), (Oh and Choi 2020), (Montequin et al. 2016), (Rota and Zanasi 2011), (Oh and Choi 2020), (Frank Cervone 2014),(Bahadori Zare, Mirjalili, and Mirabi 2016), (Brill, Bishop, and Walker 2006), (Liu and Cross 2016), (Sudhakar 2016). In contrast to previously mentioned influential factor, Sudhakar (2016) pointed out that factors, regarding the project success in many domains, include team communication, team cooperation, team coordination, team cohesion, team conflicts, team climate, team productivity, and team performance (Sudhakar 2016).

The aforementioned factors can be categorized into two distinct clusters, as depicted in the ensuing table where the first cluster is named *input factors of the project team* (related to the internal, i.e. team environment, i.e. imply the characteristics of the team) and the second *project team process factors* (imply team interactions and interactions with stakeholders).

Table 1: Clusters of the key success factors of the project, based on the team members

CLUSTERS	REPRESENTATIVE SOURCE
INPUT FACTORS: - leadership, - management support, - prizes, - knowledge/skills, - team diversity, - clearly defined goals, - management skills, - ability to use tools and techniques, - personal competences	(Liu and Cross 2016), (Chow and Cao 2008), (Belassi and Tukel 1996), (Taherdoost and Keshavarzsaleh 2015b), (Durmic 2020), (Heinz et al. 2006), (Nguyen and Hadikusumo 2017), (Rota and Zanasi 2011), (Oh and Choi 2020), (Spalek 2005; Taherdoost and Keshavarzsaleh 2015a), (Davis 2016)
PROJECT TEAM PROCESS FACTORS: - cooperation, - communication,	(Sudhakar 2016), (Liu and Cross 2016), (Belassi and Tukel 1996), (Montequin et al. 2016),(Rota and Zanasi 2011), (Oh and Choi 2020),(Frank Cervone 2014),(Bahadori Zare et al.

- activities related to learning, - cohesion, - efforts, - commitment, - conflict resolution, - team climate, - performance	2016), (Brill et al. 2006), (Belassi and Tukel 1996), (Durmic 2020)

4. CONCLUSIONS

Project success and project management is an inexhaustible and challenging field of research. This is exactly what has been the subject of numerous publications in recent years, as the concept of project management is increasingly being applied in organizations of all types. In addition to the above, in practice you can unfortunately often see failed projects or poorly managed projects. The list of factors that influence the success or failure of projects is quite long, where primacy, in addition to costs, time and quality, is certainly given to human resources, that is, to the project manager and members of the project team.

This study aimed to identify key team member's performances, required for project success in various industries. Through the literature review, 18 factors were identified, which were clustered into 2 groups. First one, input factors of the project team which included nine factors and the second one, project team process factors which is consisted of also nine factors. The greatest contribution of this paper is that it gives a broad picture of performances, i.e. it summarizes the factors mentioned by numerous authors. Future research should rely on experiential research, more precisely to check to what extent each of the factors has an impact on the project, because it is clear that all factors do not have an equal impact. Also, it is possible, in vigilance, to specifically deal with one type of organization and implement a model that will be valid and applicable in a specific branch of the industry.

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ASSESSING SOFT SKILLS IN INFORMATION SYSTEMS ENGINEERING STUDENTS: IMPORTANCE AND SELF-ASSESSMENT

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Abstract: *This research aimed to examine the soft skills required by Information Systems Engineering students for their future work. A total of 49 students participated in the study conducted in October 2022. The study focused on analyzing 18 different soft skills, with a two-step approach. In the first step, participants were asked to rate the importance of various soft skills needed for their future careers. The importance ratings provided valuable insights into the students' perceptions of the skills they considered essential. In the second step, participants were requested to assess their own skill levels for each soft skill analyzed. The results obtained from this research provide a comprehensive overview of the soft skills landscape within the Information Systems Engineering discipline. The findings can be used to tailor educational programs, mentorship initiatives, and career development strategies to foster a well-rounded skill set among Information Systems Engineering students.*

Key words: soft skills, information systems engineering, students

1. INTRODUCTION

In previous years, there has been a gap in understanding within the triangle formed by: students, i.e., future employees, higher education institutions, and companies. On one side, we have students who enter the job market with a lot of optimism and self-assurance, believing they possess everything needed to achieve great success in the careers they have been studying for. On the other side, we have higher education institutions claiming to educate employees ready for the new information age, while companies assert that their young employees lack the skills and abilities essential in the practical world awaiting them beyond classrooms and textbooks. This is particularly noticeable in industries that employ some of today's most sought-after professions: IT and the creative industry.

2. THEORETICAL BACKGROUND

A skill could be defined as “an individual’s level of proficiency at performing a particular task” (Noe et al., 2015). Earlier, companies demanded that employees possess some basic skills such as writing, reading, and arithmetic. With the growing complexity of business processes and the formation of more intricate job roles, the needs for employee skills also changed. In modern human resources literature, a distinction can be found between the terms "soft skills" which refer to skills like communication, teamwork, and work ethics, and "hard skills" which pertain to the specific job being performed. Haselberger and colleagues (2012) collected definitions of skills, soft skills and competences and proposed a comprehensive definition of soft skills: "Soft skills represent a dynamic combination of cognitive and meta-cognitive skills, interpersonal, intellectual and practical skills. Soft skills help people to adapt and behave positively so that they can deal effectively with the challenges of their professional and everyday life.". These authors developed a list of 21 soft skills divided into three groups: (1) Personal – attitudinal component of the skill; (2) Social – interpersonal skills; and (3) Methodological – methodological aspects of work – management, achievement, innovation and change. Even in the reports from the European Commission (2012) and consulting firms such as Deloitte (2017) from the last decade, there is a consensus that continuous work on improving the soft skills of the workforce is needed in order to achieve economic progress, reduce the unemployment rate, and achieve a personal business success. This is particularly important for groups such as women, younger, and older workforce. This paper focuses on the importance of soft skills as perceived by the Information Systems Engineering (ISE) students, by answering the following research questions: (1) What are the most and the least important soft skills needed for future work, as perceived by ISE students? (2) How ISE students perceive their own soft skill levels? Which soft skills are ranked highest, and which one are ranked lowest? (3) Is there a

difference between perceived importance of soft skills for future work and self-assessed level of soft skills?

3. METHODS

Previous studies analyzed existing literature to identify soft skills that have been previously researched. As previously noted, Haselberger and colleagues (2012) identified 21 soft skill, while Taylor (2016) identified 25 soft skills that were examined in earlier studies. From previous research, 14 soft skills were adopted, and an additional 5 skills were included to align the study with the curriculum needs of the subject: Motivation, Organizational skills, Feedback, Stress management, and Presentation skills. To make the survey more engaging for students belonging to Generation Z, we decided to conduct the research in the form of a quiz using the Kahoot platform. The survey consisted of two parts. In the first part of the quiz, students were asked to rate soft skills on a scale from 1 to 10 based on their importance for their future careers. Then, in the second part of the quiz, using the same order, students were asked to rate their level of proficiency in each specific soft skill on a scale from 1 to 10. In this way, we obtained a repeated measurement from the same sample of participants. The research was conducted in October 2022. The study involved second-year students of Information Systems Engineering who were taking the course on Fundamentals of Organizational Behavior at the Faculty of Technical Sciences in Novi Sad. There were 83 students enrolled in the course, out of which 75 students were present during the first lecture when the survey was conducted. Among the total number of participants, 11 students did not participate in the quiz, while 15 did not complete it. The final number of respondents in the study was 49 (59% completion rate).

4. RESULTS

The results of descriptive statistics are presented in Table 1. When it comes to the importance of various soft skills needed for future careers, students rated Team work and Communication skills as the most important, and Creativity and Leadership as the least important soft skills. When students were asked to assess their own levels of soft skills, Problem solving and Flexibility/Adaptability were rated with the highest scores, while Presentation skills and Stress management were ranked lowest.

Table 1: Descriptive statistics

	Measure*	Min	Max	Mean	Std. deviation
Communication skills	1	1	10	8.14	2.00
	2	1	10	6.08	2.98
Team work	1	1	10	8.76	1.71
	2	0	10	6.45	3.37
Leadership	1	1	10	6.00	3.08
	2	0	10	5.35	3.29
Flexibility / Adaptability	1	1	10	7.41	3.42
	2	0	10	6.73	3.41
Problem solving	1	0	10	7.80	3.65
	2	0	10	6.98	3.19
Creativity	1	0	10	5.90	3.36
	2	0	10	5.67	3.61
Interpersonal skills	1	1	10	6.55	3.41
	2	0	10	6.08	3.26
Time management	1	0	10	6.88	3.77
	2	0	10	5.02	3.43
Work ethics	1	1	10	6.96	3.63
	2	0	10	6.33	3.38
Motivation	1	1	10	6.77	3.38
	2	0	10	5.80	3.33
Organizational skills	1	0	10	6.82	3.56
	2	0	10	5.96	3.38
Negotiation	1	1	10	7.16	3.47
	2	0	10	6.00	2.95
Feedback	1	1	10	7.45	3.37
	2	0	10	6.35	3.14

Conflict resolution	1	1	10	7.20	3.70
	2	0	10	6.20	3.01
Stress management	1	1	10	7.47	3.80
	2	0	10	4.47	3.20
Decision making	1	0	10	7.02	3.67
	2	1	10	5.00	3.23
Self-confidence	1	1	10	7.02	3.47
	2	0	10	5.14	3.34
Presentation skills	1	0	10	6.90	3.79
	2	0	10	4.16	3.09

* 1- assessed need for work; 2 – assessed skill level.

Since the sample was relatively small (< 100 participants) and the data were not normally distributed, the nonparametric test equivalent to the dependent t-test was used. The Wilcoxon signed-rank test was employed to compare two sets of scores collected from the same students. Details are presented in Table 2.

Table 2: Descriptive statistics The results of Wilcoxon signed-rank test

	Z-value	p	r	Comment
Communication skills	-3.826	0.000	0.38	medium effect
Team work	-4.382	0.000	0.44	medium effect
Leadership	-1.693	0.090		
Flexibility / Adaptibility	-2.674	0.007	0.27	small effect
Problem solving	-2.981	0.003	0.30	medium effect
Creativity	-0.987	0.324		
Interpersonal skills	-1.800	0.072		
Time management	-3.319	0.001	0.34	medium effect
Work ethics	-2.127	0.033	0.21	small effect
Motivation	-2.223	0.026	0.22	small effect
Organizational skills	-2.657	0.008	0.27	small effect
Negotiation	-2.458	0.014	0.25	small effect
Feedback	-2.566	0.010	0.26	small effect
Conflict resolution	-3.032	0.002	0.31	medium effect
Stress management	-4.162	0.000	0.42	medium effect
Decision making	-3.735	0.000	0.38	medium effect
Self-confidence	-3.157	0.002	0.32	medium effect
Presentation skills	-4.434	0.000	0.45	medium effect

As the results suggest, only three out of the 18 skills did not show a statistically significant difference between the importance level of skills needed for future work and the value of student's self-assessment of soft skills. Those soft skills are Leadership, Creativity and Interpersonal skills. To provide a better insight into observed differences, effect sizes (r) were calculated by dividing the value of Z by the square root of N. Most of the observed differences between needed soft skills and self-assessed levels of soft skills can be considered to have a medium effects. When we observe Z values, the largest deviations are noticed for the following skills: Presentation skills, Team work, Stress management, Communication skills and Decision making.

5. DISCUSSION

The research has uncovered several soft skills that students consider important in the industry, while simultaneously evaluating them as insufficiently developed. Previous research have also found that Team work and Communication skills are important skills to possess and students expressed the need for their improvement (Patacsil & Tablatin, 2017). Other study (Ahmed et al., 2015) pointed out that soft skills are in demand in the software industry, with an emphasis on communication skills, while for other skills, it is necessary to understand their connection to software engineering. Some earlier research (Itani & Srour, 2016) has shown that future engineers do not consider soft skills to be important, even though employers emphasize their significance. However, this research has demonstrated that a change is happening, and students are becoming more aware of the importance of non-technical skills. Finally, it is important to highlight some of the limitations. In this study, soft skills were observed only from the perspective of students. In future research, it would be interesting to compare the results of students with those of lecturers and industry experts. This way, more detailed insights into the differences between these three

parties could be obtained. Moreover, to overcome the methodological challenges of the cross-sectional research, future studies should be preferably grounded as experimental, and after implementing interventions such as soft skills training, real differences in their improvement could be observed.

6. CONCLUSIONS

The aim of this paper was to examine the soft skills required by Information Systems Engineering students for their future work. Findings revealed the differences between the importance level of skills needed for future work and the level of student's self-assessment of soft skills. These findings suggest that educational institutions, professors, students and companies have to cooperate in order to succeed. Educational institutions and curriculum designers need to align their programs to meet the industry's demands and prepare students for the professional world effectively. In addition to working on so-called hard skills professors should implement methods to develop specific soft skills through practical work, improvisation, and simulations of real-life situations in the classroom. Finally, constant collaboration with companies is necessary to enable the creation of an appropriate curriculum based on their practical insights, and feedback on evaluations after the employment of young individuals will provide insights into the effectiveness of the conducted education.

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HUMAN RESOURCE MANAGEMENT THROUGH ORGANIZATIONAL SUPPORT FOR EMPLOYEES

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Abstract: *The theory of organizational support takes into account employees' subjective perceptions of how much the organization values their contributions and cares about their well-being. This subjective perception arises as a response to the manner in which the organization attends to employees' social and emotional needs. The practices of human resource management that empower employees and motivated organizational behavior are positively correlated. The study examines how human resource management affects employees' subjective perception of organizational support while also analyzing how employees evaluate the organization's level of support and the environment it cultivates for employees to feel valued and respected. The methodology of this paper is based on the analysis of empirical data gathered using a standardized questionnaire that was administered in a manufacturing company. The most important result of research emphasizes the fact that having a good relationship based on respect and care helps establish motivated behavior of employees.*

Key words: human resources, organizational behavior, motivation, organizational support

1. INTRODUCTION

The process of globalization, technological development, information and communication networks, and the increasing concern for ethical issues create a framework in which human resource management becomes a central function of business (Kalyani and Prakashan Sahoo, 2011). The increased complexity of operations in today's organizations, as well as more dynamic and intricate business practices, affect the way we approach employees. In addition to creating competitiveness for the organization, human resource management also creates favorable conditions for both internal and external stakeholders of the organization (Chernyak-Hai, Bareket-Bojmel and Margalit, 2023). Over time, human resource management has become a leading function that distinguishes people as the most important asset of the organization. As human resource management is one of the functions within an organization, it does not operate in isolation but constantly collaborates with other functions. Since people are the most significant asset of an organization, without whom the business cannot function, we can say that all managers are also human resource managers. The overall success of the organization depends on employee motivation, training and development, organizational commitment, and the alignment of individual goals with organizational goals. Human resource management increasingly manifests itself through perceived organizational support for employees (Côté, Lauzier and Stinglhamber, 2021). According to perceived organizational support theory, employees judge the extent to which their organization is being (un)favorable toward them. These judgments tap on employees' beliefs that the organization values their contributions and cares about them (Eisenberger *et al.*, 1986). The behaviorist school of management was developed due to the lack of inclusion of the human factor in the processes of production and organizational management. The principles advocated by the classical school of management were questioned, and the human factor significantly influenced the success or failure of production itself, and that management scientists need to understand the behaviorist school of thought in order to understand organizational behavior (Braunstein, 1972). Research on how employee satisfaction improves organizational processes becomes the focus of further theory development. The contribution of the behaviorist school lies in the fact that even today, the human being is at the center of modern organizations, and this assertion will only become stronger in the culture of organizations over time. Employee motivation, concern for their rights, working conditions, creating a pleasant organizational climate, supporting employees during their work and career development are just some of the items that today's organizations advocate, stemming from this research. Human resource management is a scientific discipline that deals with the study of employees in an organization. As a

scientific discipline, human resource management, or personnel management, was first mentioned in the 1970s and 1980s in the United States in professional literature and then began to be used in everyday communication. In modern organizations, this function is seen as strategic and thus has a significant impact on the business of the enterprise. A strategic approach to human resource management means that the defined mission, vision, and goals are in line with the overall mission, vision, and goals of the organization. Human resource management, as a strategically oriented integral part of strategic global management, has an impact on overall organizational processes by creating the relevant mechanism and climate to cultivate employees' behaviors of sharing knowledge and ideas for achieving significant changes and innovations (Beddow, 2021). The changes taking place in the world have far-reaching consequences for societies and organizations. Influences on change can be divided according to numerous factors, but when considering them in relation to the organization and the implementation of human resource management practices, they can be classified into two categories: (1) internal - everything that happens within the organization, characteristics of the organization, characteristics of employees, characteristics of the jobs performed, and (2) external - changes that the organization usually has no control over, which occur outside its framework, such as government activities, economic environment, cultural environment (Grubić-Nešić Leposava, 2014). As changes occur, organizations transition from traditional, hierarchical, centralized structures to modern organizations characterized by a holistic approach that achieves greater productivity through synergistic effects by working together. Likewise, with changes in organizations, human resource management also changes and gains new frameworks for operation. Traditional personnel management gives way to human resource management (Sparrow, Schuler and Jackson, 1994). When talking about people management as a concept, two terms are distinguished: (1) traditional personnel management and (2) human resource management. In the history of management development, the contribution of Frederick Taylor to the classical school of management is mentioned, and the idea of personnel management emerged precisely during the 1970s. At that time, the function performed basic tasks related to personnel, recruitment, selection, payroll calculation, rule compliance, social care, and regulation of employee departures from the company (retirement, redundancy). All these activities were important for the organization and mostly focused on administration and bureaucracy (Kaur, 2014). Only in the late 1970s and early 1980s, the concept of human resource management was introduced. Personnel management could no longer respond to the changes that were occurring. With the development of technology and the global economy, there was a need for frequent adaptation, i.e., flexibility. Reactive and passive people management was no longer cost-effective. Effective human resource management involves the manager's ability to recognize the differences in individual characteristics that affect behavior, satisfaction, and commitment to work. The behavior of an individual can be influenced by their personality, abilities, and other characteristics. It is crucial to create a culture that promotes respect, creativity, exchange of opinions and ideas, as it will positively impact employee satisfaction, productivity, and the creation of constructive conflicts. A motivated employee, driven to achieve goals, will direct their behavior towards achieving results (Chernyak-Hai, Bareket-Bojmel and Margalit, 2023). In addition to the employee's personality, the manager and the organization play a significant role in providing support to individuals and effectively managing their behaviors through well-defined leadership schemes and the support of organizational structure and culture. The conditions for motivating employees involve the organization providing support for positive motivation by being fair and equitable towards everyone, providing feedback, and allowing employees to rely on it. The organization primarily fulfills this function through the human resources management function.

The theory of organizational support examines the development, nature, and outcomes of the subjective perception of organizational support. According to this theory, employees develop this subjective perception in response to the relationship between their social and emotional needs and the organization's willingness to acknowledge these needs and reward the employee's efforts. Empowerment is recognized as a key component of organizational support, and research shows a positive correlation between high autonomy and increased organizational support (Eisenberger, Rhoades and Cameron, 1999). When an organization believes in its employees' ability to make appropriate and wise decisions, perform their jobs effectively, and help the organization achieve its goals, employees will reciprocate by performing their tasks in a better manner. The existence of directly impacts higher commitment, improved performance, desirable employee behavior, reduced avoidance behaviors, and unnecessary efforts (Baran, Shanock and Miller, 2012). According to research conducted by Eisenberger (Eisenberger *et al.*, 1986) organizational behaviors and treatment towards employees influence employee performance. A meta-analysis by Riggle confirmed a strong and positive relationship between

organizational support and commitment and job satisfaction, along with a strong negative relationship between organizational support and intention to quit (Riggle, Edmondson and Hansen, 2009). Studies have also shown that affective commitment is positively correlated and predictive with exhibited organizational citizenship behaviors (Liu, 2009). Engagement of employees in the workplace is referred to by various synonyms in the literature, such as job commitment, organizational dedication, or organizational commitment. Several definitions of organizational commitment can be found in the literature, although scholars studying organizational commitment have not come to an agreement as to the nature of organizational commitment, and how it develops (Mercurio, 2015). In 1971, Sheldon defined organizational commitment as "a positive evaluation of the organization and a willingness to work towards its goals" (Sheldon, 1971). In 1974, Porter defined commitment as "a strong acceptance and belief in organizational goals and a willingness to exert significant effort for the organization, as well as a desire to maintain membership in it (Porter *et al.*, 1974). Mowday, Porter & Steers in 1979 wrote that behavioral commitment "relates to the process by which individuals become locked into certain organizations"(Mowday, Steers and Porter, 1979). Meyer and Herscovitch in 2001 theorized that affective commitment is developed primarily by an individual's involvement and identification with the organization, they asserted that individuals become intrinsically motivated or involved in a course of action that develops from an identification, association, and attachment with the larger organization's values and objectives (Meyer and Herscovitch, 2001). Subjective experience of organizational support refers to employees' perception of the extent to which the organization values their contributions and cares about their well-being. Research on organizational support begins by recognizing that managers who are committed to their employees directly influence employees' commitment to them and the organization. If an organization cares about the well-being of its employees, they will experience affective commitment, a desire for involvement in achieving organizational goals, and the expectation that greater performance and engagement will lead to rewards. This mutual give-and-take relationship respects the unique individuality of each employee, celebrates small successes, and prioritizes mutual respect and care.

2. METHODS

The subject of the research is how human resource management in an organization affects the subjective experience of organizational support. The research problem relates to organizational support, specifically the subjective experience of organizational support by employees about the organization they work for, as well as the question of whether the organization creates adequate conditions in which they will feel valued and respected. The research hypotheses are H1: The organization implements human resource management through employee support. H2: Human resource management is based on care for employees. H3: Employees believe that the organization they work for is sufficiently focused on the well-being of its employees. The research on how employees perceive and whether they receive organizational support was measured using the Perceived Organizational Support (POS) test developed by Eisenberger R, Huntington R, Hutchison S, and Sowa D. (1986). The test encompasses the employees' perception of the extent to which the organization is willing to reward greater effort made by employees because it values their contribution and cares about their well-being. The test consists of seventeen items, of which eight measure the employees' perception of the extent to which the organization values their contribution, while the remaining nine relate to measures the organization could take to influence employees' well-being. The method used is the Likert scale from 1 to 5 (1-strongly disagree, 5-strongly agree). The research was conducted in a company that produces raw and refined oils, biodiesel, and protein meal. The company processes sunflower and soy and has become the largest factory in Southeast Europe for the production of biodiesel, extraction and peeling-pressing sector, and the energy-boiler sector. A total of 31 people were examined, with 80.65% male and 19.35% female. The higher percentage of males can be explained by the sectors in which the research was conducted, given that physical jobs are mostly performed by men. The average age of the participants is 41 years old, with the youngest being 23 and the oldest being 61. It was noticed that the highest percentage of participants is between 30 and 40 years old, followed by those between 40 and 55 years old, while a small number of participants are younger than 20 to 30 years old. The average work experience of the participants is 17 years. In the given organization, employees mostly have work experience of over 5 years, while only younger employees have work experience of 1 to 5 years. Out of the total number of participants, 67.74% have secondary education, 19.35% have completed university education, followed by vocational schools and primary education with the lowest percentage. None of the participants have completed specialist,

doctoral, or master's studies. Technical professions are more dominant with 80.65% compared to social professions, which have a percentage of 19.35%. When it comes to positions in the organization, less than 50% of the participants have managerial positions, and those who do mostly hold lower and middle-level management positions, while 67.74% of the participants are not managers. As for career advancement in the organization, 58% of the participants remained in the same position throughout their career in the organization, while 42% were promoted, and none of them were demoted in their career path.

3. RESULTS AND DISCUSSION

Regarding the statement "The organization values my contribution to its well-being," an identical number of respondents, 35.5%, are unsure or mostly agree with the statement that the organization values their contribution to well-being, the distribution of responses is equally divided for the other options, 9.7% of respondents fully agree with the statement, but an equal percentage strongly disagrees or disagrees with the statement. 29% of respondents completely agree that the organization would not hire someone else for a lower salary instead of them, while the same number of respondents believes that the organization would replace them with someone who has a lower salary. Considering that the research was conducted in the logistics sector and two sectors involving more manual labor, we can interpret the results from the perspective of employees performing manual jobs and understand that they are more concerned about their position being replaced by someone who will do their job for a lower salary. The data of 58.1% indicates that more than half of the employees are unsure if the organization values the effort they put in. The organization does not provide adequate feedback to employees regarding their value and recognition as essential contributors to overall operations and good results. A higher percentage of employees, 41.9%, are unsure if the organization rigorously evaluates their goals and values, followed by a percentage of 25.81% of respondents who disagree that the organization is strict in evaluations, very small percentages of affirmative responses were obtained. The largest percentage of employees, 58%, disagree that the organization ignores their complaints if they exist, indicating that the organization is there for them if they raise specific concerns. Since the highest percentage of employees, 35.5%, is unsure if the organization neglects their interests when making decisions, we can conclude that the organization, although caring about employees as shown by the percentages of 22.6% and 19.4% of employees who disagree, does not clearly communicate this to everyone. A higher percentage of employees agree that the organization, or human resource management, is willing to help if employees come to them with a problem. This percentage, in total (mostly agree and fully agree), amounts to 58.1%, which is more than half of the employees. An identical percentage of respondents, 35.5%, are unsure if the organization genuinely cares about their well-being, and mostly agree that the organization carries out its tasks with their well-being in mind. The high percentage of uncertainty among respondents can be explained by the lack of clear support and feedback from management. 48.4% of employees agree that the organization is willing to help them achieve maximum results and perform their job to the best of their abilities. A smaller percentage, 19.4%, of respondents believe that the organization is not willing to provide support in carrying out their tasks. Half of the employees, 51.7%, feel that the organization recognizes a job well done, while 19.3% of respondents think otherwise, the remaining respondents, a larger percentage of 19%, are unsure of the answer. Overall, more than half of the respondents, 58.1%, believe that the organization would assist employees if they request it, while a much smaller percentage disagrees with this statement. Connecting to the previous statement regarding the organization helping an employee when they have a problem, we can conclude that the organization will provide support to those employees who express their need for assistance or raise a problem. Job satisfaction is the most important category of employee motivation and behavior. Related to that, in organization we can conclude that nearly half of the respondents, 45.2%, believe that the organization cares about their satisfaction. However, a significant number of respondents, 32.3%, were unsure about their organization's concern for their job satisfaction. It is important to note that 22.6% of respondents believe that the organization does not care about their well-being. One of the responses where a majority of respondents disagree with the statement that the organization exploits them for its own needs amounts to 45.2%. Meanwhile, 12.9% of respondents feel that the organization does exploit them, which may be the case in sectors dominated by physical labor and manual tasks. Considering the total number of affirmative responses, the percentage of 38.8% indicates that employees do not feel that the organization genuinely cares about their needs. 22.6% of respondents were unsure about the organization's care for them. Nearly half of the respondents are unsure if the organization values their

opinion, with a percentage of 41.9%, indicating a lack of employee involvement in decision-making processes crucial for overall operations or individual aspects of their tasks. 41.9% of respondents do not believe that the organization takes pride in its achievements, while 32.3% of respondents were unsure about this statement, which likely speaks to an organizational culture that does not celebrate the "small victories" of its employees. Regarding the statement about job interest, the responses were predominantly evenly divided. 29% of respondents believe that the organization makes an effort to create interesting tasks, 25.8% of respondents were unsure, while a slightly larger percentage, 45.2% of respondents, disagree with this statement. As mentioned before, two out of the three sectors surveyed mainly involve manual, repetitive, and straightforward tasks, which can explain this result.

H1: The organization implements human resource management through employee support.

In many questions, the response "unsure" holds the highest percentage. However, looking at the overall results, we can observe that the organization provides support when employees face problems, the human resource management does not ignore complaints and it helps employees perform their job in the best possible way. Human resource management based on employee support is present in the organization, but there is room for improvement. As a suggestion for improvement, there should be a greater focus on employees performing manual tasks, considering their long tenure and loyalty to the organization. By implementing strategies to motivate these workers, they will be more satisfied and productive, leading to better overall results for the organization. The hypothesis is confirmed.

H2: Human resource management is based on caring for employees.

By examining the overall responses of employees and statements such as "The organization shows very little concern for me" and "The organization takes pride in my achievements," we conclude that half of the respondents disagree with these statements. The hypothesis is not confirmed.

H3: Employees believe that the organization they work for is adequately focused on employee well-being.

A higher percentage, of respondents agree that the organization is focused on their well-being. They do not believe that they are being exploited or that their needs and interests are ignored when decisions are made. The hypothesis is confirmed.

4. CONCLUSIONS

The purpose of this paper is to better understand the functioning and management of an organization, specifically the human resource management segment within a manufacturing organization. The essential outcome is the presence of a quality mutual relationship based on respect and care, fostering positive organizational relationships. Personal characteristics of individuals are of great importance in understanding employee behavior, as they are responsible for generating new creative ideas and solutions. However, while it is important to nurture personality differences, it is equally crucial to create an organizational culture that fosters shared values with its employees, expressing selfless concern for their well-being and welfare. Motivated employee behavior can be seen solely through well-defined organizational structures that respect these principles. It is observed that different individuals are driven by different motivators, which can be material or non-material, and it is expected that the human resource management function determines "what motivates whom". In the conducted research within the company, three different sectors were examined: logistics, extraction sector, and energy sector. More than 50% of the respondents were not in managerial positions, and those who were mostly held lower and middle-level supervisory roles. Additionally, for a significant number of statements, ten out of seventeen, the highest percentage of responses belonged to "unsure." This phenomenon can be explained by employees' fear of providing honest answers, the lack of feedback on job performance, and an inadequate support system that would help employees gain better insight into the organization's care.

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RESILIENCE OF STARTUP COMPANIES IN CRISIS CONDITIONS

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Abstract: *Startup companies operate in an extremely dynamic and volatile business environment, where they are exposed to various crises that can significantly impact their prospects for survival and growth. This paper presents a comprehensive analysis of the resilience of startup companies in the face of crises, examining the strategies and factors that contribute to their ability to adapt, survive, and even thrive in challenging times. The research analyzes the strategies employed by resilient startups during crises, including possibilities such as generating valuable products and services for customers, protecting intellectual property rights, rapidly commercializing ideas, strengthening competitive advantage, integrating into existing value chains, or defining entirely new value chains, and more. Particular emphasis is placed on the importance of building a culture of resilience within startup companies, focusing on practices that foster an entrepreneurial mindset, promote open communication, prioritize employee well-being, and implement robust risk management strategies. This paper provides valuable insights into the resilience of startup companies in periods of crisis. It offers practical recommendations for startups, decision-makers, investors, and support organizations to enhance startup resilience, creating a successful ecosystem that can effectively withstand and recover from the impacts of crises, with a particular emphasis on crises caused by the pandemic.*

Key words: startup, resilience, ecosystem, strategy, crisis

1. INTRODUCTION

Faced with unexpected challenges in the modern world and turbulent economic conditions, the resilience of all business organization has become an increasingly important topic in contemporary literature. Organizational resilience can be defined as the capacity to effectively navigate challenging conditions and ensure the survival and prosperity of the organization (Vogus & Sutcliffe, 2007). Organizations need to swiftly address unexpected disruptions or substantial changes that could potentially endanger their business operations, employees, resources, brand, or reputation.

Startup companies represent today's oasis of endless possibilities and new business models, driven by innovation, ambition, and the pursuit of innovative ideas. However, the journey from launching a startup to achieving success in the market is often incredibly challenging, with success being highly uncertain. Therefore, startups are organizations whose operations are highly uncertain and unpredictable, making them particularly vulnerable to various negative influences, including those caused by different crises.

Crisis conditions can manifest in various forms, such as economic downturns, market disruptions, natural disasters, pandemics, or regulatory changes. While such events can pose a significant threat to the very existence of startups, they also present opportunities for innovation, adaptation, and competitive advantage. During a crisis, startup founders, like all other company representatives, are compelled to reassess their strategies, redesign their business models, and redefine their offerings, which affects the value delivered to end customers. The resilience of startup companies can be understood as their ability to adapt, recover, and transform in response to crises, ensuring their survival and sustainable growth.

The theoretical framework for startup companies and their operations in the innovative startup ecosystem under crisis conditions will be presented in the paper. It is crucial to consider some of the strategies available to startup founders in these circumstances, as well as their impact on the startup's business itself. The paper showcases research results regarding the implementation of various resilience strategies by startup companies during times of crisis, particularly the pandemic crisis caused by the

COVID-19 virus. The conclusions offer suggestions for further research, as well as the advantages, limitations, and impact of this research on understanding this dynamic field.

2. THEORETICAL BACKGROUND

Understanding of startup companies and their operating encompasses various concepts and frameworks from entrepreneurship, innovation, and organizational theories. These theoretical foundations provide valuable insights into the formation, growth and development strategies, and challenges faced by startups. Furthermore, recognizing the role of startup ecosystems and support mechanisms is crucial for creating an enabling environment that cultivates entrepreneurship and fosters innovation.

Entrepreneurship is a business phenomenon with strong impact on modern economies. Entrepreneurship is widely recognized as a key driver of success, and every individual who embarks on creating a new organization or business ventures into a new paradigm of entrepreneurship (Barot, 2015). Entrepreneurship is associated with creating new value and entails a dynamic process (Fayolle, 2007).

Taking into account the purpose of innovations, they can be defined as the process of creating and introducing something new or improved with the aim of generating appropriate value and benefit (Hisrich & Kearney, 2014). Innovations also lead to the lunching of new entrepreneurial ventures and enhance their competitiveness (Abrahamson et al.,2019), placing special emphasis on creativity and the advantages derived from utilizing scarce resources, specific knowledge, and modern technologies. Innovations are actually what enable business sustainability (Kotler & De Bess, 2011) and lead to the successful fulfillment of a company's vision and mission, as well as increased success in the market. By fostering and generating innovations, companies secure significant benefits, including: retaining or increasing market share, enhancing profitability in existing markets, and creating opportunities to enter new markets (Vekić, 2023). From a macroeconomic perspective, innovations enable technological growth, more efficient handling of economic crises, employment growth, contribute to higher levels of investment, and the development of completely new industries.

Entrepreneurship and innovation form the foundation for the emergence of new entrepreneurial ventures known as startup companies. To understand this relatively new concept of startup companies, it is necessary to consider their specificities and characteristics. Startups differ from other forms of companies in that they are "a temporary organization designed to search for a repeatable and scalable business model" (Blank, 2013). Startup companies are specific entities whose business is based on opportunities, ideas, creativity, innovation, and new technologies, as well as the development of new products and services, etc. Their operations are connected to various industries and modern sectors, and are built upon advanced technologies (Digital Serbia Initiative, 2019). Innovative startup companies represent one of the most significant elements of development in contemporary economies (Walsh &Cunningham, 2016). Startup company is always capable of delivering an unlimited number of products and services in the same way with minimal production costs. Unlike entrepreneurship, which encompasses all new companies, startup companies refer to new ventures that intend to grow rapidly after their establishment, which is one of their fundamental characteristics. Building upon previous definitions, a group of authors defines a startup company as "a new and temporary company that bases its business model on innovation and technology. Furthermore, startup companies have the potential for rapid growth and scalability, meaning they have the ability to expand and increase their operations with a clear developmental perspective" (Strielkowski et al., 2015). Startup companies are recognizable for being always connected to innovations (Socorro Márquez & Reyes Ortiz, 2021) and their primary product can be hardware, software, services, materials, etc. (Thomas & John, 2021).

The increasing number of startup companies, which are drivers of innovation and development, leads to the emergence of a startup ecosystem that enables their mutual connection as well as collaboration with other participants within this ecosystem, with the goal of their survival, sustainability, and accelerated growth. A startup ecosystem is defined as a system formed by individuals, startup companies in various stages, and different types of organizations in a specific location (physical and/or virtual), where they interact with each other as a system aimed at creating new startup companies (Startup Commons, 2013). The interaction between organizations and individuals within the startup ecosystem enables the flow of resources, thereby fostering the creation of new startups and strengthening existing ones. In addition to providing standard support in the form of financial resources, these ecosystems also offer valuable assistance through a wide range of knowledge and experiences, which are crucial for business beginners (Vekic, 2023).

The main elements of a startup ecosystem are: Ideas, inventions, and research; Startups at various stages of development; Entrepreneurs; Members of startup teams; Business angels; Startup mentors; Startup advisors; Other individuals with an entrepreneurial mindset and Third-party entities from other organizations involved in startup activities (Startup Commons, 2021). Indeed, the startup ecosystem represents a well-established entity that consists of the mentioned participants and leverages their strengths and advantages to enable innovation, create exceptional companies, generate new job opportunities, and foster entrepreneurship (Aleisa et al., 2013).

3. STRATEGIES FOR STARTUP SURVIVAL AND SUCCESS IN TIMES OF CRISIS

Startups are known for their agility, innovation, and ambition, but when a crisis strikes, their survival and success can be severely challenged. Crises can come in various forms, such as economic downturns, global pandemics, natural disasters, or industry-specific disruptions. Navigating through these turbulent times requires startups to adopt strategic approaches that enhance their resilience and position them for long-term success. Periods of crisis bring unique circumstances that are unpredictable and always interesting for research and description in scientific literature. In such cases, significant changes occur in the way all companies, especially startups, operate and function. These new ventures are highly sensitive to all kinds of changes and require swift response and adaptation, as their business operations, sustainability, and attainment of business success are uncertain even in stable market conditions. The occurrence of crises highlights the resilience of startup companies, and the consideration of implementing appropriate measures becomes crucial (Doern et. al., 2019). Exactly, it involves defining appropriate business goals, strategies, and policies, or redefining existing ones. During times of crisis, startups may need to reassess their objectives and adapt their approaches to navigate through challenging circumstances successfully. This could include revising their business plans, adjusting their target markets, exploring new revenue streams, managing costs more efficiently, and ensuring their products or services remain relevant and valuable to customers in the changed market conditions.

Resilience in business implies the company's ability to perceive and embrace risks, and to leverage them as opportunities for advancement (Aldianto et.al., 2021). Some of the most significant risks that affect the business, growth, and development of startup companies are (FundingSage, 2021): Risk of business expansion capability; Product/service development risk; Economic risk with a special focus on external economic factors; Capital risk; Risk of designing innovative products and services; Risk of the life cycle of innovative products/services; Regulatory risk; Liquidity risk; Risk of implementing the business model; Operational risk; Procurement risk; Risk of researching business fundamentals; Technological risk and Demand risk.

The ability to innovate, be flexible, and maintain a strong focus on goals are essential elements of startup resilience during times of crisis. Therefore, capacity of startups to effectively overcome obstacles and challenges during crises serves as a strong indicator of its resilience (Cvijić-Čović et. al., 2023). Building a culture of resilience within an organization is essential to navigate through challenges, adapt to change, and thrive in uncertain environments. This is also important for startups, and some of the key directions for building a culture of resilience in startup companies are: focusing on practices that foster an entrepreneurial mindset, promoting open communication, prioritizing employee well-being, and implementing robust risk management strategies (Forbes, 2020). To build an effective culture of resilience in startup companies, it is crucial for them to have a clear vision and mission, to be oriented towards learning, growth, and gaining new practical experiences, as well as supporting their employees in various aspects. Additionally, having leadership that recognizes opportunities and nurtures a culture of unity, teamwork, openness, and promotes an inclusive culture and celebration of success is essential.

All of this has proven to be especially important during the recent major crisis, which is distinctive for being caused by a health crisis in the form of the COVID-19 pandemic (Sreenivasan et. al., 2023). According to the World Health Organization, a pandemic can be defined as the global spread of a new disease. Influenza pandemics are unpredictable but recurring events that can have significant consequences on human health and worldwide economic well-being (World Health Organization, 2009). The pandemic caused by the COVID-19 virus has led to significant changes in people's lives, business operations, and the functioning of entire economies. In order to build resilience to new circumstances and successfully survive in the conditions of extreme uncertainty brought about by the pandemic, startup companies have a wide range of strategies available to apply in their business. Some of the most important strategies that startup companies can implement during a crisis to survive and strengthen their position in the innovative startup ecosystem include (Scott & Stern, 2018):

- Generating valuable products/services for customers and protecting intellectual property rights to retain control over them.
- Rapidly commercializing ideas rather than retaining control during idea development.
- Commercializing and strengthening competitive advantage with a focus on integration into existing value chains.
- Defining an entirely new value chain with the goal of gaining control and achieving a market leadership position.

4. METHODOLOGY AND RESEARCH RESULTS

This research is a part of an extensive study on the innovative startup ecosystem in the Republic of Serbia and its part of doctoral dissertation one of the authors of this paper. The study focuses on examining various aspects of the startup landscape in Serbia, aiming to contribute to the understanding and development of the innovative startup ecosystem in the country. The study employed an online questionnaire designed using Google Forms, with founders of startup companies participating as respondents. The data collection period for this research took place from May to October 2021, covering startup companies across the entirety of the Republic of Serbia, including all five statistical regions. The total number of respondents in this study was 106. The research sample consists of startup companies that develop and implement innovation in their business practice.

RQ1: How do startup companies react in case of a crisis?

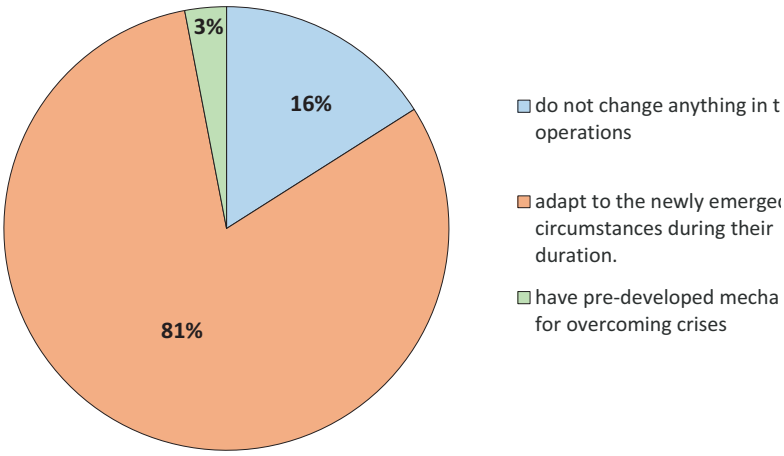

Figure 1: The reactions of startups in case of a crisis (Vekić, 2023)

Figure 1 presents the research results regarding the response of startup companies in case of a crisis. According to the research, the majority of startup companies, around 81%, adapt to the newly emerged circumstances during their duration. Approximately 16% of startup companies have pre-defined mechanisms to mitigate the consequences of the crisis, while a small percentage, only 3% of startup companies, have a strategy of not changing anything in their operations.

RQ2: How do startup companies with pre-defined mechanisms for overcoming a crisis perceive the impacts of risks on their growth and development?

The descriptive statistical method was applied with the aim of examining the perception of risk impacts on the growth and development of startup companies by companies that have pre-developed mechanisms for overcoming crises.

Table 1: Assessment of the impact of risks on the growth and development of startup companies with pre-developed mechanisms for overcoming crises (Vekić, 2023).

	Min	Max	AM	SD
Risk of business expansion capability	1	5	3,53	1,07
Product/service development risk	1	5	3,65	0,93
Economic risk with a special focus on external economic factors	1	5	3,29	1,21
Capital risk	3	5	3,76	0,66
Risk of designing innovative product/ services	1	5	3,18	0,95
Risk of the life cycle of innovative product/services	1	5	3,29	0,97
Regulatory risk	1	5	3,24	1,19

Liquidity risk	1	5	3,18	0,99
Risk of implementing the business model	1	5	3,29	1,20
Operational risk	1	5	3,18	1,01
Procurement risk	1	5	2,88	1,05
Risk of researching business fundamentals	1	5	3,29	1,21
Technological risk	1	5	3,24	0,83
Demand risk	1	5	3,18	0,90

Legend: Min- Minimum Value, Max- Maximum Value, AM- Arithmetic Mean, SD- Standard Deviation

Results of the research which are presented in Table 1, show that all observed risks have been assessed as generally high, while capital risk, business expansion capability risk, and product/service development risk have been identified as particularly pronounced risks. These findings highlight a strong sense of risk awareness among startup companies in the Republic of Serbia. Their caution is evident even when they have anticipated potential risks due to the occurrence of crises and have prepared mechanisms to overcome them, as well as to mitigate any negative consequences that may arise in such situations.

5. CONCLUSIONS

The operation of startup companies in the innovative startup ecosystem is always sensitive and subject to the influence of numerous risks. Since their inception, these companies have been striving to survive in the market and achieve their business objectives, success, and sustainability. The main comparative advantage of startups lies in leveraging innovations to strengthen their market position and assume leadership roles within their industry. Their ability to adapt and respond quickly to emerging changes greatly impacts their survival, especially during times of crisis, which affect all business segments and disrupt the functioning of companies. For this reason, it is crucial for startup companies to consider strategies for mitigating the consequences of a crisis and make important business decisions in a timely manner.

They have the option to adopt various existing strategies or create new ones based on the given circumstances. An example of this is defining new strategies necessitated by the unique crisis triggered by the COVID-19 pandemic, which has reshaped the world and introduced new paradigms in business. The effects of this crisis are not all necessarily negative, as it has led to the flourishing of certain new industries and startup companies within them.

However, there are limitations to this research, as it is based on a sample from one country, and the survey was conducted only among startup company founders, one of the main participants in the innovative startup ecosystem.

Future research could involve examining differences between industries in which startup companies operate and exploring all participants within the given innovative startup ecosystem. Additionally, a comparative analysis between different countries or regions would be desirable.

During a crisis, different types of risks combine and affect startup businesses, prompting them to make a realistic assessment to minimize these risks and proactively reduce potential harmful impact. Startup companies are compelled to develop resilience against all negative effects brought about by a crisis, and the research within this study shows that the majority of companies responded to these circumstances. This includes nurturing a culture of readiness, proactivity, and agility, allowing startup companies to maintain their growth trajectory and become stronger even in the face of adversity.

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INDUSTRY 5.0 AND THE SKILLS GAP: STRATEGIES FOR DEVELOPING A FUTURE-READY WORKFORCE

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Abstract: *Industry 5.0 represents the integration of advanced technologies, such as artificial intelligence, robotics, and the Internet of Things, with human capabilities. However, this paradigm shift poses challenges in terms of the skills required by the workforce. The main aim of this paper is to examine the concept of Industry 5.0 and its implications for the skills gap. It also focuses on identifying key aspects of the skills gap and analyzing current strategies at reducing this gap and developing a future-ready workforce. By implementing these strategies, businesses and societies may actively bridge the skills gap and provide their workforce with the talents required to succeed in the changing world of Industry 5.0. Additionally, this paper aims to provide significant insights for stakeholders to establish a resilient and flexible workforce ready to embrace the opportunities given by Industry 5.0. It can also serve as a basis for further research in the field of skill development and workforce transformation in the face of rapid technological changes.*

Keywords: Industry 5.0, Skills Gap, Workforce, Strategies, Reskilling

1. INTRODUCTION

The industrial revolution's progress has caused transformational innovations in all aspects of society. However, as new social development ideas such as human-centricity, sustainability, and carbon emissions have been introduced, the manufacturing system/paradigm has faced challenges in adjusting to the requirements of an inventive community (Leng et al., 2022). With its innovative perspective, Industry 5.0 will contribute to resolving the issue of the imbalance between industrial and societal requirements. In contrast to previous industrial revolutions, which focused on the economic aspects of sustainability, the Industry 5.0 prioritizes human well-being and societal concerns (Ghobakhloo et al., 2022).

This paper focuses on important features of Industry 5.0, with a particular emphasis on the skills gap and strategies for developing a future-ready workforce. It also provides valuable insights into the ongoing evolution of manufacturing, the challenges faced and potential future directions and emerging trends in workforce development.

2. INDUSTRY 5.0: A PARADIGM SHIFT IN MANUFACTURING

We have witnessed shifts inside manufacturing systems, particularly in the field of digitization, throughout the previous decade (Aslam et al., 2020). Information and communication technologies are used at every stage of manufacturing and this results in a variety of complications in multiple areas, including technical, logistical, organizational, and environmental (Crnjac Zizic et al., 2022). A difficult transition process is underway, which must be successfully managed. Industry 5.0 acknowledges industry's ability to achieve societal purposes beyond just employment and economic growth, to become a sustainable source of development (Alves et al., 2023). It strives to build a sustainable type of development by guaranteeing that manufacturing takes into consideration our planet's constraints and emphasizes employee well-being (Huang et al., 2022). It aspires to become a trustworthy system that provides individuals with a fulfilling and healthy profession by embracing required technical improvements (Akundi et al., 2022). While being conscious of the planet's limitations, this paradigm utilizes novel technologies to create wealth beyond conventional job opportunities and economic growth (Xu et al., 2021). It empowers workers while also meeting their evolving skill and training needs, increases industrial competitiveness and recruits top talent (Akundi et

al., 2022). Last year, the European Commission presented a new and ambitious vision for Industry 5.0. This strategy plan provides the necessary direction to promote scale innovation that generates new forms of economic and social value that successfully balance people, planet, and wealth (Renda et al., 2022).
In implementing Industry 5.0, the European Commission focused on three goals: "Europe fit for the digital age", "A European Green Deal" and "An economy that works for people" (Renda et al., 2022). Thus, Industry 5.0 is not solely built on technology but is grounded in principles such as human-centricity, societal benefits, and environmental responsibility (Akundi et al., 2022). This shift is based on the idea that technology may be designed to foster values and that ethical goals should lead to technical advancement instead of the reverse (Müller, 2020).

3. THE SKILLS GAP IN INDUSTRY 5.0

Industry 5.0 emerges as the response to the demand for a revitalized human-centric industrial paradigm and includes reorganizing production processes in structural, organizational, managerial, knowledge-based, philosophical, and cultural aspects (Carayannis & Morawska-Jancelewicz, 2022). The goal is to provide positive results that enhance not just commercial perspectives but also all parts of the innovation ecosystem (Carayannis et al., 2021). Human-centricity, resilience, and sustainability are the three pillars of Industry 5.0 (Breque et al., 2021). Taking into consideration the aforementioned aspect, it is essential for the workforce to learn a set of new professional and cross-cutting capabilities in order to achieve a sustainable, inclusive, and resilient transition to Industry 5.0 and to produce long-term good consequences (Suciu et al., 2023). In the workforce of the future, soft skills appear to be increasingly crucial, primarily because they differentiate humans from machines (Kolade & Owoseni, 2022). The reality of lifelong learning for everyone is taking shape, as new skills and technologies are being introduced at a much faster pace compared to a decade ago (Li, 2022).
Some of the core competencies that are crucial include:

- Competence in using, controlling, and monitoring technological devices;
- Technological and programming solutions development;
- Lifelong learning;
- Originality, initiative, and creativity;
- Innovative, creative, and analytical thinking;
- Ability to tackle difficult situations and solve complex problems;
- Emotional intelligence;
- Leadership (Suciu et al., 2023).

“The Future of Jobs Report 2023” by the World Economic Forum highlighted that analytical thinking and creative thinking will continue to be the most important skills for workers in 2023. Employers predict that in the next five years, 44% of employee skills will be disrupted and cognitive skills are the most important, indicating the rising relevance of complex problem-solving in the workplace (World Economic Forum, 2023). According to “The Future of Jobs Report 2023”, the third-fastest growing core competency is technology literacy. Individuals who develop these types of skills and essential abilities will be better prepared to work as a researcher, artificial intelligence (AI) specialists, Internet of Things (IoT) specialists, software developers, information security analysts, robotics engineers, database and networking specialists, process automation specialists, materials engineers, renewable energy engineer or digital marketing specialist (Suciu et al., 2023). From entry-level personnel to boards of directors, the Industry 5.0 paradigm entails cultivating mindsets, competencies, and skills, through comprehensive training aimed at adopting a systemic approach and comprehending complexity (Renda et al., 2022). Recognizing difficulty, as well as designing complexity-friendly tools and processes, thinking in systems, experiential learning, design principles, iterations and action and reflection cycles involves this training (Suciu et al., 2023). Additionally, Industry 5.0 is characterized as a green and digital technology transition aimed at creating a more sustainable industry (Alves et al., 2023). It has also been envisioned as a greener and more human-centered iteration of Industry 4.0 (Güğerçin, S. & Güğerçin, U., 2021).
Looking back at the previous concept, Industry 4.0's ultimate objective is to increase digitalization and automation and one of the key concerns of the paradigm is smart factories (Güğerçin, S. & Güğerçin, U., 2021). These factories are high-efficiency manufacturing facilities that operate with exceptional efficiency using smart technologies, eliminating the requirement for human involvement in the production process (Phuyal, Bista & Bista, 2020). Transformative technologies such as AI, IoT, robots, digital twins, 3D printing, and blockchain have been the key concepts in constructing efficient and competitive production processes in the Industry 4.0 era. These advantages,

however, were not without drawbacks, particularly in encounters involving human-machine disputes (Battini et al., 2022). Researchers identify health issues, worker satisfaction, and worker welfare as important considerations in this respect (Pizoń & Gola, 2023).

Looking at the larger picture, Industry 5.0 has two main goals. The first entails providing personalized services and manufacturing by collaborating with people, algorithms, and robots (Marinelli, 2023). The second purpose is to create an economy that encourages sustainability (Marinelli, 2023). To summarize, Industry 5.0 intends to change the working system by merging humans, algorithms, and robots, while simultaneously fostering a global bio-economy based on sustainable principles (Alves et al., 2023). Moreover, human involvement in the manufacturing process blends industrial automation's speed with cognitive abilities and critical thinking (Ivanov, 2022). Mechanical and repetitive tasks will be taken over by automated machines, while humans will contribute with their skills to creative projects (Marinelli, 2023). As a result, in the framework of Industry 5.0, employees are expected to increase their value by learning new skills and adjusting to changes through reskilling and upskilling programs (Fitsilis, Tsoutsa & Gerogiannis, 2018).

4. STRATEGIES FOR DEVELOPING A FUTURE-READY WORKFORCE

Much of the recent debate on the global economy's future has concentrated on the influence of digital transformation on corporations, governments, and industries during the last decade (Battini et al., 2022). In accordance with this, researchers and professionals have claimed that the global economic growth trajectory has shifted from a market economy to a knowledge economy (Mohamed, Liu & Nie, 2022). In this context, the Industry 5.0 paradigm requires a proactive approach to education and training to ensure employees have the necessary skills and knowledge to succeed in this new industrial paradigm (Pacher et al., 2023). The reform of vocational educational institutions, particularly business schools, is a pressing issue that necessitates a full overhaul of present academic curricula (Renda et al., 2022). Collaboration with an industry-led vanguard focused on circularity, regeneration and resilience could help universities reduce the time it takes to distribute and disseminate new knowledge, promote strategic innovation portfolios, and reform education (Siciu et al., 2023). A strengthening of public-private partnerships aimed at accelerating industrial transformation and collaboration along sustainable lines could encourage universities, primarily European universities, to become better incubators of innovation, not just through commercialization of research (licensing offices and tech transfer), but also through education renewal (content/reach/form), industrial clusters, co-creation and new forms of collaboration with SMEs and by being 'living labs' (Renda et al., 2022).

To promote the concepts of circularity, resilience, and successful regeneration within sustainable business models and value chains, it will be necessary to establish innovative collaborative industrial networks (Crnjac Zizic et al., 2022). These networks should encourage the exchange of ideas, expertise, and resources across different sectors (Crnjac Zizic et al., 2022). Furthermore, the establishment of integrated multidisciplinary teams is crucial to achieve multidimensional business models that produce many types of value (Battini et al., 2022).

5. CHALLENGES AND FUTURE DIRECTIONS

In Industry 5.0, there is a focus on improving worker well-being by developing techniques to track and incorporate more precise individual worker characteristics into work planning decisions (Lu et al., 2022). Individual talents, technological acceptance level, physical capabilities, age, gender and other factors all contribute to workforce diversity (Battini et al., 2022). Actively recognizing, assessing, and taking diversity into account in workplace policies becomes a critical strategic requirement in order to increase performance by practice decisions with the diverse qualities and attributes of individual workers and better aligning work policy (Katiraee et al., 2021). There is also a requirement to improve workforce well-being and employee satisfaction (Battini et al., 2022).

In addition to the previously mentioned systems thinking and complexity skills, Industry 5.0 will need to attract and invest in mind-sets, skills, and abilities capable of radical cross-border collaborations and governance and sustaining long-term partnerships and including cross-disciplinary co-creation (Renda et al., 2022). Currently, these skills are not emphasized in secondary and postsecondary education core curriculum (Kolade & Owoseni, 2022). Individuals often develop these talents later in life as they mature and participate in lifelong learning (Pacher et al., 2023). However, these talents must be developed at a young age, which would entail a major overhaul of educational and training institutions' structures and methods (Kolade & Owoseni, 2022).

Furthermore, it is crucial to highlight the importance of imparting these skills to decision-makers, boards of directors, and middle management within European enterprises and the public sector (Renda et al., 2022). This is essential to facilitating one of the most important intersectoral collaborations, namely the intersection of the public and private sectors, as well as the collaboration between industry and government in managing shared resources and working toward collective welfare (Kolade & Owoseni, 2022). Currently, the competencies required to assume such roles are not widely distributed among individuals. In this context, universities are emphasized for their role in building and nurturing these abilities, as well as matching university curricula with labor market demands (Siciu et al., 2023). On the other hand, the focus is on the importance of training and lifelong learning in light of new innovative and technological developments (Kolade & Owoseni, 2022). It is becoming increasingly clear that not all persons are capable of continually improving their skills and core competencies in response to technology innovation, but the Industry 5.0 paradigm also provides feasible alternate solutions to these types of circumstances (Battini et al., 2022). The Industry 5.0 model's perspective does not develop integrated solutions only for human resources with the ability to acquire such core skills and competencies (Pizoń & Gola, 2023).

AI and virtual and augmented reality may be used to construct tools that assist and guide less specialized or less competent humans in performing more difficult jobs that need advanced and high skills and competencies (Siciu et al., 2023). Furthermore, there is a potential for the development of technologies that are more intuitive and user-friendly, allowing for enhanced interactivity and effectiveness in their usage (Crnjac Zizic et al., 2022).

6. CONCLUSION

In this rapidly evolving world, fostering collaboration between automated systems and human workers is crucial. The successful implementation of the Industry 5.0 model is highly dependent on employees being involved in the development and use of new digital and industrial technologies like artificial intelligence and robots (Breque et al., 2021). By establishing seamless integration and cooperation, organizations can create synergistic workflows where humans and machines complement each other's strengths (Renda et al., 2022). This collaboration enables tasks to be performed more effectively and efficiently, leveraging the unique capabilities of both humans and digital technologies. As we transition to Industry 5.0, it is essential for employees to cultivate a proactive attitude toward learning and upskilling (Li, 2022). This proactive mindset enables individuals to adapt and thrive in this new era of constant transformation by consistently updating their knowledge and acquiring new skills that align with the evolving technological advancements and industrial practices (Crnjac Zizic et al., 2022). This approach empowers workers to manage the shifting needs of the industrial sector efficiently, contributing to the overall sustainability, competitiveness, and resilience of both companies and the broader economy (Kolade & Owoseni, 2022). By developing their core competencies and skills, individuals become better equipped to tackle new challenges and transform them into opportunities.

Additionally, the collaboration between academia, industry, and government is vital for skill development and lifelong learning initiatives (Renda et al., 2022). By leveraging the potential of emerging technologies and promoting collaborative efforts, it is possible to efficiently bridge the skill gap, equip the workforce with essential capabilities, and ensure that employees are prepared for the demands of the future (Siciu et al., 2023).

Furthermore, fostering an organizational culture of creativity, flexibility, and diversity is important for developing a future-ready workforce capable of embracing technology breakthroughs and driving innovation (Battini et al., 2022). However, challenges such as the rapid pace of technological advancements and the need for a comprehensive understanding of evolving job roles require continuous research, evaluation, and improvement of skill development strategies.

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CHALLENGES IN THE TRANSITION PROCESS TO THE CIRCULAR ECONOMY: A POINT OF VIEW OF A PACKAGING COMPANY

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Abstract: *Limitation and scarcity of natural resources, followed by rising demand and global competition for providing resources, emphasize vulnerability and dependance of different industries on import of these resources, considering increasing prices, volatility and uncertain political situations in supplier countries. European Commission explained Circular Economy (CE) as a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible, resulting in the extension of the product's life cycle and reduction of waste. Unlike the traditional linear economy based on "take-make-consume-dispose" approach, a CE strives to reduce consumption of raw materials and energy, greenhouse gases (GHG) emissions, material losses and waste, and to increase the usage of renewable or recyclable resources. In this context, it is hard to assess the readiness of companies willing to embrace the CE paradigm and which are the challenges in this transition. The research objective of this paper is to evaluate companies' readiness to implement circular business model and to detect the related potential challenges, according to measures recommended in the new national CE program. The research has been conducted from the point of view of a Serbian packaging company. In the paper are discussed results obtained in the research implementing measures recommended in the national CE strategy, as a way to improve CE potential and readiness of the analyzed company.*

Key words: circular economy, measures, packaging, resources

1. INTRODUCTION

The European Environment Agency (EEA) emphasized that worldwide population is using more resources than our planet can produce in a given time and we have to reduce the extraction and usage of materials, and the generation of waste. Limitation and scarcity of natural resources, followed by rising demand and global competition for providing resources, emphasize vulnerability and dependance of different industries on import of these resources, considering increasing prices, volatility and uncertain political situations in supplier countries. Using renewable and recyclable resources reduces above mentioned risks occur in the supply chains (European Academies' Science Advisory Council, 2015).

The Circular Economy (CE) concept was first introduced in the report of Ellen MacArthur Foundation in 2013. Then, the European Commission (EC) defined it as a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible, in order to extend a life cycle of products, to reduce consumption of raw materials, water and energy, greenhouse gases (GHG) emissions, material losses and waste, and to increase the usage of recyclable resources (European Parliament, 2016). The four key CE principles are: use less, use longer, use again and make clean. Unlike the traditional linear economy approach (take-make-consume-dispose), a CE respects limitation of resources in the nature and strive to increase the share of renewable or recyclable resources while reducing the consumption of raw materials and energy and at the same time cutting emissions and material losses (EAA, 2016). With a CE the needs of planet's population can be fulfilled with just 70% of the materials currently used. The global economy is now only 7.2% circular, and the extraction and use of materials from virgin sources has been increasing (The Circularity Gap Report, 2023).

The CE concept deserves a particular attention in developing countries (Guimaraes Araújo et. al, 2021; European Environmental Bureau, 2020). In the CE development program in the Republic of Serbia for the period 2022-2024, the CE is recognized as an important strategic concept for the green transition of the Republic of Serbia, which in recent years has been placed high on the list of development priorities

It has to be accented that each country has a different starting point and will thrive at a different speed towards the CE. Implementing different circular solution in the economy and society requires to understand and respect local, national and socio-economic environment. In this complex and heterogeneous context, it is hard to assess the readiness of companies willing to embrace the CE paradigm, based on their location and belonging to specific economies and countries, and which are the challenges in their transitions.
The research objective of this paper is to evaluate companies' readiness to implement circular business model and to detect the related potential challenges, according to measures recommended in the new national CE program. The research has been conducted from the point of view of a Serbian packaging company.
The paper is structured as follows. After introduction, the research context is presented in the Section 2. In the section 3, the research methodology is explained. Results are shown and discussed in Section 4. Conclusions are presented in Section 5.

2. RESEARCH CONTEXT

2.1 Circular Economy: performance assessment, benefits, and barriers

Transition towards CE enables a lot of opportunities including reduced pressures on the nature and environment; reduced risks in the supply chain of raw materials, increased competitiveness, innovation, growth and rising employment rate (European Parliament, 2016). CE is based on business models which replace "the end of product life" concept. CE is a renewable industrial economy that has a changed concept of production and consumption in terms of product design, use of resources and waste generation. Brown et al. (2019) considered that the EC should support CE by promoting the collaboration of different actors in product development, process design and new business models.
According to Sassanelli and Terzi (2023), manufacturing companies strive to implement circular business models to limit their resource consumption and pollution generation, but they are still not completely ready and mature enough to develop CE strategies and practices in their business processes. Transition to circular business model requests multilevel and simultaneous changes in the company's organization, technology, management, and processes.
Del Mar Alonso-Almeida et al. (2020) emphasized that the mobilization of resources could be considered as a facilitator of the transition to the CE, but should be additionally supported by the strategies, such as product-life extension, resource efficiency and the useful application of resources (Bocken et al., 2016).
It has to be accented that each country has a different starting point and will thrive at a different speed towards the CE. Implementing different circular solution in the economy and society requires to understand and respect local, national and socio-economic environment. Some countries need to radically reduce material extraction and use, while others need to stabilize or even increase usage of materials. In the Circularity Gap Report (2023) countries are divided to: world's highest-income ("Shift") countries which consume the majority of the world's materials and overcome many planetary resource limitations. These countries have to reduce resources consumption and negative impacts on the environment. In the middle-income ("Grow") countries material and resource consumption has increased due to industrialization processes and these countries should stabilize and optimize their resource consumption to preserve their environment. "Build" countries present the majority of the planet's population, but use less than a 10% of the materials of "Shift" countries. These countries should focus on the building the infrastructure and increasing living standard, even if this requires increase in materials and resource consumption. Another reason why CE should be considered locally is that demand for recycled materials relative to virgin material depends on the type of material, and may be greater for some materials in developing countries than in developed ones. Also, sorting of materials to be recycled or reused is usually labor intensive and is therefore recommended to be done in low-wage countries. At the same time, recycling of appliances and electronics should be done in a few, large centers, because of economies of scale. The overall aim should be global circularity (European Academies' Science Advisory Council, 2015). However, it is still hard and complex to assess circular performances of companies in a systematized way.
Vinante et al. (2021) assessed practice-oriented CE at the firm level by collecting and analyses of CE indicators organizing them according to a new circular Value Chain framework, and emphasized that CE indicators are not explicitly linked to the firm's organizational functions involved in CE assessment. Bressanelli et al. (2021). proposed a readiness assessment model for manufacturing companies that usually have problems in understanding how to start a transition towards CE, which changes are needed in the design of products, production processes, business models, and supply chains.

The research of Demko-Rihter et al. (2023) suggested the framework to assess the level of readiness of companies to embrace the CE paradigm in developing countries, with the possibility to assess the circularity level of their products from the business model perspective.
The benefits of a CE are mirrored in improved competitiveness by improved resource efficiency and reducing raw materials and energy dependency, reduced risks of interruptions in supply chains and increasing costs of raw materials, reducing GHG emissions, waste management, creating new jobs and increasing employment rate, GDP growth (Taddei et al., 2022; Sassanelli et al., 2023). In addition, a CE could spur innovation across different industries because of the need to redesign materials and products for circular use (European Academies' Science Advisory Council, 2015).
At the same time, transition towards a CE brings a lot of barriers and challenges, such as financial resources, key economic enablers, technical skills, consumer behavior and business models, and multi-level governance (European Parliament, 2016). At the company level, investment in digital technologies, assets, and research & development (R&D) are required in considerable amount, and for SMEs it could be seen as one of the key obstacles in adoption circular business model. Subsidies and incentives to promote new circular business models, public investments in waste management and digital infrastructure should be provided at the state level (Dwivedi et al., 2023). Key economic enablers are lacking pricing systems encouraging efficient resource reuse and reflecting full environmental costs (European Academies' Science Advisory Council, 2015). Proper comparison of circular and linear economy could be done only by comparison of the real cost of the CE model (including all externalities into prices) and the real cost of the linear economy model (which currently excludes most externalities). Enabling correct pricing, the linear economy should evolve towards a CE model, as an iterative and interacting system. The majority of employees, especially in SMEs, do not have technical and other skills needed for CE. Only consumers informed and educated about benefits and challenges of CE will change their behavior by making buying decisions and waste sorting (Chiappetta et al., 2023).
Public authorities have at disposal different instruments for enhancing the pace of CE adoption (European Academies' Science Advisory Council, 2015):

- regulatory instruments (laws and directives);
- economic instruments (environmental taxes, fees and user-charges, certificate trading, refunded emission payments, environmental financing, green public procurement, deposit and refund schemes and subsidies);
- research and educational instruments (funding or incentives for R&D, education and training);
- cooperation instruments (technology transfer);
- informational instruments (eco-labelling, sustainability reporting, supply chain reporting, consumer advice services, environmental monitoring, etc.).

Collaboration between the public and private sectors is necessary for the transition to a CE. Public authorities and policy makers should support all participants in the transition process from linear to the circular economy, by favoring long-term benefits and interests over short-term rewards (The Circularity Gap Report, 2023).

2.2 Policy actions related to CE

In 2013, the European Parliament and the European Council adopted the 7th EU Environment Action Programme to 2020 'Living well, within the limits of our planet'. In 2015, with the aim to enable sustainable development and mitigate climate changes, two very important documents were adopted at the global level. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, presented 17 Sustainable Development Goals (SDGs), as a way for action and global partnership between developed and developing countries in improvement of health and education, reduce inequality, and enhance economic growth, while mitigating climate changes and preserving natural environment.
To mitigate negative impacts of climate changes, world leaders at the UN Climate Change Conference (COP21) in Paris 2015 reached the Paris Agreement. Since enforcement of the Paris Agreement in 2016, 194 Parties (193 States plus the EU) have joined the Paris Agreement. The Paris Agreement provides a pathway for developed UN members to assist developing ones in their efforts to mitigate climate changes and prepare a framework for the transparent monitoring and reporting of countries' climate goals. Implementation of the Paris Agreement is essential for the achievement of the SDGs, and presents the beginning of a transition towards a net-zero emissions world. The Republic of Serbia, as a member of the

UN, took on the obligations from the 2030 Agenda, and also, as a signatory to the Kyoto Protocol and obligations from the Paris Agreement.
In 2015 the EC adopted its first action plan for the circular economy "Closing the loop – An EU action plan for the circular economy" (COM/2015/614). The plan included measures to encourage the EU transition to a CE, increase global competitiveness, encourage sustainable economic growth and create new jobs. The specific measures covered by the action plan related to the improvement of production, consumption, waste management, raw material markets, reduction of food waste, reduction of plastic waste generation, innovations and investments, etc.
In December 2019, the European Commission has adopted a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net GHG emissions by at least 55% by 2030, compared to 1990 levels. The European Green Deal (COM/2019/640) will transform the EU into a modern, resource-efficient and competitive economy, and will improve the well-being and health of citizens and future generations, with the overall aim that Europe becomes the first climate-neutral continent by 2050.
In November 2020 as part of the Green Deal, the Sofia Declaration on the Green Agenda for the Western Balkans was signed and included in the Communication on an Economic and Investment Plan for the Western Balkans adopted by the EC. It consists of five pillars, and one of them is the CE. In October 2021, the Action Plan for the implementation of the Green Agenda for the Western Balkans was adopted, which also includes activities in the field of CE.
The preparation of the strategic framework for the CE in the Republic of Serbia began in 2019 with the creation of an ex-ante analysis of the effects of the CE, which showed that a separate public policy document is needed for the field of CE. The Ministry of Environmental Protection initiated the development of the Circular Economy Development Program in the Republic of Serbia for the period 2022-2024. Although it is not a public policy document, an important document for the promotion of the CE concept is the Roadmap for the CE in Serbia, presented in May 2020. The Roadmap should encourage a dialogue between decision-makers, industry, the academic sector and civil society, to make systemic changes in the treatment of resources. Selected sectors analyzed in the document are: manufacturing industry; agriculture and food (accent on food waste); plastics and packaging; construction sector (accent on construction waste). Recommendations and examples of good CE practice are given for each sector.
The important segment of the Circular Economy Development Program in the Republic of Serbia is related to specific objectives and measures (regulatory, incentive, informative-educational) to achieve them. Within the Specific objective 1: Support to the economic sector in the transformation to a circular business model, is defined informative-educational Measure: Analysis of the potential for the application of the CE model in certain sectors of the processing industry and support for selected companies. The measure implies selection and detailed analysis of companies which have the potential to implement circular business model. Through the activities and processes of selected companies are realized the following aims of the CE, given in the CE Development Program:

1. increasing energy efficiency at the level of the plant or its parts;
2. reducing the use of natural resources as a result of applying the best available techniques;
3. reduction of waste generation;
4. reduction of air, water and soil pollution;
5. use of renewable sources of energy and materials;
6. application of new technologies and use of renewable materials;
7. extending the life of the product through design and maintenance;
8. reprocessing and recycling of certain components and materials;
9. research projects and innovations;
10. digitization.

3. RESEARCH METHODOLOGY

In this research mixed methods were used, including the data presented on the websites of the surveyed company and in the company's Sustainability report, prepared according to the standards of the Global Reporting Initiative. First, the researchers read the documentation prepared by the company about sustainability topics (the Yearly Sustainable Report of the last two years and the SDG Progress Report). Then, a meeting with the sustainability manager and her assistants was organized to discuss the topic introduced in the reports and to make the company's employees familiar with the research framework

proposed in this research. A week later, a workshop was conducted for presenting them the CE Development Program and gathering their answers in a form. The researchers analyzed in the back office the answers gathered and, a last workshop was organized to discuss the results with the company's sustainability manager and other employees.

3.1 Company selection

After comprehensive and detailed analyze of companies operating in Serbia, in the recommended industries, suitable to implement circular business model and principles of circularity, the leading domestic manufacturer of printed and laminated cardboard packaging and blister cardboard with 143 employees, was selected. The biggest and the most important clients of the analyzed company operate in the food industry. The company was chosen because of its leading role in the Serbian manufacturing industry, in terms of the responsible usage of raw materials, energy, water, reduction in GHG emission, and constant developing of employees' awareness to behave manage resources responsibly.
The company has established effective monitoring and reporting of GHG emissions. All relevant GHG are taken into account and converted to CO_2 equivalents (CO_2e) as the base unit, and multiplied by their global warming potential. The company is committed to achieving zero GHG impact on the environment, and measures its impact and report on it transparently. The basic methodology of monitoring and reporting on GHG emissions was created according to the international GHG Protocol, currently includes the complete Scope 1 and Scope 2, while preparations for the Scope 3 scope are underway.

4. RESULTS AND DISCUSSION

Through the activities and processes given in the CE Development Program, the potential for the application of the CE model in the selected company was analyzed:

1. Increasing energy efficiency at the level of the plant or its parts

- *Reactive energy compensation*

The installation of a reactive energy compensation facility mitigates collision of frequencies and increases the degree of utilization of electrical energy. A reactive energy compensation facility the degree of utilization of electricity drawn from the power grid, thereby increasing the company's energy efficiency and reducing GHG emissions.

- *System for in-line control of ink application on sheets in the press*

New machines must have the possibility of installing a system for in-line control of the application of ink on the sheets in the press, which shortens a preparation and ensures uniform printing on all sheets. This system directly reduces resource consumption and waste generation, and increase the energy efficiency. The company has a Lithec system on all printing machines for in-line control of the application of color on the sheets in the press.

- *System for automatic logistics of displaying pallets on a printing machine*

Installing this system enables automatic display of pallets with printed sheets and insertion of empty pallets into the machine's feeder. This significantly reduces the process time and increases energy efficiency.

- *Installation of frequency regulators on electric motors*

Installed frequency regulators reduce large oscillations in the electrical grid during sudden switching on and off of powerful motors which lead to increased energy efficiency.

- *Energy efficiency lighting*

In the company were also installed LED lighting with motion sensors which reduce energy consumption, and taps with sensors which reduce water consumption.

2. Reducing the use of natural resources as a result of applying the best available techniques

The use of natural resources in the production has been decreasing and last year 94.7% of total chromocardboard and packaging paper that company processed were from recycled sources.

3. Reduction of waste generation

- *Upgrade of the system for automatic ejection and baling of paper and cardboard waste*

At the beginning of 2022, the company expanded the system for the automatic removal of paper and cardboard waste from production, and bought a baling press, able to meet the growth of production capacity. With the installation of a new improved baling system, GHG emissions caused by the stoppage of the paper waste disposal system were reduced by 64.15%.

- *Installation of an improved automatic machine for tying and stretching pallets of finished products*

New line for tying and stretching pallets of finished products was installed, able to use less thick tying tapes and stretch film, thus reducing the amount of packaging waste generated. The line has a greater capacity of tying and stretching a larger number of pallets of finished products in a shorter time, thus reducing resource consumption.

- *Responsible waste management*

The waste is managed responsibly with strict adherence to laws and best practices, which is reflected in the following processes and activities:

a) Reducing the amount of generated waste, both waste resulting from the company's business activities (technical and process improvements), and waste generated by employees, their families and members of the local community (through employee and local community awareness activities, local community support projects and others).
b) Sorting of waste at the moment of its generation, and after that in accordance with the waste management plan.
c) Recycling island is technically equipped for temporary waste storage, with a minimum impact on human health and the environment. Given that the company is slowly outgrowing the capacity of the existing Recycling Island with the growth of its business, the Project of a new Recycling Island with surrounding greening was done in order to reduce the potential negative impact on the environment.
d) The company uses the services of exclusively authorized waste operators, and all further activities related to the delivered waste are requested in order to ensure that the waste is managed responsibly and sustainably.
e) Reuse of the waste whenever possible.
f) Recycling - Most of the waste generated in company is recycled. In 2022, 96.94% of the total waste was recycled.

4. Reduction of air, water and soil pollution

In order to reduce emissions of polluting substances into the air, the burner was replaced on one of the CNG boilers for steam production and the combustion parameters of the heating boilers (pellets) were adjusted.

A grease and oil separator were installed with the function of purifying waste storm water before its discharge into the natural recipient - the nearby river.

The printing process is realized without the use of alcohol in the wetting system.

5. Use of renewable sources of energy and materials

- *The solar power plants*

The company installed solar power plants on the roofs of production and storage facilities, to significantly improve the company's energy efficiency.

An analysis of the justification for setting up a solar power plant in the company was done. Investing in the construction of a solar power plant with a capacity of 580 kWh, which would annually produce about 800,000 kWh of electricity for own needs, which accounts for about 40% of the total electricity needs, and at the same time 40% reduction in the consumption of electricity obtained from non-renewable sources. Due to the favorable location and the big average number of sunny days per year, a significant amount of energy could be saved, with the contribution to the " Zero CO2" project.

6. Application of new technologies and use of renewable materials

- *Robotization of packaging of finished products*

The company is currently working on the development of a project for the robotization of the process of packing transport boxes with finished products on pallets. This system will speed up and increase the productivity of the production process, reduce resource consumption and GHG emissions.

7. Extending the life of the product through design and maintenance

- *Eco Design*

Eco Design is the packaging design philosophy, which implies close cooperation with clients and optimization of the packaging production to reduce negative impact on the environment. In the production of packaging, company uses the minimum necessary amount of material, which is mainly recycled, and ecological paints and varnishes.

Eco-designed packaging is:

a) produced using the least necessary number of materials while maximizing the utilization of all production resources and materials;
b) produced using solely materials from sustainable and responsible sources, with the increasing percentage of FSC certified;
c) designed to be easy, economical and fully recyclable at the end of its life;
d) compliant with the requirements of the European Parliament and Council Directive 94/62/EC on packaging and waste packaging;
e) gives added value to the product by enabling more functions (utility, protection, storage-transport and sales-marketing) and extended life;
f) communicates the values of sustainable consumption and encourages responsible end-of-life management (PAP sign - recycling instructions).

8. Reprocessing and recycling of certain components and materials

- *Using generated wood waste for heating*

The wooden pallets for transportation of ordered goods and materials, had no function and were ending their life cycle in the company's warehouse. Wooden pallets go through the process of mechanical wood chipping, and wood chips can be used later for heating. Wood chips from wooden pallets could cover 38% of the annual need for heating fuel.

- *Using waste heat for heating company's buildings*

The company has started several projects for the reuse of waste heat generated in production processes, and its use for heating buildings during the heating season, among which are:

a) Replacement of existing air compressors with modern ones which are more energy efficient, have a system for recovering waste heat generated during operation.
b) Installation of a heat exchanger on the steam recovery system from the wave machine, which will remove excess heat from the steam returning to the boilers and conduct this steam to the heating system.

9. Research projects and innovations

B2B2C approach to packaging design is applied to respond to changing consumer demands and increase the value of clients' products. The company is mapping consumer needs to understand their expectation from packaging. A few years ago, was noticed the need for ecological and sustainable packaging, with an extended life cycle.

The innovation process resulted in several packaging solutions that have attractive design, protective function, an extended life, with the possibility of reuse after fulfilling primary function. After the end of the life cycle, such packaging is recycled, enabling circularity and significant savings.

10. Digitization

Digital transformation implies complete transformation of technology, business processes and the way of thinking through the application of digital tools and ideas that bring overall changes. In the analyzed company digital transformation is a continuous and comprehensive process, related to all aspects of the company's operations: business planning, production scheduling, information management, reporting, performance monitoring, performance-based incentives and so one.

- *MES – Manufacturing Execution System*

The Manufacturing Execution System enables monitoring and managing the production, providing real-time insight into the operation of machines, the realization of planned activities, the degree of capacity utilization and the possibility of real time planning production scheduling.

MES collects data directly from sensors embedded in production equipment and matches them with data from the ERP system, in order to provide more accurate data.

MES enables increase of the efficiency of production processes and easily identification the losses points, which directly increases energy efficiency and reduces the consumption of resources and the amount of waste generated. MES enables monitoring of employees' performances, based on their direct efforts, as a key input for calculating their salaries.

- *BI*

Using Business Intelligence (BI) technology will accelerate reporting and business analysis processes, reduce manual work and support decisions making.

Results of research of processes and activities in the analyzed company, operating in the packaging industry indicate that a company has already embedded circular business model, to neutralize the negative impact on the environment, reduce energy consumption from non-renewable sources and achieve savings in the

production process. In the last few years, the company has significantly improved its production process, enabling products and materials at the end-of-life to be used again in production through modular design. In production are used recyclable materials, technological processes are based on clean technologies, zero waste concept is implemented.
The company publishes the results of their corporate social responsibility (CSR) and commitment through a sustainability report aligned with the Global Reporting Initiative (GRI) methodology. The implementation of the CE concept is expected to lead in the long-run to improved financial performances, optimization of the production process, increased effectiveness and efficiency, with the positive impact on the local community and employees, which is always company's main motive and driving force. The company discloses annual GHG reports since 2022, and the company prepares for reporting according to the SBTi reporting methodology.

5. CONCLUSIONS

The analyzed company cooperates with key stakeholders - clients, suppliers and local community in order to overcome the challenges of modern business, related to sustainability. The company actively working on reducing the negative impact on the environment and invests in local community. Company's products (packaging) are responsible and sustainable throughout the entire life cycle. Company creates partnerships with its suppliers and includes them in all phases of product development, in order to response to the needs and demands of its clients. In addition, company strives to promote ethics, quality, environmental protection, employees' safety and health, responsible business and commitment to sustainability, and choose suppliers who share the same values and principles, and are ready to cooperate.
The direction of further research could be an analysis of potential to implement circular business model in other companies operating in different industries in Serbia, by testing fulfilling of specific objectives listed in the Measure defined in the CE Development Program of Republic of Serbia.

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ANALYSIS OF IMPACT OF CLIMATE-RELATED DISCLOSURE ON FINANCIAL REPORTING

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Abstract: According to the International Financial Reporting Standards (IFRS) there is no obligation of disclosure climate-related information in the financial statements, although climate-related risks considerably affect decision-making of different stakeholders. The information is considered as material if its omitting or misstating significantly influence users of financial information – investors, creditors and other stakeholders. An assessment of materiality of climate-related information should be done by combining quantitative and qualitative factors, keeping in mind industry within a business entity operates and expectations of relevant stakeholders. The aim of the paper is to give a review of the most common climate-related risks that are non-financial companies exposed to, and to list potential financial impacts of those risks, manifested in the change of revenue, costs, liabilities, cash flows, and assets value. For the application case will be used the framework "Task Force on Climate-related Financial Disclosures (TCFD)" developed by The Financial Stability Board, to enhance investment decisions more focused on climate-related issues and risks.

Key words: *climate-related risks, financial reporting, investments, stakeholders*

1. INTRODUCTION

The business environment has been changed radically in the last 10-15 years, which requires identification and managing of new risks, threats, but opportunities too, which should be implemented in the company's business model and strategy, resetting missions and basic values. Climate change as recognized as one of the top global risks, and the climate-related disclosure of companies does not provide investors and other stakeholders enough information to make investment decisions. Climate risks are financial risks and have key impact on financial decisions.

Numerous researches indicate rising interest of companies for climate changes and actions, emphasizing that increasing number of companies join different global initiatives - The World Economic Forum's First Movers Coalition or Science Based Target Initiative – SBTi, United Nations' "Race to Zero" campaign, etc. (Jastrzebska, 2023; Principale & Pizzi, 2023; Chua et al., 2022; Hain et al., 2022). The trend of non-financial reporting, with the focus on climate-related information, has been accepted by the increasing number of companies worldwide. Climate-related disclosure in the form of sustainability report, ESG (Environment, Social, Government) report, Corporate social responsibility (CSR) report, present a part of an integrated report, together with mandatory financial report.

Stakeholders, such as consumers, markets and value chain partners have expectations and demand proactive behavior of companies directed toward mitigation of climate changes, as a tradeoff in the purchase of companies' goods and services, capital investments or partnership. In addition, there are rising pressures from the regulatory global and national institutions, as well as natural environment (Galeone, 2023).

In the empirical part of the paper will be used Task Force on Climate-related Financial Disclosures (TCFD) framework or recommendations, set up in 2015 by the Financial Stability Board, and published in 2017. TCFD represents fundamental guidelines for assessing and managing climate-change-related risks. Applying TCFD recommendations contributes to protection of interests of investors and other stakeholders, through the more transparent disclosure of climate-related risks. TCFD framework enables integrated risk management. TCFD recommendations have been adopted in the UK and the EU as the standards for the disclosure of climate change-related risks, and many companies have already voluntarily adopted the TCFD recommendations as part of their sustainability reporting.

The main objective of this research is to give a review of the most common climate-related risks that are non-financial companies exposed to, and to list potential financial impacts of those risks, manifested in the change of revenue, costs, liabilities, cash flows, and assets value.
The paper is structured as follows: after introduction and literature review, research methodology has been presented. After that results of research has been discussed. The next part of the paper is conclusion, followed by the list of references.

2. LITERATURE REVIEW

Jastrzebska (2023) researched the scope of reporting climate-related information of 20 companies considered as CSR leaders in Poland, by employing a climate-related disclosures index, covering 18 indicators, recommended by TCFD. The study showed that all climate-related disclosure initiatives of researched companies are in compliance with TCFD recommendations, but the value of index indicates that companies perceived as CSR leaders in Poland do not have high awareness of climate changes. The similar conclusion is also found in the other Polish studies on climate-related reporting.
According to the research of Galeone et al. (2023) sustainability and climate change issues should be included in the business model and reporting, allowing stakeholders to participate in the actions of mitigating of limiting climate challenges.
The 2021 Ernst & Young (EY) Global Climate Risk Disclosure Barometer indicated that companies should accelerate the implementation of climate strategies and adapt their business models to climate changes and increasing climate risks. The EY researched the disclosures of more than 1,100 companies across 42 countries and found that although companies continuously improve the quality and coverage of climate risk disclosure reporting, with an average coverage of 70% of the TCFD recommendation, only 41% of the companies in the sample apply scenario analysis, and only 15% feature climate change in their financial statements. EY recommended that climate risks and opportunities should be the central part of companies' growth strategies.
Braasch and Velte (2022) investigated the quality of climate reporting by German DAX30 companies, from 2018 to 2020, related to the recommendations of TCFD, and found that companies showed poor reporting rates in the corporate governance domain, using climate reporting symbolically to present themselves in a favorable light and to gain legitimacy in society, i.e. using „greenwashing"practices through intentionally disclosing mainly positive information. Companies from less carbon-sensitive industries already have a lower carbon impact, and therefore their management might be less concerned with identifying and managing climate risk. On the other hand, carbon-sensitive firms face greater pressure from stakeholders to disclose their efforts and actions related to climate issues. This might lead to „windows dressing "climate reporting and „greenwashing"practice.
Wedari, Jubb, and Moradi-Motlagh (2021) also found that potential "greenwashers" are companies that have poor environmental indicators, and strive to change negative perceptions by stakeholders. Researchers found no evidence of greenwashing among companies that mark decrease in GHG emissions from year to year.
Andersson and Arvidsson (2022) emphasized that although most firms map and report climate-related risks, the understanding of the nature and impact of these risks, differs across firms and industries. Policymakers have to support firms in mapping, understanding and strengthening capacity to manage climate-related risks.
Principale and Pizzi (2023) analyzed the non-financial statements (NFSs) of 122 Italian companies, and found that company size, board size, and the integration of ESG risks into risk-management systems positively contribute to the compliance of NFSs with the recommendations of climate experts. The results of the study also showed that larger companies exposed to higher environmental risk are more likely to disclose climate- related information, and have resources to comply their corporate behavior and disclosures with TCFD framework. But generally, the majority of Italian companies have decided not to align corporate disclosure with the TCFD recommendations, and one of the reasons could be the complex scenario analysis.
Bingler, Senni, and Monnin (2022) found that complexity of assessing climate risks impose the heterogeneity of risk metrics of different providers, methodologies, and data underpinning these metrics. According to Hain et al. (2022) some commercial providers and large credit-rating agencies have started developing of climate risk scores to provide investors with firm-level indicators of physical climate risk, aiming to set climate risk assessment and scoring as a standard procedure, like evaluating financial performances of a company.

Research of Amel-Zadeh (2023) emphasized information asymmetry between investors and companies in terms of exposure to climate-related risks and the types of risks, which have considerable impact on investors' making decisions. The findings indicate that current disclosure practices do not support investors with adequate information about climate-related financial risks.
Pavlovic and Miler (2022) investigated non-financial reporting practices of Croatian companies and found that key weaknesses of current practice in the communication and disclosure of climate related information are: „climate change is not perceived as significant as other business risks; companies are not applying the concept of "double materiality"; they are (still) not combining qualitative and quantitative information; they are not putting this information in the context of the goals set by the Paris Agreement; and they are not prepared to develop various climate-related scenarios."
Companies should consider and disclose an emerging risk, including climate related risk, if that risk could affect amount reported in the financial statements and could have impact on the investors' decision making. Climate-related risks are derived from potential natural disasters, change in climate patterns and the related technology, market, legal and changes in government policies risks (AASB, 2019, p. 4).

Table 1: Climate related disclosure and IAS/IFRS

IAS/IFRS	Potential financial impact
IAS 1 - Presentation of Financial Statements	Companies must consider all the circumstances related to the going concern principle. If climate-related matters create material uncertainties related to events or conditions that cast significant doubt upon a company's ability to continue as a going concern, IAS 1 requires disclosure of those uncertainties. (IFRS, 2020, 2).
IAS 2 - Inventories	Inventories can become obsolete. In that case companies must reduce the value of the inventory to net realizable value. (IAS 2). Inventory impairment will increase the company's costs and decrease company's profit. In accordance with Serbian Income Tax Law that costs cannot be recognized before those inventories are sold.
IAS 16 refers to the recognition, valuation and disclosure of Property, Plant and Equipment (PP & E)	Climate-related risks can affect whether some costs relating to real estate, plant and equipment can be recognized in their purchase value. (Vicentijevic & Markovic, 2023). Also, climate change may have impact on how long items of PP&E are used. (EY, 2023, 13). Shorter useful life will have impact on amortization and depreciation costs.
IAS 37 Provisions, Contingent Liabilities and Contingent Assets	Climate -related risks can increase provisions for rehabilitation of environmental damage and onerous contracts. (Anderson, 2019). That means that companies will have lower profits. Also, some expenses might not be tax-deductible.
IFRS 9 Financial Instruments	IFRS 9 requires companies have to recognize expected credit losses in their statements. Potential impact refers especially to the banks that lend money to the different sector. Banks have to consider increase in credit risk of the borrowers. If there is increase in credit risk, bank will increase their expenses and decrease profit. On the other hand, borrowers might not be able to lend money.

3. RESEARCH METHODOLOGY

In this research were used different methods, including questionnaire fulfilled by company's management, the data presented on the websites of the analyzed company, and in the company's Sustainability report, prepared according to the standards of the Global Reporting Initiative (GRI).
The literature review analysis was done within Scopus database, including the following keywords: climate-related disclosure, financial reporting, and 46 documents were found. Firstly, the title, abstract and keywords were analyzed, and in the second phase, 31 complete papers were chosen and analyzed. The papers were selected according to the relevance of climate-related financial disclosure for decision making of investors and other stakeholders. After detailed literature review, the TCFD framework developed by The Financial Stability Board, was chosen for assessment of climate-related risks and opportunities and their impact on financial performances of a company. The TCFD conceptual framework was used for this research because of detailed overview of climate related risks and opportunities whose disclosure considerably impacts key financial indicators. To assess exposure to climate-related risks, listed in the TCFD conceptual framework, a questionnaire to be fulfilled by the company's management was prepared.
The researched company is a leading Serbian manufacturer of printed and laminated cardboard packaging and blister cards board. Company use responsibly raw materials, energy and water, striving to

reduce GHG emission. Analyzed company respects the principles of socially responsible business, management systems, the environment, safety and health of employees, forest protection, and is certified according to the requirements of ISO 9001, ISO 14001, ISO 45001, FSC™. The basis of rapidly growing business is a constant investment in development. It is the only domestic company that is indexed on the first Serbian CSR index list for all six areas of socially responsible business. That means that the company is committed to employees, the local community, and the environment. Company's CSR strategy supports the UN SDGs. Company is rated as a Supplier on Smeta Sedex platform, and on Eco Vadis ratings platform as a Platinum Supplier (among the top 1% out of 100,000 companies). Eco Vadis is platform for assessment of CSR and sustainable procurement which rates companies in all categories of CSR.

The researchers read the company's Annual Sustainable Report, and the Sustainable Development Goals (SDG) Progress Report, and discussed relevant topics with the company's Chief Business Sustainability Officer and her assistants. The questionnaire has been fulfilled by the company's Chief Business Sustainability Officer.

In the research was used a five-point Likert scale to measure and to express the attitudes of respondent about a certain phenomenon. The numbers were added to certain characteristics of the observed phenomenon, and then scaling has been carried out. The phenomena were positioned on a certain scale depending on how many characteristics the variables had, determined via a five-point Likert scale. The Chief Business Sustainability Officer had to express the degree of agreement or disagreement for each individual statement, on a five-point scale (1. "Very low", 2. "Low", 3. "Medium", 4. "High", 5. "Very high"). Each respondent's answer was scored, and calculated the average value of points for each statement.

Analyzed company has been calculating its GHG emissions for several years, and from 2020 they also prepare annual GHG emissions report according to the international GHG Protocol standard. GHG emissions report contains SCOPE 1 (direct GHG emissions from company-owned and controlled resources, released into the atmosphere as a direct result of a company's activities); SCOPE 2 (indirect GHG emissions released in the atmosphere from the consumption of purchased electricity, steam, heat and cooling), and SCOPE 3 (all indirect emissions not included in Scope 2, that occur in the value chain of the reporting company, including both upstream and downstream emissions).

4. RESULTS AND DISCUSSION

In this section, the results of this research are reported.

The TCFD conceptual framework developed by The Financial Stability Board (2017) was used for assessment of climate-related risks and opportunities and their potential impact on financial performances. The TCFD framework covers (1) risks related to the transition to a low-carbon economy, and (2) risks related to the physical impacts of climate changes. In terms of transition risks, exposure to policy and legal, technology, market, and reputation risks, were assessed. Regarding physical impacts of climate changes, exposure to acute and chronic risks were assessed. Different climate related risks have been listed in the above-mentioned categories and their potential financial impacts have been assessed, and on the base of the company's answers and data availability, risk exposure has been measured.

The Task Force divided climate-related risks into two major categories: transition risks and risks related to the physical impacts of climate change. The Task Force identified certain subcategories under each of these categories.

In TCFD framework, the main risks to be assessed are detailed in Table 2:

Risks related to the transition to a low-carbon economy

- Exposure to Policy and Legal risks with the focus on possible Increased pricing of GHG emissions; Enhanced emissions-reporting obligations; Mandates on and regulation of existing products and services; Exposure to litigation;
- Exposure to Technology risks with the assessment of possible Substitution of existing products and services with lower emissions options; Unsuccessful investment in new technologies; Costs to transition to lower emissions technology;
- Exposure to Market risks with the focus on possible Changing customer behavior; Uncertainty in market signals; Increased cost of raw materials;
- Exposure to Reputation risks with the focus on possible Shifts in consumer preferences; Stigmatization of sector; Increased stakeholder concern or negative stakeholder feedback.

Table 2: Assessment of exposure to climate-related risks

Risk type	Climate related risks	Exposure to risk	Score
Transition risks	1. Policy and Legal risks	1.1. Increased pricing of GHG emissions	2
		1.2. Enhanced emissions-reporting obligations	1
		1.3. Mandates on and regulation of existing products and services	2
		1.4. Exposure to litigation	1
		Average value	**1,50**
	2. Technology risks	2.1. Substitution of existing products and services with lower emissions options	2
		2.2. Unsuccessful investment in new technologies	3
		2.3. Costs to transition to lower emissions technology	2
		Average value	**2,33**
	3. Market risks	3.1. Changing customer behavior	3
		3.2. Uncertainty in market signals	2
		3.3. Abrupt and unexpected shifts in energy cost	3
		3.4. Change in revenue mix and sources, resulting in decreased revenues	3
		3.5. Re-pricing of assets (e.g., fossil fuel reserves, land valuations, securities valuations)	1
		Average value	**2,40**
	4. Reputation risks	4.1. Shifts in consumer preferences	1
		4.2. Stigmatization of sector	1
		4.3. Increased stakeholder concern or negative stakeholder feedback	2
		Average value	**1,33**
Physic risks	1. Acute risks	1.1. Increased severity of extreme weather events such as cyclones and floods	4
		Average value	**4,00**
	2. Chronic risks	2.1. Changes in precipitation patterns and extreme variability in weather patterns	3
		2.2. Rising mean temperatures	3
		2.3. Rising sea levels	1
		Average value	**2,33**

In terms of Transition risks, Policy and Legal risks, there is a very small chance that there will be an increase in GHG prices, especially for analyzed company, and its industry in Serbia, in the next few years; the current price is 0. Regarding Enhanced emissions-reporting obligations it has to be noted that analyzed company has been rated by *EcoVadis* sustainability rating platform as a Platinum supplier.
Regarding Technology risks, analyzed company consider costs to transition to lower emissions technology through the cost of investing in solar panels.
In terms of Market risks and Changing customer behavior, it has to be added that market conditions and competition force customers to think primarily profit-oriented, and to use packaging that is less "green". Uncertainty in market signals comes from the chain value, having in mind that the majority of analyzed company's suppliers are subsidiaries of multinational companies.
Analyzed company is a leader in the packaging industry in terms of circular business model, implementing ESG principles and CSR, and it is not expected higher exposure to the Reputation risk.
Regarding Physic acute risks, there is a flood risk in the closer area of analyzed company. In terms of Physic chronic risks extreme variability in weather patterns and rising mean temperatures could cause forest fires, which could affect supply chain, primarily suppliers of a paper.

Table 3: Assessment of potential financial impacts of climate-related risks

Risk type	Climate related risks	Potential financial impact	Score
Transition risks	1. Policy and Legal risks	1.1. Increased operating costs (e.g., higher compliance costs, increased insurance premiums)	2
		1.2. Write-offs, asset impairment, and early retirement of existing assets due to policy changes	2
		1.3. Increased costs and/or reduced demand for products and services resulting from fines and judgments	1
		Average value	1,67
	2. Technology risks	2.1. Write-offs and early retirement of existing assets	2
		2.2. Reduced demand for products and services	3
		2.3. Research and development (R&D) expenditures in new and alternative technologies	2
		2.4. Capital investments in technology development	4
		2.5. Costs to adopt/deploy new practices and processes	4
		Average value	3,00
	3. Market risks	3.1. Reduced demand for goods and services due to shift in consumer preferences	2
		3.2. Increased production costs due to changing input prices (e.g., energy, water) and output requirements (e.g., waste treatment)	3
		3.3. Increased cost of raw materials	4
		Average value	3,00
	4. Reputation risks	4.1. Reduced revenue from decreased demand for goods/services	1
		4.2. Reduced revenue from decreased production capacity (e.g., delayed planning approvals, supply chain interruptions)	1
		4.3. Reduced revenue from negative impacts on workforce management and planning (e.g., employee attraction and retention)	2
		4.4. Reduction in capital availability	1
		Average value	1,25
Physic risks	1. Acute risks	1.1. Increased severity of extreme weather events such as cyclones and floods	4
		Average value	4,00
	2. Chronic risks	2.1. Changes in precipitation patterns and extreme variability in weather patterns	3
		2.2. Rising mean temperatures	3
		2.3. Rising sea levels	1
		Average value	2,33

Assessment of financial impacts of climate-related risks indicate that in terms of Technology risk pressure by competitors who have adopted new technology, is expected, which could reduce demand for products and financial impact is assessed as “medium”; R&D expenditures in new and alternative technologies are covered by all participants in the chain value, which reduces financial impact of that risk; Need for trained and specialized employees could have significant impact on the increase of Costs to adopt/deploy new practices and processes.

Regarding Market risks Energy price increase is expected and planned, and measures are taken to reduce that impact (solar panels). But, considering global disruptions the risk of a catastrophic disruption of energy supply is greater than a few years ago. Financial impact of market risks to the Change in revenue mix and sources, resulting in decreased revenues is assessed at the medium level, having in mind that competition has attacked some of company’s production segments by using different production technology, and company adapt by deploying new product and market niches.

Financial impact of Reputation risk is not expected at the higher level, having in mind company's effort to attract and retain qualified workforce, and that company fulfills majority of the ESG requests by banks in the case of borrowing capital.
The possible financial impact of exposure to Physic acute risk is assessed as high because of possible supply chain interruptions. Significant financial impact of exposure to physic chronic risks is not expected.
Sustainability manager assessed each type of climate related risk exposure and assigned a score in the 5-point Likert scale. The average value was calculated for each group of transition risks and physic risks. Results are graphically presented in the radar chart shown in Figure 1.

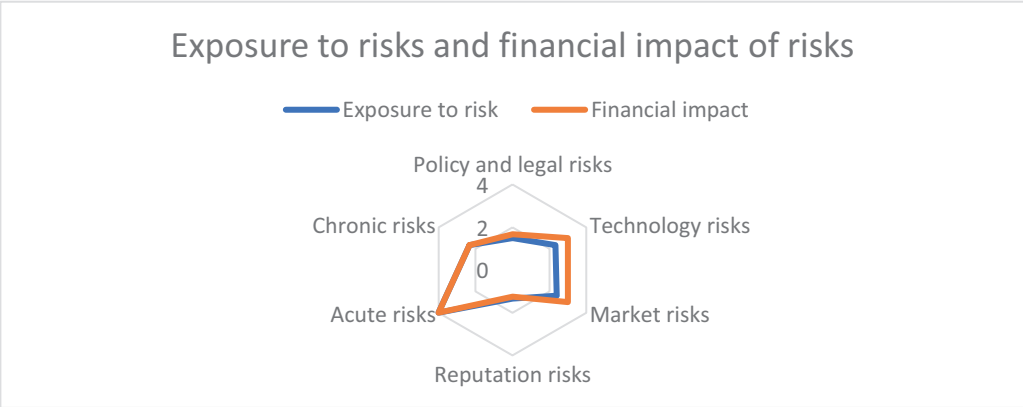

Figure 1: Exposure to risks and financial impact of risks

Data on radar chart indicate that regarding Transition risks, the exposure of analyzed company to the Technology and Market risks are between low and medium. Below that is the exposure to Policy and legal, and Reputation risk. In terms of Physic risks, company is more exposed to Acute, than to Chronic risks. Similar situation is with the financial impact of the exposure to the abovementioned risk groups. Financial impacts of Market and Technology risks are assessed at the medium level. That means that Market and Reputation risks, as well as Physic acute risk, and their financial impact, should be considered as material, and disclosed in annual reports.

5. CONCLUSIONS

Climate change is a global phenomenon and the solution for rising climate risks, and their impacts should be considered at the global level, through the integration of climate-related disclosure in the mandatory corporate reporting.
Although climate related disclosure is not mandatory for companies, they should monitor climate risks because of rising impact of those risks on the business and infrastructure, but what is more important is the way to show their CSR. Company's success and progress are considerably determined by the way how investors and other stakeholders perceive the company, having in mind their continuous pressure on the company to disclose real and objective environmental indicators, in the terms of global climate crisis. Existing and potential investors are especially interested in company's exposure to climate related risk and the managing of these risks, but that information is usually not disclosed in annual reports, although those risk have material significance for making decisions.
Research results were presented for only one company, although this company is a leader in the paper packaging industry of Serbia. The company selection could also be seen as one of the limitation factors of this research. Also, research results based on the subjective assessment of the respondent should be treated with caution. This article could be the basis for further research in the manufacturing industry of a developing country.

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STRATEGIC DEVELOPMENT OF HIGHER EDUCATION ACCORDING TO THE NEEDS OF EMPLOYERS - DUAL HIGHER EDUCATION IN MONTENEGRO AS A RESPONSE TO THE CHALLENGES OF MODERN EDUCATION

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Abstract: *The modern business environment, which is characterized by global competition and rapid changes, requires continuous adaptation from the company. At the same time, this imposes on the employees the need for continuous improvement and acquisition of new knowledge and skills, which enable them to have the necessary flexibility in the workplace and to successfully overcome new work challenges that arise in front of them. Within the given business framework, higher educational institutions also face the challenge of training young people for successful integration into the dynamic labor market, which requires an ever-widening spectrum of formal and informal knowledge and skills. The intensification of cooperation between employers and educational institutions, through the introduction of a dual higher education program, was recognized as an effective way of overcoming the aforementioned challenges. In this regard, the aim of this paper was to examine the degree of satisfaction of employers with the piloting of dual higher education in Montenegro. The results revealed a high level of satisfaction of employers, whose main motive for participation in the project stemmed from the possibility of networking with educational institutions and the future workforce, as well as increasing the social reputation and social responsibility of the company itself. The obtained results enable a more detailed overview of the benefits, but also the challenges that need to be overcome in the future, in order to ensure the improvement of formal higher education through the development and implementation of the future strategy of dual higher education.*

Key words: dual higher education, strategy, students, employers, Montenegro

1. INTRODUCTION

The modern market environment imposes the need for accelerated adaptation of employees' knowledge and skills to new business challenges that arise every day. In such circumstances, providing space for the professional development of personnel becomes one of the most important tasks not only of companies but also of educational institutions. The above points to the need for a higher degree of compliance of curricula and programs at higher education institutions with the real needs of the labor market (Tobolowsky & Allen, 2016; Basit et al., 2015)). However, what characterizes formal higher education is the insufficient degree of flexibility, that is, the possibility to introduce changes in the curriculum to fully follow the continuous changes in the labor market (Ayoubi et al., 2017; Annie & Hamali, 2006). One of the possible solutions to the previously mentioned problem is reflected in the introduction of dual higher education, where students, in addition to acquiring theoretical knowledge at the university, have the opportunity to gain practical knowledge through learning through work, which will significantly facilitate them the overcoming work challenges in the modern workplace environment (Basit et al., 2015). In this way, the gap between theory and practice is bridged, making graduates more prepared for the labor market through a better understanding of economic trends, and also by solving everyday problems that arise in the business environment. An important benefit of such an education program is a better connection between the economy and institutions of higher education. In other words, employers are enabled to "identify" students who, with their mentoring and the theoretical knowledge acquired at the university, will be ready to respond to the challenges and real problems of the company where he is being trained. In this way, the students not only adopt working habits but also learn how to professionally behave in an organization and communicate with colleagues, which enables them to nurture increasingly

important and popular soft skills (Succi & Canovi, 2020), in addition to further improvement of hard skills that they already possess. Besides of that, this type of education provides students with strong professional and/or practical relevance of chosen study program, lecturers with higher practical competencies and good chances on the employment market and future prospects (Hesser, 2018; Kilgore & Wagner, 2017). However, it is important to point out that dual education offers benefits not only to students but to universities and companies as well (Pogatsnik, 2018). Past experiences in many countries, including Austria, Germany, Slovenia and Serbia, have shown that universities, by implementing dual study programs, gain young, highly motivated, interested and responsible students, lower the dropout rates, strengthen their cooperation network with other organizations, acquire a broad insight into technological change within different companies and ensure access to new technologies in innovative companies (Hesser, 2018). When it comes to employers, although dual higher education requires them to invest certain amount of time and effort in the practical education of students, it results in securing highly qualified and performance-oriented recruits who tend to exhibit strong loyalty to the company, long familiarization period which enables them to better understand the competencies of the student and determine the best area of his employment, all that while intensifying the contact between universities and other educational institutions that provides them facilitated transfer of technology and knowledge (Hesser, 2018).

Precisely due to the fact that the model of dual higher education provides important benefits for all stakeholders and facilitates the solving of the problem of the mismatch between formal education and requirements of the labor market, a structural project DUALMON – "*Strengthening capacity for the implementation of dual higher education in Montenegro*", has started (Dualmon, 2020). It is a structural ERASMUS+ project of the University of Montenegro, (UOM) which is being piloted by four faculties (the Faculty of Economics, the Faculty of Electrical Engineering, the Faculty of Maritime Affairs, and the Faculty of Tourism and Hotel Management), with the main aim to introduce the dual higher education in Montenegro through its recognition into legal framework and inclusion in the existing and/or new study modules on the higher educational institutions. The implementation of this project started at the beginning of 2021. and by now the first group of students from all faculties involved had the opportunity to complete a 6-week internship in reputable companies that operate in Montenegro (Dualmon, 2022).

The experiences of all parties involved (i.e. students, faculties, and employers) in this process are of great importance for understanding the main challenges that must be solved to make dual study programs an integral part of higher education in Montenegro in the future. The experiences of other countries revealed that one of the important challenges that arise when it comes to the introduction of dual higher education stems from the companies' initial resistance to engage in this type of education, due to the significant effort that they have to invest in educating students, which is often difficult to harmonize with the ongoing working tasks and processes (Sîrbu et al., 2022; Pinnow, 2019). Bearing in mind that, within the implementation of the DUALMON project, Montenegrin employers were included in the dual higher education program for the first time, this paper aims to investigate the degree of their satisfaction with the piloting of the project. In other words, the main research question that the authors aim to answer is: *How satisfied are employers with the way in which the dual higher education project - DUALMON was piloted in Montenegro*? Answering this question is of great importance because employers' experience and readiness to engage in a similar process in the future enable foreseeing the main opportunities and challenges of the implementation of dual higher education in this country. In this way, the paper will provide not only a theoretical contribution, in the form of supplementing the existing literature on this topic but also a practical contribution by giving insight into the perception of employers and their readiness for further participation in the process of dual education of students, which is of great importance for creators of future education policies in Montenegro.

2. MATERIALS AND METHODOLOGY OF THE RESEARCH

Based on the aim of the paper, for the purposes of data collection, an empirical survey was conducted in June 2023, on a sample of 22 respondents. The survey was conducted using a questionnaire, which was distributed online to all employers, i.e. mentors who were in charge of practical training of students during the internship at the employer. The questionnaire consisted of questions of open and closed types, as well as questions based on the Likert scale for measuring attitudes. The first set of questions was aimed at researching the basic motives, expectations, and barriers that employers faced when making a decision on engagement in a dual higher education program. The second part of the questionnaire was aimed at evaluating the satisfaction of employers with established cooperation with

students during the internship itself, while the third set of questions was related to the satisfaction with the communication that employers had with the faculties, as the main initiators of the project. The researchers primarily employed a qualitative research approach to handle the data collected from the aforementioned sample, as the main focus of this research was to assess the perception and attitudes of the employers. The acquired data underwent analysis using descriptive statistics. During the data analysis process, the authors adopted an abductive research approach. They examined the attitudes of individual mentors from companies using an inductive method and subsequently drew general conclusions about their perception and level of satisfaction utilizing a deductive approach. The outcomes of this analysis are presented in the subsequent section of the paper.

3. RESULTS OF THE RESEARCH

Data analysis resulted in encouraging results regarding employers' satisfaction with participation in the dual higher education project - DUALMON. Namely, almost all respondents are satisfied with the way in which the DUALMON project was piloted (ratings 4 and 5), while only 1 respondent rated his satisfaction with the method of piloting the project with a grade of 3. Among the most important motives for participating in the project was the possibility of networking with educational institutions and the future workforce, as well as increasing the social reputation and social responsibility of the company itself, which is presented in Figure 1.

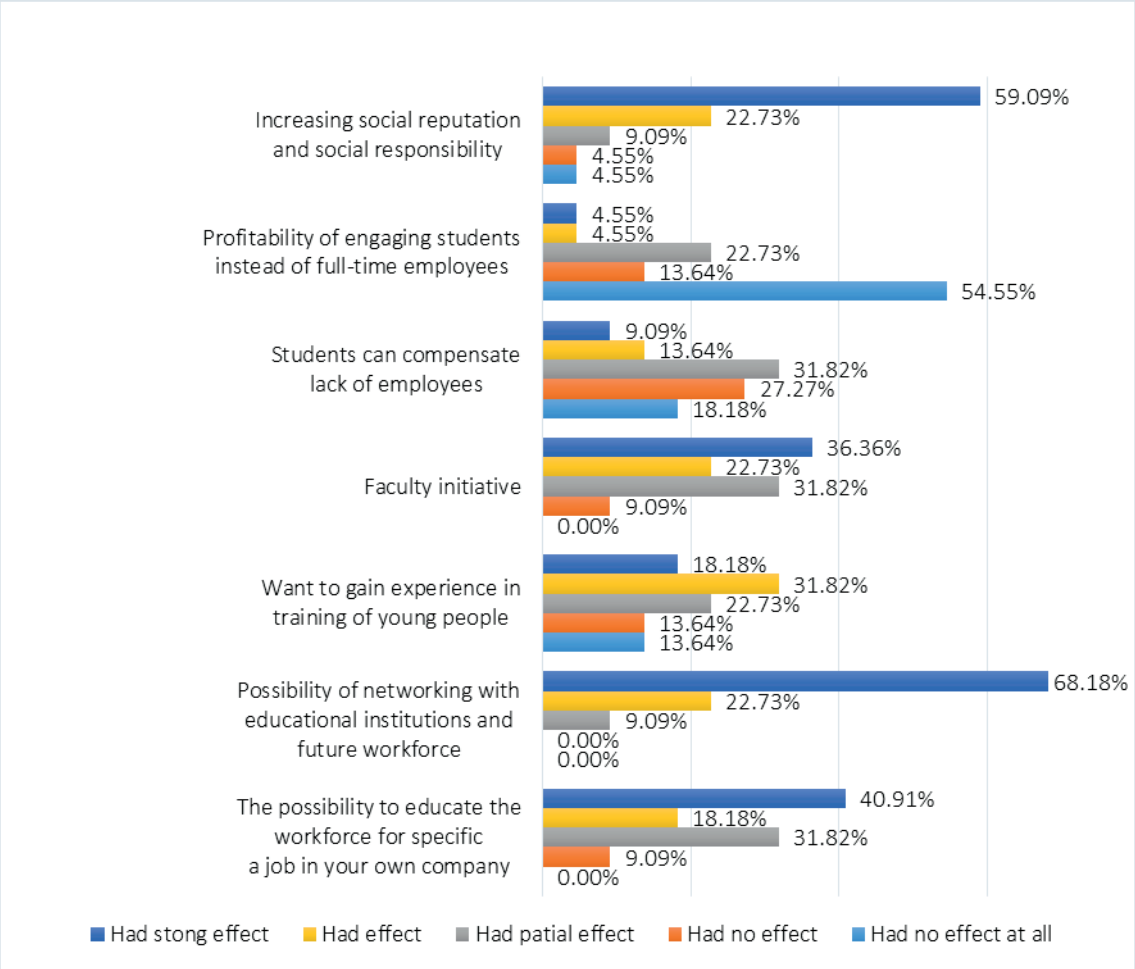

Figure 1: Reasons that influenced employers to participate in the DUALMON project (source: own processing)

As given in the Figure 1, most of the respondents (59.09%) also recognize dual model of studies as an opportunity to participate in the education of future workforce for specific jobs in their companies, which can long-term contribute to solving problems that they face in the process of recruiting. However, employers have a divided opinion regarding the issue of whether dual students can significantly

contribute to the realization of working tasks in the company during the internship. While almost a third of them (23.73%) think that students cannot compensate lack of employees, the opposite opinion 45.45% of respondents, so this can be considered an important motive for joining the project. Still, the majority of respondents (68.19%) believe that it is not profitable to hire students instead of full-time employees.
When it comes to the main barriers that prevent employers from participating in a dual higher education program, respondents believe that the most important is the lack of information about dual higher education (59.09%) and the absence of adequate legislation governing this area (54.78%). Among important ones, they also emphasize the lack of conditions and time to train students (36.37% of respondents), as well as the insufficient number of hours that the student spends in the company (31.82%). Detail overview of the importance of barriers is presented in the Figure 2.

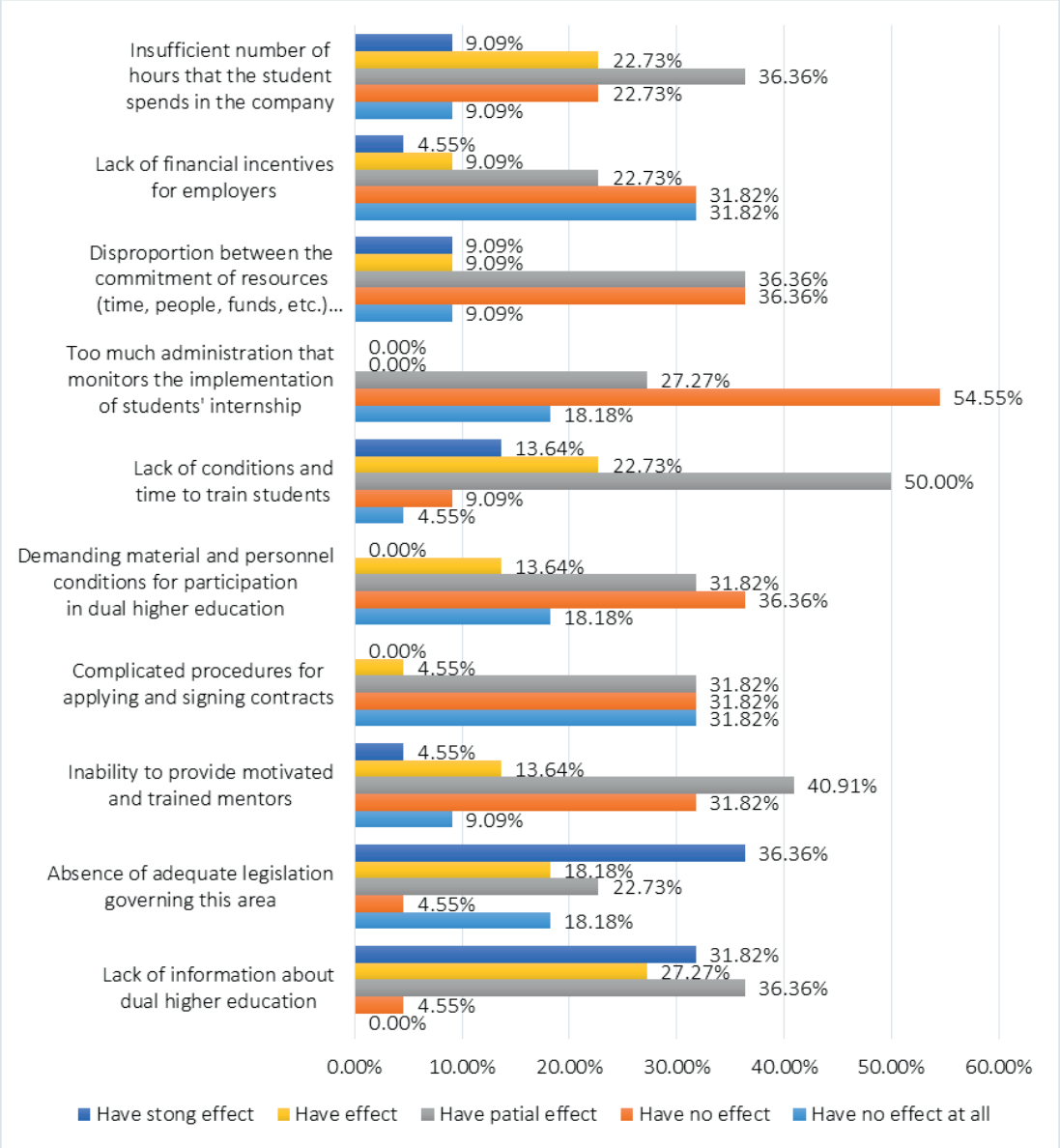

Figure 2: Barriers that prevent employers from participating in a dual higher education program (source: own processing)

However, it is important to point out that all respondents believed that the time the students spent interning in the company within the project was sufficient for the implementation of the task and the acquisition of knowledge defined by the learning outcomes. Additionally, it is encouraging that 90.9% of respondents point out that the students expressed their willingness to learn not only the tasks given in the project assignment but also what the company mentor pointed out to them as relevant. Accordingly, 50% of the respondents stated that their company expressed the willingness to hire a student who was

performing “learning by doing”, while 36.4% stated that their company was still considering this option. This is in line with the experience of other countries where the introduction of dual education significantly contributed to the youth employment rate (Maier, 2022). However, the opinion of respondents is divided regarding the question of whether students, who attended practical education in a given company, acquired the knowledge and skills to be able to work effectively at another employer. While 36.4% of respondents agreed with this attitude, more than half of respondents (54.5%) did not have a defined opinion. When it comes to the quality of established communication between educational institutions and companies, the respondents' satisfaction is at a high level. 86.3% of the respondents are satisfied with the quality of communication with the academic mentor during the internship (grades 4 and 5), but 72.7% indicated the problem that the learning outcomes at the Faculty are not in accordance with the real business tasks performed by companies. This clearly highlights a need to establish more intensive cooperation between educational institutions and the economy, not only during the implementation of study programs but also in terms of the creation of curricula that will be included in given study programs, in order to successfully respond to the challenges imposed by a dynamic business environment. Another recommendations obtained from the respondents refer to the provision of financial incentives to mentors in companies so that they have the motivation to devote more time to working with students because this additional obligation is difficult to harmonize with their daily working tasks. Besides of that, they believe that the internship period should last longer, so that the mentors in the companies would be relieved of the time of working with the students on a daily basis, and the students would have more time to master more complex working tasks that they could later perform independently. The common opinion of the majority of respondents is that in the coming period, it is necessary to work on the promotion of dual higher education programs, so that a greater number of employers, i.e. the companies become aware of all the benefits that such programs would provide them in the long term. Taking into account that employers stated their contentment with various aspects of the implementation of the DUALMON project, including the quality of communication with educational institutions, cooperation with academic mentors in the process of defining student project tasks, and the overall commitment of the dual students, it can be concluded that employers expressed a high level of satisfaction the way in which the DUALMON project was piloted in Montenegro, which is the answer to the research question posed by the authors in this paper.

4. CONCLUDING REMARKS

The previously presented results of the survey of employers' satisfaction with participation in the pilot project of dual higher education - DUALMON provide several important implications. Namely, the obtained results indicated the relevance of implementing dual higher education in Montenegro in the future, viewed from the perspective of employers. Additionally, the obtained results clearly indicate the areas that require improvement, i.e. modification, in order to improve the quality and effectiveness of the management of higher dual education programs in the future, with the final aim to align the theoretical knowledge that students acquire during formal studies with the real needs and requirements of the business environment. Besides that, the obtained research results can serve as guidelines to decision-makers in the higher education sector, with the suggestion that special effort should be made in establishing stronger cooperation with the economy in designing syllabuses and courses studied at various programs. This would ensure the necessary synergy and cooperation among all key stakeholders (educational institutions, employers, and students) and eliminate the perceived gap between the formal education system and the requirements of the dynamic labor market.

However, it is important to point out that the aforementioned research does not include the perception and satisfaction of students and academic mentors from the faculty, as equally important factors in the dual higher education program, which represents a limitation of the work, but also suggests the direction in which future research in this area should be directed. Additionally, further analyses can be aimed at comparing the perception of employers from other countries that have already successfully implemented dual higher education programs (such as Serbia, Slovenia, Austria, etc.) with the aim of better understanding the barriers that need to be overcome in order to achieve long-term sustainability of dual higher education program in Montenegro.

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PRODUCTION PLANNING AND "DEFINE, MEASURE AND ANALYSIS" TOOLS IN AUTOMOTIVE INDUSTRY AS PREREQUISITE OF AUTOMATION: A CASE STUDY

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Abstract: *For the production planning process to be successful, an enterprise's internal business processes must be effective and efficient, while the DMAIC cycle is important aspect of practice-based continuous improvement. In accordance to those facts, this preliminary research includes the first part of the DMAIC methodology - "define" and "measure" tools, applied to a case study in automotive industry, with the aim of improving production planning processes. Analysis in "define" phase starts with SIPOC, continues with calculation of critical indicators in "measure" phase and is followed by Pareto charts. Research shows that the existing method of manual collection of production data is not precise enough, and during two months observation period, between 14 and 52 percent of planned production time on 9 observed machines, passed as unnoticed downtime. Further data analysis showed that this time is 1.5 to 9 times higher than the total reported downtime on individual machines. Results show that the further development of data collection tools is crucial, and the recommendation is to move in the direction of automation of that process in order to make the most of available technical resources, in "improve" phase and to "control" it by statistical comparison of previous and new state indicators.*

Key words: *DMAIC, Automotive industry, Production data, Process automation*

1. INTRODUCTION

Produc on planning in modern systems is very sensiti e to changes of di erent factors, and a good answer to these problems can be found in adequate decision support systems (Graves, 2011). As a required base for support systems, data and informa on can be considered the primary assets of a fi m, and most organiza ons strive to collect and process as much data as possible (Bendoly, 2016; Demirkan et al., 2013). In order to increase the quality of the collected data as a result of increased business performance, it is necessary to have a desire for constant process improvement (Spasojević et al., 2020). When beĀer quality of data about productio elements and processes is available, it should be used to improve the system performance, by a constant cycle of improvement (Lee, 2018). In di erent branches of industry and di erent countries, processes improvement can be done using a variety of methods (Brkić et al.; Tomic et al., 2017), but the DMAIC (DeĀne Measure Analyse Improve and Control) method that drives Lean Six Sigma approach proved to be a good universal tool for ensuring the smooth movement in the cycle (Smetkowska et al., 2018). With its structure, DMAIC cycle provides a rigorous approach of results-oriented process management (Sokovic et al., 2010). As numerous case studies show, for resolving performance problems in automoti e industry, the most appropriate approach is implementati n of DMAIC cycle (Ani et al., 2016; Rifqi et al., 2021; Rozak et al., 2020), and the star ng point for all research is the evalua on of data collected from the producti n process.

This paper contains the fi st three phases of DMAIC tool, as it aims to explore the necessary elements for the company to successfully implement the automati n of its produc on. A er introductio of the topic explored which points out to the interrelati n between quality of data about productio , automati n and performance improvement, the next sec on describes the methodology used in this research. In the third part the results are presented and later on, aĀer discussion part, is concluded that the recommendati n is to move in the direc on of automati n in order to make the most of available technical resources, in "improve" phase and to "control" it by stati cal comparison of previous and new state indicators.

2. METHODOLOGY

The fi st 3 phases of the DMAIC cycle, “defi e“, “measure“ and “analyse“, were applied to a case study in medium sized company which deals with the productio of automoti e components. Out of 35 installed machines, 9 of them were selected according to their capabilities for interconnecti ity and ful lling the demands that Rubmann et al., (2015) suggest . Data collec on was performed using a manual method, in manner that aĀer removing the cause of the stoppage, the worker on machine recorded the reason for the stoppage and its durati n. Such a method was applied for a long period of ti e in this sector, and the aim of this paper is to examine the e ecti eness of this method.

3. RESULTS

The fi st step towards system improvement is comprehensive analysis of the problems that appear in standard everyday work. Figure 1 shows the SIPOC diagram of the improvement process, where input data and their suppliers, as well as output data and their users are presented. This diagram makes a good starting point for “defi e“ phase of the DMAIC methodology, as it provides a comprehensive overview of the flow of data through the process.

S	I	P	O	C
Suppliers	Inputs	Processes	Outputs	Customers
Production sector Machine workers Sector of maintenance External partners Sector of quality	Capacity plan Production plan Congestion tables Information obtained from machine workers Written reports on machine operation Report on defect products	Data collection Analysis of machine efficiency Data accuracy analysis Determining the type and frequency of downtime Identification of the cause of the stoppage Ranking of causes by priority for solving	Weekly and monthly machine performance reports Proposal of measures for process optimization Work instructions Training plan Investment justification report	Machine workers Sector of production Logistics sector Sector of maintenace Higer management

Figure 1: SIPOC diagram for process of improving production

This paper is focused to the fi st element of output secti n of SIPOC, namely monthly machine performance reports. An example of one monthly report is shown in Figure 2, on which it can be seen that 53.3% of planned machine working ti e, machine was in stoppage. The problem appears in the part where more than half of that period (28.45%) belongs to unnoted down me, about which no data is recorded.

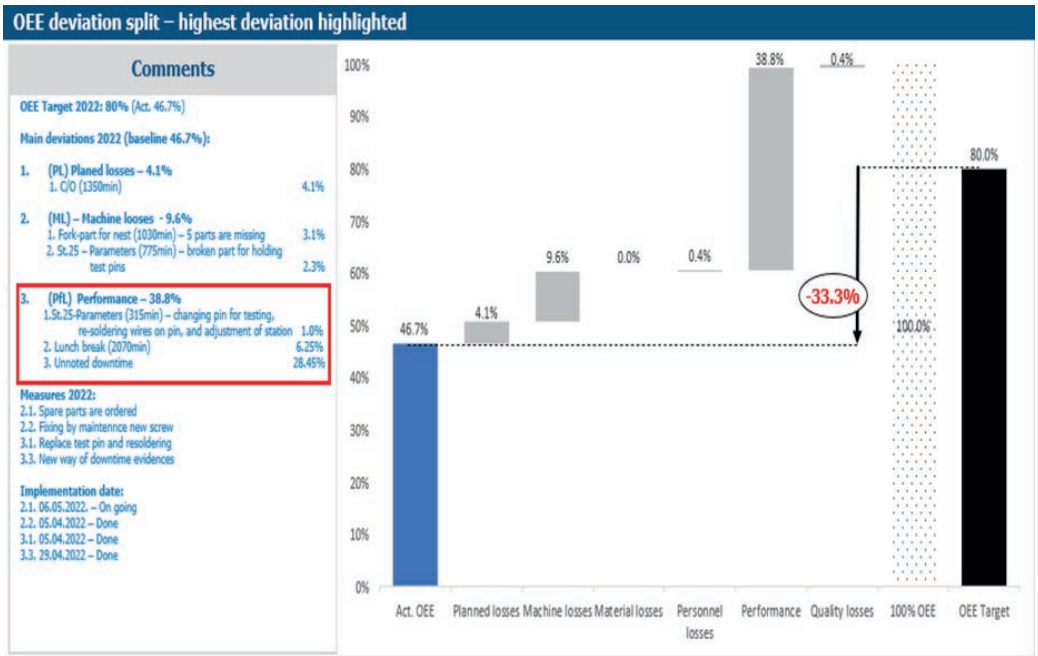

Figure 2: Monthly report for machine no. 2

In order to confi m this deviati n, the operati n of another 8 machines was monitored in 2 consecuti e months, resulting in data collectio from 9 machines in total. Obtained results for the fi st month are shown in Table 1 and for second month in Table 2. Parameters that are recorded are:

- Number of good parts (*OK*)
- Number of bad parts (*NOK*)
- Total planned productio ti e of machine (T_{pl})
- The actual working ti e of the machine (T_{pr})
- Time out of producti n (T_{pl} - T_{pr})
- Time of recorded stoppages (T_z)
- Share of unde ned Āme in planned producti n ti e (T_u).

Table 1: Recorded parameters for the first month

	OK (pc.)	*NOK* (pc.)	T_{pl} (min)	T_{pr} (min)	T_{pl} - T_{pr} (min)	T_z (min)	T_u (%)
Machine 1	423400	1472	33120	19119	14001	5465	19.5%
Machine 2	367900	3522	33120	15476	17644	5995	28.9%
Machine 3	623000	2072	33120	18752	14368	3490	26.6%
Machine 4	606700	3747	37440	25944	11496	2100	18.8%
Machine 5	197400	1369	29760	9143	20617	8125	35.7%
Machine 6	352700	1639	29760	14174	15586	2700	37.1%
Machine 7	542300	2683	32160	21799	10361	1415	21.6%
Machine 8	532980	3969	32160	21478	10682	2010	20.7%
Machine 9	568000	1407	32160	22776	9384	2140	16.3%

Table 2: Recorded parameters for the second month

	OK (pc.)	*NOK* (pc.)	T_{pl} (min)	T_{pr} (min)	T_{pl} - T_{pr} (min)	T_z (min)	T_u (%)
Machine 1	493600	2692	34560	22333	12227	2450	22.0%
Machine 2	331000	2971	34560	13915	20645	4115	41.6%
Machine 3	562200	1941	34560	16924	17636	3195	35.5%
Machine 4	543800	5667	40320	23352	16968	3280	27.7%
Machine 5	190320	1583	28800	8828	19972	3315	51.6%

Machine 6	238000	1105	19200	9564	9636	2260	32.2%
Machine 7	428600	2790	34560	17256	17304	5045	29.2%
Machine 8	581360	3978	34560	23414	11146	1145	22.7%
Machine 9	618000	1473	34560	24779	9781	2660	14.4%

The parameter of undefin d Āme in planned produc on Āme is calculated using a formula:

$$Tu = \frac{(Tpl - Tpr) - Tz}{Tpl} * 100\% \quad (1)$$

The represented collected data shown above mark the end of the "measure" phase. The data of total machine working ti e and total downti e recorded per month are presented on Figure 3.

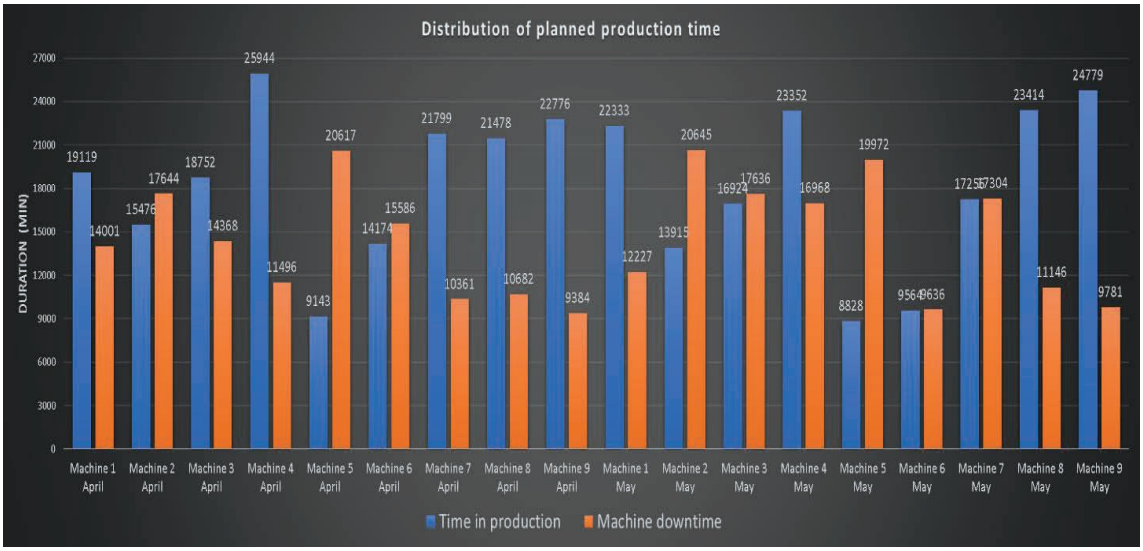

Figure 3: Distribution of planned production time

In order to have beĀer understanding of collected data, the recorded downti es are grouped by the statio on the machine where they occurred and presented by Pareto diagrams. The example of Pareto diagram for downti es that occurred during the fi st month on machine no. 7 is shown in Figure 4.

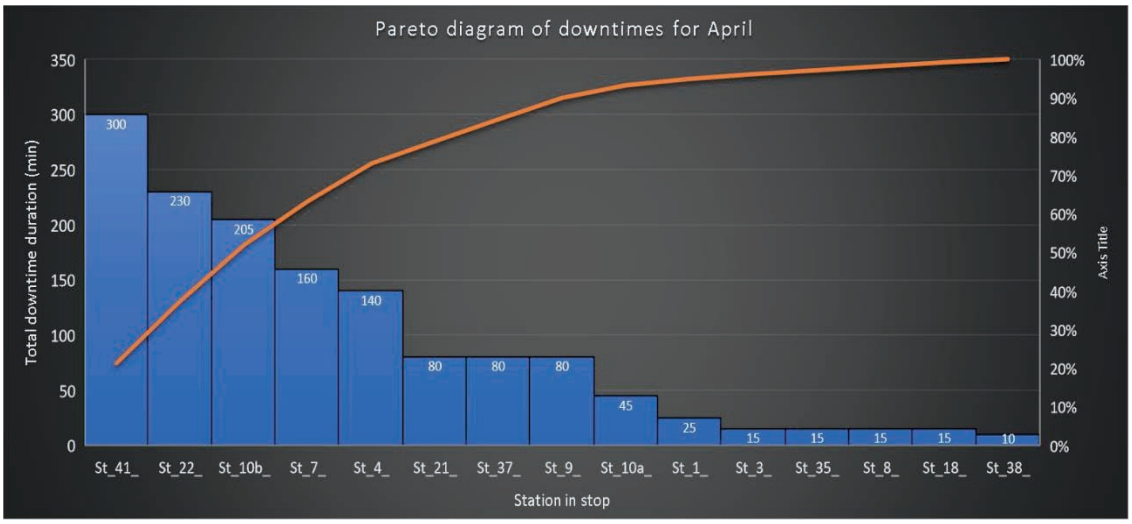

Figure 4: Pareto diagram of downtimes on machine no. 7

The ra o between recorded downti es and unidentifie downti es in both observed months are shown in Figure 5.

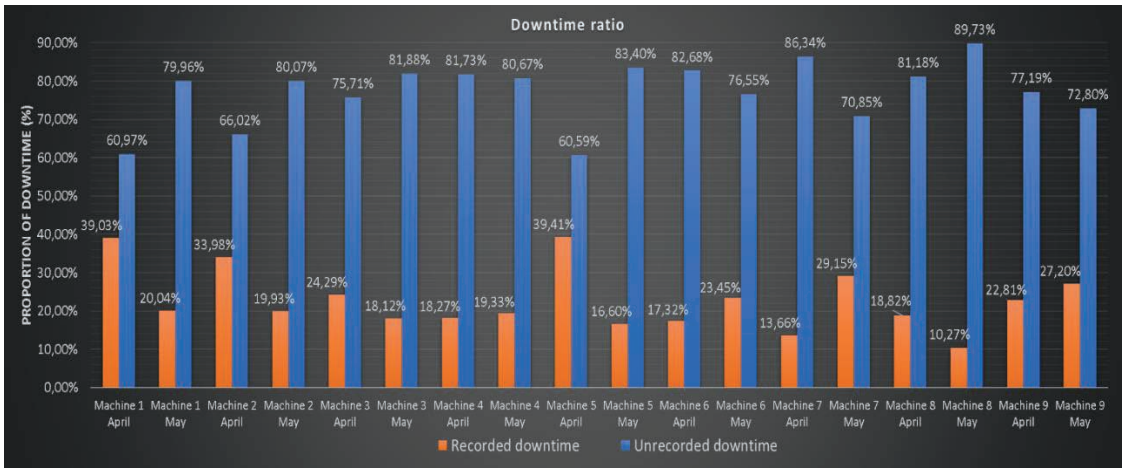

Figure 5: Downtime ratio

4. DISCUSSION

In order to successfully apply the DMAIC cycle, the fi st and the most demanding step is to define the problem of interest that requires solving. It is done by comprehensively looking at the di erent parts of the process, its inputs and outputs as well as the suppliers of inputs to the process and users of outputs from process. In this case, according to the process output, monthly reports, it can be seen that data collectio , analysis of machine e ciencies, data accuracy analysis, determining type and frequency of downti e and identi catio of the cause of downti e, have problems with data reliability. The measurement phase that was conducted over the period of two months, confi med that with manual reporting and recording of downti e, between 14 and 51 percent of planned produc on ti e is spent in machine downti e, which is not recorded (Table 1 and Table 2). The whole problem can be beĀer seen when data is displayed on diagram. For example, on Figure 3 it can be seen that during observed period some machines had more downti e than work ti e, and because decisions for improving elements of productio process are made according to Pareto charts, it is of crucial importance, that all causes and durati ns of downti e are available in the decision-making process. The potentia and benefit of the improvement can be seen in Figure 5, which shows that only 10 to 40 percent of total machine downti e is reliably recorded.

5. CONCLUSION

Previous researches that included the applica on of DMAIC cycle for process improvement has shown signi cant increase in business performance, pointi g out importance of reliable collected data for good quality management (Godina et al., 2021; Karout et al., 2017; Kaushik et al., 2009).

A er analysis and presentati n of the collected data, which as pointed out in the discussion part of this paper, unequivocally confi m the existence of the deviati n in process data, further research was conducted with the company's senior management, and the conclusion was drawn that due to size of the producti n system and the number of visible problems, there are not enough resources left to carry out a detailed research on data quality, so decisions are made on the basis of available data.

In that aim, the main purpose of this paper is fulfil ed. It confi med the necessity of improving data collectio tools and iden fy the weak points of the current collecti n process and with eliminati n of manual downtime recording and the introduc on of a more automated system, plant producti ity can be dras cally increased. This solutio can be designed through the remaining stages of "improvement" and "control" of the DMAIC cycle, which would be recommended for further research.

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E-LEARNING COVID AND POST-COVID RESEARCH TRENDS: A BIBLIOMETRIC ANALYSIS APPROACH

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Abstract: *E-learning has reached its peak during the Covid-19 pandemic, when educational institutions started to implement online education and e-learning as a way of doing business. As a result of this implementation, teaching staff and students had to learn how to use different tactics, and digital tools for collaboration, so the effectiveness of lectures and courses improves or, at least, stays the same. Although the Covid-19 pandemic has ended, people continued to use digital solutions in education and learning, because of the benefits they have experienced. Accordingly, this paper has an aim to investigate Covid and Post-Covid research trends in the field of e-learning. The main results show the most productive authors, the most productive relevant journals, the main keywords, and the most productive countries in this field.*

Key words: e-learning, higher education, Covid-19, bibliometric analysis;

1. INTRODUCTION

The Covid-19 pandemic has caused a worldwide social isolation, which caused a need for adapting everyday life activities to new circumstances (Raza et al., 2021). As a part of everyday life, education was affected, and it needed to be made accessible to all students and teachers, through different solutions powered by technology (Rizun & Strzelecki, 2020; Scherer et al., 2021). Although roots of distance learning date back to the middle of the 19th century, e-learning started to attract attention at the end of 2019 (Bezhovski & Poorani, 2016; Coman et al., 2020). E-learning is a concept which combines electronic devices, digital solutions, and mediums which facilitate the learning process with an aim to share information and knowledge with large audiences (Sangra et al., 2011; Suresh Babu & Sridevi, 2018).

Research has shown that students which had a higher level of participation in online courses realised through collaborative digital platforms achieved better grades at the end of the course (Rakic et al., 2020). Also, students have shown interest and satisfaction with some of the platforms which were used (Almusharraf & Khahro, 2020). From the teachers' perspective, high implementation costs and needed financial support are the biggest deficiencies, but the benefits of e-learning justify the costs – students can develop technological skills, which are required in the modern world, and digital solutions provide more effective ways of learning which results in better memorisation (Lapitan et al., 2021; Maatuk et al., 2022).

Even when the pandemic ended and lectures went from online platforms back to classrooms, some ways of e-learning, such as polling tools, and digital collaborative whiteboards kept their place in education as essential factors (Coman et al., 2020). As a result, numerous research groups attempted to execute and assess the impacts of e-learning during Covid-19 (Iivari et al., 2020; Lapitan et al., 2021). Additionally, prior Covid-19, researchers conducted bibliometric studies to synthesize information in the subject (Martin et al., 2020). This form of analysis, however, is not sufficiently investigated during the Covid-19. As a result, the authors chose to conduct bibliometric analysis to fill a gap in the literature and describe the new information gained via e-learning during the Covid-19. Scientific papers were used and are still being used as one of information sources. Accordingly, research questions suggested by the authors are:

RQ1: *Which authors have the biggest influence in the field of e-learning in higher education?*

RQ2: *Which articles are the most cited in the field of e-learning in higher education?*

RQ3: *Which journals have published the highest number of articles in the field of e-leaning in higher education?*

RQ4: *Which countries have the biggest article production in the field of e-learning in higher education?*

The structure of this paper shows the methodology in Section 2, research results and discussion in Section 3, and main research conclusions in Section 4.

2. METHODOLOGY

With an aim to investigate research trends in e-learning, data collection is gathered from the Scopus database, as one of the most relevant databases for scientific papers. The obtained data was converted to a suitable format and loaded in the R studio "bibliometrics" tool. All chosen articles include "e-learning" and "higher education" in the title, abstract or keywords. Additionally, only articles from years 2020, 2021, 2022, and 2023 are included, since the research is about Covid and Post-Covid research trends. All articles are published in international journals and written in English language. The data collection has 1,954 articles which are analysed using the tool for quantitative research in bibliometrics – R studio. Segments which are analysed are production by authors, the most cited article, production by journals, and production by countries. The visual presentation of data is done using the VOSviewer software.

3. RESULTS AND DISCUSSION

To answer proposed research question, this section is divided into four segments: the most influential authors, the most cited articles, the most relevant journals, and the most productive countries.

3.1 The most influential authors

In this paper, author's influence is measured by the number of published articles. Table 1 shows 10 most productive authors in the field of e-learning in higher education.

Table 1: The most influential authors in the field of e-learning in higher education

Number	Author	Number of published articles
1	Li X.	13
2	Li J.	8
3	Zhang L.	8
4	Liu J.	7
5	Wang X.	7
6	Elshaer I.	6
7	Wang L.	6
8	Yang L.	6
9	Zhang J.	6
10	Zhang X.	6

According to Table 1, the most influential author is Li X. with 13 published articles in the field of e-learning in higher education. Li J. and Zhang L. have 8 published articles each, and have taken the second and third places. Fourth and fifth places are taken by Liu J. and Wang X. with 7 published articles each. Places from sixth to tenth have 6 published articles each and are taken by Elshaer I., Wang L., Yang L., Zhang J. and Zhang X.

3.2 The most cited articles

Significance of an article is measured by the number of times it was cited. The most cited articles in the field of e-learning in higher education globally are shown in Table 2.

Table 2: The most cited articles in the field of e-learning in higher education

Number	Authors	Article title	Number of citations
1	Radianti J., Majchrzak T. A., Fromm J., Wohlgenannt I.	A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda	762
2	Iivari N., Sharma S., Venta-Olkkonen L.	Digital transformation of everyday life – How COVID-19 pandemic transformed the basic education of the young generation and why information management research should care?	394
3	Coman C., Tiru L. G., Mesesan-Schmitz L., Stanciu C., Bularca M. C.	Online Teaching and Learning in Higher Education during the Coronavirus Pandemic: Students' Perspective	375
4	Sundarasen S., Chinna K., Kamaludin K., Nurunnabi M., Baloch G. M., Khoshaim H. B., Hossain S. F. A., Sukayt A.	Psychological Impact of COVID-19 and Lockdown among University Students in Malaysia: Implications and Policy Recommendations	289
5	Al-Balas M., Al-Balas H. I., Jaber H. M., Obeidat K., Al-Balas H., Aborajooh E. A., Al-Taher R., Al-Balas B.	Distance learning in clinical medical education amid COVID-19 pandemic in Jordan: current situation, challenges, and perspectives	270
6	Waheed H., Hassan S., Aljohani N. R., Hardman J., Alelyani S., Nawaz R.	Predicting academic performance of students from VLE big data using deep learning models	191
7	Scherer R., Howard S. K., Tondeur J., Siddiq F.	Profiling teachers' readiness for online teaching and learning in higher education: Who's ready?	177
8	Martin F., Sun T., Westine C. D.	A systematic review of research on online teaching and learning from 2009 to 2018	175
9	Tang Y. M., Chen P. C., Law K. M. Y., Wu C. H. Lau Y., Guan J., He D., Ho G. T. S.	Comparative analysis of Student's live online learning readiness during the coronavirus (COVID-19) pandemic in the higher education sector	167
10	Raza S. A., Qazi W., Khan K. A., Salam J.	Social Isolation and Acceptance of the Learning Management System (LMS) in the time of COVID-19 Pandemic: An Expansion of the UTAUT Model	161

The most cited article is "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda" written by Radianti et al, and it has 762 citations. Second place is taken by "Digital transformation of everyday life – How COVID-19 pandemic transformed the basic education of the young generation and why information management research should care?" from Iivari et al, with 394 citations. Article "Online Teaching and Learning in Higher Education during the Coronavirus Pandemic: Students' Perspective" written by Coman et al is in the third place, with 375 citations. With 289 citations, in the fourth place is "Psychological Impact of COVID-19 and Lockdown among University Students in Malaysia: Implications and Policy Recommendations" written by Sundarasen et al. Next, in the fifth place is "Distance learning in clinical medical education amid COVID-19 pandemic in Jordan: current situation, challenges, and perspectives" written by Al-Balas et al, with 270 citations. In the sixth place is "Predicting academic performance of students from VLE big data using deep learning models" by Waheed et al, with 191 citations. "Profiling teachers' readiness for online teaching and learning in higher education: Who's ready?" by Scherer et al is in the seventh place, with 177 articles. Eight place is taken by "A systematic review of research on online teaching and learning from 2009 to 2018" from Martin et al, with 175 citations. "Comparative analysis of Student's live online learning readiness during the coronavirus (COVID-19) pandemic in the higher education sector" written by Tang et al is in the ninth place with 167 citations. Tenth place is taken by "Social Isolation and Acceptance of the Learning Management System (LMS) in the time of COVID-19 Pandemic: An Expansion of the UTAUT Model" written by Raza et al, with 161 citations.

3.3 The most productive journals

The most productive journals are ones which have the highest number of published articles in the field of e-learning in higher education. Ten most productive journals are shown in Table 3.

Table 3: The most productive journals in the field of e-learning in higher education

Number	Journal	Number of published articles
1	International Journal of Emerging Technologies in Learning	116
2	Computers and Education	81
3	International Journal of Environmental Research and Public Health	69
4	Sustainability (Switzerland)	59
5	British Journal of Educational Technology	36
6	International Journal of Advanced Computer Science and Applications	33
7	Education and Information Technologies	32
8	IEEE Access	30
9	Plos One	29
10	Technology, Knowledge and Learning	28

According to Table 3, the most productive journal is International Journal of Emerging Technologies in Learning with 116 published articles in the field of e-learning in higher education. In second place is Computers and Education with 81 published articles. Third place is taken by International Journal of Environmental Research and Public Health with 69 published articles. Sustainability (Switzerland) is in the fourth place, with 59 published articles in this field. Fifth place is taken by British Journal of Educational Technology with 36 published articles. Next, in the sixth place is International Journal of Advanced Computer Science and Applications with 33 published articles, followed by Education and Information Technologies with 1 published article less. Eight place is taken by IEEE Access with 30 published articles. Plos One is in the ninth place with 29 published articles, and Technology, Knowledge and Learning is in the tenth place with 28 published articles.

3.4 The most productive countries

Country's production is measured by the number of published articles. Figure 1 presents a world map which shows countries that have the highest number of published articles in the field of e-learning in higher education. Countries which are coloured in deep blue are the most productive – China, and United States of America.

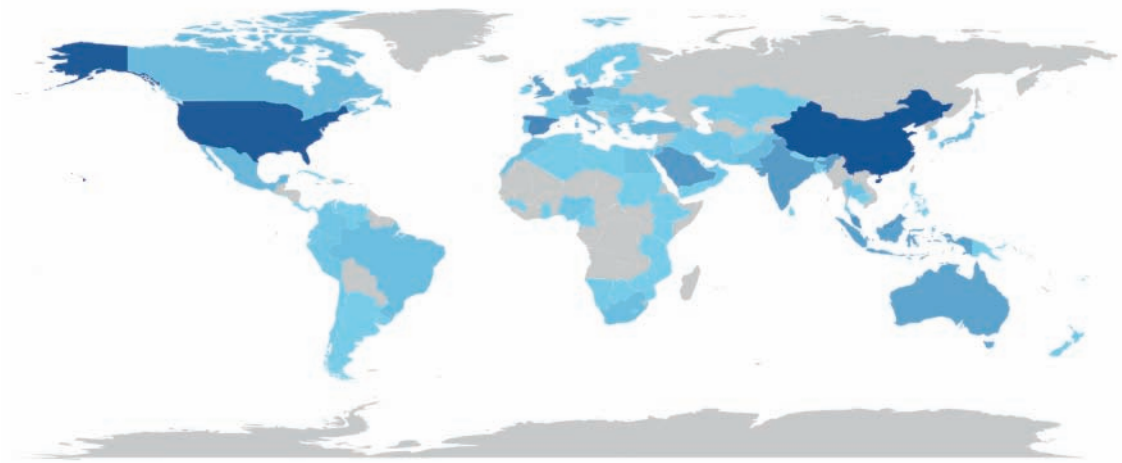

Figure 1: The most productive countries in the field of e-learning in higher education

While Figure 1 visually presents data, Table 4 shows tabular view of 10 countries which have the highest number of published articles in the field of e-learning in higher education.

Table 4: The most productive countries in the field of e-learning in higher education

Number	Country	Number of published articles
1	China	805
2	United States of America	756
3	Spain	425
4	Malaysia	336
5	Germany	316
6	Saudi Arabia	309
7	India	296
8	United Kingdom	272
9	Indonesia	258
10	Australia	237

As shown in Table 4, China took the first place with 805 published articles in this field, and is followed by United States of America with 756 published articles. Spain has 425 published articles, and is in the third place. Fourth place is taken by Malaysia with 336 published articles. With 20 published articles less comes Germany in the fifth place. Germany is followed by Saudi Arabia with 309 published articles. India took the seventh place with 296 published articles, and is followed by United Kingdom with 272 published articles. Indonesia is in the ninth place with 258 published articles, and Australia is in the tenth place with 237 published articles.

4. CONCLUSION

E-learning in higher education has rapidly drawn attention during the Covid-19 pandemic (Becker et al., 2020). The use has risen and reached its peak during the pandemic, and it has also transformed the course realisation process at Universities worldwide and affected curriculums (Iivari et al., 2020). With an aim to discover Covid and Post-Covid research trends in e-learning, this paper answered four research questions regarding the most productive authors, articles, journals, and countries in this field according to data of 1,954 articles from the Scopus database. When it comes to authors, Li X. has the highest impact with 13 published articles in the field of e-learning in higher education, which is 5 articles more than the next most influential author. The most cited article is “A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda” written by Radianti et al. This article is cited 762 times, almost two times more than the second most cited article, and gives information about different ways of implementing virtual reality into education, as well as scenarios which have shown benefits and gained success in learning based on virtual reality. The highest number of articles in the field of e-learning in higher education – 116 published articles – are published in the International Journal of Emerging Technologies in Learning, while the most productive country is China, with 805 published articles in this field of research. As a result, the key findings suggest that China and the United States, as leading global countries, have the most impact in the e-learning community. Furthermore, the top ten most productive journals are published by eight different publishing houses, demonstrating high diversity in this discipline. The most cited article is written by Norwegian, German, and Liechtenstein authors. These findings suggest that e-learning is the most researched issue among developed countries. Although this paper answers proposed research questions, its limitation is that the used data is gathered only from the Scopus database. Future research should include data from the Web of Science database. With the information from the WoS and Scopus database authors could propose future research perspectives in the field of e-learning.

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THE IMPORTANCE OF PROJECT SCALE FOR FDI LOCATION CHOICE: EVIDENCE FROM SERBIA

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Abstract: *Domestic investment by itself is not enough in today's era of globalization and accelerated economic growth, thus, it is necessary to direct capital beyond the borders of the country. Similar to that, project management must also move across borders. Management across borders require specific set of skills in order to contribute to the successful implementation of projects in the host countries. The aim of this paper is to examine the relationship between project scale and foreign direct investment in the Republic of Serbia. According to a few previous studies in this area, the project scale is expressed through capital expenditures and employment, while foreign direct investments are expressed as net inflows of foreign capital to Serbia. It was concluded that there is a significant interdependence between the project scale and foreign investments, in the terms of the sensitivity of foreign investments to the choice of investment location. In the future, it is important to pay more attention to this issue and provide a quantitative model that would include some other important macroeconomic variables.*

Key words: project scale, project management, fdi, fdi location choice, pearson correlation

1. INTRODUCTION

Foreign Direct Investments (FDI) are considered to be the most acceptable form of engaging private foreign savings in the process of financing economic growth. On the other hand, Project Scale (PS) is proportional to the size and experience of the company that is the project host (for example, a project worth 25 million EUR may be a simple project for one company, but a daunting project for another company).

Foreign investors do not invest the excess of their capital in the market of each country, but make a strict selection when choosing an investment location. There is still controversy in the professional literature about what exactly are the factors that attract foreign capital to the markets of the host countries. According to Belkhodja, Mohiuddin and Karuranga (Belkhodja, Mohiuddin and Karuranga, 2017), protection of intellectual rights, agglomeration economies, investments in education, and gross regional product (GRP) affect the most the location choice of FDI in China, but this choice varies depending on the origin of the FDI. The choice of locational determinants of foreign investors in this paper was made on the basis of numerous contemporary professional literature summarizing the locational determinants of foreign capital (Jain, Kothari & Kumar, 2016; Belkhodja et al., 2017; Nielsen, Asmussen & Weatherall, 2017; Feng & Wang, 2021; Warsame, 2021). Those determinants are as follows: market size; labour costs; taxation; and institutional quality.

This paper is structured as follows: the first part of the paper (section 2.) provides an overview of previous research on the relationship between PS expressed as capital expenditures and employment, and FDI location choice (above mentioned location choice determinants). The second part of the paper (section 3.) deals with data sources and methodology. The third part of the paper (section 4.) presents the results of the research. In the last, fourth part of the paper (section 5.), discussion and conclusions are given.

The aim of this paper is to analyze and discuss the relationship between PS and FDI location choice, considering the sensitivity of foreign investors to the chosen location determinants in Serbia using the Pearson correlation coefficient (r) in the twelve-year observed period.

2. PREVIOUS RESEARCH

A number of foreign researchers have addressed the issue of the relationship between PS, i.e. capital expenditures and employment and FDI location choice determinants.

Thus, Loncan (Loncan, 2021) conducted a study on a large project sample of over 15,000 FDIs directed at 25 emerging economies over a twelve-year period. The research confirmed that larger PS makes FDI

location selection more sensitive to larger market size and cheaper workforce, and less sensitive to higher corporate taxes and lower institutional quality. Owusu-Nantwi (Owusu-Nantwi, 2019) analyzed the influence of institutional quality on FDI flows, on the example of South America. This study revealed a strong and statistically significant relationship between the observed variables, i.e. improvements in institutional quality lead to FDI flow increase, and that foreign investors will always prefer to choose host countries with a stronger quality of institutions. Shen and Puig (Shen & Puig, 2018) in one of their studies were engaged in analysis of two essential foreign investor decisions – the entry mode and location choices. It has been proven the host-country entry strategies of foreign investors consider conditions that vary among countries and within the host country, as well as that the above mentioned essential investor decisions can be considered as alternative strategies for overcoming barriers to entry, where a trade-off between both is required.

3. DATA AND METHODOLOGY

This paper first analyzes the relationship between PS and FDI net inflows of Serbia in the period 2010. – 2021. All necessary data were taken from the official website of Statistical Office of the Republic of Serbia, World Bank – World Development and World Governance Indicators, and Tax Foundation. The linear relationship between selected variables (PS expresses as Capital Expenditures and Employment) and FDI net inflows was examined, and Pearson's bivariate correlation was used for this purpose.

Capital Expenditures (CapEx), in short, are investments in fixed assets. Fixed assets (land, buildings, machines, equipment, etc.) are part of the balance sheet and are recorded on its left side, which is called assets. Two expressions are important here: a) OpEx (Operating Expenditures), and b) CapEx (Capital Expenditures). In this paper, the focus is on CapEx. In order for an expenditure to be considered as CapEx, it must meet the following conditions: 1) to last longer than one year; 2) that it has a value greater than some reasonable amount (around EUR 400 in Serbia); and 3) that there is future economic benefit. Data were taken from the official website of Statistical Office of the Republic of Serbia, as expenditures for investments in fixed assets by financing sources and activities, total, in million RSD.

Employment (Emp), according to the International Labour Office (ILO), is defined as the total number of persons aged 15 and over in a country, who perform at least one hour of paid work in a given week, or who are absent from work for various reasons (sickness, maternity, etc.) and for certain period of time. Data were collected from the official website of Statistical Office of the Republic of Serbia, in total, as a number of active working population.

FDI net inflows (FDI), according to the United Nations (UN) definition, represent the value of inward direct investments made by non-resident investors in the observed country, including reinvested earnings and the company's internal loans, net of repatriation of capital and repayment of loans. Data were collected from official website of World Bank – World Development Indicators, expressed as percentage of Gross Domestic Product (GDP).

In the next step, location determinants were introduced into the analysis, as factors of the greatest influence on the location choice made by a foreign investor, considering PS. Four significant location determinants were singled out: 1) market size; 2) labour costs; 3) taxation; and 4) institutional quality.

Market size (MS), also known as market volume, can be defined as total number of customers multiplied by purchases expected in a given period of time. It is also calculated as total trade divided by GDP. Data were collected from official website of World Bank – World Development Indicators, expressed as percentage of GDP.

Labour costs (LC) refers to all payments in cash and kind to employees in exchange for their work, as well as government contributions to social insurance schemes (social security, pensions, etc.) that provide benefits to employees. Data were collected from official website of World Bank – World Development Indicators, expressed in billion current LCU.

Taxation (Tax) refers to corporate tax rate. Data were collected from official website of Tax Foundation, expressed as percentage.

Institutional quality (IQ) is a measure of the quality of government as well as the quality of institutions in a country. It consists of six important elements: Control of Corruption (percentile rank); Political Stability and Absence of Violence/Terrorism (percentile rank); Regulatory Quality (percentile rank); Rule of Law (percentile rank); and Voice and Accountability (percentile rank). Data were collected from official website of World Bank – World Governance Indicators, expressed as percentage.

In both steps, IBM SPSS Statistics software package was used to calculate Pearson's r.

4. RESULTS

Before calculating the Pearson correlation coefficient (r), the ratio of the analyzed variables (CapEx, Emp and FDI) is represented by the scattering matrix (Figure 1).

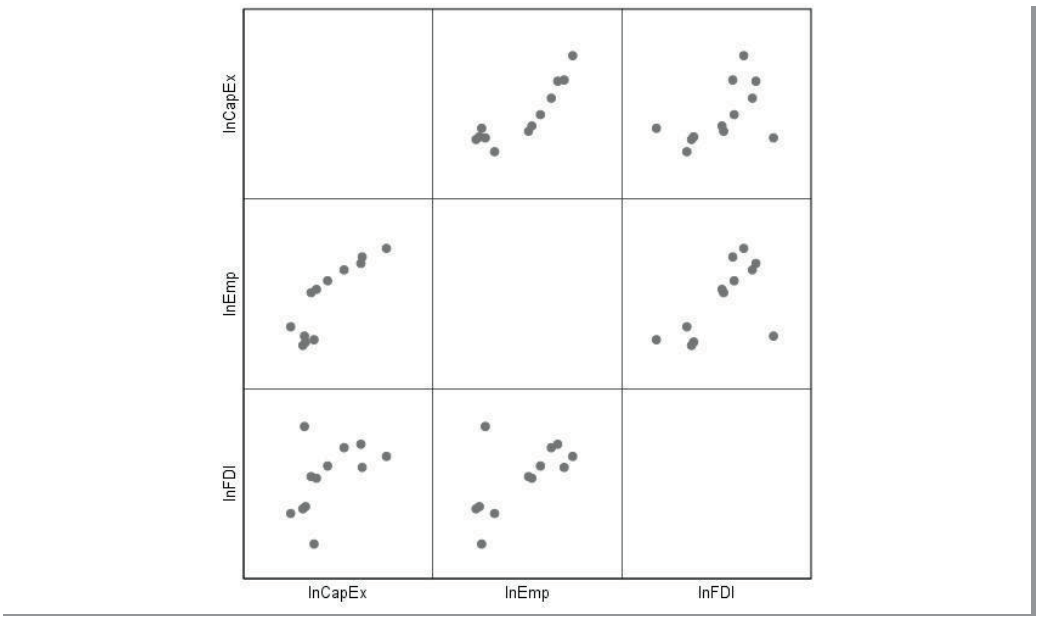

Figure 1: Relationships between the observed variables (CapEx, Emp and FDI). Source: SPSS analysis output, author's interpretation.

Figure 1 shows the potential bivariate relationships between the analyzed variables. It can be concluded that there are probably two positive linear correlations (CapEx – Emp, and Emp – FDI) of the observed variables. There is another positive correlation between CapEx and FDI, however, it is not linear, ie. statistically significant. The following Figure 2 represents the ratio of the analyzed variables (CapEx, FDI, MS, LC, Tax, and IQ).

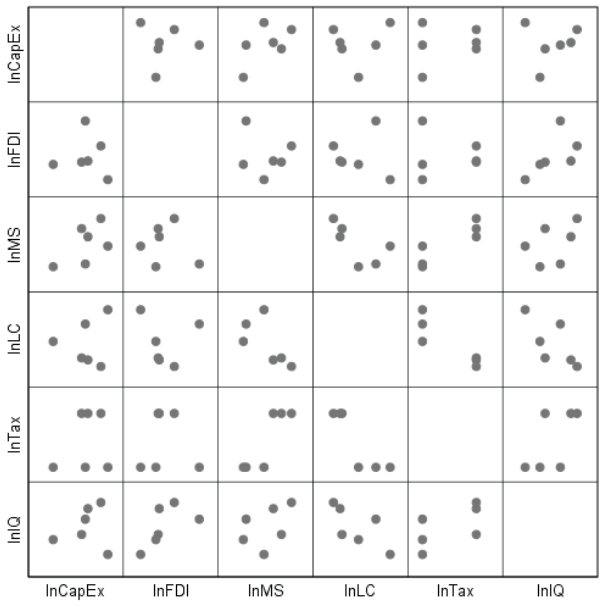

Figure 2: Relationships between the observed variables (CapEx, FDI, MS, LC, Tax, and IQ). Source: SPSS analysis output, author's interpretation.

It can be concluded that there are probably three positive, statistically significant linear correlations (CapEx – MS, CapEx – LC, and MS – Tax) of the observed variables.

The next step is to calculate the Pearson's r. The following tables, Table 1 and Table 2, give the output result of the performed SPSS data analysis.

Table 1: Correlation between selected variables (CapEx, Emp and FDI) in Serbia, in the period 2010. – 2021.

		lnCapEx	lnEmp	lnFDI
lnCapEx	Pearson correlation (r)	1	0.876**	0.509
	Significance (p)		0.000	0.091
	Number of years (N)	12	12	12
lnEmp	Pearson correlation (r)	0.876**	1	0.603*
	Significance (p)	0.000		0.038
	Number of years (N)	12	12	12
lnFDI	Pearson correlation (r)	0.509	0.603*	1
	Significance (p)	0.091	0.038	
	Number of years (N)	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: SPSS analysis output, author's interpretation.

Based on the obtained results for the observed period (2010. – 2021.), it can be concluded that there is a positive correlation between CapEx and Emp, due to the positive value of the correlation coefficient ($r = 0.876$). As $0.88 \leq 0.89$, this is a strong correlation. As $p < 0.01$, there is a statistically significant relationship between the observed variables.
There is a positive correlation between Emp and FDI, due to the positive value of the correlation coefficient ($r = 0.603$). As $0.60 \leq 0.69$ this is a moderate correlation. As $p < 0.05$ there is a statistically significant relationship between the observed variables.
Due to the positive value of the correlation coefficient ($r = 0.509$), there is another positive correlation between CapEx and FDI, but this moderate correlation is not statistically insignificant since $p > 0.05$.

Table 2: Correlation between selected variables (CapEx, Emp and FDI) in Serbia, in the period 2010. – 2021.

		lnCapEx	lnFDI	lnMS	lnLC	lnTax	lnIQ
lnCapEx	Pearson correlation (r)	1	0.509	0.830**	0.695*	0.492	0.129
	Significance (p)		0.91	0.001	0.012	0.104	0.808
	Number of years (N)	12	12	12	12	12	6
lnFDI	Pearson correlation (r)	0.509	1	0.460	0.203	0.294	0.616
	Significance (p)	0.91		0.132	0.527	0.353	0.193
	Number of years (N)	12	12	12	12	12	6
lnMS	Pearson correlation (r)	0.830**	0.460	1	0.203	0.819**	0.434
	Significance (p)	0.001	0.132		0.527	0.001	0.390
	Number of years (N)	12	12	12	12	12	6
lnLC	Pearson correlation (r)	0.695*	0.203	0.203	1	-0.226	-0.699
	Significance (p)	0.012	0.527	0.527		0.481	0.122
	Number of years (N)	12	12	12	12	12	6
lnTax	Pearson correlation (r)	0.492	0.294	0.819**	-0.226	1	0.623
	Significance (p)	0.104	0.353	0.001	0.481		0.186
	Number of years (N)	12	12	12	12	12	6
lnIQ	Pearson correlation (r)	0.129	0.616	0.434	-0.699	0.623	1
	Significance (p)	0.808	0.193	0.390	0.122	0.186	
	Number of years (N)	6	6	6	6	6	6

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: SPSS analysis output, author's interpretation.

It can be concluded that there is a positive correlation between CapEx and MS, due to the positive value of the correlation coefficient ($r = 0.830$). As $0.83 \leq 0.89$, this is a strong correlation. As $p < 0.01$, there is a statistically significant relationship between the observed variables. There is a positive correlation between CapEx and LC, due to the positive value of the correlation coefficient ($r = 0.695$). This is a moderate

correlation. As $p < 0.05$ there is a statistically significant relationship between the observed variables. There is a positive correlation between MS and Tax,due to the positive value of the correlation coefficient ($r = 0.819$). As $0.82 \leq 0.89$, this is a strong correlation. As $p < 0.01$, there is a statistically significant relationship between the observed variables. Due to the positive value of the correlation coefficient ($r = 0.509$), there is another positive correlation between CapEx and FDI, but this moderate correlation is statistically insignificant since $p > 0.05$.

5. DISCUSSION AND CONCLUSIONS

The relationship between the price and the size of the project i.e. project scale, as well as the size and method of its performance, still seem to be incomplete and insufficiently clear (Aleksić, 2016). However, PS expressed as CapEx and Emp, and determinants of FDI location choice are very important to observe in today's conditions of business risk and uncertainty at the global level.

The main goal of this research was to examine the relationship between PS and FDI location choice, considering the sensitivity of FDIs to the chosen location determinants in Serbia. For that purpose, Pearson bivariate correlation (Pearson's r) was applied.

In step one, two positive, strong and statistically significant correlations were detected. The first one is correlation between CapExp and Emp - higher PS means higher employment, and vice versa (when the workload increases due to a large, complex project, the project cannot survive in the long-run without additional workers). The second one is correlation between FDI and Emp – higher FDI net inflows mean higher employment in the host-country, and vice versa (creation of new jobs, pilot projects, greenfield investments, etc.). In step two, three positive, strong and statistically significant correlations were detected. The first one is correlation between MS and CapEx – the effect of MS on FDI location choice is positively alleviated by PS. The second one is correlation between LC and CapEx – larger project scale makes FDI location choice more sensitive to lower labour costs. The third one is correlation between MS and Tax – larger MS leads to higher corporate taxes, and higher corporate taxes are not attractive to foreign investors.

Unfortunately, there is a scarce number of research on this issue in Serbia and the region, therefore the recommendation to future researchers from this area and in this field would be to pay more attention to this important issue.

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FACTORS INFLUENCING PRODUCTIVITY IN CONSTRUCTION INDUSTRY

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Abstract: *The construction industry plays a vital role in economic development, and improving productivity within this sector has been a persistent challenge. This paper presents a review of the factors influencing productivity in the construction industry. Through an extensive analysis of existing literature, this study identifies and examines key factors that have been widely recognized as influential determinants of productivity in construction projects. These factors include project management practices, labor productivity, technological advancements, supply chain management, regulatory environment, safety and health considerations, and external factors such as economic conditions and market demand. The review explores the complex relationships and interactions between these factors, highlighting their impact on overall productivity levels. Additionally, the study discusses the various measurement methods and metrics used to assess productivity in the construction industry, providing an overview of the existing frameworks and approaches. By synthesizing the findings from numerous studies, this research contributes to a deeper understanding of the multifaceted nature of productivity in construction, offering insights into the challenges and opportunities for improvement. The review also highlights the need for holistic approaches that integrate various factors and stakeholders in order to enhance productivity and achieve sustainable growth in the construction industry. The findings of this study can inform industry practitioners, policymakers, and researchers in developing effective strategies, best practices, and targeted interventions aimed at enhancing productivity and driving positive change in the construction sector.*

Key words: Construction industry, Productivity, Factors

1. INTRODUCTION

Due to its frequent discussion within the construction industry, 'Productivity' is widely acknowledged as a crucial aspect by a significant number of economists (Yi and Chan, 2014). The construction sector is characterized by a high demand for labor and relies significantly on the expertise and abilities of its workforce. The workforce represents the industry's greatest asset, contributing to at least 25% of the overall project expenses (Jang *et al.*, 2011). To enhance project performance and mitigate cost overruns and delays, it is essential to possess knowledge and comprehension of the diverse factors impacting construction labor productivity. Typically, the decline in construction productivity is attributed to multiple factors rather than a singular cause. Furthermore, the factors impacting labor productivity in construction are often interconnected, with some factors stemming from the same root cause, while others may be triggered by the occurrence of other factors (Dai *et al.*, 2009). This understanding aids in identifying the key areas requiring attention and facilitates the implementation of effective measures aimed at improving productivity and achieving timely project completion (Soekiman *et al.*, 2011). Researchers worldwide have made numerous efforts to identify the factors that influence construction productivity. Consequently, a significant number of variables impacting construction productivity have been put forward as a result of these endeavors (Hasan *et al.*, 2018). In order to enhance the economic performance of construction projects, it is crucial to identify and address the factors that impact productivity in a suitable manner. By gaining a thorough and comprehensive understanding of these factors, it becomes possible to focus research efforts and effectively direct them, thereby maximizing the potential for improving productivity.(Hasan *et al.*, 2018). Although, many researchers agree that it is a useful strategy to identify a set of global factors, this agreement usually ends on the question of dependence of productivity on a wide range of factors (Soekiman *et al.*, 2011) (Ghoddousi and Hosseini, 2012)(Jarkas and Bitar, 2012).

2. FACTORS INFLUENCING PRODUCTIVITY IN CONSTRUCTION INDUSTRY

Construction productivity can be influenced by various factors including weather conditions, site and job conditions, labor skill levels, training, and motivation. This is due to the labor-intensive nature of construction projects and their exposure to both internal and external environments (Hasan *et al.*, 2018).
Previous studies have identified 113 factors that impact construction labor, which have been categorized into 15 groups based on their characteristics. These groups are as follows: design (5 factors), execution plan (5 factors), material (8 factors), equipment (6 factors), labor (18 factors), health and safety (4 factors), supervision (6 factors), working time (6 factors), project factor (15 factors), quality (3 factors), financial (6 factors), leadership and coordination (5 factors), organization (12 factors), owner/consultant (4 factors), external factors (10 factors). These factors have been identified through previous research and play a significant role in influencing various aspects of construction labor (Oglesby CH, 1989) (Thomas and Sanders, 1991)(Thomas, 1992)(Langford *et al.*, 1995)(Makulsawatudom, Emsley and Sinthawanarong, 2004)(Ibbs, 2005)(Hanna and Sullivan, 2004) (Nepal, Park and Son, 2006) (Enshassi *et al.*, 2007)(Alinaitwe, Mwakali and Hansson, 2007)(Hanna *et al.*, 2008) (Kazaz, Manisali and Ulubeyli, 2008).
Considering their consistent importance across different studies and the diverse project environments in both developing and developed construction markets, it is justifiable to assert that the key factors that significantly hinder construction productivity, ranked in decreasing order of their criticality, are as follows: non-availability of materials, insufficient supervision, shortage of skilled labor, inadequate tools and equipment, incomplete drawings and specifications, ineffective communication, rework, inadequate site layout, unfavorable weather conditions, and change orders. (Hasan *et al.*, 2018)
(Assaf and Al-Hejji, 2006) conducted surveys that identified 56 primary factors contributing to delays in large-scale construction projects, Delay factors are assembled into nine major groups with different levels of importance to different parties.
(Jarkas and Bitar, 2012) conducted a questionnaire survey among a statistically representative sample of contractors, focusing on 45 productivity factors categorized into four primary groups: management, technological, human/labor, and external. Among the explored factors, the following ten were found to have the most significant impact on labor productivity: clarity of technical specifications, extent of variation/change orders during execution, coordination level among design disciplines, lack of labor supervision, proportion of work subcontracted, design complexity level, lack of incentive scheme, lack of construction manager's leadership, stringent inspection by the engineer, and delay in responding to requests for information.
The study carried out by (Kazaz, Manisali and Ulubeyli, 2008) using questionnaire survey, examined the impact of 37 factors on construction worker productivity in Turkey, classifying them into four main groups: organizational, economic, physical, and socio-psychological factors. Surprisingly, organizational factors were found to have the most significant effect on productivity, followed by economic, physical, and socio-psychological factors. Although economic factors have historically been highly regarded, the findings highlight the increasing recognition of organizational management's importance in developing countries. The study emphasizes the need to consider all four groups comprehensively to effectively motivate the workforce by improving motivating factors and addressing demotivating ones simultaneously.
(Alinaitwe, Mwakali and Hansson, 2007) findings revealed the ten primary factors impacting labor productivity, which are identified as follows: incompetent supervisors, insufficient worker skills, rework, inadequate tools/equipment, poor construction methods, ineffective communication, inaccurate drawings, work stoppages due to consultant rejection, political insecurity, equipment breakdown, and harsh weather conditions. Notably, despite the lack of materials being ranked highest in terms of time loss based on the average rating, it did not make it into the top ten when considering the importance index, which accounts for factors such as time, cost, and work quality.

3. DISCUSSION AND CONCLUSIONS

The construction industry is inherently labor-intensive and susceptible to various internal and external factors that can significantly influence productivity. This conclusion is supported by several studies that have explored the numerous elements impacting construction labor productivity. These factors can be broadly categorized into different groups, such as design, execution plan, material, equipment, labor, health and safety, supervision, working time, project factors, quality, financial aspects, leadership and coordination, organization, owner/consultant factors, and external influences.

From a multitude of studies conducted in both developing and developed construction markets, certain key factors consistently emerge as critical hindrances to construction productivity. These factors, ranked in decreasing order of their criticality, include non-availability of materials, insufficient supervision, shortage of skilled labor, inadequate tools and equipment, incomplete drawings and specifications, ineffective communication, rework, inadequate site layout, unfavorable weather conditions, and change orders.

Delays in large-scale construction projects have also been investigated, and various contributing factors have been identified and grouped into different categories. These delays impact different parties involved in the projects to varying degrees.

In terms of improving construction labor productivity, it is essential to recognize the significance of organizational factors. Studies have shown that organizational management plays a crucial role in motivating the workforce and enhancing productivity. Economic, physical, and socio-psychological factors also have their share of influence, but the focus on organizational management is gaining importance, especially in developing countries.

Moreover, when considering the impact of various factors on construction worker productivity, it is evident that the role of supervisors, the competence of workers, the availability of suitable tools and equipment, and effective communication are of utmost importance. Furthermore, external factors such as political insecurity and harsh weather conditions can significantly affect productivity.

One notable finding is that the lack of materials, although causing substantial time loss according to the average rating, does not rank among the top ten most critical factors when considering the importance index that accounts for time, cost, and work quality.

In conclusion, construction productivity is a complex interplay of numerous factors, both within and beyond the control of the project stakeholders. To improve productivity, it is vital to address organizational management, ensure competent supervision, provide proper training and resources to workers, and foster effective communication throughout the construction process. Understanding and managing these factors will be instrumental in enhancing labor productivity and overall project success in the construction industry. As construction practices continue to evolve, ongoing research and proactive efforts to mitigate productivity-impacting factors will be essential for the sustainable growth and development of the construction sector.

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THREE LEVERS OF EMISSION CONTROL (3-LOEC)-MODEL: AT THE CORE OF GHG EMISSION-MANAGEMENT CONTROL SYSTEMS

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Abstract: *The Corporate Sustainability Reporting Directive (CSRD) requires from European enterprises to intensively engage in reporting and monitoring their sustainability related performance. Known as "climate-first" approach, fighting climate change has become the priority in politics. To contribute to that aim, companies face new regulations with a special focus on their greenhouse gas (GHG) emission performance. For the product specific measurement of GHG emissions, references are given to the methodology proposed in the established GHG Protocol Product Standard (GHG Protocol, 2011). In this standard the product's GHG emission – subsequently called "unit carbon footprint" (uCFP) – is measured via a generic activity-based methodology. Due to its deliberately generic definition, this methodology constitutes a conceptual model that contains no operationalization which is needed for practical implementations. In this paper this gap is closed by introducing the "3-Levers of Emission Control (3-LoEC)"-model, which has the following advantages: it measures the uCFP via three levers of emission control that are related to the consumption and procurement of energy, it is connected to data contained in activity-based costing (ABC) systems, and it is a forecasting instrument so that it is at the core of activity-based GHG emission budgeting and the corresponding management control system (MCS) with respect to GHG emission.*

Key words: greenhouse gas emission, carbon footprint, activity-based costing and budgeting, 3-Levers of Emission Control-model, management control system

1. INTRODUCTION

The CSRD requires certain European companies to apply new reporting standards from the financial year 2024 onwards. The ESRS comprise a set of individual standards that cover environmental, social and governance (ESG) matters, i.e. "topical standards", as well as cross-cutting reporting requirements. Over the next years, the number of ESRS that have to be applied will be extended constantly (Baumüller & Grbenic, 2021, p. 375). So far, only consultative versions of a first set of twelve standards are available, published by the EU Commission on June 9th, 2023 (European Commission, 2023a).

Out of all topical standards, the most concrete and extensive reporting requirements address environmental matters. This is arguably due to the fact that the scientific as well as political discourse is most advanced with regard to these matters, whilst social or governance matters are more difficult to formalize and to agree upon priorities. Within those environmental matters, however, there is again one standard that stands out in prominence: ESRS E1 on "climate change". The work on this standard has received most attention over the last years, which in turn reflects an "climate-first" approach that is the consequence of political priorities in the wake of Paris 2015 (HLEG on Sustainable Finance, 2018, p. 13). With regard to reporting, the ESRS oblige companies to measure these emissions, to report on actual emissions, on targeted reductions and on monitored achievements of the reduction objectives over time.

"*With regard to climate-related information, users are […] interested in the level and scope of GHG emissions and removals attributed to the undertaking, including the extent to which the undertaking uses offsets and the source of those offsets. […] Users are also interested to know the efforts made by companies to effectively reduce absolute GHG emissions as part of their climate mitigation and adaptation strategies, including scope 1, scope 2 and, where relevant, scope 3 emissions.*" (European Commission, 2022, rec. 47) For these purposes, the CSRD sets forth that companies shall refer to the accounting methodology developed by the GHG Protocol. ESRS E1 specifies, amongst other things, that "[…] *the undertaking shall disclose whether and how it has set GHG emissions reduction targets and/or any other targets to manage material climate-related impacts, risks and opportunities, for example, renewable energy deployment, energy efficiency, climate change adaptation, and physical or transition risk mitigation.*" (European Commission, 2023b, para. 34) Also, "*by reference to GHG emission reduction targets […], an explanation of the decarbonisation levers identified, and key actions planned, including*

changes in the undertaking's product and service portfolio and its adoption of new technologies". (European Commission, 2023b, para. 16)

The referenced methodology from the GHG Protocol also encompasses a Product Life Cycle Accounting and Reporting Standard ("GHG Protocol Product Standard", GHG Protocol, 2011) for the product specific measurement of GHG emissions – subsequently called "unit carbon footprint" (uCFP). It is an activity-based measurement model. Furthermore, this activity-based uCFP, i.e. AB-uCFP measurement model is defined deliberately generically in order to allow different operationalizations for implementations. It only requires activity data to be multiplicatively connected with emission factors and global warming potential (GWP) factors. But there are many different possibilities of selecting activity data and corresponding emission and GWP factors. Furthermore, most companies have nowadays activity-based costing (ABC) systems in place. Hence, an alignment of the AB-uCFP measurement model with the ABC methodology would be beneficial for establishing a common and consistent information system for reporting, forecasting, managing and monitoring issues. The research problem addressed in this paper is the development of an adequate specification of the activity data and the emission and GWP factors for establishing an information system that integrates reporting as well as management issues for costing and carbon footprinting at the same time.

This research problem is an alignment problem as the specification of activity data and corresponding factors has to be aligned with the measurement methodology from the GHG Protocol Product Standard. Furthermore, the GHG Protocol measurement methodology constitutes a conceptual model due to its undefined operationalization specifications. Consequently, the alignment problem has to be solved by defining an adequate operationalization of the "conceptual GHG Protocol methodology" that allows its practical implementation within companies. For this purpose, an operationalized model will be designed that solves the research problem. The designed model – called "3-Levers of Emission Control (3-LoEC)"-model – specifies the activity data in terms of information contained in AB-costing systems and the factors in terms of publicly available information. This separation is guided by the special focus of the 3-LoEC model upon energy which is consumed in the company's activities and which has to be procured. Due to its origin in the GHG Protocol Product standard's measurement methodology it is automatically compliant with this methodology. Finally, the desired common and consistent information system foundation is established as the 3-LoEC-model uses information from the ABC system and as it is used for an activity-based measuring and forecasting the carbon footprint of the company's production domain what is needed for reporting and what is at the core of a GHG emission-MCS.

The structure of this paper is as follows: In the next section the GHG Protocol's key requirements on GHG emission measurement are identified and summarized concerning the emissions life cycle assessment (LCA) requirement and the requirement related to the activity-based emission measurement model. Subsequently, the design for the operationalization of the conceptual measurement model will be addressed and the developed design in form of the 3-LoEC-model is presented. Afterwards, the embedding of the 3-LoEC-model within a management information system (MIS) and its application within a GHG emission-MCS are demonstrated. Finally, the paper is concluded.

2. GHG PROTOCOL REQUIREMENTS: ACTIVTY-BASED GHG EMISSION MEASUREMENT

The conceptual GHG Protocol methodology requires the GHG emission measurement of the studied product over the product's life cycle. Concerning the measurement model to be applied, two approaches are possible, i.e. the direct physical emission measurement and the indirect measurement where the emission is calculated by multiplying activity data with emission and global warming potentials (GWP) factors. Due to the reference on activity data, the indirect model is an activity-based approach. It is the standard model applied in practical GHG measurement implementations, and this paper exclusively relies on this activity-based uCFP (AB-uCFP) model.

2.1. GHG Protocol Requirement: Life Cycle Assessment (LCA) of GHG Emission

In Chapter "*07 Boundary Setting*", "*Illustrate the product's life cycle process through a process map*" (GHG Protocol, 2011, p. 33) requires that the GHG emission not only is measured over all activities in the product's life cycle, which are summarized in five main process stages, but that the product's stages also are visualized. These requirements are conceptualized in Figure 1 via the activity diagram model that is expressed in the formal activity diagram modeling language of the unified modeling language UML (http://www.omg.org/spec/UML/). Of special interest in this modeling is that it contains the information

objects (represented as rectangles) for the material and product flow next to the activities (represented as rounded rectangles) for the five stages in the product's life cycle. The stereotypes, which are indicated by the «Guillemet» brackets, specify the meaning of the used modeling elements in the activity diagram, i.e. «Activity» refer to the main process stages, «Resource» refer to the material and the studied product itself and the «GHG Emission» stereotype shows that the emissions from all stages are considered. Finally, the filled and the crossed circles are indicating the starting and the ending of the corresponding activities.

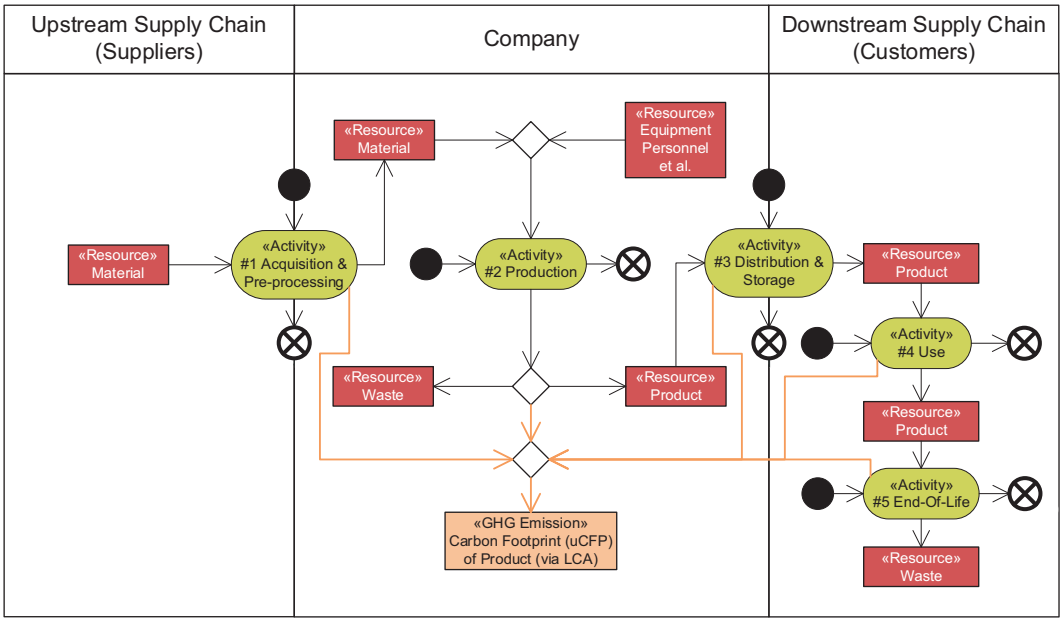

Figure 1: Assessment of GHG Emission over the Product Life Cycle (LCA) – Carbon Footprint of Product (uCFP)

2.2. GHG Protocol Requirement: Activity Based-Carbon FootPrint (AB-CFP)-Model

"*The following equations illustrate how to calculate CO_2e for an input, output, or process based on activity data, emission factors, and GWP. More information on data collection and sources of emission factors are available in chapter 8. When process or financial activity data is collected, the basic equation to calculate CO_2e for an input, output, or process is:*" (GHG Protocol, 2011, p. 88)

$$kg\ CO_2e = \underbrace{ActivityData}_{[unit]} * \underbrace{EmissionFactor}_{[kgGHG/unit]} * \underbrace{GWP}_{[kgCO_2e/kgGHG]} = \underbrace{uCFP_{act,fG}}_{[kgCO_2e]} \quad (1)$$

where

$uCFP_{act,fG}$	… unit Carbon Footprint, i.e. CFP per unit of product (*fG*) w.r.t. activity (*act*)
GWP	… Global Warming Potentials relative to CO_2
[*UOM*]	… Unit Of Measurement

"*Activity data are the quantitative measure of a level of activity that results in GHG emissions. Activity data can be measured, modeled, or calculated. There are two categories of activity data: process activity data and financial activity data. Process activity data are physical measures of a process that results in GHG emissions or removals. These data capture the physical inputs, outputs, and other metrics of the product's life cycle. Process activity data, when combined with a process emission factor, result in the calculation of GHG emissions. Examples of process activity data include: Energy (e.g., Joules of energy consumed) […] Financial activity data are monetary measures of a process that results in GHG emissions. Financial activity data, when combined with a financial emission factor (e.g., environmentally extended input-output [EEIO] emission factor), result in the calculation of GHG emissions.*" (GHG Protocol, 2011, p. 51).

The description of the conceptual AB-uCFP model in formula (1) clearly shows its generic structure as it does not provide a specific operationalization neither of the activity data nor of the emission factors. It

only says that the activity data is quantified in units, where the unit of measurement [UOM] is not provided and accordingly can be selected as needed. This modeling flexibility carries over to the type of emission factor as the type depends on the activity data's UOM and accordingly is not yet specified as well.

3. GHG EMISSION MEASUREMENT: 3-LEVERS OF CONTROL-MODEL

Subsequently, the conceptual AB-uCFP model in formula (1) is operationalized by connecting it to activity data available in ABC costing systems so that it can consistently be used for practical AB-uCFP measurements. But before proceeding to this operationalization, the conceptual model is refined for building it upon an energy-based foundation.

3.1 2-LoEC-Model: Including Energy Resource View into AB-CFP-Model

The energy-based foundation of the conceptual AB-uCFP model provides a refinement that sharpens the focus, gives a solid common understanding and keeps substantial modeling flexibility at the same time.

$$\underbrace{uCFP_{act,fG}}_{[kgCO_2e]} = \underbrace{EnergyConsumption_{act}}_{[kWh/unit]} * \underbrace{EmissionCoefficient_{act}}_{[kgCO_2e/kWh]} \quad (2)$$

where

act	… activity
fG	… finished Good

The energy-based foundation of formula (1) is shown in formula (2) where the activity data is now connected to the consumption of energy in the activity that is measured with a common kWh-UOM related to one unit of the studied product. It is also important to note that the term "unit" in formula (2) has a different meaning compared to formula (1): in (2) it relates to a single unit of the product, whereas in (1) it refers to the quantity in which the activity data is measured.
The refined conceptual uCFP model in formula (2) separates activity data from emission and GWP factors into "energy consumption" and "emission coefficient" that are connected via kWh as the common UOM for measuring energy. It is important to note that the delineation along the kWh-UOM does not restrict the focus on electric energy. Instead, it is a common and generic denominator for measuring energy in any type of activity. From a control perspective, the energy-based separation assigns the AB-uCFP measurement to two different control domains, i.e. the domain responsible for the energy consumption (e.g. production domain) and the domain responsible for the procurement of the energy. Accordingly, the refined conceptual model contains two levers of control, so that it constitutes a "2-Levers of Emission Control (2-LoEC)-model".
In the refined conceptual AB-uCFP model the term "emission coefficient" is used for expressing the special nature of the involved type of emission (GWP) factor. As its *$kgCO_2e/kWh$* UOM indicates, the emission coefficient converts the amount of consumed energy measured in kWh into CO_2e, i.e. CO_2 equivalents. Consequently, in the refined conceptual model only one special type of emission factor is needed. The emission coefficient corresponds to the procurement control domain. In the case electric energy is procured for covering the activity's energy consumption the emission coefficient corresponds to the "grid emission factor" of the supplier of the electric energy.

3.2 3-LoEC-Model: Connecting AB-CFP-Model to Activity Based Costing (ABC)-Data

Now the refined conceptual GHG measurement model is operationalized by specifying the activity data involved in the activity's energy consumption. Analogously to the ABC costing methodology this specification corresponds to the identification of drivers which relates in the AB-uCFP context to the energy consumption. In the Time Driven (TD)-ABC methodology from Kaplan/Anderson (2007) the "unit-time" is used as the activity's key resource driver. In formula (3) the unit-time form the TD-ABC dataset, i.e. the time needed in the activity for producing one unit of the product is taken as the energy consumption driver. In the simplest case the energy consumption is calculated by multiplying the unit-time measured in hours [time/unit (h)] with the power coefficient [kW], i.e. the power level applied during the activity's consumed unit-time.

(3) $$\underbrace{uCFP_{act,fG}}_{[kgCO_2e]} = \underbrace{d_{act,res,fG}}_{[time/unit\ (h)]} * \underbrace{p_{act,res,fG}}_{[kW]} * \underbrace{e_{res,scope,ghg}}_{[kgCO_2e/kWh]}$$

where

d	… **production coefficient** (unit-input) measured via unit-time [time/unit]
p	… **power coefficient** [kW]
e	… **emission coefficient** [$kgCO_2e/kWh$]
res	… economic resource
scope	… direct emission (scope 1) and indirect emission (scope 2 and 3)
ghg	… greenhouse gas

In formula (3) the energy consumption is decomposed into the two parts, i.e. firstly, the unit-time (d) needed in the activity (act) for producing the product (fG) by applying e.g. an equipment resource (res) and secondly, the power level (p) applied in the activity over the unit-time. This splitting of the energy consumption into its driver and the applied power introduces two different levers of control, so that the operationalized AB-uCPF model in formula (3) constitutes a "3-Levers of Emission Control (3-LoEC)-model".

The 3-LoEC-model in formula (3) operationalizes the refined conceptual AB-uCFP model via three levers of control that are expressed in terms of the models three coefficients, i.e. the production coefficient that measures the unit-input (e.g. unit-time), the power coefficient that measures the applied power level and the emission coefficient that converts the consumed energy into GHG emission. It is important to note that this operationalization is the simplest variant of a 3-LoEC-model. More advanced model variants can easily be developed by including multiple energy consumption drivers. E.g., in an activity not only an equipment resource but also material and personnel resources might be used. Moreover, the unit-time-UOM of the driver is only adequate for activities where the energy consumption is mainly (exclusively) driven by time. This is not the case for transportation activities where time is inferior to e.g. mass and distance of the transported product. In this case a "unit-gram-meter-UOM" is more adequate.

An advanced variant of the 3-LoEC-model is also needed when further GHG reporting requirements have to be fulfilled. E.g., if GHG emissions have to be distinguished between direct (scope 1), indirect within the company (scope 2) and indirect along the up- as well as downside supply chain (scope 3) or different carbon footprint boundaries are considered like "Gradle to Grave", "Gradle to Gate", "Gate to Gate" or "Gate to Grave". For such measurement requirements adequate advanced 3-LoEC-models have to be established by including suitable energy consumption drivers and corresponding UOMs, suitable power coefficients and correctly aligned emission coefficients for all (aggregated) activities needed. This flexibility of 3-LoEC-modeling also allows the implementation of advanced concepts like the "Accounting for Climate Change" from Kaplan & Ramanna (2021).

4. GHG EMISSION REDUCTION AND MONITORING: GHG EMISSION-MCS

The AB-uCFP measurement and reporting of the actual GHG emission is not the only requirement from CSRD and ESRS E1. Additionally, the GHG emission reduction objective as well as information concerning the implemented GHG emission-management control systems and monitored objective achievements have to be reported.

4.1 X-Management Control System (X-MCS): Plan/Do/Check/Act-Cycle with related information flows

The 3-LoEC-model is suitable not only for measuring the actual uCFP and identifying emission reduction potentials. Instead, it also can be used for activity-based forecasting as well as activity-based budgeting of future GHG emissions and thereof derived GHG emission reduction objectives.

(4) $$CFP^{bud} = \sum_{act} \sum_{fG} uCFP^{bud}_{act,fG} * x^{bud}_{fG}$$

where

CFP^{bud}	… budgeted CFP over all manufactured products (*fG*)
$uCFP^{bud}_{act,fG}$	… budgeted CFP for activity *act* of product *fG*
x^{bud}_{fG}	… budgeted production units of product *fG*

Formula (4) shows the calculation of the budgeted CFP for all manufactured products via multiplying the budgeted uCFP with the budgeted production units and summing the results over all manufactured products and all therefore needed activities.
For being able to report on the implemented GHG emission-management control systems it is advisable to refer to the ISO 14.000 environmental management system standard family. The working of such a management system can be seen in the management activity diagram (MAD) visualization shown in

Figure 2. The four activities of the Plan/Do/Check/Act (PDCA) cycle are depicted as stereotyped rounded rectangles together with the measurement activity («Measure»). The information flow between the different activities relate to the rectangles. The thereby stereotyped information specifies its meaning.

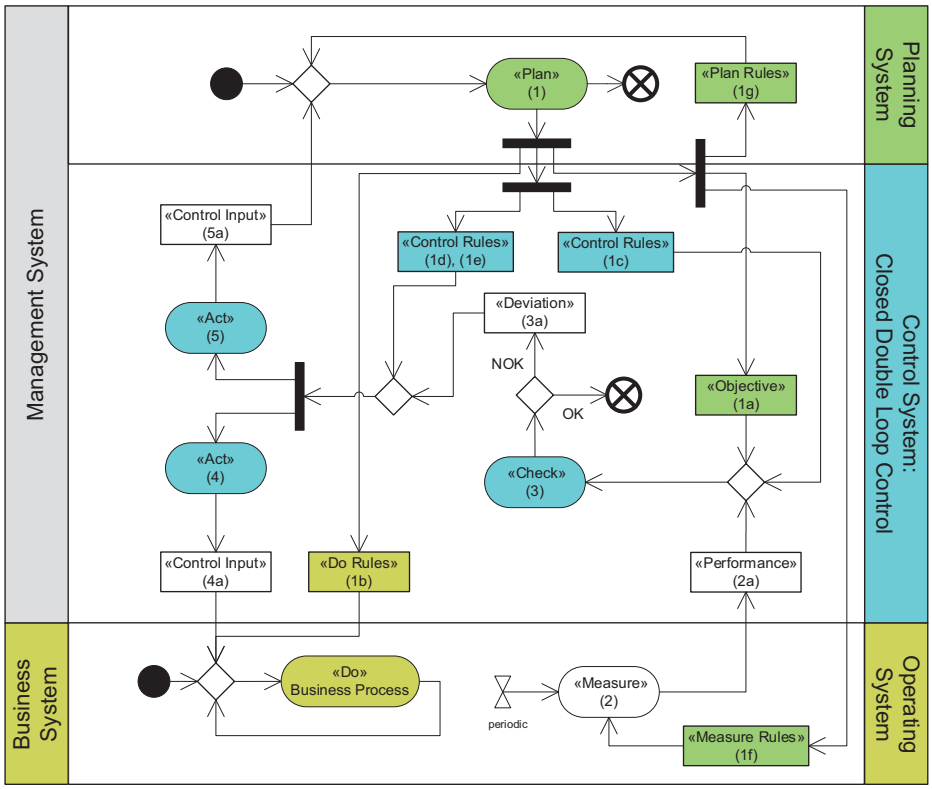

Figure 2: X-Management Information System (MIS) – Management Activity Diagram (MAD)-Model

"One of the fundamental principles is that all the standards can work together. Those who already use an MSS in one part of their business, and are considering implementing additional ones in another area, will find that the process has been made as intuitive as possible. That's thanks to the Harmonized Structure (HS). The concept of HS is that management standards are structured in the same way, regardless of the domain of application. Users who are familiar with one MSS will immediately feel at ease with another, even when using if for the first time." (ISO Management System Standards 2023 as well as 2023a, 2023b).

4.2 GHG Emission-MCS: Planning and Control of GHG Emission Performance

The management activity diagram in Figure 2 is a template into which the activities and related information flows of the environmental management system can be inserted. In Figure 3 this contextualization is summarized by describing the contents of the different activities and related information flows. The interpretation starts with the Plan activity (1), where among others the "Reduction of GHG emission" objective (1a) and the "Use 3-LoEC-model for measurement" measurement rule (1f) are specified. Over time the Do rules (1b) are executed in the Do activity and the performance measure "GHG emission" (2a) is assessed in the measure activity. In the Check activity (3) the measured GHG emission performance is compared with the GHG reduction objective. If the objective is not achieved the resulting deviation (3a) triggers two adjustments. In the corrective Act activity (4) the Do activity is instructed to "reduce waste by lowering operating power level" (4a) and in the adaptive Act activity (5)

the Plan activity (1) is requested to “rethink the plausibility of the required reduction objective” (5a). Due to the two adjustment loops this system is a “closed double loop control system”.

	GHG-Management Control System
(1) PLAN-Activity	
(1a) Objective	Reduction of GHG emission
(1b) DO-Rules	Operate equipment
(1c) CHECK-Rules	Compare actual to budget emission
(1d) Corrective ACT-Rules	Improve equipment performance
(1e) Adaptive ACT-Rules	Adjust reduction objective
(1f) Measure-Rules	Use 3-LoEC-model for measurement
(1g) PLAN-Rules	Alignment with GHG Protocol requirements
(2) Measure-Activity	
(2a) Performance Measure	GHG emission
(3) CHECK-Activity	
(3a) Deviation	Deviation from reduction objective
(4) Corrective ACT-Activity	
(4a) Closed Loop Control Input	Reduce waste by lowering operating power
(5) Adaptive ACT-Activity	
(5a) Closed Loop Control Input	Rethink plausibility of reduction objective

Figure 3: GHG Emission-Management System – Demonstration Case

An PDCA-based environmental management system is the “diagnostic management control system” in the “4-Levers of Control” framework of Simons (1995). A comprehensive analysis of applications of the 4-LoC-framework in the context of environmental management systems is provided by Beusch et al. (2022).

5. CONCLUSIONS

The primary research object is the design of an operationalized AB-uCFP-model that firstly, is consistent with the legal requirements coming from the CSRD and ESRS E1 and the thereby referenced GHG Protocol standards, secondly, is built upon a common information system that puts different management control domains on a shared information basis, and thirdly, is usable for practical implementations related to reporting and management control issues. This objective was achieved in two steps, i.e.

- by starting from the conceptual GHG Protocol measurement methodology and designing from there a refined conceptual AB-uCFP model by placing the original conceptual model upon an energy-based foundation and
- by operationalizing the refined conceptional model with respect to a shared base of activity data and publicly available emission factors.

Accordingly, the research objective is achieved as the designed 3-LoEC-model solves all three above mentioned criteria connected to the objective’s underlying alignment problem. The advantages derived from the 3-LoEC-model can be summarized as follows: it measures the uCFP via three levers of emission control that are related to the consumption and procurement of energy, it is connected to data contained in ABC systems, and it is a forecasting instrument as well so that it is at the core of the activity-based GHG emission budgeting and the corresponding MCS with respect to GHG emission.
For demonstrating the practical applicability of the 3-LoEC-model this paper ends with this simple use case example. Imagine, for manufacturing a product an electric equipment resource is applied that operates 1 hour (unit-time as production coefficient) under full power of 10 kW (production coefficient). This gives an energy consumption of 10 kWh. Imagine furthermore, according to an energy supply shortage this energy can only be procured from a brown coal operated power plant. In this worst-case scenario the emission coefficient amounts to 1.188 $kgCO_2e/kWh$. According to formula (3) this gives a uCFP of uCFP = 11.88 $kgCO_2e$. As already its name suggests, the 3-LoEC-model contains three levers for controlling the uCFP, i.e. the production coefficient in form of the unit-time, the power coefficient in form of the applied power level and the emission coefficient in form of the grid emission factor. All three levers can be used to mitigate and especially reduce the uCFP. Finally, if for the next year controls were

identified that – when implemented – reduce the uCFP by 0.688 $kgCO_2e/kWh$, the GHG emission reduction objective for a budgeted 10 product units amounts to 6.88 $kgCO_2e/kWh$. In order to achieve this objective, the rules for the PDCA activities in the GHG emission-MCS are specified and – of course – executed accordingly.

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HARNESSING CULTURAL INTELLIGENCE: CHINESE EXPATRIATES LEADING THE WAY IN INNOVATION

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Abstract: *In 1978, China embraced globalization, and opened its doors to the world. As a result, the Chinese economy has experienced significant global growth, leading to an increased integration of Chinese workers in international businesses. The purpose of this paper is to explore the relationship between Cultural Intelligence and Innovation by examining Chinese expatriates, individuals of Chinese origin who live and work abroad. Innovative Work Behavior was used to further explain the link between Cultural Intelligence and Innovation; and Creativity was used as a mediator between Cultural Intelligence and Innovative Work behavior. For our research methodology we used a survey aimed for Chinese expatriates measuring Cultural Intelligence, Creativity, Innovative Work Behavior and Organizational Innovation. We hypothesized that there is a positive correlation between Cultural Intelligence and Innovative Work Behavior, Creativity mediates the effect of Cultural Intelligence on Innovative Work Behavior and that Innovative Work Behavior is positively associated with Organizational Innovation. It was found that Chinese expatriates with specific qualities had more innovative capabilities that enabled them to bring innovation to organizations and help them become more sustainable in a highly competitive global economy.*

Keywords: Chinese expatriates, Cultural Intelligence, Creativity, Innovative Work Behavior, Innovation

1. INTRODUCTION

Globalization refers to the integration of economies worldwide through cross-border trade, investment, and production (Lattemann *et al.*, 2012). It is an initiative embraced by countries throughout the world to facilitate the exchange of economic goods and processes. In 1978, China decided to open its economy to the world and started the process of its economic reform (Bell, 1993). China started to create trade and investment partnerships with economies around the world, no longer depending solely on its internal business affairs. This "opening up" strategy proved highly successful, as China transformed from a poor nation to the third largest economy globally within three decades (Yueh, 2010). As of 2023, China stands as the second largest economy, following the United States (Largest Economies in the World, 2023). To clarify, a country's economy is measured by its GDP (Gross Domestic Product), which represents the total value of all finished goods and services produced within its borders during a specific time period (Fernando, 2022).

With the rapid globalization of companies and organizations, there has been an increasing demand for globalized and international employees, commonly known as expatriates. Expatriates are individuals who live and work outside their country of origin. For instance, Chinese expatriates are Chinese individuals who work and live outside of China. Expatriates can be from anywhere in the world and can work anywhere in the world, Chinese can work in the United States, French can work in Israel, British can work in China and so on. The research on expatriates is still developing, as the combination of individuals from different countries in different cultural settings offers endless possibilities for cross-cultural research. For example, Wang, Fan, Freeman, and Zhu (2017) examined the cross-cultural skills necessary for Chinese expatriate managers that work in different countries.

There is a lack of research specifically focusing on Chinese expatriates. Existing literature on expatriates and China mainly explores the experiences and adaptation of Westerners working in China, such as coping strategies of business expatriates (Selmer, 2002), psychological well-being of expatriates (Wang and Kanungo, 2004), language barriers faced by Westerners (Selmer, 2006), and experiences, opportunities, and challenges encountered by expatriates in China (Boncori, 2013). Studies on Chinese expatriates in academic literature often examine their interactions with different cultures and their management. It seems there is a research gap when it comes to studying the challenges, experiences, competencies, and characteristics unique to Chinese expatriates. In other words, most research addressing Chinese expatriates focuses on their relationships with other actors, such as managers or colleagues, rather than exploring their own variables. This research aims to fill this gap by specifically focusing on Chinese

expatriates and investigating how Cultural Intelligence, Creativity and Innovative Work Behavior may influence their capacity for innovation.

2. METHODS

2.1 Sample and Data Collection

This study was conducted on Chinese expatriates- Chinese that live and work abroad. The focus was on Chinese expatriates without specific consideration for the country of work or the type of company. The participants were both employees and managers. A total of 113 responses were collected through a questionnaire consisting of 51 questions divided into four parts: General information (age, gender, country of work, years working at the current job), Cultural Intelligence, Creativity, Innovative Work Behavior, and Organizational Innovation. The questionnaire was written in both English and Chinese. Data collection involved distributing the questionnaire to Chinese expatriate groups and on social media platforms, as well as sending private messages through a social platform.
The majority of respondents fell within the age range of 18-30 years (79%), followed by 10% between 31-40 years, 7% between 41-50 years, and the remaining respondents were 51 years or older. Among the sample, 60% were female and 40% were male. The respondents represented a diverse range of countries where they worked, with the majority located in France (34.5%) and the United States (20%). Additionally, 12% worked in Israel, 5% in the UK and Luxembourg, and a small percentage worked in other countries such as the United Arab Emirates, Australia, Switzerland, Singapore, and more, totaling 25 countries. Regarding the duration of employment at their current job, the majority of respondents (57.5%) had been working for less than a year, while 26.5% had worked for 1-5 years, 8% for 5-10 years, and 8% for more than 10 years. Given that the largest age group of respondents was 18-30 years old, it is not surprising that many of them had been in their current jobs for less than a year, potentially indicating recent graduates entering the workforce.

2.2 Measures

Cultural Intelligence (CQ): The 20 statements Cultural Intelligence Scale Self Report developed by Ang and Van Dyne (2015) was used in this study. In their research, CQ was divided into 4 dimensions: Metacognitive CQ- Mental Capabilities, Cognitive CQ, Motivational CQ, and Behavioral CQ. Each dimension contains 4 to 6 statements to be rated on a scale of 1 (strongly agree) to 7(strongly disagree). One example of a statement is" I am sure I can deal with the stresses of adjusting to a culture that is new to me."
Creativity: 7 items from George and Zhou (2001) 13-items 7 points scale self-report were used in this study. The scale was from 1 (strongly disagree) to 7 (strongly agree). A sample of an item is: "I suggest new ways to achieve goals or objectives."
Innovative Work Behavior (IWB): The 17 items that were used in this study were developed by De Jong and Den Hartog (2010). They divide IWB to three constructs: Participative Leadership, External Work Contacts and Innovative Output. For each construct they provide between 5 to 6 statements to be rated from 1 (Never) to 7 (All the Time). A sample of a statement under the Innovative Output construct is: "In your job, how often do you make suggestions to improve current products or services?". The 6 statements under the Participative Leadership construct were optional in the case the individual does not have a superior.
Organizational Innovation: Three questions were introduced to measure Organizational Innovation. The questions were taken from the OECD Community Innovation Survey (CIS) which is the reference survey on innovation in enterprises. In this part of this research questionnaire, it was asked to state whether an innovative activity described was introduced in the participant's place of work or not in the past 5 years (2018-2023). For example: new business practices for organizing procedures were introduced (for example: first time use of supply chain management, business re-engineering, knowledge management, etc.). The answers were: "Yes", "No" or "I don't Know".

2.3 Hypotheses Development

Cultural Intelligence (CQ) is the ability of an individual to understand gestures that are not necessarily from within their own culture or country of origin. In essence, Cultural Intelligence is a valuable attribute that enables individuals to engage and immerse themselves in unfamiliar cultures, thereby presenting an opportunity for personal growth and the acquisition of knowledge. Having a high level of CQ promotes effective communication among peers, facilitating the exchange of unique ideas, perspectives, and

approaches (Afsar et al., 2020). In this paper, we argue that the qualities associated with a high CQ contribute to the display of innovative work behavior by Chinese expatriates. Individuals with high CQ exhibit effectiveness both within their own culture and across different cultures (Ng and Early, 2006), enabling them to interact skillfully with individuals from diverse cultural backgrounds and navigate various cultural contexts (Brislin *et al.*, 2006).

Leveraging these skills, it is argued that individuals can generate novel ideas and successfully implement them with the support of their peers, which can ultimately lead to new and improved product or business process in an organization that differs from the product or process that was introduced before. Consequently, we argue that innovative work behavior of employees directly contributes to organizational innovation. Specifically, within the context of this study, organizational innovation refers to the implementation of novel ideas and practices that bring about changes and advancements within the organization.

H1: Cultural Intelligence is positively related to Innovative Work Behavior

H2: Innovative Work Behavior is positively related to Organizational Innovation

Ang and Van Dyne (2015) have developed a multidimensional construct for Cultural Intelligence that divides CQ into four groups, each group relates to a specific dimension of CQ: (1) Metacognitive CQ- mental capabilities to acquire and understand cultural knowledge, (2) Cognitive CQ- reflects general knowledge and knowledge constructs about culture, (3) Motivational CQ- reflects individual's intent to invest energy toward learning about and functioning in intercultural situations, (4) Behavioral CQ- reflects the capability of an individual to present appropriate verbal and nonverbal actions in cross-cultural interactions.

Past research has found that metacognitive, cognitive and motivational CQ were positively associated with creativity (Yunlu *et al.,* 2017). We argue that CQ and its different dimensions allow individuals to explore and acquire knowledge that can be reintegrated into a new and innovative form which is the definition of creative work (Stein, 1953). To explain further, a high level of CQ helps individuals to navigate effectively in multicultural environments by self-awareness, general and specific knowledge and motivation to immerse in non-native cultures (MacNab *et al.,* 2012).

These actions an individual does to develop high CQ can make expatriates feel more at ease and positive at the workplace due to better ability to communicate, understanding the culture and its cues and even having the motivation to learn more. Connecting to that, creativity occurs when individuals feel safe, positive and at ease (Claxton 1997). Creativity is the generation of novel ideas and innovation is the implementation of ideas (West, 2000), creativity is also a part of innovative work behavior where employees recognize gaps and initiate ideas to fill the need for innovation (Afsar *et al.,* 2014).

H3: CQ is positively associated with Creativity

H4: Creativity is positively associated with Innovative Work Behavior

H5: Creativity mediates the effect of CQ on IWB

3. RESULTS

3.1 Structural Model

In the figure below, a comprehensive structural model was constructed to facilitate the execution of this research study. This model served as a framework that guided the entire investigation. By adhering to this model, we were able to formulate relevant hypotheses related to their research objectives. These hypotheses were subsequently extracted from the model and subjected to testing and analysis.

By employing this systematic approach, we ensured a well-organized and thorough investigation, enhancing the credibility and reliability of our findings. The use of a structural model provided a solid foundation for the research study and contributed to its overall success in achieving its objectives.

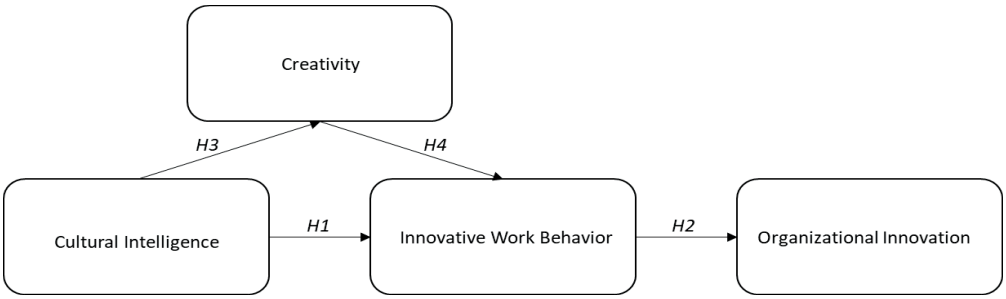

Figure 3.1: Structural model and hypotheses

3.2 Measurement Model

Prior to examining the hypothesized relationships among the constructs of this study, a reliability test was run to ensure the validity of the measurement items. Cronbach's alpha coefficient was calculated for each set of questions associated with our variables, in order to ascertain the internal consistency of the items within each construct. In Table 1 we can clearly observe that all of our variables have a Cronbach's alpha greater than 0.7. This implies that the items within each construct exhibit a high degree of reliability and are well-correlated with each other. This demonstrates a strong level of internal consistency within our measures, validating their utility in subsequent analyses. It is also indicative of the quality of our data and the robustness of the relationships between each item within its respective variable. Based on these results, we can confidently move forward with further analyses using these variables, as they are likely to yield reliable and valid outcomes.

Table 3.1: Reliability Statistics. Cronbach's Alpha calculation for the construct model variables.

Variable	Cronbach's Alpha	N of Items
Cultural Intelligence	0.864	20
Creativity	0.878	7
Innovative Work Behavior	0.904	17
Organizational Innovation	0.755	3

3.3 Hypotheses Testing

To test our hypotheses, we used linear regression. Hypothesis 1 proposed that Cultural Intelligence (CQ) is positively related to Innovative Work Behavior (IWB). As we can see at Table 3.1, it was found that CQ significantly predicts IWB and accounts for about 11% of its variance. Meaning, 11% of the variance of IWB can be explained by CQ. The beta coefficient is 0.474 which means that for every one-unit increase in Cultural Intelligence, we can expect a 0.474 increase in Innovative Work Behavior, holding all other variables constant. The f ANOVA statistic is 13.727 with a significance level of less than 0.001. This is statistically significant at a 95% confidence level, indicating that the regression model predicts the outcome variable significantly well.

The results also demonstrate that IWB significantly predicts Organizational Innovation (OI) and accounts for about 13.2% of its variance as it was proposed by Hypothesis 2. Meaning, 13.2% of the variance of OI can be explained by IWB. The beta coefficient of H2 is 0.263 which means that for every one-unit increase in Innovative Work Behavior, we can expect a 0.263 increase in Organizational Innovation, holding all other variables constant. The f ANOVA statistic is 16.891 with a significance level of less than 0.001. At a 95%

confidence level, the statistical significance indicates that the regression model effectively predicts the outcome variable.

For Hypothesis 3 and 4 it was proposed that CQ is positively related to Creativity (CR) and Creativity is positively related to IWB respectively. For Hypothesis 3 it was found that CQ significantly predicts CR and accounts for about 13.5% of its variance. Meaning CQ can explain 13.5% of Creativity variance. The beta coefficient of H3 is 0.368 which means that for every one unit increase in Cultural Intelligence, we can expect a 0.368 increase in Creativity. The f ANOVA statistic is 17.370 with a significance level of less than 0.001. This tells us that the regression model we are utilizing to predict Creativity from Cultural Intelligence is statistically significant, implying that the independent variable is relevant.

For Hypothesis 4 we found that CR significantly predicts IWB and accounts for about 41.6% of its variance. Meaning Creativity can explain almost 50% of IWB variance. The beta coefficient of H4 is 0.645 which means that for every one unit increase in Creativity, we can expect a 0.645 increase in Innovative Work Behavior. The f ANOVA statistic is 79.147 with a significance level of less than 0.001, pointing to a statistically significant regression model. This finding indicates the relevance of Creativity in predicting Innovative Work Behavior.

Table 3.2: Results of Hypotheses Testing, H1-4 (NOTES: CQ- Cultural Intelligence, IWB- Innovative Work Behavior, OI- Organizational Innovation, CR- Creativity)

Hypothesis	b	f	R2
CQ-IWB (H1)	0.474**	13.727**	0.110
IWB-OI (H2)	0.263**	16.891**	0.132
CQ-CR (H3)	0.368**	17.370**	0.135
CR-IWB (H4)	0.645**	79.147**	0.416

*p<0.05, **p<0.01

Hypothesis 5 proposed that Creativity acts as a mediator between Cultural Intelligence and Innovative Work Behavior. To test this hypothesis, two models were utilized, as presented in Table 3.3: Model one (M1) examined the relationship between Cultural Intelligence and Creativity, while Model two (M2) investigated the association between Creativity and Innovative Work Behavior.

Table 3.3: Results of Hypotheses Testing, H5 (NOTES: CQ- Cultural Intelligence, IWB- Innovative Work Behavior, CR- Creativity)

Model	R2	
CQ-CR (M1)	0.1353*	
CR-IWB (M2)	0.4266*	
Mediation Effect H5	**BootLLCI**	**BootULCI**
CQ-CR-IWB	0.1444*	0.5262*

*p<0.05, **p<0.01

In the first model (M1), where Creativity was the outcome variable, a statistically significant positive association was observed with Cultural Intelligence, with an R-squared value of 0.1353. This implies that approximately 13.53% of the variance in Creativity can be explained by Cultural Intelligence. Moving on to

the second model (M2), where Innovative Work Behavior was the outcome variable, the model yielded an R-squared value of 0.4266, indicating that it explains a substantial proportion of approximately 42.66% of the variance in Innovative Work Behavior.

A bootstrap test was then conducted to assess the direct effect of Cultural Intelligence on Innovative Work Behavior and its indirect effect through Creativity. The results showed that the direct effect of Cultural Intelligence on Innovative Work Behavior was not statistically significant ($p = 0.1624$), as its confidence interval includes zero. However, the indirect effect of Cultural Intelligence on Innovative Work Behavior through Creativity was found to be statistically significant, as the confidence interval did not include zero. This implies that when the mediating variable, Creativity, is taken into account, there is a significant indirect effect of Cultural Intelligence on Innovative Work Behavior. These findings suggest that while Cultural Intelligence may not directly impact Innovative Work Behavior, it can positively influence it through its effect on enhancing Creativity. Thus, enhancing Cultural Intelligence could potentially lead to increased Innovative Work Behavior by fostering greater levels of Creativity.

Two different tests were run to analyze the hypotheses of this study: linear regression and a bootstrap. The wo test yielded contradictory results. When regression was run it was found that cultural intelligence significantly predicts innovative work behavior. Surprisingly, when a bootstrap test was run it was found that the direct effect of cultural intelligence on innovative work behavior was not statistically significant but the indirect effect through creativity was found significant. That is to show that while the link between cultural intelligence and innovative work behavior in the Chinese expatriates' community exists, it can be enhanced through creativity.

4. DISCUSSION

Cultural Intelligence has received attention across various research fields, exploring its effects on interpersonal trust in multicultural teams (Rockstuhl and Ng, 2015), cultural judgment and decision making, cultural adaptation and task performance (Ang *et al.*, 2007), and expatriate performance (Lee and Sukoco, 2010), among others. Recent research has further explored the relationship between Cultural Intelligence and Innovation. Drawing data from 113 Chinese expatriates working in 25 countries, this study supports the notion that Cultural Intelligence influences Expatriates' Innovative Work Behavior, corroborating the findings of Afsar *et al.* (2020) and Li *et al.* (2021).

Additionally, the study confirms the link between Cultural Intelligence and Creativity, as previously examined by Yunlu *et al.* (2017). This research expands the literature on the connection between Cultural Intelligence, Innovative Work Behavior, and Creativity, particularly focusing on Chinese expatriates, a novel area of investigation with no prior research on this specific group.

Furthermore, the study highlights a noteworthy correlation between expatriates' creativity and their innovative work behavior. Past research by Bagheri *et al.* (2022) demonstrated that individual and team creativity can enhance employees' innovative work behavior by encouraging engagement in creative activities and implementing innovative ideas within the organization. By incorporating Cultural Intelligence as a catalyst, this study adds to the existing literature on the relationship between creativity and innovative work behavior.

The research also reveals that expatriates' innovative work behavior significantly impacts organizational innovation. The hypothesis is grounded in the definition of Innovative Work Behavior, which encompasses transforming the fundamental principles of organizational work.

Existing academic discourse on Innovative Work Behavior has explored its associations with different factors, such as transformational leadership (Afsar *et al.*, 2014) and personality traits (Woods *et al.*, 2018). This study goes beyond viewing Innovative Work Behavior solely as an end product, considering it as a mediator leading to actual organizational innovation.

Finally, this research stands among the pioneers in examining the relationship between Cultural Intelligence and Innovation, specifically using Chinese expatriates as the sample data. It provides empirical evidence of the significantly positive impact of Cultural Intelligence on Innovative Work Behavior through Creativity.

Additionally, the study establishes that Chinese Expatriates' Cultural Intelligence, in conjunction with Creativity and Innovative Work Behavior, can foster organizational innovation. This expansion of Chinese expatriate literature contributes not only to Cultural Intelligence and Innovation research but also to the broader field of "China goes global" literature, by shedding light on the capabilities of Chinese expatriates rather than solely focusing on their interactions with other cultures.

5. CONCLUSIONS

As China continues to undergo rapid globalization and the internationalization of its organizations, there has been a significant rise in the number of Chinese expatriates working in multicultural environments. As a result, their interactions with individuals from diverse cultures have also increased. This study highlights the importance of enhancing Cultural Intelligence (CQ) as a means to promote more innovative work behavior through increased creativity, ultimately leading to organizational innovation.

In the current competitive market landscape, innovation has become crucial for organizations to maintain sustainability and relevance. International organizations actively seek for ways to foster innovation among their employees. The findings of this study demonstrate that by improving employees' Cultural Intelligence, their creativity and innovative work behavior can be significantly enhanced. This practical insight has meaningful implications for corporations, as they can invest in cultural intelligence training for their expatriates or select candidates with higher Cultural Intelligence for international assignments.

From a theoretical perspective, this research expands the existing body of knowledge on Cultural Intelligence, Creativity, and Innovative Work Behavior. The empirical evidence presented in this study contributes to the development of theories related to Cultural Intelligence and its impact on innovation, specifically within the context of the Chinese expatriate community.

However, it's important to acknowledge the limitations of this paper. The study primarily focuses on Chinese expatriates without considering industry or firm-related variables, which may influence the relationship between cultural intelligence and innovative work behavior. As presented in the results, using two different tests yielded two contradicting results concerning the direct effect of cultural intelligence on innovative work behavior. Thus, different variables added or missed can greatly affect the results of a study. To advance the analysis further, future research could explore Chinese expatriates in specific industries or countries, considering factors like job level (managers vs. employees) and additional control variables, such as education level. Additionally, conducting similar studies with samples from different cultures and countries would enable insightful comparisons between expatriates of distinct origins and provide a more comprehensive understanding of the relationship between Cultural Intelligence and Innovation.

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SOLID OXIDE FUEL CELL COMBINED HEAT AND POWER PLANT OPERATED WITH DIESEL

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Abstract: S*olid Oxide Fuel Cells (SOFCs) are high efficient energy converter because they are able to convert chemically bound energy directly into electrical energy. In addition, SOFCs have a high fuel flexibility since they can not only be operated with hydrogen, but also with ammonia, biogas and other hydrocarbons. However, operating SOFCs with complex fuel mixtures such as conventional liquid fuels or biofuels bears several risks which can lead to early degradation of the SOFC. To reduce the risk, external fuel reforming and investigations on optimal operating conditions have to be conducted. Here we demonstrate the operation of an in house developed small scale SOFC combined heat and power (CHP) plant with standard Austrian diesel. The SOFC operation was monitored and characterized by applying temperature measurements, continuous gas analysis, electrochemical impedance spectroscopy and voltage and current measurements. These results may be useful to demonstrate the potential of SOFCs for future applications such as energy supply of greenhouses. The in house developed SOFC CHP system can be used for further investigations regarding the fuel flexibility and long term behavior.*

Key words: *solid oxide fuel cell (SOFC), combined heat and power plant, system development*

1. INTRODUCTION

During the transmission of the electric power supply from fossil fuels, to sustainable energy sources, it shows up that for some applications, fuels with high gravimetric energy density are necessary. Such applications can be aircraft (Santarelli et al., 2010), ships (Nehter et al., 2017) or isolated areas such as islands, or rural areas and agriculture facilities (DePippo & Peppley, 2019). Isolated areas have often only limited access to different kind of power grids but still need heat and electric energy supply. For these purposes, liquid synthetic- and bio- fuels are necessary. In addition, the fuels should be converted with high efficiencies and without emitting pollutants such as NO_x. One energy converter with potential high efficiencies due to direct electrochemical conversion of chemical bound energy is the solid oxide fuel cell (SOFC) (Song, 2002). Due to the operating principle of the SOFC, oxygen ion conduction and high operating temperatures, a variety of fuels can be applied to the SOFC. Possible fuels are hydrogen, ammonia (Stoeckl et al., 2020), biogas (Gandiglio et al., 2020) or liquid hydrocarbons (Bae et al., 2009). However, to use hydrocarbons, often a fuel pre-treatment is required since direct utilization of hydrocarbons in the fuel cell can lead to early performance loss of the SOFC due to carbon deposition. To minimize this risk, a fuel pre-treatment such as reforming can be used (Li et al., 2023). During reforming, hydrocarbons get mixed with other substances and converted in a hydrocarbon rich syngas. Depending on the substance mixed with the hydrocarbon, different reforming strategies exist. Most important reactions for the following work are the endothermal steam reforming reaction, the exothermal partial oxidation with air and its combination, in the following referred to as auto thermal reforming (Rostrup-Nielsen, 1993). Till now, only limited work is available about monitoring and efficiency analysis of diesel operated SOFCs (Kleinohl et al., 2014; Lawrence & Boltze, 2006). Further, most of diesel operated systems are built as auxiliary power units (APU) instead of combined heat and power supply units (Rechberger et al., 2013; Reissig et al., 2015). Here we report about characterization tests of an in house developed diesel operated heat and power SOFC system. We additionally applied a variety of monitoring measurements to investigate the behavior of a SOFC which is operated with liquid fuels. This could help us in future to optimize such systems and gain knowledge about the system- and electrochemical behavior.

2. METHODS

In this section, the in house developed combined heat and power SOFC system, which is operated with diesel as fuel, and its main components are described. The system consists of a (i) fuel supply line, (ii) a steam supply, (iii) an air supply, (v) a diesel mixing and evaporation chamber, (vi) a reformer, (vii) the SOFC stack, (viii) a catalytic burner, (ix) a gas water heat exchanger and (x) a control cabinet. The fuel supply line pumps a controllable fuel flow rate from a fuel tank via a nozzle in the mixing and evaporation chamber. In addition to fuel, at least steam is added to the mixing chamber to generate a mixture suitable for steam reforming. If auto-thermal reforming should be conducted, air is also added to the mixing chamber. The air supply line further supplies the SOFC air electrode, the catalytic burner and additional aggregates such as the pneumatic needle valve from the steam supply line and cooling units. The air flow rates for the reformer, SOFC and catalytic burner are controlled by mass flow controllers. The mixing and evaporation chamber is heated to 400 °C. The reformer consists of four parallel tubes which are filled with an inert bulk, Pt based catalyst pellets and commercial Ni catalysts (Höber et al., 2022). The control temperature of the reformer is 780 °C. The SOFC stack consisting of 30 anode supported cells is placed downstream of the reformer and supplied with the reformer outlet-gas and pre-heated air. The air and the reformer outlet gas are additionally heated in the furnace where the SOFC stack is placed, to reach the SOFC operating temperature of 750 °C. Downstream of the SOFC, the gases from the SOFC fuel electrode and air electrode are mixed and let into the catalytic burner. The catalytic burner is filled with Pt based catalyst pellets and is cooled with an additional controlled air supply. The gas water heat exchanger is placed downstream of the catalytic burner and is used to heat up water for external heating circuits.
The system is operated during the presented test results with diesel and steam flows or with diesel steam and air flows on the fuel side, to achieve steam reforming or auto-thermal reforming conditions respectively.

3. RESULTS

The flow rates and the electrical power output of the SOFC are shown over time in Figure 1 for the two tested operating conditions. A constant diesel and water flowrate is set for both operating conditions. The stack air supply was constant at 55 slpm except for a short duration while operating with diesel, steam and air mixtures, where it was increased to 60 slpm. To achieve diesel, steam and air mixtures, an additional air flow (reformer air) was added in the mixing chamber, upstream of the reformer, to the fuel line. We observed that operation with diesel and steam mixtures led to higher electrical power outputs of the system compared to operation with diesel, steam and air mixtures. This is the case because to reform the diesel and steam mixtures, external heating is required due to the observed endothermal diesel steam reforming reactions. The externally provided heat combined with the reforming process leads to an increased heating value of the gas mixture at the reformer outlet (equal to SOFC inlet) compared to the reformer inlet. By mixing air to the diesel and steam mixture upstream of the reformer, additional exothermal reactions from partial oxidation of the fuel are observed. These exothermal reactions lead to a decrease in external heat demand. Hence, diesel, steam and air mixtures can be beneficial to increase the heat output of the system. We observed, that the electrical efficiency is mainly dependent on the ratio of fuel flow to electrical power output. By adjusting the fuel flow to the actual electrical demand, no to only small efficiency losses can be achieved, allowing high efficient operation also in partial load conditions. The electrical power output of the SOFC can be varied between 0 W and an upper power output limit of the SOFC. The upper power output limit is determined by a voltage limit of 0.7 V per single cell to avoid re-oxidation of the Ni in the SOFCs fuel electrode. This would result in 21 V for the presented system. Due to inhomogeneity's in temperature and gas distribution, which could lead to local differences of the voltage, it was observed that a SOFC stack voltage of more than 21 V should be maintained to extend the system lifetime.

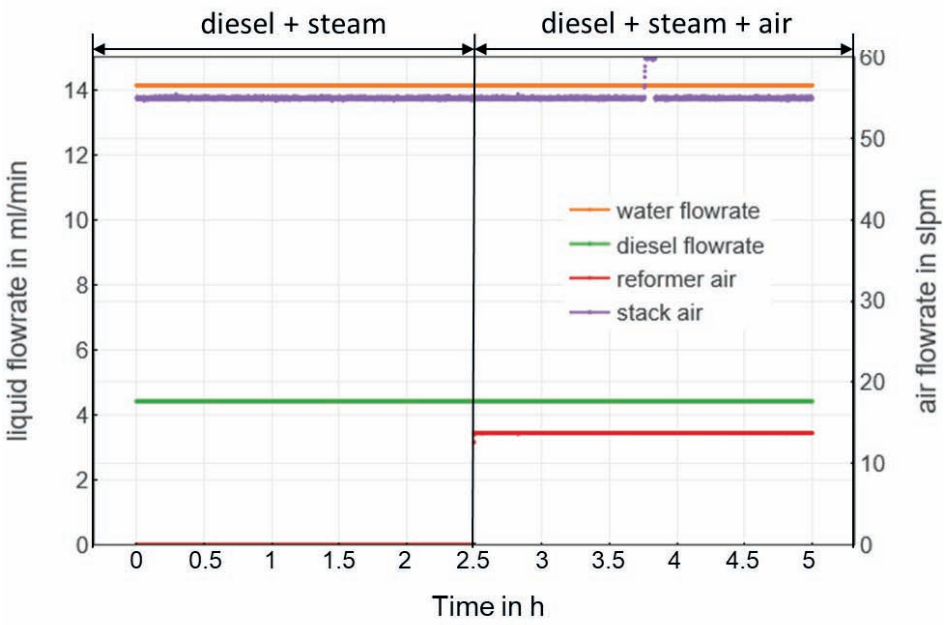

Figure 1: SOFC relevant flow rates and SOFC electrical power output over time.

4. DISCUSSION

Within the results section, we compared operation with diesel and steam mixtures and operation with diesel, steam and air mixtures of the developed diesel driven SOFC system. The partial load in terms of electric energy output is only limited by the lower voltage limit of the stack which is found to be above 21 V and can else be adjusted as needed.

5. CONCLUSIONS

In this work, a characterization experiment of a system able to utilize diesel in SOFCs is shown. The system consists of several components including fuel pre-treatment where diesel, water and air mixtures are reformed to a hydrogen rich gas mixture. System operation with diesel and steam mixtures and with diesel, steam and air mixtures were discussed. The overall high efficiency potential including partial load conditions show the potential of SOFC applications not only for hydrogen or methane based fuels but also for liquid fuels such as diesel or bio-diesel. The developed system can be used to further investigate SOFC operation with different liquid fuels and optimize operating conditions. Such SOFC systems could in future be used for areas where the high gravimetric energy density of liquid fuels is necessary and high electric energy efficiencies or coupled heat and electric power supply is needed.

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PERFORMANCE OPTIMIZATION OF SOLID OXIDE FUEL CELL OPERATION WITH ARTIFICIAL INTELLIGENCE

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Abstract: *With their ability to convert chemically bound energy directly into electrical energy, solid oxide fuel cells (SOFCs) are a promising solution to meet the increasing demand for clean and efficient electricity. To accelerate the successful commercialization of this technology, knowledge of the optimal process parameters for efficient, long-term stable and safe operation is of great importance. To reduce the amount of time-consuming and money-consuming experiments required to determine the optimal operating parameters, we used artificial intelligence and combined it with various optimization algorithms to optimize the process parameters of a SOFC. Using a stacked artificial neural network with algorithm-optimized model architecture, we were able to predict the cell voltage of an industrial-scale electrolyte-based SOFC from the cell temperature, gas composition and flow rate on the fuel side, air flow rate, and current. Due to the tremendous prediction speed in the range of milliseconds, a genetic algorithm could be used to optimize the process parameters. The optimization resulted in electric efficiencies >54% and process efficiencies >68% with 80% fuel utilization for operation with methane/steam mixtures and electrical system efficiencies of >66% for operation with hydrogen/steam mixtures and ideal exhaust gas recirculation.*

Key words: *solid oxide fuel cell (SOFC), performance optimization, artificial intelligence (AI)*

1. INTRODUCTION

In this age of climate change and skyrocketing electricity and energy prices, clean, reliable and efficient power generation is of significant importance. High-temperature solid oxide fuel cells (SOFCs) enable the direct conversion of chemically bound energy of gaseous fuels into electricity, without the limitations of Carnot efficiency. SOFCs are thus a technology with great potential to meet this demand for clean and efficient electricity generation. Due to their high operating temperature in the range of 700-1000°C, precious metals such as platinum are not required.

In addition, unlike low-temperature fuel cells, SOFCs can run on a wide range of fuels, including hydrogen, ammonia, and hydrocarbons such as methane, methanol, or even biodiesel. Despite its unique properties and advantages, further research on this technology is needed for successful large-scale commercialization. In particular, knowledge of efficient but long-term stable and safe operating parameters is essential for proper operation on an industrial scale. In order to determine these operating parameters, time-consuming and costly experiments usually have to be performed. The authors of this paper propose a cheaper and faster alternative by using modeling, algorithm-based optimization and artificial intelligence. Several steps were necessary to get optimized operation parameters. In Figure 1 the steps conducted for this work are summarized.

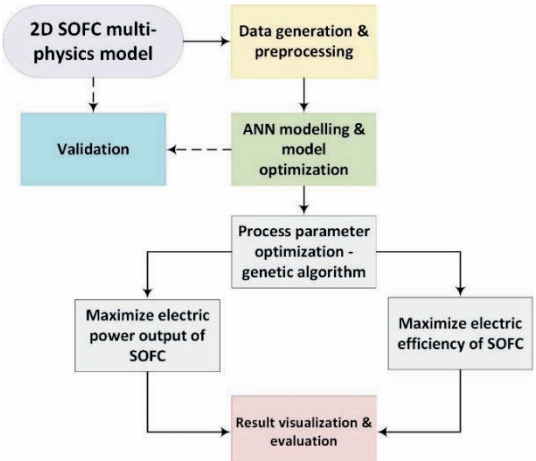

Figure 1: Simplified workflow of SOFC operation parameter optimization

In a first step a multi-physics SOFC model was used to generate a dataset, which represents the whole potential operation range. After preprocessing, this data is used to set up and train an artificial neural network (ANN) model. Both the multi-physics and the ANN model were validated by means of experimental data. The trained and validated ANN model is coupled with a meta-heuristic optimization algorithm (genetic algorithm) to enable a fast optimization of the operation parameters. Following this approach four different scenario cases were investigated:

- Maximum electric efficiency with H_2/H_2O – mixtures as fuel and off-gas recirculation
- Maximum electric power output with H_2/H_2O – mixtures as fuel
- Maximum electric efficiency with CH_4/H_2O – mixtures as fuel
- Maximum electric power output with CH_4/H_2O – mixtures as fuel

2. METHODS

In the following section mainly used methods (see Figure 1) are described more in detail.

2.1 Multi-physics model

To have an as accurate as possible representation of a real SOFC, a 2D multi-physics SOFC model based on more than 120 equations (Subotić et al., 2020), was further enhanced by reaction kinetics (represented by Maier et al., 2011), heat fluxes and local current density distribution (Goodwin et al., 2021). With this complex model the cell voltage, temperature distribution in flow direction, local current density distribution and the magnitude of the ohmic-, activation- and concentration-over potential can be predicted for the cells used. In order to examine the accuracy of the model developed, predictions of the model were compared with measured data from industrial-sized (81 cm^2 active area) single cell tests. Maximum deviations of 2.1% could be observed. The time required to compute the cell voltage for one operation mode (= temperature, gas composition and current density) with this model is in the range of 2-3 minutes. A direct combination of a multi-physics SOFC model and an optimization algorithm (e.g. a genetic algorithm) therefore might result in an undesired long computation time.

2.2 Artificial neural network model

In order to have a prediction speed, that is fast enough for the coupling with the genetic algorithm, an artificial neural network (ANN) was used in this work. With this meta-model, the cell voltage for a set of input parameters, namely: current density, cell temperature, mass flow rate of H_2, H_2O, CO, CO_2, CH_4 and N_2, could be predicted within milliseconds. To achieve a high model consistency and prediction accuracy, a repeated k-fold cross validation with cyclic learning rate and an algorithm-based hyperparameter-tuner was implemented. These measures led to a negligible additional prediction error of 3mV at maxima, whereby a speed-up by a factor of >3500 compared to the multi-physical model could be achieved. For more details on the specific details of the individual steps interested readers may have a look at (Mütter et al., 2023).

2.3 Genetic algorithm

A genetic algorithm is a meta-heuristic that mimics the process of natural selection and evolution. In general, this algorithm consists of four steps which are repeated until a certain performance criteria or the maximum number of iteration is reached.

- Selection: A population of input parameters is evaluated regarding its "fitness" and only the fittest share is selected to form new a new members of the population.
- Recombination: Pairs from the selected fitter share of the population are recombined to form "parents". These parents combine their features to form new population members until the population limit is reached
- Mutation: Some features of the newly formed population members may be mutated randomly.
- Evaluation: The population is evaluated again regarding its fitness

Due to two different scenarios (CH_4/steam and H_2/steam operation) and two different optimization targets (max. efficiency, max. el. power) per scenario, several different fitness functions were defined.

To maximize the electric power for both CH_4/steam and H_2/steam operation, the fitness function was defined as:

$$Fitness = P_{electric} = Voltage_{cell} \cdot current\ density \quad (1)$$

For the optimization of electric system efficiency of the H_2/steam scenario, the efficiency was defined as:

$$Fitness = \eta_{electric\ sys.} = \frac{P_{electric}}{LHV_{H_2\ processed}} \quad (2)$$

Thereby the unused fuel was assumed to be recirculated with an ideal off-gas recirculation (e.g.: an ejector). For the operation scenario with methane no off-gas circulation was assumed, as its implementation would be much more complex. In order to avoid a CO_2 saturation of the fuel gas, CO_2 would have to be removed from the exhaust gas, which increases system complexity and cost significantly. The electric efficiency for the optimization was defined in a similar way as for the H_2/steam-case as:

$$Fitness = \eta_{electric\ cell.} = \frac{P_{electric}}{LHV_{CH_4\ inlet}} \quad (3)$$

Because the unused fuel can further be utilized, e.g. in gas turbine, in addition to the definition for the fitness function, also only the directly in the SOFC processed fuel was considered for the CH_4/steam efficiency case as process efficiency:

$$\eta_{process\ CH_4/Steam} = \frac{P_{electric}}{LHV_{CH_4\ inlet} \cdot Fuel\ utilization} \quad (4)$$

With the fitness functions defined above, for each scenario and optimization target optimal process parameters were searched. One optimization run thereby required <1h to converge.

3. RESULTS

3.1 Scenario Methane/Steam

For the operation with methane and steam the optimization was facilitated within the boundaries defined in Table 1.

Table 1: Optimization domain and boundary conditions for CH_4/steam scenario.

	Max	Min	Unit
Fuel flow rate	~0.75	~0.32	slpm
S/C-ratio	2	1.5	-
Temperature	805	850	°C
Fuel utilization	80	20	%
Current	90	13	A
Voltage	-	0.65	V

The overall fuel flow rate could be defined at such low rates due to the internal reforming reaction of methane. Through that reaction one mole of methane and one mole of steam are converted to 3 moles of hydrogen and one mole of carbon monoxide (see (5)) and thus increase the overall volumetric fuel flow rate within the fuel cell.

$$CH_4 + H_2O \leftrightarrow CO + 3\,H_2 \quad (5)$$

The Steam/Carbon ratio, which is defined as the molar fluxes of steam over the molar fluxes of all carbonaceous species (in this case only methane):

$$S/C - ratio = \frac{\dot{n}_{steam}}{\dot{n}_{CH_4}} \quad (6)$$

is a metric, which can be used to evaluate the risk of carbon depositions. Those unwanted depositions cause a deactivation of the catalytic active surface of the SOFC and thus should be avoided. The range of the S/C-ratio was defined to stay within safe, yet reasonable operation modes where no carbon deposition may occur. The temperature range was defined in a way, so that the recommended temperature from the cell manufacturer (835°C) lies within the boundaries. Fuel utilization was limited according to manufacturer's recommendation and the current limited based on the capabilities of the in-house available

measurement equipment. Due to potential Ni-reoxidation below 0.65V the cell voltage was limited to values above 0.65V for the optimization.
For the maximum power optimization target, an electric power up to 53.5 W of electric power were suggested by the optimization algorithm. Thereby the following operation conditions were revealed as favourable:

- Maximum possible temperature
- Lowest allowable S/C-ratio
- Maximum possible fuel flow rate
- Highest possible current without violating the lower voltage border

For the maximum power optimization target in the H_2/steam-scenario, the same operation conditions as for the maximum power CH_4/steam scenario were revealed as favourable, whereby an electric power output of up to 60 W could be achieved:

- Maximum possible temperature
- Maximum possible fuel flow rate
- Highest possible current

To have a more realistic system evaluation, thermal losses were also considered for the efficiency evaluation. Overall, the thermal losses were assumed to be 10% of the total thermal energy within the system. These losses were considered by means of a heat exchanger with 90% efficiency. With this added heat exchanger also the pre-heating of fuel and air gas streams, as well as additionally required heating within the oven could be considered.
In Figure 2, the results of the efficiency optimization for the scenario CH_4/steam were visualized in a Sankey diagram. Thereby chemical bound energy is held in blue, thermal bound energy in red and electric energy is coloured in yellow and the following operation parameters and assumptions (marked with *) were used:

Table 2: Input values suggested by optimization algorithm for the CH_4/steam scenario for maximum electric efficiency.

Fuel util.	Temperature	CH4	H2O	Air flow rate	Heat exchanger eff.	El. Power
79%	850°C	0.126 slpm	0.19 slpm	4 slpm	90%*	40.8 W

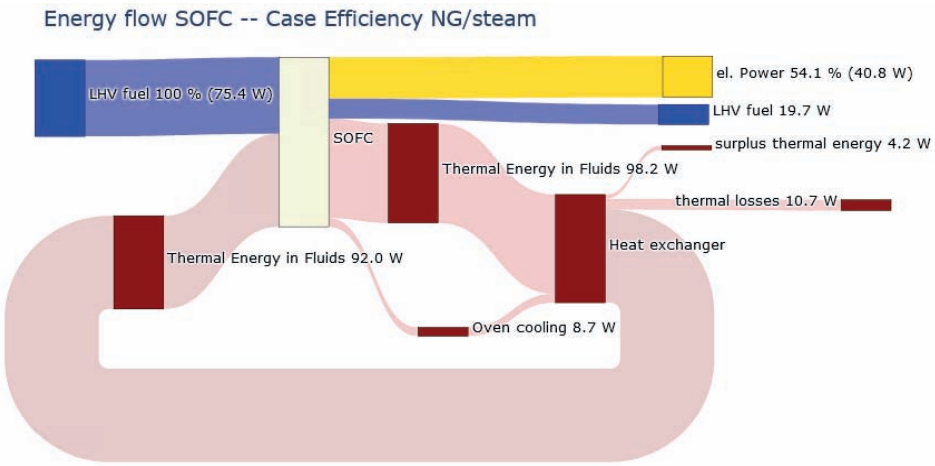

Figure 2: Sankey diagram for optimization target "maximum electric efficiency" for the CH_4/steam scenario. Blue paths represent chemical bound energy, red paths thermal bound energy and the yellow path represents electric energy. Oven cooling was used to close the energy balance.

Without considering the fuel utilization an electric efficiency of 54% could be achieved. Considering the fuel utilization, a process efficiency of up to 68% was observed (see equation (4)).

3.2 Scenario Hydrogen/Steam

For the scenario with only hydrogen and steam as fuel mixture the potential operation range for the optimization can be seen in Table 3.

Table 3: Optimization domain and boundary conditions for H_2/Steam scenario

	Max	Min	Unit
Fuel flow rate	2.437	0.522	slpm
Temperature	805	850	°C
Fuel utilization	80	20	%
Current	90	13	A
Voltage	-	0.65	V

The overall fuel flow rate range was defined with higher boundary values than for the CH_4/steam case due to the missing internal reforming that would have increased the fuel flow rate. For the parameters temperature, fuel utilization, current and voltage the same limitations than for the CH_4/steam case were applied.

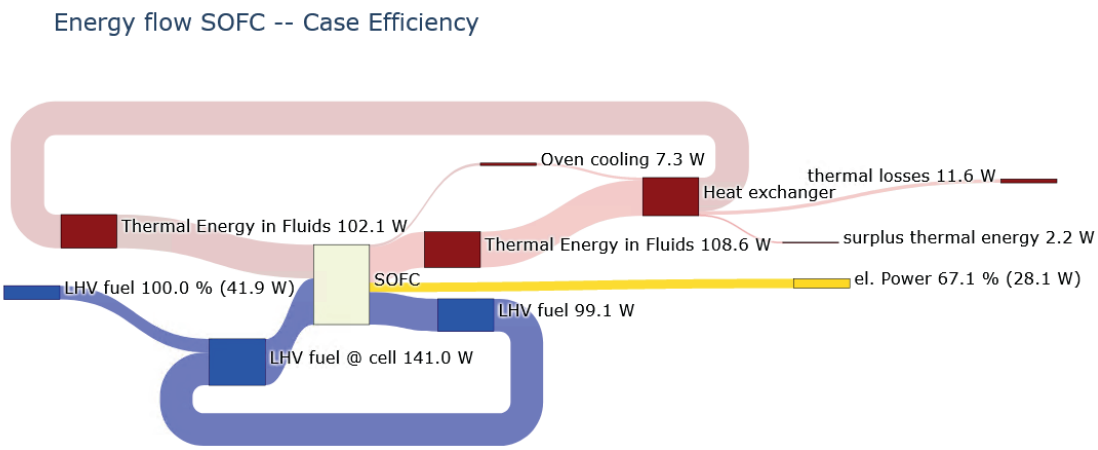

Figure 3: Sankey diagram for optimization target "maximum electric efficiency output" for scenario H_2/steam with off-gas recirculation

In Figure 3 the results of the efficiency optimization for the scenario H_2/steam were visualized in a Sankey diagram. Thereby chemical bound energy is held in blue, thermal bound energy in red and electric energy is coloured in yellow and the following operation parameters
and assumptions (marked with *) were used:

Table 4: Operation parameters for case „maximum electric efficiency" in hydrogen/steam scenario

Fuel util.	Temperature	H2	H2O	Air flow rate	Heat exchanger eff.	El. Power
30%**	850°C	0.784 slpm	0.196 slpm	4 slpm	90%*	28.1 W

** 30% of the total hydrogen supplied to the SOFC is utilized

4. DISCUSSION

4.1 Scenario Methane/Steam

The trends revealed for the maximum power output case can be explained as follows:
With maximum temperature the ionic conductance of the electrolyte is increased and thus the overpotential is reduced. This means that a higher current can be drawn from the cell and thus higher electric power output is achieved. The lowest allowable S/C-ratio leads to the highest possible reactant concentration in the fuel composition and together with higher overall fuel flow rates the chance of local fuel starvations that would lead to higher losses is reduced.
The reason, why maximum possible temperature and lowest allowed S/C-ratio are favourable also for maximum electric efficiency operation can be explained in the same way as for the maximum power case. In contrast to the maximum power case for maximum efficiency the fuel utilization rate is of higher importance. Every unused quantity of fuel has a direct negative influence on the electric efficiency as it increases the denominator in Equation (3) without also increasing the electric power output, leading to a

lower electric efficiency. The suggestion of applying the lowest possible overall fuel flow rate can be explained with the reduction of diffusion losses with lower fuel flow rates.

4.2 Scenario Hydrogen/Steam

In contrast to the CH_4/steam scenario, where the algorithm suggested solutions at the lower voltage limit, for the H2/steam scenario solutions with current values at the upper current limit were suggested. This behaviour can be explained by several effects. Firstly, with both H_2 and CO in the fuel mixture the Nernst voltage is lower than with just H_2 in it. Secondly, due to larger molecular size CO may cause higher diffusion losses and thirdly reaction kinetics for the H_2 are faster than for CO.For the maximum electric efficiency optimization target values above 70 % were suggested by the optimization algorithm. These values were only reached when thermal losses were neglected. When considering thermal losses of 10% of the overall thermal bound energy (here modelled as heat exchanger losses) a slight reduction of the overall achievable electric efficiency to around 67 % could be observed (see Figure 3). An explanation for that is that it is more efficient to utilize process heat from the SOFC than to electrically compensate (=heat up) the losses that occur.

5. CONCLUSIONS

The optimization revealed the following main trends regarding desirable operation parameters:

- Maximum temperature for both scenarios (operation with hydrogen and methane) and both max. efficiency and max. power
- Minimum allowable S/C-ratio for CH_4/steam mixtures
- Trade-Off between electric efficiency and electric power output

The highest electric power achieved through the optimization was in scenario H_2/steam with up to 60W for a commercial sized electrolyte supported single cell (126.5cm² active surface area). Electric efficiencies higher than 67% could be achieved for H_2/steam operation when using off-gas recirculating and assuming 10% thermal losses. Operation with CH_4/steam led to slightly lower performance values with ~54W maximum power and 54% electric efficiency at 79% fuel utilization. Thereby it has to be highlighted that no off-gas recirculation was assumed for this case and thus 20% of the reactants are discarded unutilized. When just considering the processed fuel gases a process efficiency of 68% was observed for the CH_4/steam operation scenario. With the method shown in this work, the optimization of the process parameters of industrial-sized solid oxide fuel cells could be carried out with significantly less time and financial effort than if experiments were performed. By using artificial neural networks as a meta-model, the time to predict the voltage for a set of operating parameters was reduced by more than 3500 times compared to the multi-physics model originally used. This speedup enabled the use of a genetic algorithm to optimize the process parameters, which required less than an hour in total to optimize the process parameters for one scenario and one optimization objective, which is significantly less than that required with experiments. With the time and cost reduction achieved, the commercialization of SOFC technology could be significantly accelerated.

6. ACKNOWLEDGMENTS

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THE IMPACT OF INDUSTRY 4.0 ON SUSTAINABLE DEVELOPMENT GOALS: SUSTAINABILITY, SOLAR ENERGY AND IOT ON CLEAN WATER FOR MARGINALISED COMMUNITIES

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Abstract: *The 17 Sustainable Development Goals, formulated in 2015 by the United Nations General Assembly, have been established in order to end poverty, improve health and promote prosperity and well-being through environmental sustainability. Sustainable development is defined as a balance between sustainable economic growth and ecological regeneration, requiring the fulfilment of environmentally friendly technologies that are efficient and adaptable to local conditions through the integration of ecological and engineering postulates. Significant technological evolutions have been listed during the last decades, in particular the so-called 4th Industrial Revolution, which refers to a technological, social, economic, political and cultural phenomenon that brings about a greater adaptability to the needs of production and an improvement in resource efficiency. The objective of this work is to propose how through the use of 4.0 technologies it is possible to respond to several of the SDGs, such as sustainable communities, social welfare and good health, water purification and sanitation, solar energy, and zero poverty. We present a case study featuring a portable, cost-effective solar-powered device for water purification, which exemplifies the potential of the Internet of Things (IoT) connectivity. This device incorporates a water quality monitoring system with satellite connectivity to facilitate timely notifications to technicians regarding repairs or replacements, thereby enabling marginalised populations to access clean water.*

Key words: SDG, Industry 4.0, solar energy, water purification, digitalisation

1. INTRODUCTION

The Sustainable Development Goals (SDGs), or Global Goals, are 17 goals that have been established in order to end poverty, improve health and education, and promote prosperity and well-being through environmental sustainability. They were formulated in 2015 by the United Nations General Assembly (UN-GA) with the proposal to achieve them by 2030. The philosophy of the 2030 Agenda is that "no one is left behind" and requires global alliances and participation in the integration of environmental dimensions, social, economic and governance in the development process. Sustainable development goals were established to end poverty, improve health and education, and promote prosperity and well-being through environmental sustainability (Berawi, 2019).

The concept of sustainable development is conceived as a balance of sustainable economic growth and ecological regeneration. Sustainable development requires the implementation of appropriate environmentally friendly technologies that are both efficient and adaptable to local conditions (Berawi, 2019). In this situation, ecotechnology can facilitate the conservation and restoration of the environment through the integration of ecological and engineering principles.

In relation to Engineering, important technological evolutions have been registered during the last decades. The advent of the global data communications network (Internet), Artificial Intelligence (AI) and cyber-physical systems (CPS) no longer produce an evolution but a technological revolution with high social impact (Salimbeni, 2019). All these technologies aim to improve the connectivity between the components within the industry, and to build an inclusive and sustainable industrial development (Hidayatno, Destyanto and Hulu, 2019).

Towards the end of the 18th century, the beginning of the 1st Industrial Revolution was determined, primarily, by the invention of the steam engine, but the entire process originated in England brought with it profound economic, social, scientific and technological transformations that established the development achieved as a consequence. In addition, the exodus of the population residing in rural areas towards industrial areas allowed the growth of cities by modifying their structure and size, such as the

construction of factories. Thus, the 1st Industrial Revolution ended in the 1840s and during the 19th century, with the industrial use of electricity, the 2nd Industrial Revolution began, which implied the expansion of development by countries in Europe, Asia and North America. Not only were there the technological advances acquired in the 1st Revolution, but also access to natural resources that were not previously available or were considered of little use, such as the use of metals like steel, aluminium or copper, among others, and chemical products. The world of transportation had new technologies, allowing the connection and expansion of markets that were previously unconnected and the transportation of people and merchandise by rail or other transportation that implemented the use of fossil fuels such as oil. The so-called 3rd Industrial Revolution, in the middle of the 20th century, began with the invention of semiconductor and digital techniques. The concept of "Information Society" was formulated based on the confluence of new communication technologies between markets. Thus, the 3rd Revolution introduced information technologies, communication, process automation and the development of renewable and sustainable energy. Finally, the 4th Industrial Revolution, a concept introduced in 2011, refers to a technological, social, economic, political and cultural phenomenon that has been developing since the 1st Revolution originated in Europe in the 18th century, and which gave rise to to an urbanised and industrialised society and to smart factories (4.0 factories), which included greater adaptability to production needs and improved resource efficiency. The 4th Revolution is based on AI, the use of CPS, the Internet of Things, mobile communications and interoperability between the "real" and the "virtual" world, connecting the first 3 Industrial Revolutions in terms of organisation and automation of production and marketing processes and means. In line with these objectives, the 4th Industrial Revolution is believed to have significant relation with sustainable energy (Hidayatno, Destyanto and Hulu, 2019). Data collected in 2020 during the testing of the tool for 28 EU countries indicate that, initially, strengthening social aspects should become a priority. This means that social smartness is a basis for smart and sustainable EU 4.0. However, the main long-term objective should be a high balance of technological and social indicators. Consequently, the organisation's knowledge of the factors to develop in the first place and the factors that can be achieved at a high level in the long run is important (Adamik and Sikora, 2021).

This article presents the design of a device that works as a solution to deliver drinking water to marginalised communities, in emergency situations and/or without the possibility of accessing urban centres or their basic services due to distance, weather conditions, difficulty or inability to move, among others. The solution is not only proposed to generate an immediate impact, but also as a resource for the introduction of a notable improvement in the quality of life of people and their conditions of access to drinking water. Using solar energy collected by solar panels strategically located in areas where a response to the problem is imperative, a portable device capable of purifying water from rivers, wells, streams or other sources of nearby fresh water was designed, with the capacity of performing process monitoring using IoT sensors. These sensors will collect relevant information such as temperature, humidity, pressure, presence of minerals and chemical contaminants (such as arsenic) in the water, among other variables, and the data will be sent to the cloud via satellite communication to be processed. In addition to allowing monitoring and control of the process, this data flow will enable preventive, corrective, prescriptive and predictive maintenance. This development makes use of some of the most important enabling technologies of Industry 4.4 (I4.0), such as satellite communication, Cloud Computing, Big Data & Analytics, AI, among others.

In this way, the objective of this work is to propose a solution to this problem through the use of 4.0 technologies, responding to several of the Sustainable Development Goals (SDGs), such as sustainable communities, social well-being and good health, purification and sanitization of water, solar energy and zero poverty (Mabkhot et al., 2021).

2. I4.0 & ENERGY EFFICIENCY

2.1 Industrial and Sustainable Development

Industrial development refers to the practice and study of how industry responds to current sustainability challenges and eventually becomes part of a larger, fully sustainable system. For its part, sustainable development can be understood as development that raises the standard of living of current generations in such a way that the same aspirations can be fulfilled by future generations. This addresses not only environmental responsibility, but also economic and resource efficiency, and social equity (for example, advanced technologies linked to social sustainability, as they can improve ergonomics, worker safety, and facilitate risk assessment, etc.) (Adamik and Sikora, 2021).

One of the sources of sustainable development are intelligent organisations. They have the ability to dynamically adapt by creating, obtaining, organising and sharing knowledge that can then be used to create and exploit new opportunities to increase operational effectiveness, sustainable development and competitiveness in the global marketplace. In other words, when something is "smart", its innovations are implemented proactively with an aspirational and goal-oriented purpose, thus leading to the achievement of a desired future (Adamik and Sikora, 2021).

Furthermore, energy efficiency is linked to the digital transformation that may change the processes in the industry, which are highly influenced by technological innovations. While the number of industries using I4.0 technology increases, industrial productivity will also experience the same growth (Hidayatno, Destyanto and Hulu, 2019).

Sustainable I4.0 should include many elements, such as: energy management, reduction of greenhouse gas emissions, reduction of negative environmental impact, reduction of raw materials consumption, water management, social and economic sustainability, and even life cycle assessments (LCA) (Gajdzik et al., 2020).

2.2 Circular Economy, I4.0 and Sustainability

Like sustainable development, I4.0 emphasises efficiency, productivity, continuous improvement, and a better customer experience, contributing to sustainable manufacturing. These initiatives can provide manufacturers with many advantages such as cost savings due to material, energy and resource efficiency, brand reputation, public trust and competitiveness (Ching et al., 2022).

Likewise, we are currently facing the challenge of producing more and more products to satisfy growing consumption, from increasingly scarce resources and trying to reduce pollution and damage. Therefore, I4.0 offers a way to face these challenges, since they are aimed at achieving sustainable development in the economic, social and environmental dimensions (Gajdzik et al., 2020).

The Circular Economy is a systematic change towards a viable but regenerative economic model, based on the reinsertion of used resources through material cycles (technological and biological). In addition, the Circular Economy model promotes the minimization of resource consumption, waste generation and emissions while ensuring socioeconomic development (Dantas et al., 2021). However, the transition from a Linear Economy to a Circular Economy requires investment and technological development. That is why the Circular Economy is closely related to the revolution brought about by I4.0 (Sulich and Rutkowska, 2021).

Nevertheless, despite the relationship between both models, Circular Economy and I4.0 were considered for many years as two individual processes or flows (Reddy, Reddy and Prakash, 2020). Their convergence and combination is called the CE-I4.0 nexus and is a promising research topic linking innovative technologies with system-wide changes in our economic and industrial models (Dantas et al., 2020).

The I4.0 revolution promises significant changes in technology and part of them can be dedicated to supporting the transition to CE or protecting the environment (Sulich and Rutkowska, 2021). The Circular Economy proposes an innovative path towards sustainable development introducing a different way of perceiving value in the management of natural resources (Dantas et al., 2020).

The Circular Economy is a useful tool to achieve the 2030 agenda of the SDGs. The transition to a Circular Economy can keep the value of resources and products at a high level and minimise waste production (Khajuria et al., 2022). This has significant potential to achieve sustainable development by halting the depletion of natural resources, reducing environmental damage from the extraction and processing of virgin materials, and reducing pollution from processing, use, and end-of-life procedures (Khajuria, 2021).

2.3 Technological Pillars in I4.0

The I4.0 allows the complete digitization of value chains, from suppliers to end customers, through the integration of data processing technologies, intelligent software and sensors, in order to be able to monitor, predict, control, plan and intelligently produce what generates the greatest value for the entire chain. The IoT, AI and CPS are pillars of the I4.0 (The Industrial Internet of Things Volume G1: Reference Architecture, 2019).

The I4.0 concept is based on key pillars which result from continuous advances in new technologies, such as the Internet of Things, cloud computing, Big Data, modelling and simulation, autonomous systems AS), augmented reality (AR), additive manufacture (AM) and cybersecurity (Gajdzik et al., 2020).

The implementation of technology advances in I4.0 can result in cutting-edge solutions based on data collection and intelligent manufacturing processes. These technologies are not only beneficial due to their

manufacturing advantages, but also because they can be used to reduce waste generation, minimise environmental impacts, and help push industrial development to cleaner production processes. However, investing in technology is not enough to achieve the SDGs because a single focus on technology development may lead to industrial growth, but at the same time, it can increase greenhouse gas emissions and further diminish the availability of natural resources.

2.4 AI in achieving the Sustainable Development Goals

The application of Artificial Intelligence (AI) has the potential to play a crucial role in the achievement of the Sustainable Development Goals by facilitating the delivery of essential services such as food, health, clean water, and sustainable energy to communities worldwide (Vinuesa et al., 2020). It can also contribute to the development of low-carbon systems by enabling the creation of Circular Economies and smart cities that optimise resource utilisation (Chui, Lytras and Visvizi, 2018).

One of the significant advantages of AI lies in its ability to analyse vast interconnected databases to develop joint actions aimed at preserving the environment and promoting sustainable practices. Reported potential impacts of AI indicate both positive and negative impacts on sustainable development. The integration of AI into various sectors holds promise. For example, in agriculture AI-powered systems can enhance crop yields by optimising irrigation, fertilisation, and pest control, leading to increased food production and reduced food waste (Dharmaraj and Vijayanand, 2018).

Another promising field is healthcare, where AI algorithms can assist in early disease detection and personalised treatment plans, improving health services and patients' lives (McKinney et al., 2020). Furthermore, AI can contribute to the development of clean and renewable energy sources through the optimisation of energy production, distribution, and consumption.

On the other hand, it is important to acknowledge that the development of AI also presents challenges and potential risks to sustainable development. The large-scale collection and analysis of data required for AI systems involves large amounts of energy to power and cool the facilities where the programs are being run. In addition, the production of the hardware necessary for AI to function also entails a significant energy consumption. Moreover, it also raises concerns regarding privacy, data security, and ethical considerations. Therefore, it is essential to ensure responsible and inclusive AI deployment, considering its potential impacts on social, economic, and environmental dimensions and sustainable development.

In summary, AI has the capacity to act as an enabler for achieving the SDGs by supporting the provision of vital services. However, careful consideration must be given to the ethical, social, and economic implications of its implementation. By addressing these challenges and harnessing the potential of AI in a responsible and inclusive manner, we can accelerate progress towards a more sustainable and equitable future.

2.5 IoT in Sustainable Analytical Chemistry

The Internet of Things (IoT) plays a significant role in enabling real-time data acquisition and analysis, not only for industrial processes but also for monitoring various environmental conditions and human health. By leveraging IoT technology, it becomes possible to remotely access and examine analytical information, providing valuable insights and facilitating informed decision-making. In the context of sustainability, the development of analytical methods is crucial, and it necessitates the consideration of several key factors (Cadeado et al., 2022).

Firstly, these methods should have minimal environmental impact, ensuring that they do not contribute to pollution or resource depletion. By adopting sustainable practices in analytical processes, such as reducing chemical waste and energy consumption, it becomes possible to minimise the environmental footprint associated with analytical testing.

Secondly, sustainable analytical methods should also bring economic benefits to society. This can be achieved by optimising resource utilisation, reducing costs, and improving efficiency. By implementing cost-effective and resource-efficient analytical techniques, the financial burden associated with testing and monitoring can be reduced, making these methods more accessible and affordable for various stakeholders.

For instance, one innovative example of a sustainable analytical device is the use of fibre optics to transport light directly to a detector, such as a Raspberry Pi Camera. This device employs absorption and fluorescence measurements to detect contaminants like E. coli and total coliform in water. Using fibre optics, this method minimises the use of chemical reagents and reduces waste generation, making it environmentally

friendly, and its portability facilitates *in situ* analysis. Additionally, the Raspberry Pi Camera provides a cost-effective and accessible platform for data collection and analysis.

3. CASE STUDY & DISCUSSION

3.1 Real Life Case Study: I4.0 Enabling Technologies

The integration of I4.0 (I4.0) enabling technologies presents real-life case studies that demonstrate their potential in addressing sustainable development challenges. One such example is a portable water purification equipment, prominently featured in the photo. This innovative solution operates on battery power and is further supplemented by solar panels, highlighting its self-sufficiency and renewable energy reliance. The equipment, manufactured by a Brazilian company called PWtech, is specifically designed to provide drinking water to marginalised communities.

Figure 1: Portable water purification equipment. Source: PWTech photo.

By leveraging IoT connectivity, cloud computing, and big data analytics it becomes possible to remotely monitor and assess water quality, enhancing efficiency and effectiveness. This integrated approach allows for real-time testing and analysis of water samples, enabling proactive interventions and preventive measures to maintain water quality standards.

Furthermore, the autonomous operation of the water purification equipment is facilitated by solar energy. This ensures continuous and sustainable operation, even in areas with limited or no access to traditional power sources. The use of solar power aligns with the goal of promoting renewable energy solutions and reducing carbon emissions.

Additionally, the implementation of advanced analytics and predictive maintenance techniques for the equipment ensures optimal performance and longevity. By analysing data collected from the equipment's sensors, it becomes possible to detect potential issues or malfunctions in advance, enabling timely maintenance or repairs. This proactive approach minimises downtime, increases equipment lifespan, and reduces operational costs.

By combining IoT connectivity, cloud computing, big data analytics, and solar energy, this case study showcases the practical application of I4.0 technologies in promoting sustainable development and improving the well-being of marginalised communities through the provision of clean drinking water. It serves as a testament to the positive impact that technology can have on achieving the United Nations' Sustainable Development Goals (SDGs) and fostering a more sustainable and equitable future.

3.2 Discussion

Urbanisation prompts a larger migration of rural population to an urban area, leading to an increase in energy usage and consumption (Zakari et al., 2021). The need for Solar Water Heater (SWH) is increasing daily due to some factors such as electric power deficiency, high fuel price, rapid urbanisation, low cost of installations, government intervention and environment-friendly applications, which acts as a direct replacement to fossil fuels. Considering the epileptic nature of electric power outages in developing countries, the reliance on solar applications for water heating will lead to better reliability of service for hot water needs and will have minimal negative impact on environment pollution (Bori et al., 2022). Not only are marginalised communities unable to provide themselves with hot water for bathing, for example, but also clean water for consumption. The consumption of non-potable water in developing countries generates thousands of deaths per year. In both developed and developing countries, current infrastructure for wastewater treatment and the safe production of water that is readily available is struggling to stay up with more and more severe regulations and the growing need for superior purity water. The rapid growth of population expansion in emerging regions will proceed to increase hygienic water needs from a residential, agricultural, industrial, and energy viewpoint in the coming decades. By 2025, it's expected that half of the globe's population would live in water-stressed areas (WHO, 2014) (Singh, Singh and Rai, 2021).

Water is the most valued and important resource in the world and the lack of it has become a serious problem. Industrialization, urbanisation, and climate change have created an urgent demand for the clean water that is so essential to human health. Lack of water can cause diseases such as typhoid fever, dysentery, cholera, and diarrhoea, resulting in many deaths worldwide. There are traditional methods that include processes such as filtration, sedimentation, distillation, and chlorination, but these have limitations and can be resistant to, for example, antibiotics. Water purification involves removing undesirable chemicals, biological contaminants, or even suspended solids from water systems to produce clean, safe water for human consumption and other purposes (Spoiala et al., 2021).

4. CONCLUSIONS

Different research projects are promoted to encourage smart and sustainable growth through innovation and to create an ecosystem favourable to the development of companies. A case has been presented where the new applied technologies are applied for the good of the most vulnerable communities. The 4th Industrial Revolution is currently in a new phase where the effects caused to the ecosystem and society are fundamentally considered. More attention is being paid to ecology, to the reuse and/or recycling of products once their useful life is over. Organisations make use of the new T4.0 in order to consider sustainability, sustainability and the Circular Economy as an additional factor of utmost importance and with the Sustainable Development Goals (SDGs).

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TRAFFIC LIGHT SIGNALIZATION BASED ON RENEWABLE ENERGY SOURCES: FEASIBILITY AND CHALLENGES

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Abstract: *On the path to carbon neutrality, the leaders of the European Union have agreed to cut greenhouse gas emissions by at least 55% by 2030. The Republic of Serbia and Bosnia and Herzegovina are following the same path and plan to increase the share of renewable energy sources to at least 40% by 2040. During our research as part of the project "Application of Systems Based on Renewable Energy Sources in the Area of AP Vojvodina and the Republic of Srpska" (2022-2023), funded by AP Vojvodina, we concluded that the availability of solar powered traffic light signalization is very scarce in the territory of Serbia and the Republic of Srpska. In our research, we used an ad-hoc questionnaire and personal interviews to collect data from representatives of all municipalities in the Republic of Srpska as well as from representatives of the City of Novi Sad. The results of this research, in addition to the overview of the current situation, will provide the basis for understanding the challenges and potential issues of the substitution of conventional traffic light signalization with signalization based on renewable energy sources on a national scale.*

Key words: Renewable energy, Carbon-neutral, Solar energy, Traffic signalization, Green energy

1. INTRODUCTION

According to the 2030 Climate Target Plan, the European Union set a path to achieve climate neutrality by 2050, while stimulating the creation of green jobs and continuing the EU's track record of cutting greenhouse gas emissions. This plan is in line with the Paris Agreement objective to keep the global temperature increase well below 2°C and pursue efforts to keep it at 1.5°C (European Commission, 2023). The Green Plan states that "No person and no place is left behind", which means that the proposal includes mechanisms for fair transition that should facilitate transition to regions that depend on thermal power plants and coal mines.

Serbia and Bosnia and Herzegovina have also committed to achieving carbon neutrality by 2050 and to aligning with the European Green Deal's key elements by endorsing the Green Agenda for the Western Balkans at the Summit in Sofia in 2020 (Regional Cooperation Council, 2023). The European Green Deal covers all sectors of the economy, from biodiversity to energy and from transport to construction. It includes key policies and measures such as the Farm to Fork Strategy and the New Circular Economy Action Plan.

In March 2021, the Government of Serbia adopted a law on climate change that set a legal framework for future action on reducing greenhouse emissions. Additionally, in April 2021, Serbia adopted a package of important energy laws, including new laws on renewables and energy efficiency and set strategies for the transformation of its energy sector. One of the main targets of this strategy is to increase the share of renewable energy sources to at least 49.6% by 2040, compared to 26.3% at the end of 2020 (Chamber of Commerce and Industry of Serbia, 2023). Bosnia and Herzegovina have significant renewable energy potential, particularly in hydropower, solar and wind power capacity. Hydropower provided 37 percent of the country's total electricity production in 2021 and there is room for additional growth. Recently, solar and wind power plants have emerged but remain a small percentage of the overall energy mix at about 5 percent (International Trade Administration, 2022). The main issue with further migration from the current main energy source, coal, is the lack of initiative from the already established coal industry and outdated legislation that is not in line with the energy sector trends (Miljevic et al, 2020).

There are many challenges when switching to renewable energy sources, as there is an issue with their availability. Renewables, such as solar power and wind power, are available in sufficient supply during certain seasons or times of day, and in certain regions. Therefore, battery storage system or connection

to the grid must be deployed. Determining an appropriate diversification of renewables that can enable uninterrupted energy supplies and satisfy various requirements, such as budgets and national regulations, is a great challenge for all governments (Nguyen et al, 2021; Mulugetta et al, 2022). When defining the spatial allocation of wind turbines and photovoltaic power plants, environmental impacts and disturbance to humans must be taken into consideration (Drechsler et al, 2017). This is also the case when using hydropower, as it can affect aquatic ecosystems and increase cross-sectoral water conflicts (Gonzalez et al, 2023). In order to maximize the benefits of hybrid wind/solar solutions and provide energy stability, it is important to strongly promote regional cooperation (Liu et al, 2020).

Traffic light systems are universally and widely used signalling devices for traffic regulation around the world. They have undergone many changes since they were first introduced in the nineteenth century. However, there are many aspects of its functionality that can be improved and aligned with the progress of both the information technology and energy sectors. There is significant research centred around increasing the energy efficiency of traffic light systems by switching to renewable energy sources and light-emitting diodes (LEDs). Widespread replacement of incandescent bulbs with LED lamps has been conducted in most regions, but they are still mostly powered by a high-voltage power supply (Diong, 2014). Recent developments have the goal of reducing costs and improving the energy efficiency of traffic light systems by providing a low voltage power supply, usually while relying on renewable energy sources and a backup battery storage system. Proposed solutions (Costa et al, 2010; Jeon et al, 2015; Saji et al, 2019) validate the energy efficiency of such systems, while (Diong, 2014) and (Chiradeja et al, 2020) verify their economic feasibility.

This paper presents the results of the research conducted as part of the project "Application of Systems based on Renewable Energy Sources in the Area of AP Vojvodina and the Republic of Srpska" (2022-2023), funded by AP Vojvodina. Solar panels have been chosen as a renewable power source due to their price decrease and increasing lifespan. Considering the questionnaire results and interviews with transportation sector representatives, current setbacks and challenges have been analysed. The results of this research can be used to broaden understanding of the potential issues and challenges that can emerge when solar powered traffic light systems are implemented.

2. MATERIALS AND METHODS

Our research has been conducted in Serbia and Bosnia and Herzegovina, during 2022 and 2023. We used an ad-hoc questionnaire and personal interviews to collect information from representatives of all municipalities in the Republic of Srpska and from representatives of the City of Novi Sad. The questionnaire required information about the current state of traffic light systems in the municipality, the availability of solar powered traffic lights, availability of other solar powered traffic signalization and whether there are any funds allocated for their implementation in the future.

In the City of Novi Sad, the largest municipality and the capital of the Autonomous Province of Vojvodina, we also carried out personal interviews with the supervisors, engineers and the Head of Department for the Development and Traffic Management for the City of Novi Sad. In the interview, we gathered information about challenges that could arise if traditional traffic lights were replaced with solar powered traffic lights.

3. RESULTS AND DISCUSSION

Based on the data received through the questionnaire that has been answered by the officials for the development and traffic management of the City of Novi Sad, there are no solar powered traffic lights on the territory of the City of Novi Sad and no resources are allocated for their future implementation. However, there are a dozen solar-powered road traffic counters and solar-powered flashing traffic signs (Figure 1).

Figure 1: Solar-powered flashing traffic signs

Current state is similar for all fifty analysed municipalities of the Republic of Srpska, where there are no traffic light systems powered by solar panels. However, there are 55 solar-powered road traffic counters and 10 solar-powered flashing traffic signs. Same as in the City of Novi Sad, there are no resources allocated for the future substitution of conventional traffic lights with solar powered traffic lights.

When discussing potential issues that could emerge if solar panels replaced conventional power sources for traffic light systems, the traffic sector representatives pointed out that the priority of traffic lights is to enable safe and reliable traffic flow. Their uninterrupted functionality must not be hindered under any circumstance, which can be a potential problem if solar panels are used as the main power source. Despite the favourable photovoltaic potential of the region, the number of sunshine hours and photovoltaic power output is not uniform across the whole year (Figure 2). Therefore, a solar panel on its own cannot always generate a sufficient amount of electricity. This issue can be solved by using a battery storage system and connection to the grid, but their integration into the system introduces new issues. With several power supplies, it is more difficult to supervise the system and ensure that a continuous power supply is available at all times. In case of damage to the solar panel or the battery, the system would have to immediately switch to the grid.

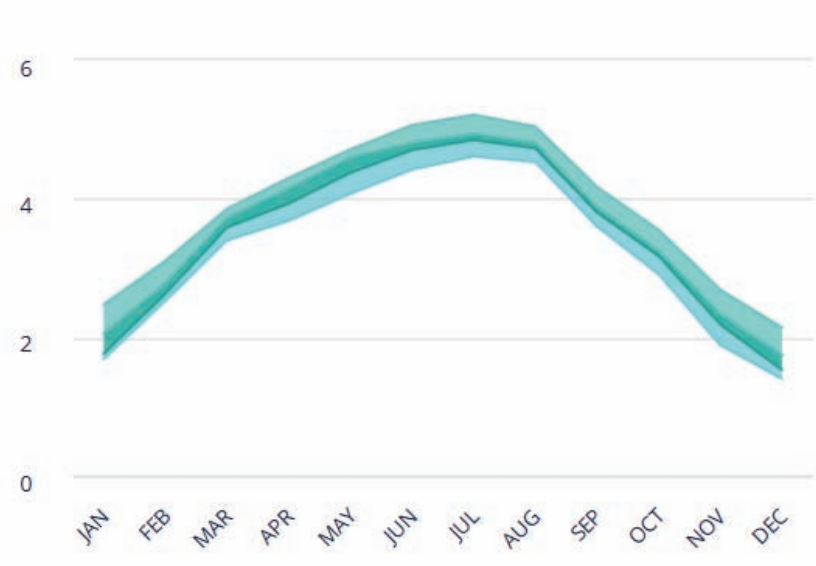

Figure 2: Monthly variation of photovoltaic power output (ESMAP, 2020)

Regular maintenance of such systems would be problematic due to several reasons. The first is their location. Solar panels require regular cleaning, which can interrupt traffic. Repair of solar panels would cause an even greater disturbance to the traffic, as in this case the equipment would have to be approached with a crane or similar vehicle that can block an intersection. The second issue is a lack of trained manpower that can handle the maintenance of traffic light systems, which would be even more persistent if solar powered traffic lights would be introduced. Lastly, the manufacturers of solar panels require that the equipment is maintained through the official manufacturing channels, but this service only includes regular maintenance and could not provide enough support for emergency repairs and replacements needed for normal functionality of traffic light systems.
The officials also pointed out the issue of installing the equipment in such way and position that does not interfere with traffic. If the solar panel would be the main source of electricity for these systems, it would be important to position them in such a way that they do not block the signalization or distract the traffic participants. The battery must also be properly stored, which can take up a lot of space. However, the storing container must be according to the standards, as the batteries are sensitive to low temperatures and their capacity could be greatly diminished if they are not well protected. The battery containers of the currently installed solar powered traffic signalization, with their large cases (Figure 3), have protected the batteries well from harsh temperatures. However, when scaling this battery to a more demanding traffic light intersection, this case could be too cumbersome and would take too much space.

Figure 3: Solar powered traffic sign battery case

An additional issue that is aggravated with the introduction of solar powered traffic systems is the cost of each piece of equipment in the system, which leads to a high price for their replacement. Apart from regular replacement due to equipment malfunction or exceeding the equipment lifespan, there is also the case of vandalism. Comparing to the conventional traffic lights, solar powered traffic lights' components are frailer and thus easier to damage.

4. CONCLUSION

In our research we analysed the current state of traffic light systems in the territory of the Republic of Srpska and the City of Novi Sad, as well as potential issues that could arise if solar powered traffic lights were introduced. As the availability of solar-powered traffic signalization is very limited in these regions, there is a lot of room for improvement in this area, which is in line with the European carbon neutral future. According to our research and available research results in the rest of the world, the transition to solar powered traffic lights has both environmental and economic benefits. Our region, with its continental climate that has no extreme high or low temperature, but also a sufficient number of sunshine hours and wind, is suitable for the widespread implementation of renewable energy power sources.

Currently, there are many challenges that are recognized by transportation sector officials and experts, but renewable energy technology and its availability on a global level are improving each day. Using information about all issues and challenges presented in this research paper, local communities should make an effort to overcome the initial barrier and convey the transition to renewable energy powered traffic systems. It is possible to introduce such traffic systems gradually, which would put less strain on municipal budgets and organization. Also, this would give more time to retrain current workers and hire new ones to operate solar-powered equipment, which would increase employment. Future research can be directed toward determining the exact financial benefits and greenhouse gas emission reduction when all traffic light systems use solar panels as their primary power source. Also, appropriate diversification of renewables by each region could be determined to expand the renewable energy source to wind and potentially hydropower.

5. ACKNOWLEDGMENTS

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CYBER RISK MANAGEMENT WITH THE HELP OF ARTIFICIAL INTELLIGENCE IN SMES: ANALYSIS OF BARRIERS AND NEEDS

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Abstract: *Cyber Risk Management is a critical concern for Small and Medium Enterprises as they increasingly become attractive targets for cyber-attacks. Despite this, many Small and Medium Enterprises lack awareness about the growing cyber threats they face. With artificial intelligence tools' emergence, opportunities and threats for cyber attackers and defenders have heightened. Small and Medium Enterprises require resources and knowledge to protect themselves against cyber-attacks effectively. Social engineering attacks like phishing emails or malware-infected websites are common in the digital landscape. This paper provides an overview of barriers and needs in Cyber Risk Management for Small and Medium Enterprises, based on a literature review conducted via Web of Science, Scopus, and Google Scholar. The current state of Cyber Risk Management in Small and Medium Enterprises is analyzed, focusing on identified shortcomings. Additionally, the availability of AI tools for Small and Medium Enterprises is examined, and best practice examples are provided to guide Small and Medium Enterprises in improving their cybersecurity.*

Keywords: Cybersecurity, Cyber-Risk-Management, Artificial Intelligence

1. INTRODUCTION

In recent years, cyber security has become an enormous issue for companies. Small and Medium Enterprises (SMEs) have emerged as desirable targets. In these companies, there is usually no dedicated cyber risk management, if there is any risk management. This neglect of cyber security can lead to existentially threatening damage. Computer networks are becoming more complex. More and more machines and systems are being added to these networks and thus offer more and more attack surfaces for harmful cyber-attacks. Phishing, malware, and ransomware attacks are widely spread and do not only target large corporations (Bin & Ali, 2022).

Artificial intelligence (AI) is also a factor that has caused more and more turmoil in recent years, notably in recent months. Artificial intelligence can become a danger in the cyberspace, especially for SMEs, but it can also be used to protect against attacks (Kant & Johannsen, 2022). Cybercrime can be reduced with the help of this technology, and attacks can be detected and averted. With AI, decisions can also be made in crucial cyber risk management. Above all, malware can be identified with the help of AI-based tools. (Jakka et al., 2022).

To find out exactly how aware SMEs are of the seriousness of the situation, this research analyses the current literature using a systematic literature review. This literature review aims to analyze the current threats in the cyber environment of SMEs. In section 2, possible risks that threaten SMEs are searched for and explored in more detail. Section 3 explains the threats in more detail and explains possible counter-strategies. These are described in best practice examples. A small focus is set on Artificial Intelligence.

2. Systematic Literature Review

The Systematic Literature Review (SLR) guidelines by Wright et al., (2007) were used as orientation. This paper explains a simple seven-step plan to help create an SLR. The seven steps are the definition of a research question, the creation of a search protocol, the literature search, the data extraction, a quality appraisal, a data analysis and results and finally the interpretation of the results. To begin the systematic literature review, the following research question was asked first:

"What are the current cyber risks SMEs face, and what is the role of Artificial Intelligence in cyber security?"

The databases Web of Science, Scopus, and Google Scholar were searched. Scopus, the largest citation database for peer-reviewed literature, offers a dynamic and configurable search system. In the first search, the following search string was used: (TITLE-ABS-KEY (smes AND cyber AND security). This string yielded 196 results. The second search extended the string to (TITLE-ABS-KEY (artificial AND intelligence AND smes AND cyber AND security), which got 15 results. The second search was conducted on Web of Science, a comprehensive research database and citation index provided by Clarivate Analytics. It was chosen because

it has a curated, published, peer-reviewed content database. The same two search strings were used to search. The first search yielded 107, and the second 12 results. The last search was conducted on Google Scholar, a freely accessible web search engine provided by Google that focuses on academic literature. This database lacks a configurable search system, and the search terms yielded 34.200 and 15.900, respectively. However, only the first few pages are relevant results, and none of the papers found were new.
Exclusions and inclusion criteria were defined to narrow the search further following limitations. The language of the literature was kept in English only. Only information technology (IT), operational technology (OT), Computer Engineering Business, and Management literature were used. Articles and conference papers were included, whereas books and book chapters were excluded.
After a title analysis, the individual abstracts of the papers were reviewed for relevance. In the end, 69 papers remained that were equipped with relevant information. These articles were sorted by title and year, and relevant risks were extracted. Mendeley was used to sort the research results, where entries found twice were eliminated.
The following paragraphs show some of the more interesting papers. Haastrecht et al. (2021) show some promising findings in their work. They identify many threats SMEs face, like malware attacks, ransomware attacks, Phishing, and DoS and DDoS attacks. In their paper, they write about cyber threat intelligence (CTI) to improve collective cybersecurity resilience and want to bring this strategy to SMEs. Haastrecht et al. (2021) published a second paper in which they write about motivating SMEs using Self-Determination Theory (SDT) to implement cyber risk management and conduct a cyber risk assessment.
Artificial intelligence was also a focus of the investigation. Rawindaran et al. (2021) write about the cost benefits of using machine learning features in Network Intrusion Detection systems NIDs for cyber security. They mention a cyber pandemic where the pattern recognition of machine learning tools can be used to protect data and prevent cyber-attacks. Automated security event responses are the focus of the research of Fraley & Cannady (2017). In combination with Neural Networks, or Deep Neural Networks, a vast amount of data can be analyzed, and different patterns could be found that indicate threats like data leaks or network intrusions.

3. RESULTS AND DISCUSSION

This Section presents the results of the systematic literature review. It is interesting to look at the publication years of the individual papers. Figure 1 shows that in the early 2000s, hardly any articles were published on cyber security in SMEs. Cybersecurity was a generally new topic, and much basic research had to be done. Around the beginning of the 2010s, interest in this area began to take root. Cyber security concepts were concretized and also applied to SMEs. Only at the end of the 2010s can one see the beginning of an upswing. Especially the years during and after the COVID-19 pandemic show a significant increase in interest in the topic. Cyber security naturally became a big issue here with the forced digitalization. Smaller companies have also brought their networks online and thus offered a large surface for potential attacks. The need for solutions and information about risks has naturally also increased.

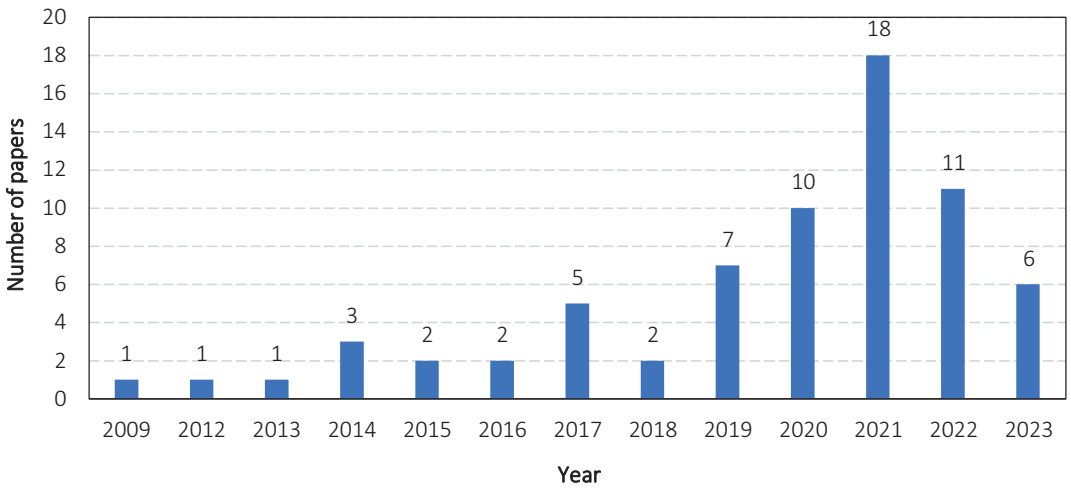

Figure 1: Publication Year of the Found Research Results (N=69)

In Figure 2, it can be seen that the main threat from SMEs is malware attacks. Malware is malicious software that can enter corporate networks through multiple routes. It is often a carelessly clicked link that leads to

an infection. There are many different types of malware. Ransomware, spyware, and adware were explicitly mentioned in the papers. Ransomware usually locks a system and demands a ransom to rerelease it. Spyware is used to steal data such as passwords, and adware is an annoying ad that gets stuck in the PC's software, usually the browser.

The second most frequently mentioned attack is phishing. The term phishing is made up of the word's password and fishing. The attacker tries to appear as a trustworthy person or institution to steal sensitive data from the victim via email, telephone, or text message. Spear phishing was also mentioned. This is a phishing attack that targets a specific person or company. Phishing and spear phishing belong to the group of social engineering attacks where the social characteristics of people are actively exploited to obtain information (Bada & Nurse, 2019).

In third place, there is another point that has often been mentioned. Lack of awareness was noted in 24 articles. The management has much catching up to do in this area. In addition to this problem, there is a lack of resources, a lack of knowledge, and the a of cyber risk management. The management must inform their staff about potential risks, provide enough funding, and help keep the potential of cyber threats as low as possible. Employees, in general, could be a risk to the company's cyber security. A lack of training can make them susceptible to social engineering attacks like phishing attacks, and they could become an insider threat. This can happen intentionally or unintentionally. Weak passwords can lead to data breaches or identity theft. It can be seen that the human factor can lead to a variety of problems (Kalhoro et al., 2022).

Denial of Service or Distributed Denial of Service attacks, also known as DoS and DDoS attacks, specifically target servers or web applications to interrupt the service of these systems. In general, the network of SMEs is constantly strained (Pawar & Palivela, 2022). Be it attacks like the Man in the Middle attack, where an attacker interposes himself between two communicating systems, or an Eavesdropping attack where communications of networks are intercepted and essential data is stolen (Zeadally et al., 2020).

The networking of devices and the ever-smarter development of companies also lead to new risks and areas of attack. Internet of Things threats have become increasingly relevant in recent years. Smartphones, old machines connected to the company network, or laptops carried from the company network to public networks for home offices offer new attack opportunities (Vakakis et al., 2019).

Not only threats from the company can become dangerous, but stakeholders can also lead to problems. External bank accounts can get hacked and robbed of funding or cloud services used by the company to store data, which can get breached and lead to many problems.

Most of the formerly mentioned threats can be reduced or even avoided with straightforward policies and steps in the right direction. However, most SMEs face a barrier. Often, there is a lack of financial resources, or the companies are overconfident in cyber security (Alahmari & Duncan, 2021). Emer et al. (2021) have provided examples of how to mitigate those cyber risks and threats, and some of the strategies shown can be implemented without the need for enormous resources or knowledge. Proper cyber risk management is the key to a working cyber security strategy. First of all, a risk assessment should be conducted with a focus on cyber risk.

Low-hanging fruits like antivirus software and a proper firewall can help guard the system and prevent cyber-attacks. Those systems will be able to detect most malware and lower the chance of a network intrusion or data breach. To combat human-based threats, companies need to inform and train their employees about cyber-attack risks. Proper user management is also advantageous. Employees only get the rights for systems they need and use during their workday. This mitigates the risks of intentional or unintentional human-based threats. Methods such as two-factor authentication and regular password updates with precise specifications should be implemented to combat employee threats further.

Investing in artificial intelligence and machine learning solutions is undoubtedly a sound decision, as highlighted Rawindaran & Jayal (2021), who discuss the application of AI tools in intrusion detection. These tools enable the detection and prevention of malware attacks and their associated damage. The constantly evolving cyber threat landscape presents persistent challenges in cybersecurity for companies. In response, the adoption of artificial intelligence has given rise to both offensive and defensive strategies in the realm of cyber warfare. Offensive AI enhances the efficiency and effectiveness of cyber-attacks, while defensive AI is geared towards fortifying cybersecurity measures. For small and medium-sized enterprises, which often struggle with limited resources, effective defensive cybersecurity solutions are of immense importance. In light of this, the integration of AI-based defenses has become imperative. Although AI primarily serves as a protective measure, it's crucial to recognize that attackers are increasingly leveraging AI for a wide array of sophisticated attacks, as highlighted by Kant & Johannsen.

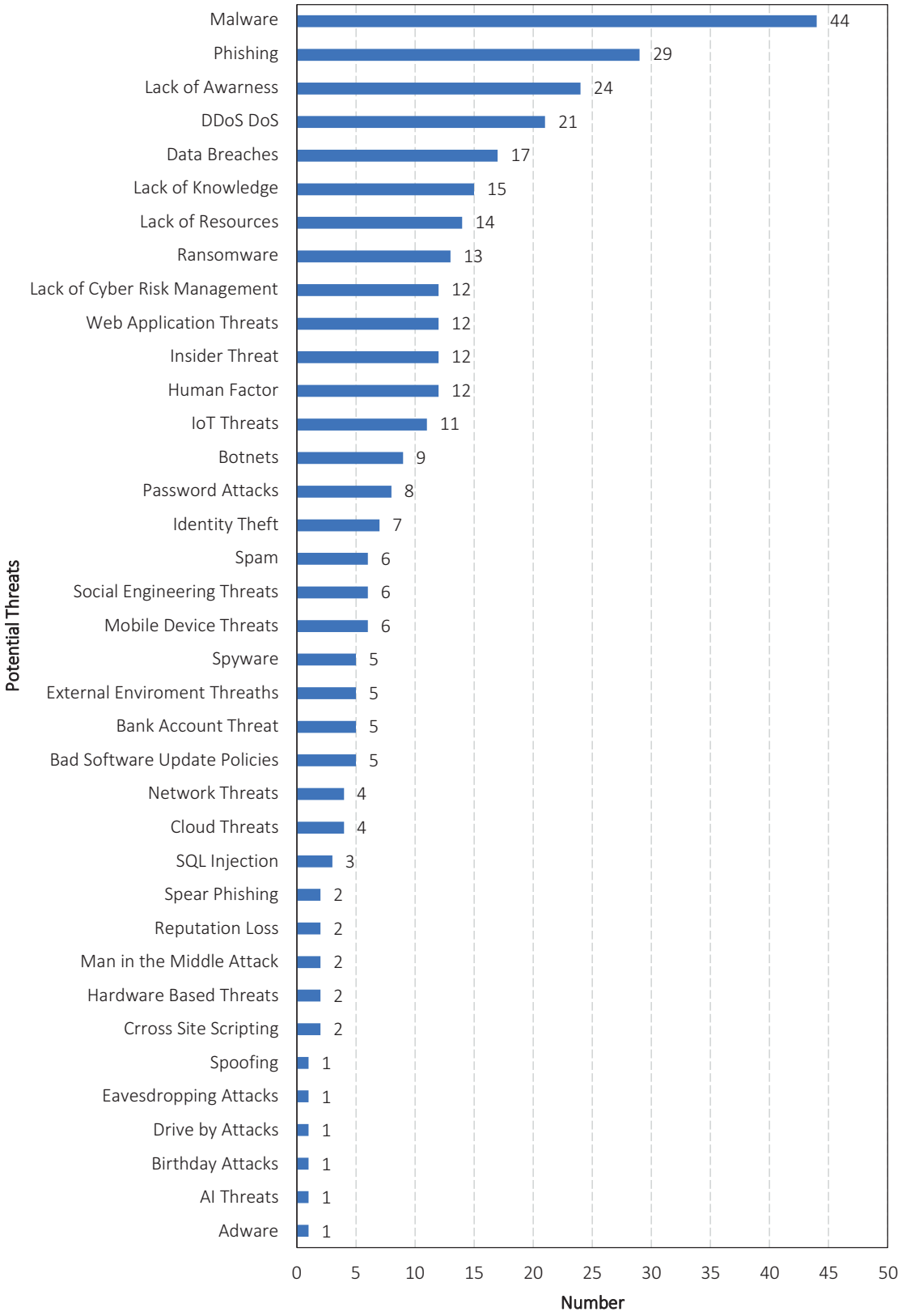

Figure 2: Cyber Threats mentioned and discussed in the Literature (N=325)

4. CONCLUSIONS

In conclusion, this paper highlights the critical importance of cyber risk management for Small and Medium Enterprises and the need for increased awareness and resources to protect against cyber-attacks effectively. The systematic literature review conducted in this research provides valuable insights into the current state of cyber risk management in SMEs, focusing on identified barriers and needs. The findings reveal that malware attacks, phishing, lack of awareness, and denial of service attacks are among SMEs' significant threats.

One significant aspect discussed in the paper is the role of artificial intelligence (AI) in cyber security. AI has the potential to both enhance cyber-attack capabilities and strengthen defense mechanisms. It can detect and prevent attacks, identify malware, and make informed decisions in cyber risk management. Incorporating AI tools and technologies can significantly benefit SMEs in improving their cybersecurity posture.

The publication analysis presented in the paper indicates a growing interest in cyber security for SMEs, particularly in recent years. The increased attention can be attributed to the evolving cyber threat landscape and the digitalization trends accelerated by events such as the COVID-19 pandemic. As SMEs increasingly rely on digital systems and networks, effective cyber risk management solutions become paramount.

Overall, this research emphasizes the importance of addressing the identified barriers and needs in cyber risk management for SMEs. It provides best practice examples and highlights the potential of AI tools in mitigating cyber risks. By raising awareness, allocating sufficient resources, and adopting appropriate cyber risk management strategies, SMEs can enhance their cybersecurity resilience and protect their critical assets from cyber threats. The insights and recommendations presented in this paper serve as a valuable resource for SMEs seeking to strengthen their cyber risk management practices in the face of an evolving threat landscape.

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APPENDIX 1. List of paper used for the Systematic Literature Review

Title of the Paper	Year	Author
The severity and effects of Cyber-breaches in SMEs: a machine learning approach	2023	Arroyabe et al.
Small-Scale Cyber Security	2023	Osborn & Simpson
Data-driven Intrusion Detection System for Small and Medium Enterprises	2023	Elezaj et al.
Cybersecurity Awareness and Capacities of SMEs	2023	Erdogan et al.
Cyber risk assessment in small and medium-sized enterprises: A multilevel decision-making approach for small e-tailors	2023	Sukumar et al.
It Won't Happen to Me: Surveying SME Attitudes to Cyber-security	2022	Wilson et al.
Improving Cybersecurity Awareness Among SMEs in the Manufacturing Industry	2022	Johansson et al.
How Personality Traits Impacts on Cyber Security Behaviors of SMEs Employees	2022	Kalhoro et al.
Exploration of the Impact of Cybersecurity Awareness on Small and Medium Enterprises (SMEs) in Wales Using Intelligent Software to Combat Cybercrime	2022	Rawindaran & Jayal
LCCI: A framework for least cybersecurity controls to be implemented for small and medium enterprises (SMEs)	2022	Pawar & Palivela
Artificial Intelligence in Terms of Spotting Malware and Delivering Cyber Risk Management	2022	Jakka et al.
Evaluation of AI-based use cases for enhancing the cyber security defense of small and medium-sized companies (SMEs)	2022	Kant & Johannsen
Machine learning approach for intrusion detection systems as a cyber security strategy for Small and Medium Enterprises	2022	Baci et al.
Capability oriented RE for Cybersecurity and Personal Data Protection: Meeting the challenges of SMEs	2022	Kavakli
SENTINEL - Approachable, tailor-made cybersecurity and data protection for small enterprises	2022	Trantidou et al.
Cybersecurity Infrastructure adoption Model for Malware Mitigation in Small Medium Enterprises (SME)	2022	Bin & Ali
A cyber situational awareness model to predict the implementation of cyber security controls and precautions by SMEs	2021	Renaud & Ophoff
Intrusion Detection System using Autoencoder based Deep Neural Network for SME Cybersecurity	2021	Ubaidillah et al.
Investigating Cyber Security Factors Influencing The Perception Behavioral Intention of Small and Medium Enterprise	2021	Bisma et al.
A Shared Cyber Threat Intelligence Solution for SMEs	2021	Haastrecht et al.
A Threat-Based Cybersecurity Risk Assessment Approach Addressing SME Needs	2021	Haastrecht et al.
A Cybersecurity Assessment Model for Small and Medium-Sized Enterprises	2021	Emer et al.
Classifying SMEs for Approaching Cybersecurity Competence and Awareness	2021	Shojaifar & Järvinen
Cost Benefits of Using Machine Learning Features in NIDS for Cyber Security in UK Small Medium Enterprises (SME)	2021	Rawindaran et al.
Cyber risk management in SMEs: insights from industry surveys	2021	Hoppe et al.
Cybersecurity for SMEs: Introducing the Human Element into Socio-technical Cybersecurity Risk Assessment	2021	Boletsis et al.
Exploring Cybersecurity Ecosystem in the Middle East: Towards an SME Recommender System	2021	Ahmed & Nanath
Information Security and Cybersecurity Management: A Case Study with SMEs in Portugal	2021	Antunes et al.
Investigating Potential Barriers to Cybersecurity Risk Management Investment in SMEs	2021	Alahmari & Duncan
It's Not My Problem: How Healthcare Models Relate to SME Cybersecurity Awareness	2021	Pickering et al.
Machine Learning Cybersecurity Adoption in Small and Medium Enterprises in Developed Countries	2021	Rawindaran, Jayal, & Prakash
On Strengthening SMEs and MEs Threat Intelligence and Awareness by Identifying Data Breaches, Stolen Credentials and Illegal Activities on the Dark Web	2021	Pantelis et al.
Practical Autonomous Cyberhealth for resilient Micro, Small and Medium-sized Enterprises	2021	Mantas et al.
The good, the bad and the missing: A Narrative review of cyber-security implications for Australian small businesses	2021	Tam et al.
Towards Cybersecurity Risk Management Investment: A Proposed Encouragement Factors Framework for SMEs	2021	Alahmari & Duncan

A dynamic simulation approach to support the evaluation of cyber risks and security investments in SMEs	2020	Armenia et al.
Calculated risk? A cybersecurity evaluation tool for SMEs	2020	Benz & Chatterjee
Cyber risk at the edge: current and future trends on cyber risk analytics and artificial intelligence in the industrial internet of things and industry 4.0 supply chains	2020	Radanliev et al.
Cybersecurity Standardisation for SMEs: The Stakeholders' Perspectives and a Research Agenda	2020	Ozkan & Spruit
Cybersecurity Risk Management in Small and Medium-Sized Enterprises: A Systematic Review of Recent Evidence	2020	Alahmari & Duncan
Harnessing Artificial Intelligence Capabilities to Improve Cybersecurity	2020	Zeadally et al.
Intelligent Detection and Recovery from Cyberattacks for Small and Medium-Sized Enterprises	2020	Lopez et al.
Systematic Approach to Cyber Resilience Operationalization in SMEs	2020	Carías et al.
The dark side of data science - An empirical study of cyber risks in German SMEs	2020	Ulrich et al.
The business benefits of cyber security for SMEs	2020	Lloyd
A Novel Cybersecurity Framework for Countermeasure of SME's in Saudi Arabia	2019	Ajmi et al.
Survey and Lessons Learned on Raising SME Awareness about Cybersecurity	2019	Ponsard et al.
Predicting CyberSecurity Incidents using Machine Learning Algorithms: A Case Study of Korean SMEs	2019	Mohasseb et al.
Developing cybersecurity education and awareness programmes for small- and medium-sized enterprises (SMEs)	2019	Bada & Nurse
Defining a New Composite Cybersecurity Rating Scheme for SMEs in the U.K.	2019	Rae & Patel
Cybersecurity in SMEs: The Smart-Home/Office Use Case	2019	Vakakis et al.,
A big data framework for network security of small and medium enterprises for future computing	2019	Kyun et al.
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GEOMETRY OF CONTACT AND TECHNOLOGICAL ASPECTS OF RELIEVING OF GEAR CUTTING WORM HOBS

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Abstract: *Contact line geometry at relieving of tooth flanks of gear cutting hobs and functional relations for calculation of relieving machine setting parameters for achieving the required accuracy of the tooth profile of the generating rack are determined. They include the setting angle of the grinding wheel axis and profiles of grinding wheel active surfaces for each of the tooth flanks. A method of calculating the single setting angle of the grinding wheel axis for both tooth flanks of the hob is developed.*

Key words: radial relieving, tooth flanks of hobs, relieving machine, grinding wheel profiling, involute helical surface, curvature radii, curvature, contact lines, double-sided relieving

1. INTRODUCTION

The basis of the generating worm of a hob at cutting spur and helical gears of the involute meshing is the generating rack of the hob which is a set of cutting edges of teeth in one groove of the hob. When cutting the teeth of spur and helical gears, the generating worm of a cutting tool on a gear hobbing machine is formed by positioning the axis of the helical surface of tooth cutting edges in such a way that the generating rack in the machining area is parallel to the normal cross section (or perpendicular to the direction) of the gearwheel teeth to be cut. The helical surface of the hob on which the cutting edges of the hob teeth are located is the generating surface of the hob. The relieved surfaces of the hob flanks which form rear angles during cutting are analogs of helical surfaces with helix angles one of which is increased for one flank relative to the helix angle of the hob generating surface thread, and decreased for the other flank.
The nomenclature of hobs and deviations from the straightness of the cutting edges profile of the hob teeth are specified by the valid standards ISO 2490:2007 “Solid (monobloc) gear hobs with tenon drive or axial keyway, 0.5 to 40 module – Nominal dimensions” and ISO 4468:2020 “Gear hobs - Accuracy requirements”. These standards only apply to single-thread precision hobs.
In the technological process of hob production, relieving of flanks with a grinding wheel is still the most time-consuming operation.
The author's works on relieving the teeth of gear-cutting hobs in accordance with the mentioned standards were related to determining the principal possibility of achieving the required profile accuracy for each of the hob flanks with parallel axes of the disk grinding wheel and the hob. However, when machining the flank with a smaller helix angle of the relieved surface, the parallel arrangement of the grinding wheel and hob axes leads to a significant limitation of the grinding wheel diameter due to undercutting the upper part of the tooth following the machined one.
In the practice of tool production of hobs, a method of machining each of the flanks with the setting angle of the grinding wheel axis equal to the helix angle of the generating surface of the hob on the pitch cylinder has been established. At the same time, the geometry of generation of contact lines of the grinding wheel and the relieved surfaces has not been functionally determined until now. In order to obtain the required accuracy of tooth cutting edge profile, a long adjustment of the relieving machine by the setting and profiling parameters of the grinding wheel is carried out; trial grinding passes and intermediate control operations are performed. Thus, the problems of relieving the tooth flanks of precision hobs for spur and helical gears remain relevant up to the present time [1 – 5].
The aim of the present work is, first of all, to clarify the geometry of formation of contact lines of grinding wheel surfaces and relieved surfaces during the operation of relieving the flanks. On the basis of this research for the operation of radial (the most widespread type) relieving we define functional relations for the calculation of the basic parameters of relieving machine setting to achieve the required accuracy of the tooth profile of the generating rack: the inclination angle of the grinding wheel axis relative to the horizontal plane and profiles of the grinding wheel active surfaces for machining each of the flanks. In particular, we define the method of calculating a single angle of the grinding wheel axis, so that the machine resetting for machining the second flank consisted practically only in replacing the grinding wheel (on the faceplate) with the appropriate active surface on the grinding spindle of the machine.

2. BASIC PARAMETERS OF HOB FLANKS

Parameters of the ground surface are determined on the basis of the initial data: module m_0 of the generating rack (teeth of the cut gearwheel), pressure angle α_0 =20° of the generating rack profile, helix angle γ_{m0} on its pitch cylinder and axial angle α_{0x} of the profile of the generating surface of the hob:

$$\mathrm{tg}\,\alpha_{0x} = \mathrm{tg}\,\alpha_0 \,/\, \cos\gamma_{m0} \tag{1}$$

The value of the angle γ_{m0} is determined from the known relation:

$$\sin\gamma_{m0} = Z\,m_0 \,/\, d_{m0} \tag{2}$$

where d_{m0} is the pitch cylinder diameter. For a new hob you can accept $d_{m0} = d_{a0} - 2{,}5\ m_0$ where d_{a0} is the standardized value of the hob external diameter.

To get the required profile axial angle α_{0x} of the generating surface of the hob with helical chip grooves (tooth faces), the relieved surface of teeth should have the profile angle α_x defined taking into account the lead P_z of the chip groove, the number of threads Z of the generating surface, the decline K of the relieved surface on one angular pitch of the hob teeth. For right side hobs, the values of angles α_x for the right ($_R$) and left ($_L$) flanks are determined by the formulas [6 – 8]:

$$\alpha_{xR} = \alpha_{0x} + 57{,}296\,k\,\sin^2\alpha_{0x} \,/[P + p + k\,\mathrm{tg}\,\alpha_{0x}];\ \ \alpha_{xL} = \alpha_{0x} - 57{,}296\,k\,\sin^2\alpha_{0x} \,/[P + p - k\,\mathrm{tg}\,\alpha_{0x}] \tag{3}$$

where $P = P_z / 2\pi$ is the helical parameter of the face surface, P_z is the lead of the chip groove (helical face surface); $p = 0{,}5\ m_0 Z / \cos\gamma_{m0}$ is the helical parameter of the generating surface of the hob, $k = K\,z_0/2\pi$ is the parameter of relieving, K is the decline of the tooth back assigned in the direction of relieving movement (for radial relieving - perpendicular to the hob axis); z_0 is the number of chip grooves of the hob (or teeth in its cross section); 57,296 is the coefficient of transition from the radian to degree value of the angular correction.

Thus, for a right-handed hob the axial angle α_{xR} of the right flank profile is greater than the axial angle α_{0x} of the generating surface profile of the hob, the angle α_{xL} of the left flank profile of teeth is less than the angle α_{0x}. For left-hand hobs, it is the reverse order: $\alpha_{xL} > \alpha_{0x} > \alpha_{xR}$.

Calculated values of the back decline K for hob versions 1 and 2 are given in Table 1 with the accuracy of setting of K value to 0,1 mm. On some models of used relieving machines, the scale division value of setting K is up to 0,5 mm. Therefore, in Table 1, in addition to the calculated values, the recommended values of the decline K of the relieved surface are shown in brackets, rounding the values to 0,5 mm.

Table 1: Values of decline K of the tooth back at the angular pitch of the hob (rounding to 0,5 mm)

Version 1				Version 2					
m_0, mm	**0,5…1,0**	**0,5…1,125**	**1,25…2,0**	**1,0…1,375**	**1,5…1,75**	**2,0…2,25**	**2,5…2,75**	**3,0**	**3,5**
d_{a0}, mm	24	32	40	50	55	65	70	75	80
z_0	12	12	10	14	14	14	14	14	14
K, mm	1,3 (1,5)	1,7 (2)	2,5	2,3 (2,5)	2,5	3,0	3,1 (3,0)	3,4 (3,5)	3,6 (3,5)
Version 2									
m_0, mm	**4,0**	**4,5**	**5,0**	**5,5**	**6,0**	**6,5**	**7,0**	**8,0**	**9,0**
d_{a0}, mm	85	90	95	100	105	110	115	120	125
z_0	14	14	14	12	12	12	12	10	10
K, mm	3,8 (4,0)	4,0	4,2 (4,5)	5,2 (5,0)	5,5	5,7 (5,5)	6,0	7,5	7,8 (8,0)
m_0, mm	**10**	**11**	**12**	**14**	**16**	**18**	**20**	**22**	**25**
d_{a0}, mm	130	150	160	180	200	220	240	250	280
z_0	10	10	9	9	9	9	9	9	9
K, mm	8	9,5	11	12,5	14,0	15,0	16,5	17	19

Helix angles $\gamma_{R,L}$ of both relieved flanks on the pitch cylinder of the right-hand hob are determined by the formula:

$$\mathrm{tg}\,\gamma_R = (p + k\,\mathrm{tg}\,\alpha_{xR})/r_{m0};\ \ \mathrm{tg}\,\gamma_L = (p - k\,\mathrm{tg}\,\alpha_{xL})/r_{m0} \tag{4}$$

$r_{m0} = d_{m0}/2$ is the radius of the hob pitch cylinder.

On an arbitrary radius r_i of lateral surfaces, the helix angles γ_i in each point of the profile are determined from expressions:

$$\mathrm{tg}\,\gamma_{Ri} = (p + k\,\mathrm{tg}\,\alpha_{xR})/r_i;\ \mathrm{tg}\,\gamma_{Li} = (p - k\,\mathrm{tg}\,\alpha_{xL})/r_i \tag{5}$$

For left-handed hobs, the indices $_{R, L}$ in formulas (3)...(5) are reversed.

3. CONTACT LINES WHEN GRINDING HELICAL AND RELIEVED SURFACES

There is the possibility of grinding of helical surfaces of worm threads and relieving of hob flanks by the grinding wheel as initially involute ones at parallel axes O_1-O_1 of the workpiece and O_w-O_w of the grinding wheel with the rectilinear axial profile. The contact line of the wheel and the ground surface touches the base cylinder and intersects the axis of the grinding wheel.

When grinding helical and relieved surfaces with a rectilinear axial profile by a disk grinding wheel, each of the points of the axial profile on the radius r_i of the ground surface with the assigned profile angle α_x and helix angle γ_i can be considered as an element of the involute helical surface. For each point of the axial profile, its base cylinder with radius r_{bi}, can be defined. The angle α_{bi} of the ground surface profile in the plane tangent to the base cylinder is equal to helix angle γ_{bi} of the generatrix and profile angle α_{wi} of the grinding wheel in the same plane. The values of these angles are calculated by a known formula based on the axial angle α_x of the ground surface profile and the helix angle γ_i of the surface in the calculated point of the profile:

$$\mathrm{tg}\ \alpha_{bi} = \mathrm{tg}\ \gamma_{bi} = \mathrm{tg}\alpha_{wi} = (\mathrm{tg}^2\ \alpha_x + \mathrm{tg}^2\ \gamma_i)^{0,5} \tag{6}$$

We determine the radius r_{bi} of the base cylinder for each point of the axial profile as:

$$r_{bRi} = (p + k\,\mathrm{tg}\ \alpha_{xR})/\mathrm{tg}\ \alpha_{bRi}; \quad r_{bLi} = (p - k\,\mathrm{tg}\ \alpha_{xL})/\mathrm{tg}\ \alpha_{bLi} \tag{7}$$

We set the axial angle α_x of the profile of the ground helical or relieved surface to be constant. At the section of the teeth adjacent to the hob tooth heads, the helix angle of the ground surface is the smallest for the profile due to the larger diameter, therefore, the angle $\alpha_{ba} = \gamma_{ba} = \alpha_{wa}$ of the profile and inclination of the generatrix of involute surface is the smallest, so here the radius r_{ba} of the base cylinder will be the largest for the ground profile. For the section of tooth roots the similar angle $\alpha_{bf} = \gamma_{bf} = \alpha_{wf}$ is the largest, respectively, the radius r_{bf} of the base cylinder will be the smallest.

Let us refer to Fig. 1. When the axes O_w-O_w of the wheel and O_1-O_1 are parallel, all the tangents to the base cylinders of the points of the tooth profile converge on the axis of the grinding wheel.

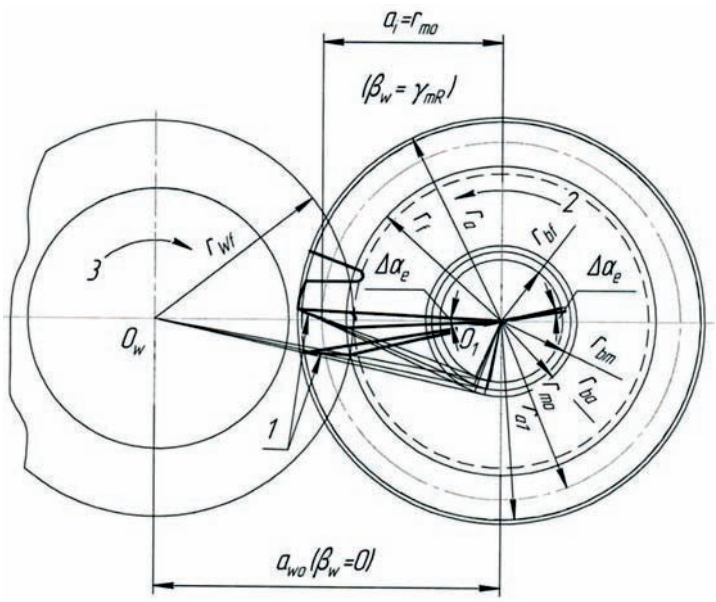

Figure 1: Generation of contact lines when grinding the surface with a rectilinear profile
1 - contact lines of the straight section of the profile, 2 - direction of rotation of the cutter,
3 - direction of rotation of the grinding wheel

The assigned point of the axial profile of the ground surface on the contact line of the wheel surfaces and the workpiece is obtained at the intersection point of a tangent to the base cylinder and the cylinder, on which the assigned point is located. All tangents to base cylinders corresponding to the axial profile points of the ground surface converge in one point of the interaxial perpendicular, and the enveloping line of contact points obtained in this way is the locus of points of common normal lines to these surfaces and it determines the contact line of the surfaces of the wheel and the workpiece.

When the inclination angle β_w of the grinding wheel axis relative to the workpiece axis is changed, tangents to the base cylinders of the ground surface also change their position. Thus, at the value β_w equal to the helix angle of the ground surface on the pitch cylinder, the contact line of the wheel and the ground tooth surface crosses the interaxial perpendicular at the point on the pitch cylinder, and, thus, all the tangents to base cylinders of the ground surface profile points cross the interaxial perpendicular in the same point.
Obviously, the tangents to base cylinders of the ground surface and the contact line of the latter with the grinding wheel surface may also occupy other positions relative to the interaxial perpendicular, depending on the value of the angle β_w of the grinding wheel axis setting.
And the position of the point of the interaxial perpendicular, where all tangents to base cylinders corresponding to profile points converge, determines the value of the inclination angle β_w of the grinding wheel axis relative to the workpiece axis. If the inclination angle β_w of the wheel axis is equal to the helix angle γ_i of the ground surface within the height of the ground profile, then the intersection of the contact line of the wheel and the ground surface with the interaxial perpendicular takes place within the height of the ground profile at the point on the radius r_i where these angles are equal.
If the inclination angle of the grinding wheel axis differs from the values of angles of elevation of the ground surface, then the tangents to the base cylinders of points of the ground profile intersect with the interaxial perpendicular outside the profile of the ground surface, at a distance a_i from the hob axis. And for a given value of the angle β_w, it should be determined (for example, for the right flank of the teeth of a right-handed hob) from the expression:

$$a_i = (p + k \operatorname{tg} \alpha_{xR}) \,/\, \operatorname{tg} \beta_w \tag{8}$$

If the angle β_w is set equal to the pitch helix angle γ_{m0} of the generating surface of the hob, which is defined as $\operatorname{tg} \gamma_{m0} = p \,/\, r_{m0}$, then formula (8) will be as:

$$a_m = r_{m0} \,(1 + k \operatorname{tg} \alpha_{xR} \,/ p) \tag{9}$$

The length and configuration of the contact line inside the extreme points of the ground profile with a change in the angle β_w are practically not changed, since the central angle $\Delta\alpha_e$ covering the contact line of the grinding wheel surface and the ground surface is unchanged. Its slope and distance are changed relative to the interaxial perpendicular (Fig. 1).
For the left side of the teeth of the right-handed hob (on the right side of the root, if you look at the front surface of the teeth) in formulas (8), (9) we should replace the sign (+) with the sign (–) and the index ($_R$) with ($_L$) in the notation of the angle α_x.

4. DETERMINATION OF CONTACT LINE COORDINATES

Let us refer to Fig. 2. The initial position of the contact line takes place when the axes of the wheel and hob are parallel, i.e. when $\beta_w = 0$.

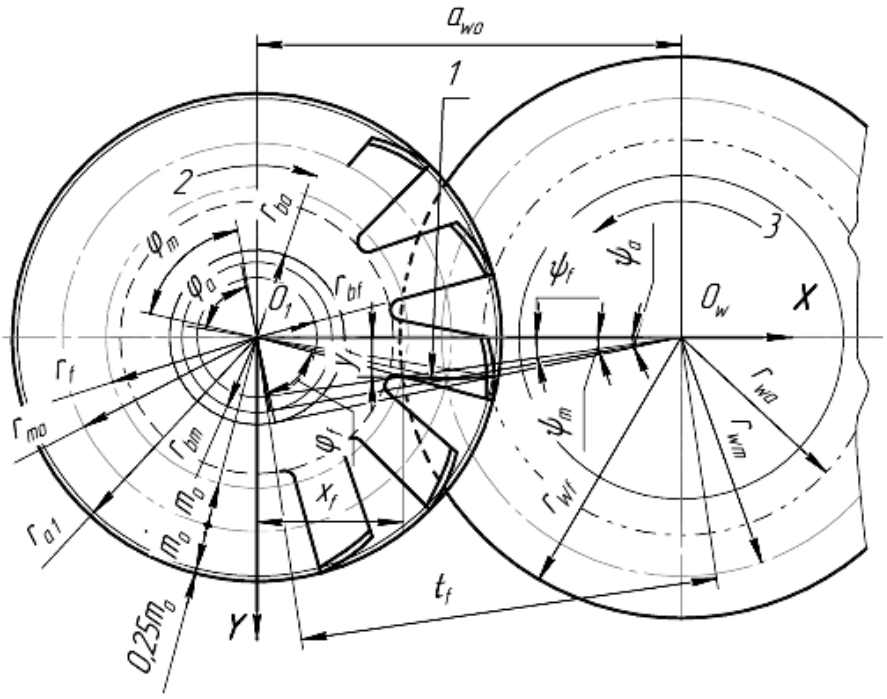

Figure 2: Determination of coordinates of contact lines
1 - contact line, 2 - direction of rotation of the cutter, 3 - direction of rotation of the grinding wheel

This position is remarkable by coincidence and certainty of angles of the ground surface profile and axial profile of the grinding wheel for all points of the ground surface profile due to equality (6) and, therefore, certainty of parameters of the grinding wheel profile curvature, compensating the deviation of the initial involute relieved surface profile from the necessary Archimedean one.

To find coordinates *X, Y* of contact line points, it is first necessary to determine the length a_{w0} of the interaxial perpendicular of wheel and hob axes. It is most convenient to do it with the help of a tangent to the base cylinder of radius r_{bf} of the point of the grinding surface profile on the cylinder of roots of radius r_f, as at this point there is a contact with the grinding wheel on its maximum radius r_{wf} of the active surface. From the axis of the hob, we draw a perpendicular to the tangent of the base cylinder. The tangent passes through the root profile point at radius r_f. The length of the tangent t_f is defined as:

$$t_f = r_{wf} + r_{bf} \text{ tg } \varphi_f \tag{10}$$

where φ_f is the angle between the radii r_{bf} and r_f determined from the expression:

$$\cos \varphi_f = r_{bf} / r_f \tag{11}$$

Similarly, we find the values of the angles φ for the profile points on the head of the hob tooth φ_a and its pitch cylinder φ_m from the expressions:

$$\cos \varphi_a = r_{ba} / r_a; \quad \cos \varphi_m = r_{bm} / r_{m0} \tag{12}$$

The maximum radius r_{wf} of the grinding wheel is taken either from the technical data of the relieving machine: 60 mm for hobs with a diameter d_a up to 160 mm and module up to 12 mm, or 87 mm - for hobs of greater dimensions, or by measuring the current working diameter of the grinding wheel.

Then determine the angle ψ_f between the tangent and the interaxial perpendicular from the expression:

$$\text{tg } \psi_f = r_{bf} / t_f \tag{13}$$

and we find the value a_{w0} by formula:

$$a_{w0} = r_{bf} / \sin \psi_f \tag{14}$$

With the value a_{w0} of the grinding wheel and hob interaxial distance found from (14), we find the values of the angles ψ_a, ψ_{m0} between the tangents to base cylinders and the interaxial perpendicular for contact points on the head and pitch cylinders:

$$\psi_a = \text{asin } (r_{ba} / a_{w0}), \quad \psi_m = \text{asin } (r_{bm} / a_{w0}) \tag{15}$$

We draw the coordinate axes: the origin of axes at the point O_1 of projection of the hob axis, the *X* axis - in

the direction of the interaxial perpendicular, the *Y* axis - perpendicular to the *X* axis. Coordinates of reference points of the contact line on cylinders: roots with radius $r_f = r_{m0} - m_0$, pitch with radius r_{m0} and heads with radius $r_{a1} = r_{m0} + m_0$ are defined by expressions:

$$\begin{aligned} X_f &= r_f \sin(\varphi_f + \psi_f); & Y_f &= r_f \cos(\varphi_f + \psi_f); \\ X_m &= r_{m0} \sin(\varphi_m + \psi_m); & Y_m &= r_{m0} \cos(\varphi_m + \psi_m); \\ X_a &= r_{a1} \sin(\varphi_a + \psi_a); & Y_a &= r_{a1} \cos(\varphi_a + \psi_a) \end{aligned} \tag{16}$$

The coordinates of any points within the contact line and, consequently, the length of any section of the contact line can be determined in a similar way.

5. CALCULATION OF THE GRINDING WHEEL PROFILE ALONG THE CONTACT LINE

Let us refer to Fig. 3, which shows the axial section of the grinding wheel. At parallel axes of the grinding wheel and hob, knowing from (6) angles $\alpha_{wi} = \alpha_{bi} = \gamma_{bi}$ of the grinding wheel profile in the key points of the grinding surface profile - on cylinders of heads α_{wa}, pitch α_{wm} and roots α_{wf} - you can define radii R_f, R_a of curvature of the axial profile of the grinding wheel.

In the plane tangent to the base cylinder, at the profile point of the hob on its pitch cylinder, the contact point of the wheel profile has the profile angle α_{wm}. This point of the wheel profile is the junction point of the curve sections of radii R_a and R_f. The length of working sections of the wheel profile is defined as $m_0 / \cos \alpha_{wm}$. The radius R_a of the curvature of the ac surface of the grinding wheel machining the hob tooth head is defined as:

$$R_a = (m_0 / \cos \alpha_{wm}) / \sin(\alpha_{wm} - \alpha_{wa}) \tag{17}$$

Radius R_f of curvature of the active surface of the grinding wheel machining the hob tooth root is defined as:

$$R_f = (m_0 / \cos \alpha_{wm}) / \sin(\alpha_{wf} - \alpha_{wm}) \tag{18}$$

Convexity arrows δ_a and δ_f of the wheel profile in these sections are determined by the formulas:

$$\begin{aligned} \delta_a &= (m_0 / \cos \alpha_{wm})^2 / 2R_a = 0{,}5 m_0 \sin(\alpha_{wm} - \alpha_{wa}) / \cos \alpha_{wm}; \\ \delta_f &= (m_0 / \cos \alpha_{wm})^2 / 2R_f = 0{,}5 m_0 \sin(\alpha_{wf} - \alpha_{wm}) / \cos \alpha_{wm} \end{aligned} \tag{19}$$

Thus, at $\beta_w = 0$ (parallel to the axes of the wheel and hob) the contact line defined above and the specified arrows of convexity of the grinding wheel profile compensate the deviation of the axial profile of the involute relieved surface relative to the rectilinear axial profile of the Archimedean relieved surface, which, strictly speaking, is what we aim to obtain.

The radius R_f is somewhat smaller than the radius R_a of the curvature of the section machining the tooth head. Accordingly,

$$\delta_f > \delta_a \tag{20}$$

If the difference in values ($\delta_f - \delta_a$) is within the tooth profile tolerance of ISO 4468:2020 (for a certain hob range), then the axial profile of the wheel can be dressed to a single radius of curvature, preferably to the R_a value. Since in this case the profile of the relieved tooth surface (and the cutting edge) on the hob tooth root closer to the cavity will be more complete (tooth profile deflection in +), and the gear head on the hob will have a small flange. This is in principle acceptable by the standard; and it helps to improve the characteristics of gear meshing in terms of the noise level.

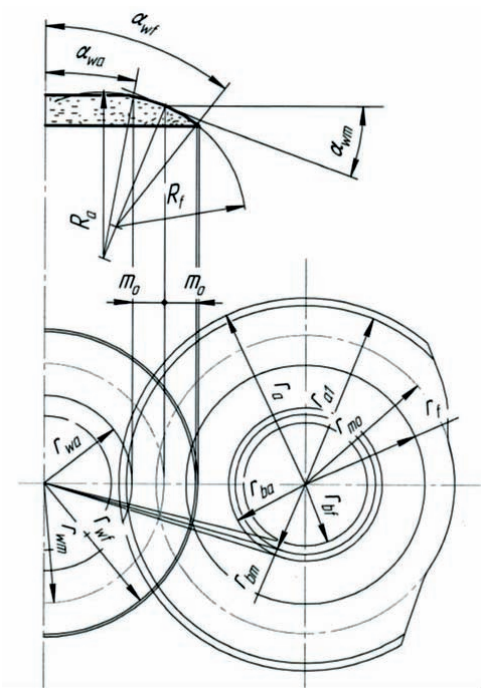

Figure 3: Determining the grinding wheel profile along the contact line

6. CONTACT OF THE GRINDING WHEEL AND TOOTH SURFACES WHEN SETTING THE GRINDING WHEEL AXIS TO ASSIGNED ANGLE

With an arbitrarily assigned angle β_w of the grinding wheel axis, the characteristic of the grinding wheel active surface contact with the relieved surface of the hob teeth is changed. The length of the contact line and its configuration within itself are constant, because the values of the angles φ_i at contact points depend only on the parameters of the relieved surface - the radii of base cylinders and radii of the cylinders of the location of these points. However, when the angle β_w is changed, the contact line rotates relative to the hob axis and shifts relative to the grinding wheel axis. The distance a_i from the hob axis to the intersection point of the tangents to the base cylinders on the interaxial perpendicular does not coincide with the dimension a_{w0}. As a consequence of the above, the angle μ_β is formed between the tangent to the base cylinder of the contact point on the pitch cylinder of the relieved surface and the axial section of the grinding wheel, passing through the same point of the axial profile of the tooth surface (Fig. 4). And to calculate the axial profile of the grinding wheel, this change in position of the contact line of the wheel and the relieved surface should be taken into account.

By formula (8) we determine the value of a_i, then for the key points of the profile (f, m, a) we find:

angles ψ_i between the tangents to the base cylinders and the interaxial perpendicular from the expression

$$\sin \psi_i = r_{bi} / a_i \tag{21}$$

lengths t_i of the tangents to the base cylinders

$$t_i = r_{bi} / \operatorname{tg} \psi_i \tag{22}$$

lengths of the segments b_i from the point of intersection of the tangents with the interaxial perpendicular to the corresponding point of the ground surface profile:

$$b_i = t_i - r_{bi} / \operatorname{tg} \varphi_i \tag{23}$$

and then you can calculate the coordinates X_i, Y_i of points of the contact line by the formulas:

$$X_i = a_i - b_i \cos \psi_i; \qquad Y_i = b_i \sin \psi_i \tag{24}$$

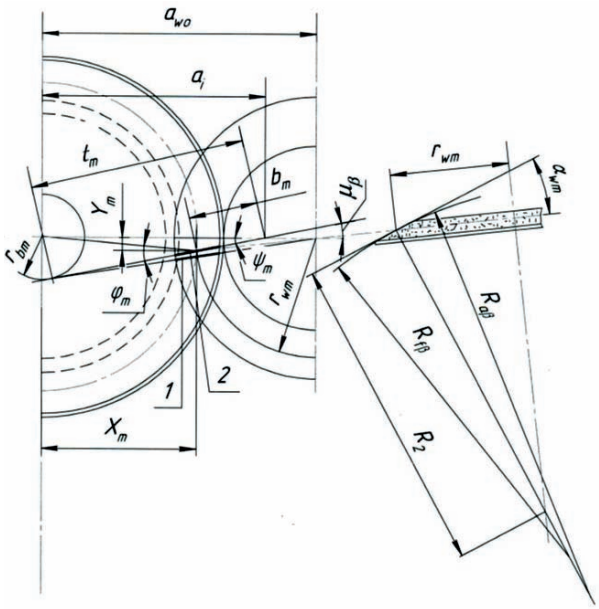

Figure 4: Determination of the contact line and axial profile of the grinding wheel at $\beta_w \neq 0$
1 – contact line at aw0, βw = 0; 2 – contact line at ai, βw ≠ 0

In general case we refer parameters R_a, δ_a, R_f, δ_f of curvature of the grinding wheel profile defined by formulas (17) ... (19) to the normal section of the grinding wheel surface in the plane, tangent to the base cylinder of the profile point on the pitch cylinder, as the contact point on the pitch cylinder is a junction point of two sections of the grinding wheel profiling. The value of the angle μ_β of the deviation of the plane, in which the curvature parameters of the grinding wheel are defined, from the axial section of the grinding wheel will be determined from the relation:

$$\mu_\beta = \mathrm{acos}\,(Y_m / r_{wm}) - (90° - \psi_m) \tag{25}$$

where $r_{wm} = (r_{wf} - m_0)$ is the radius of the grinding wheel at the contact point on the pitch cylinder of the hob.

To determine the parameters of the axial profile curvature of the grinding wheel at an arbitrarily assigned angle β_w we will use the Euler formula, which describes the ratio of curvatures of lines on the surface: for each normal section of the surface its curvature $1/R$ is defined as[9 - 11]:

$$1/R = (\cos^2\mu / R_1) + (\sin^2\mu / R_2) \tag{26}$$

where R_1 and R_2 are the basic radii of curvature, i.e. *the largest and the smallest* values of R; they are obtained at the basic normal sections [11];

μ is the angle between the planes of normal sections with the basic radius of curvature R_1 and the current radius of curvature R; in this case, it is between the axial section of the grinding wheel and the section tangent to the base cylinder, where the radii of curvature are defined by formulas (17) and (18).

$$\mathrm{tg}\,\mu = \mathrm{tg}\,\mu_\beta \cos\alpha_{bm} / \cos\beta_w \tag{27}$$

With respect to the question under consideration, in formula (26) R are the radii R_a and R_f of the curvature sections in the defined (25) normal section to the surface of the grinding wheel along the contact line found by formulas (17) and (18); R_1 are the sought radii of curvature of the axial section of the wheel, corresponding to the profiling sections for the heads and roots of teeth; R_2 is the radius of curvature of the grinding wheel in the plane perpendicular to the axial profile of the grinding wheel at the contact point on the hob pitch cylinder. R_2 is determined by the formula:

$$R_2 = r_{wm} / \sin\alpha_{wm} \tag{28}$$

The value of the angle α_{wm} of the grinding wheel profile in its axial section at the contact point with the hob pitch cylinder is determined from the relation:

$$\mathrm{tg}\,\alpha_{wm} = \mathrm{tg}\,\alpha_{bm} \cos\mu \tag{29}$$

The values of sought radii $R_{a\beta}$ and $R_{f\beta}$ of curvature (as R_1) in the axial section of the grinding wheel are obtained from (26):

$$R_1 = R_{a,f}\, R_2 \cos^2\mu / (R_2 - R_{a,f} \sin^2\mu) \tag{30}$$

Our experience showed that when grinding the face of the hobs of the most widespread type Version 2, for the flank of these hobs where the helix angle of the generating surface is greater than the helix angle of the relieved surface (for example, the left flank of the hob teeth with the right direction of the generating surface), the accuracy of the profile of the generating rack is ensured with a multiple margin for all the hob types when grinding with a straight profile, and the contact line is also practically straight. For the opposite flanks (right flank of the tooth of a right-handed hob) in hobs with modules up to 2.25 mm, the accuracy of the flank profile is also technologically ensured according to accuracy class 4A without the use of radius dressing. With increasing the module, depending on the required accuracy class of the hob, radius dressing of the grinding wheel profile is required according to the above method.

7. DETERMINATION OF A SINGLE ANGLE OF INCLINATION OF THE GRINDING WHEEL AXIS

Setting of the grinding wheel axis inclination angle, which is uniform for grinding both flanks, provides reducing the machine readjustment to the change of grinding wheel on the machine spindle and thus limiting the time of readjustment only by achieving the required profile of the grinding wheel active surface. In addition, when using machines with a dressing mechanism that allows profiling both sides of the grinding wheel, such a setting will make it possible to produce a double-sided relieving of teeth of worm hobs.
The conditions for a single angle of the grinding wheel setting for grinding both relieved surfaces are: firstly, the intersection of the grinding wheel axis by normal lines to these surfaces; secondly, a single starting point for grinding both flanks of the teeth.
The beginning of tooth machining on each flank takes place at the apex of the tooth, since it is the apex of the tooth that initially crosses the contact line of surfaces of the hob tooth and the grinding wheel. In addition, on the side where the helix angle is greater than that of the generating surface of the hob (on right flanks of right-handed hobs), due to greater values of the radii of the base cylinders of profile points, there is a more extended area of tooth entry to the full grinding height and, accordingly, the length of the relieving stroke and the arc of hob rotation during this stroke. In this regard, a single starting point for both flanks as a necessary condition should be defined by crossing the contact lines of the right and left flanks not on the outer diameter of the straight section of the tooth profile, but at the point near the pitch cylinder, where there is the middle of the infeed section on both flanks; and where the helix angles of the generating surface of the hob and the front surface of teeth coincide.

7.1 Determining the point of intersection of contact lines

The intersection of contact lines of flanks on the pitch cylinder is defined as the intersection of the tangents to the base cylinders at the profile points on the pitch cylinder.
In accordance with ISO 2490:2007, the relieved surfaces of hob teeth with modules to 11 mm have different directions (right and left), the distances a_{wR}, a_{wL} from the hob axis to the points of intersection of tangents to the base cylinders with the interaxial perpendicular have different signs, and tangents to base cylinders are on the same side of the interaxial perpendicular (Fig. 5).
The relieved surfaces of teeth of hobs with modules of 12 mm and more have one direction - right for right-handed hobs; the distances a_{wR}, a_{wL} have the same signs (+), the beginning of tangents to the base cylinders are on different sides of the interaxial perpendicular (Fig. 6), and the intersection point of these tangents is on the side which refers to the base cylinder with a greater diameter.
The point of intersection of the tangents to both base cylinders of the profile points on the pitch cylinder of the rectilinear part of cutting edges is found in general form as follows:
1. The value of the angle β_{w2} is assigned. The index ($_2$) denotes a single angle for both flanks.
2. The distances a_{wR}, a_{wL} from the hob axis to the points of intersection of tangents to the base cylinders of points of profiles with the interaxial perpendicular are determined by expressions:

$$a_{wR} = (p + k \operatorname{tg} \alpha_{xR}) / \operatorname{tg} \beta_{w2}; \quad a_{wL} = (p - k \operatorname{tg} \alpha_{xL}) / \operatorname{tg} \beta_{w2} \tag{31}$$

3. The angles between the tangents and the interaxial perpendicular (ε_R for the right flank, ε_L for the left flank) are determined from the expressions:

$$\sin \varepsilon_R = r_{bRm} / a_{wR}; \quad \sin \varepsilon_L = r_{bLm} / a_{wL} \tag{32}$$

4. The distance Y_{c1} from the interaxial perpendicular to the point of intersection of the contact lines of the profiles is determined from the geometric constructions by the expression:

$$Y_c = (a_{wR} - a_{wL}) \operatorname{tg} \varepsilon_R \operatorname{tg} \varepsilon_L / (\operatorname{tg} \varepsilon_R + \operatorname{tg} \varepsilon_L) \tag{33}$$

5. We find the radius r_{yc1} of the hob at which the point of intersection of the tangent projections and,

respectively, the contact lines of the profiles is located:

$$r_{yc} = [(Y_c \,/\, \mathrm{tg}\, \varepsilon_L) + a_{wL})^2 + Y_c{}^2\,]^{0,5} \tag{34}$$

and compare its value with r_m.
The values r_{bLm} and a_{wL} in the above formulas are taken with the corresponding sign from (7) and (31).

7.2 Calculating the angle of inclination of the grinding wheel axis

The initial value of the angle $\beta_{w2\text{-}1}$ of the grinding wheel axis setting for relieving the corresponding dimension type of the hob is determined from (2), equal to the helix angle γ_{m0} of the generating surface on the pitch cylinder.
The necessary search of the setting begins with calculation of coordinates Y_c and r_{yc} of the intersection point of contact lines by formulas (31 ... 34). The values of radii r_{bRm}, r_{bLm} of the base cylinders for profile points on the pitch cylinder should be determined by formula (7). If the obtained value of radius r_{yc1} does not coincide with the value of radius r_m of the pitch cylinder, then we find the parameter p_{rc} of change of radius r_{yc1} depending on the angle β_{w2} in the form:

$$p_{rc1} = r_{yc1}\, \mathrm{tg}\, \beta_{w2\text{-}1} \tag{35}$$

The index ($_1$) in formula (35) indicates the order of approximation to the sought value of r_{yc}. Next, we find the following approximation of the angle $\beta_{wc2\text{-}2}$ of the inclination of the grinding wheel axis to get the point of intersection of the contact lines on the hob pitch cylinder:

$$\mathrm{tg}\, \beta_{wc2\text{-}2} = p_{rc1} \,/\, r_m \tag{36}$$

And again, we repeat the calculation by (32) ... (34) of coordinates of the point of intersection of tangents to the base cylinders of the points of ground surface profile on the pitch cylinder. If in this case it is also $r_{yc2} \neq r_m$, we again specify the parameter p_{rc} of radius similarly to (35): $p_{rc2} = r_{yc2}\, \mathrm{tg}\, \beta_{wc2\text{-}2}$ and determine a new approximation of the angle of the wheel axis setting similarly to (36): $\mathrm{tg}\, \beta_{wc2\text{-}3} = p_{rc2} \,/\, r_m$.
Calculations stop at achieving the approach of values r_{yc} and r_m within limits ±0,1mm. Thus, by method of consecutive approximations we define the required angle β_{w2} of the grinding wheel axis installation, at which almost simultaneous entrance in machining of both flanks is provided.
Fig. 5 shows the search for the point *C* of intersection of contact lines on the example of a single-thread right-handed hob with the module of 4 mm. Table 2 shows the calculated parameters of successive approximation to the required result - the location of the intersection point of tangents to the base profile cylinders on the pitch cylinder of this hob. The initial data: m_0 = 4 mm, Z = 1, d_{a0} = 85 mm; the design data: r_m = 37,5 mm, γ_{m0} = 3,0643°, p = 2,003 mm, k = 8,467 mm, α_{Rx} = 20,107°, α_{Lx} = 19,934°, γ_{Rm} = 7,7487°, γ_{Lm} = –1,631 °, α_{bRm} = 21,333°, α_{bLm} = 19,990°, r_{bRm} = 13,0654 mm, r_{bLm} = – 2,935 mm.

Table 2: Example of calculating the setting angle β_{w2} of the axis of the grinding wheel for relieving hobs with the ratio of parameters $p < k\ \mathrm{tg}\ \alpha_{x0}$

№ of approximation	β_{w2}, °	a_{wR}, mm	a_{wL}, mm	ε_R, °	ε_L, °	Y_c, mm	r_{yc}, mm	p_{rc}, mm	$\beta_{w2\text{-}1,2,3}$, °
1	3,0643	95,318	–19,945	7,8784	8,4622	8,264	36,546	1,9567	2,9868
2	2,9868	97,7937	–20,463	7,6778	8,2465	8,2595	37,445		
By the machine scale	3,0	97,365	–20,373	7,7118	8,2831	8,2602	37,292		

During real machining, the calculated value β_{w2}, at which the value $r_{yc} = r_m$ is achieved, is assigned on the relieving machine with the accuracy of the reference scale for setting the angle of inclination of the grinding wheel axis. For older models of machines, the accuracy of setting for this parameter was 0,1°. That is, in the case considered, this relieving machine should be set to β_{w2} = 3,0°. The radius of the point of intersection of the contact lines will be ≈37.3 mm. The deviation will be 5% of the module.

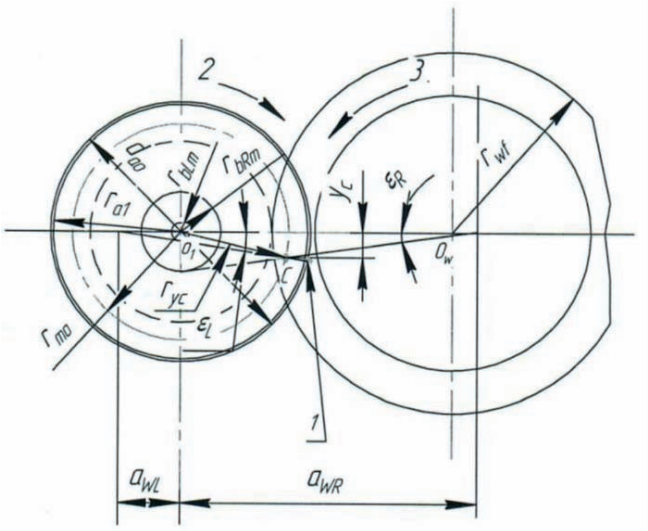

Figure 5: Determination of the angle β_{w2} when relieving the flanks with different directions (m_0 = 4 mm)
1 - the top of the cutter tooth, 2 - the direction of rotation of the cutter,
3 - the direction of rotation of the grinding wheel

For hobs with the parameter ratio $p > k$ tg α_{0x} the method of calculation of coordinates of the point *C* of intersection of the contact lines remains the same, using the parameter p_{rc} and the contact radius r_{yc}, as it is shown in (35) and (36). Fig. 6 shows the location of point *C* when relieving the right-handed hob with a module of 16 mm.

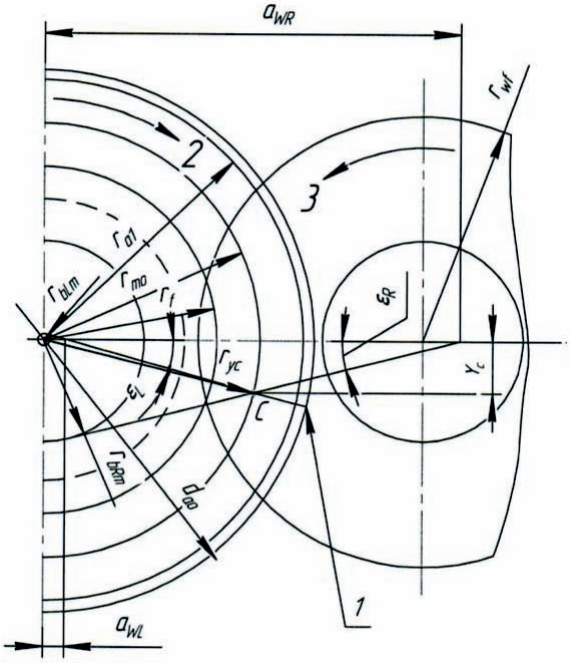

Figure 6: Determination of the angle $\beta w2$ when relieving flanks with one direction (m_0 = 16 mm)
1 - the top of the cutter tooth, 2 - the direction of rotation of the cutter,
3 - the direction of rotation of the grinding wheel

Table 3 shows a sequential approximation of the radius of the point location to the radius of the pitch cylinder with the calculation of the value of the inclination angle of the grinding wheel axis when relieving this hob. The initial data: m_0 = 16 mm, Z = 1, d_{a0} = 200 mm; the design data: r_m = 80 mm, γ_{m0} = 5,739°, p = 8,04 mm, k = 20,0535 mm, α_{Rx} = 20,26°, α_{Lx} = 19,923°, γ_{Rm} = 10,925°, γ_{Lm} = 0,553°, α_{bRm} = 22,614°, α_{bLm} = 19,929°, r_{bRm} = 37,072 mm, r_{bLm} = 2,13 mm.

Table 3: Example of calculation of the setting angle β_{w2} of the grinding wheel axis for relieving of hobs with the ratio of parameters $p > k\ tg\ \alpha_{x0}$

№ of approximation	β_{w2}, °	a_{wR}, mm	a_{wL}, mm	ε_R, °	ε_L, °	Y_c, mm	r_{yc}, mm	p_{rc}, mm	$\beta_{w2\text{-}1,2,3...}$ °
1	5,739	153,654	7,682	13,961	16,096	19,495	77,725	7,811	5,577
2	5,577	158,153	7,907	13,557	15,627	19,456	79,87		
By the machine scale	5,6	157,494	7,8745	13,614	15,694	19,461	79,556		

When relieving on a machine with a vernier accuracy of 0.1° the reference scale for the angle β_{w2} should be set to β_{w2} = 5,6°. The radius of the location of the intersection point of the contact lines will be 79.556 mm - the deviation from the pitch cylinder is 0.444 mm, which in this case is negligibly small – 2.8% of the module.
Obviously, by creating machines with a dressing mechanism that allows both sides of the grinding wheel to be profiled simultaneously, this setup will allow for double-sided relieving of hob teeth.

8. CONCLUSION

A method of constructing the contact lines between grinding wheel surfaces and ground flanks of hob teeth on the basis of considering each of the points of axial profile of the relieved surface as an involute helical surface element has been found.
It is determined that all the tangents to the base cylinders corresponding to the axial profile points of the ground surface, converge at one point of the interaxial perpendicular, and the enveloping line of the contact points thus obtained is the locus of the points of common normal lines to these surfaces and determines the contact line of the grinding wheel surfaces and the hob teeth. A procedure for calculating the coordinates of contact line points is given.
The length and configuration of the contact line inside the extreme points of the ground profile with changing the inclination angle β_w of the grinding wheel axis is practically not changed, as the central angle covering the contact line of the grinding wheel surface and the ground surface is unchanged. Its inclination and distance relative to the interaxial perpendicular is changed.
A procedure for calculating the grinding wheel profile for obtaining a rectilinear profile of the relieved surface is developed, including the case when the contact line does not coincide with the axial section of the grinding wheel.
The method of calculating the inclination angle of the grinding wheel axis, which is uniform for adjustment of grinding both flanks, is determined. The value of this angle for a number of dimension types of hobs differs from the generally accepted one, equal to the helix angle of the generating surface on the pitch cylinder.

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APPROACHES TO MONITORING OIL AND GAS PIPELINES

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Abstract: *Effective monitoring of oil and gas pipelines is critical to the safety of both the energy infrastructure and the surrounding environment, making it an integral part of any nation's energy system. Protecting the energy system and the environment requires thorough monitoring of oil and gas pipelines, recognizing their indispensable role in a country's overall energy infrastructure. Adequate monitoring of oil and gas pipelines is essential as they are woven into the energy system of any nation and play a critical role in preserving the environment through which they pass. There are different approaches for monitoring oil and gas pipelines, the main objective of which is to have their conditions in real-time, especially in cases where they are exposed to various natural events, such as seismic effects, movements of tectonic blocks, karsts, landslides, frost and other natural phenomena, which often lead to the accidental destruction of oil and gas pipelines. This paper provides an analysis of the various approaches used to monitor major oil and gas pipelines.*

Key words: reactive and proactive monitoring, SCADA, oil and gas pipelines

1. INTRODUCTION

To better understand the importance of oil and gas pipelines to human civilization, it is best to look at all the wars of the last 120 years that have been fought over the resources transported by these pipelines (Meierding, 2020). The struggle for resources such as oil and gas has its own direct and indirect effects, which can be seen in the analysis of the most recent conflict in Europe (European Parliament, 2023). In addition to the economic, social and political aspects of this pipeline, it should also be considered from a technical point of view.

The history of oil and gas pipelines can be traced back to the mid-19th century when the first gas pipeline was built in the United States of America (USA). The first pipeline was used to transport natural gas from a well in Fredonia, New York to a nearby production facility. However, it was not until the early 20th century that oil and gas pipelines began to be used on a larger scale to transport crude oil and natural gas. The first major oil pipeline in the United States was built in 1917. This oil pipeline, which was over 200 km long, was built by the Texas Company (Texaco). Many more were built after this, and by the 1920s pipelines had become a common method of transporting oil and gas across the U.S. In the years that followed, pipelines became longer and more complex, and their construction and operation had to be constantly monitored. The first transcontinental pipeline was built in the 1950s, and by the 1960s pipelines were being used to transport oil and gas across international borders. Today, oil and gas pipelines are a critical component of the global energy infrastructure, with millions of kilometers of pipelines transporting oil and gas around the world. The transport of crude oil, natural gas and other petroleum products is an essential part of the supply chain for the entire energy infrastructure, not only of individual countries but of the entire world (Smirnov, 2023, Tusiani 2005, Andrews 2014).

In many cases, oil and gas pipelines are part of a complex technical system. There are generally two main approaches to monitoring technical systems: reactive monitoring and proactive monitoring. These two main approaches can also be applied to the monitoring of oil and gas pipelines. In addition, oil and gas pipelines can be viewed as a complex network of sensors and communications. Reactive monitoring in a technical system usually means the detection of problems or failures and the reaction to them after they have already occurred. This approach is typically based on using a variety of sensors, alarms and feedback mechanisms to detect any deviation from the normal operating conditions. This means, when a problem is detected, alerts or notifications are triggered to prompt immediate action for diagnosis and resolution. In other words, reactive monitoring aims to minimize downtime and mitigate the impact of failures by responding quickly to problems as they occur (Dilman, 2002). Proactive monitoring focuses on the detection and resolution of potential problems in a technical system before they result in failure or

downtime. This approach involves the continuous monitoring of system performance and the analysis of data trends in order to identify patterns or indicators of impending problems. Proactive monitoring allows preventive action to be taken to minimize the likelihood of system failure or disruption by identifying early warning signs (Koliousis, 2007).
In most cases, various SCADA (Supervisory Control and Data Acquisition) platforms are used to monitor, control and collect data on the condition of oil and gas pipelines. Most of today's SCADA systems allow you to use both main approaches to monitoring oil and gas pipelines (Bailey 2003, Yadav, 2021).

2. DATA ACQUISITION

Both approaches to monitoring oil and gas pipelines are based on data acquisition. The main source of data is sensors installed to measure/detect the conditions (like pressure, temperature, and flow) of pipelines, but also data can be collected from other elements in pipelines, such as networks, pumps, transfer terminals, ... (Prodanovic, 2021, Sarang, 2023, https://janaf.hr/). The choice of sensors depends on the specific requirements of the pipelines and the type of data that is needed for monitoring, control and maintenance purposes. In addition to these conditions, other data related to the production of elements in pipelines are also very important, especially in the approach of proactive monitoring (Klasnja 2019, Stankovski, 2020, Stevanov, 2022). Some of the most common sensors in use for monitoring oil and gas pipelines are:

- pressure sensors,
- flow meters,
- temperature sensors,
- level sensors,
- positions sensors
- ultrasonic sensors
- optical sensors,
- corrosion sensors,
- vibration sensors,
- voltage sensors,
- current sensors,
- location sensors.

Communication between sensors and the monitoring system for oil and gas pipelines is crucial/critical for reliable and efficient data transfer between these entities. Of course, the type of communication technology used will depend on the type of sensors, distance, communication channels, monitoring system, etc. Typically, the monitoring systems for oil and gas pipelines use wired and wireless sensor communications for data transfer.
Wired communication involves the physical connection of sensors to the monitoring system using cables. Depending on the type of sensors, distance, communication channels, security and other requirements, different protocols are used for data transfer, such as Modbus, Profibus, DNP3, Ethernet/IP, PROFINET. Usually, we can find different protocols in one monitoring system.
Wireless communication is the transfer of data between sensors and the monitoring system without the use of cables. Depending on the type of sensors, distance, security, protocols and other requirements, radio waves, GSM, WiFi, Bluetooth, satellite communication, etc. can be used for data transfer. Usually, we can find different wireless communication channels in one monitoring system.
Other aspects of data transfer are also very important, such as redundancy and data integrity. Redundant communications, redundant servers and backup databases are some techniques used to increase redundancy. To ensure quality data integrity, some secure communication protocols are used, such as encryption, which protects data from unauthorized access.
Having in mind the consequences that can have on the operation of oil and gas pipelines, it is often not possible to identify the conditions that lead to incidents without adequate data. Unfortunately, the number of incidents is high, as is the impact on the pipeline systems themselves and the environment in which they are located (Shan 2017, Dröge 2018, Lu 2023). Figure 1 shows the number of incidents per year in Europe for gas pipelines for the period 1970-2016. Besides technical conditions, the main factors that cause significant damage to pipelines are geological and hydrological natural phenomena (Lu, 2023). These factors create loads that are short-term or transient and are difficult to predict at the design stage, requiring constant monitoring of their operation.

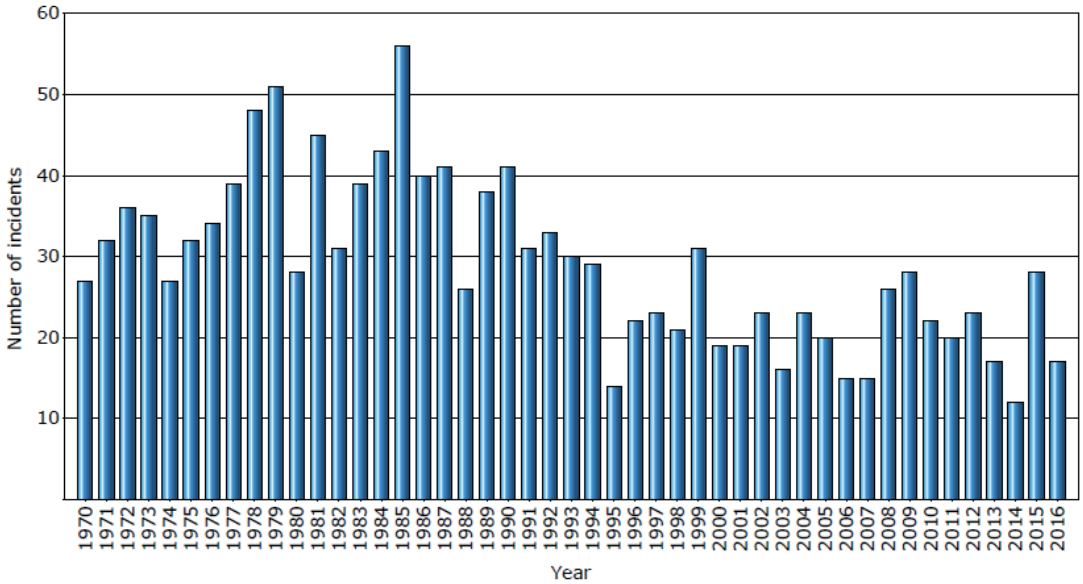

*Figure 1: Number of incidents per year (*Dröge 2018*)*

Despite the fact that there are a significant number of systems for monitoring oil and gas pipelines, research continues and in recent years one of the main focuses has been to develop/add new functionality for predicting undesirable conditions.

3. DISCUSSION

One of the main objectives of proactive monitoring is to prevent system downtime. There are several aspects of proactive monitoring that contribute to achieving the main objectives. The first is mentioned in the last section and relates to data acquisition of key conditions in oil and gas pipelines. Monitoring specific parameters or indicators that reflect conditions in pipelines can detect early signs of failures that lead to downtime. The second is preventive maintenance, which refers to maintenance activities that are scheduled based on the condition of the system and failure probabilities to reduce the likelihood of unexpected failures and downtime (Basri 2017). The third is the use of various predictive analytics techniques. These techniques use historical data and algorithms to predict future behaviours, detect anomalies and predict potential failures or performance degradation (Feblowitz 2013, Kumar 2018).
Based on research conducted in NIS (Naftna indsutrija Srbije), as well as on the basis of available literature, one of the important trends in proactive monitoring is the use of digital twins (Wanasinghe, 2020). The deployment of digital twins is still at an early stage in the monitoring of oil and gas pipelines and it needs time to understand the full potential of digital twins. The current status of research activities in the monitoring system of oil and gas pipelines in NIS shows the wide scale of opportunities in the deployment of digital twins and how their importance in proactive monitoring and predictive maintenance. The initial results are very encouraging and show that digital twins can be easily implemented in the existing SCADA system and that digital twins with historical data can reliably predict alarm situations.

4. CONCLUSIONS

Successful monitoring of oil and gas pipelines ensures energy stability and at the same time prevents damages or quickly repairs damages that can significantly impact the environment in which they are located. Proactive monitoring is an approach that enables the use of various methods of data analysis in addition to preventive and corrective maintenance so that all the benefits of predictive maintenance can be exploited.
The analysis of approaches to the implementation of oil and gas pipeline monitoring presented in this paper shows that we are entering a period in which particular attention will be paid to the collection, analysis and use of data.

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USE OF CERAMIC AND HYBRID ROLLING BEARINGS IN MODERN TECHNOLOGY AND THEIR COMPARATIVE TESTS

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Abstract: *The analysis of the support units of high-speed rotors with rolling bearings made of steel or ceramic materials is carried out in terms of the possibility of their use for modern and advanced turbines of diesel engines. Hybrid bearings have become widespread in medical equipment, vacuum pumps for various applications, spacecraft, food industry, chemical industry, entertainment and sports, miniature gas turbine engines for aircraft models, electric vehicles, CNC machine tool spindles, the military industry, etc. Possible advantages and shortcomings of ceramic or hybrid (steel and ceramic) rolling bearings and the ambiguity of data on their characteristics given in the literature. The design of an experimental setup for conducting comparative tests of steel and ceramic bearings and a methodology for their implementation have been developed. The setup allows testing of angular contact rolling bearings in the presence of radial and axial loads, external cooling or heating. In the process of testing, control and measurements are carried out: temperature of the outer ring of the bearing; oil temperature at the inlet and outlet of the bearings; air temperature at the inlet and outlet of the unit; rotational resistance moment for a pair of bearings; oil flow through the bearings.*

Key words: silicon nitride, turbines, engines, tank, compressor, supercharger

1. INTRODUCTION

The recent trend in engine building to increase power due to the use of engine turbo-charging leads to a decrease in the dimensions of parts and an increase in speeds at which rotor parts have to work including bearings. The reliability of an engine de-pends to a large extent on the reliability of the bearings, so the reliability of the bearing plays an important role in the performance of the turbine and the entire engine. In the turbine engines of the last decade, the bearings have to operate at their maximum speeds. At such high levels of the speed parameter, it is necessary to resort to various kinds of design solutions (Heshmat, et. all, 2018) to ensure a high level of durability and stability of the rolling bearings. In the practice of designing such stressed bearings in mechanical engineering, they went in two ways: the improvement of conventional rolling bearings and the replacement of rolling bearings with plain bearings with gas, liquid and less often magnetic working environment.

The use of plain bearings (Nazin, Determining…, 2021) in turbine rotors (Nazin, Revealing…, 2021), diesel engine turbines has become widespread. However, their use has a number of negative effects:

1) high frequency of stops and starts of the engine, which reduces the reliability of the support as a whole due to the instability of bearings in transition periods;
2) the relative complexity of the nodes of the sliding supports and the system for supplying the working environment;
3) greater sensitivity of the support to changes in the supply of the working environment, which leads to the complication of the supply system;
4) each plain bearing is unique in its characteristics and therefore requires an individual approach to tuning and maintenance;
5) the production of plain bearings requires special high-precision production facilities (Gnytko, et. all, 2022, 2023), while the creation of rolling bearings is carried out at existing specialized mass enterprises.

In connection with the foregoing rolling bearings and seals (Kolomoets, et. all, 2012) still prevail in structures, for example, aircraft engines, etc. Rolling bearings are also used as supports for the tank supercharger and compressor. Rolling bearings are widely used in medical instrumentation (He, et. all, 2021). There are a large number of works on the development of the use of rolling bearings in the design

of spindle assemblies of CNC machines in terms of vibration (Miao, et. all, 2021), thermal analysis (Krstić, et. all, 2018), wear characteristics (Pham, et. all, 2022), other.

As a result of an increase in the speed parameter and loads on bearings, a number of works have been carried out to improve their characteristics:

- specialized bearing materials have been developed and improved (Quaranta, et. all, 2022);
- accuracy of manufacturing of the parts (accuracy and cleanliness of surfaces) was increased;
- various nanostructures: a single-crystalline metal oxide nanostructures (Guo, et. all, 2019), 1D metal oxide nanostructures (Baranov, et. all, 2021), copper oxide nanowires (Baranov, et. all, 2019), (Breus, Anodic…, et. all, 2022) are considered as perspective means to reduce friction in contact with other parts;
- surface treatment: TiN coatings (Baranov, et. all, 2013), carbon nanostructure (Breus, et. all, 2021), (Breus, Catalytic…, et. all, 2022), coating grows (Baranov, et. all, 2012) methods have been developed and can be applied to increase their wear resistance;
- special forms of rolling tracks have been developed to increase the bearing capacity of bearings and reduce friction losses during rolling;
- methods have been developed to reduce the mass of rolling elements;
- means and methods of cooling and lubricating (Piet, et. all, 2022) bearings are being improved, which includes the use of new materials for lubrication (Sun, et. all, 2022);
- accuracy of calculations of bearing characteristics by taking into account a larger number of factors that affect them was increased (Wu, et. all, 2022).

The use of ceramic materials for rolling bearings has become one of the possible ways to improve the performance of bearings.

The widest spread are the so-called hybrid bearings, in which the rings are made of conventional bearing steels, and the rolling elements are made of ceramics. The use of bearings with ceramic rings is limited by the complexity of finishing ceramic rings and the complexity of mounting the bearing on the shaft, as well as the rather low impact strength of ceramics. Ceramic materials have the following features compared to steel:

- low density (~60% less);
- high modulus of elasticity (more by ~50%);
- chemical inertness in more aggressive environments;
- coefficient of dry friction in ceramic-steel pair is less than in steel-steel pair;
- lower coefficient of thermal expansion and high heat capacity and heat resistance;
- ceramics - dielectric;
- low impact strength.

These features provide a number of advantages of ceramics over steel when used as materials for rolling elements of bearings:

- reduction of centrifugal forces;
- reduction of power losses due to friction;
- increase in the service life of the lubricant and rolling elements in aggressive environments;
- reduction of preload in the bearing (up to 33%);
- complete electrical isolation of the inner ring from the outer one;
- reduction of radial clearance in the bearing;
- reduction of operating temperatures of the bearing;
- reduction of vibration and noise of the bearing;
- the possibility of long-term operation in the absence of lubrication.

The first experience with bearings with silicon nitride balls has been known since 1975. However, works in this area, judging by the content and the attached discussion, do not provide unambiguous answers to a number of important questions. These works confirm the possibility of reducing the preload up to 30%, however, they differ in the results of studies regarding friction losses. It is indicated that the fatigue life of hybrid bearings does not show any special advantages over conventional steel bearings when operating up to dn = 3•106. However, further work led by Ervin V. Zaretsky on bearing life prediction led to the fact that the idea of revising the theory of life calculation based on the Lundberg-Palmgren equation was proposed, and the opinion that all-metal bearings under the same operating conditions have a longer service life than hybrid bearings, but there is no experimental confirmation of this opinion.

Experimentation with ceramic rolling elements for aerospace bearings began decades ago when NASA's space shuttle engines used them in the early 1990s.

In 2005 Timken was awarded two contracts under VAATE's gas turbine engine optimization program to develop hybrid bearings for an aircraft gas turbine engine.
Recently Timken engineers have worked closely with defense aircraft manufacturers to develop hybrid roller bearings for several applications, including aircraft gas turbine engine development. Timken intends to begin full-scale production to support aerospace customers by 2023.
Electric vehicle component manufacturers, including SKF, are tackling the issue of future-proofing hybrid bearings by improving their performance, efficiency and reliability.
Hybrid bearings provide efficient operation under conditions of improper lubrication and contamination, but the reasons for this and their effect on performance are still not fully investigated. According to the results of SKF's research only the steel component is subject to moderate wear in a hybrid bearing, while the ceramic part is practically unaffected. Under conditions of contamination, moderate wear, plastic deformation and maintenance of surface smoothness at the edges of dents in hybrid bearings contribute to the reduction of local stresses. It is shown that the increase in the service life of hybrid bearings with dents occurs due to high resistance to surface destruction and damage associated with extreme lubrication conditions and the lubricating film integrity failure.
From the above, we can conclude that hybrid bearings are widely used in various industries.

2. METHODS

Of all ceramics, silicon nitride (Si3N4) is the most widespread (Li, et. all, 2022). Properties of silicon nitride in comparison with bearing steel are given in Table 1.

Table 1: Properties of bearing materials

Material	Modulus of elasticity ($\times 10^6$ PSI)	Density (Lbs/in^3)	Poisson's ratio	Coefficient of linear thermal expansion (µin/inch/°F)	Hardness (HRC)	Limit operating temperature (ºF)
Steel AISI 440C (M&I)*	30	0,28	0,28	5,7	60 – 63	300
Steel AISI 440C (S&T)*	30	0,28	0,28	5,7	56 – 60	600
Ceramic	46	0,1156	0,26	1,7	78	2000
Steel AISI M50	30	0,288	0,29	6,6	61 – 64	650
Steel SAE 52100 (M&I)	30	0,28	0,29	6,7	62 – 65	350
Steel SAE52100 (S&T)	30	0,28	0,29	6,7	58,5 – 65	390

*Barden designations: M&I - Miniature & Instrument - miniature bearings and bearings for measuring instruments (d=4…35 mm); S&T - Spindle & Turbine - bearings for machine tool spindles and turbomachines (d=22…290 mm).

The properties of balls made from various ceramic materials are given in Table 2.

Table 2: Properties of balls made from various ceramic materials

Material	Rockwell hardness at 294 K	Limiting temperature of bearing use*, K	Density, g/cm3	Modulus of elasticity at 294 K, 109 N/m2	Poisson's ratio	Thermal conductivity, W/(m·K)		Thermal expansion coefficient at 273…1073 K, 10^{-6} m/K	Weibull module**
						at 294 K	at 1073 K		
Crystalline glass ceramics	53	> 644	2.5	87	0.25	1.6	2.0 at 873 K	0.4	3.3
Alumina	85	~ 1367	3.9	350	0.25	7.2	1.7	8.5	2.7
Silicon carbide	90	< 1367	3.2	410	0.25	35	12	5	2.1
Titanium carbide with nickel-based binder	67	< 867	6.3	390	0.23	14	6.8	10.7	1.4
Silicon nitride	78	1367	3.11…	310	0.26	7.3	4.7	2.9	1.7

			3.24						

* From the condition of maintaining hardness and experimental data
** From experiments to determine the fatigue of rolling elements

The lack of specific recommendations on the use of hybrid bearings and the calculation of support units with them in the available domestic and foreign literature prompted us, together with the experimental design company, to prepare comparative tests of traditional aircraft bearings and their counterparts with ceramic rolling elements. The interest of experimental design company is due to the fact that the enterprise has a need to increase the resource of the auxiliary power installation. One of the areas of work to increase the resource was to consider the possibility of replacing a serial bearing with its hybrid counterpart. This led to the choice of bearing sizes for testing. The main parameters and operating conditions of the auxiliary power unit bearing are shown in Figure 1.

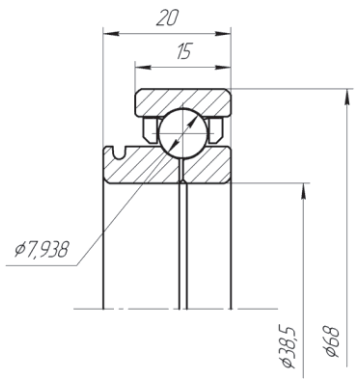

Figure 1: Parameters and operating conditions of the bearing. Working conditions: working speed 40000 - 55000 rpm; load on one bearing: radial - 38 kgf, axial - 200 kgf; operating temperature of the bearing 250 ºC

To test the bearing, a test complex was developed, the basic design of the block of tested bearings of which is shown in Figure 2.

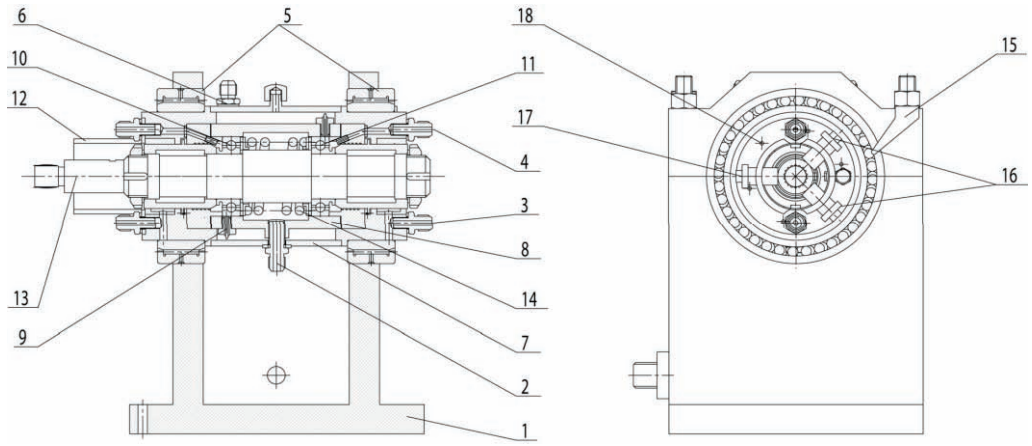

Figure 2: Block of tested bearings:1 - bearing block housing; 2 - oil outlet; 3 - air supply to create a radial force; 4 - oil supply; 5 - thrust bearings; 6 – fitting for air supply for bearing heating; 7 - heating casing; 8 - bearing housing; 9 - thermocouple; 10, 11 - tested bearings; 12 – body of sensors; 13 - shaft; 14 - spring; 15 - retainer; 16 – rotor oscillation sensors; 17 – speed measurement sensor

The axial load on the bearings is created using a compression spring 14, which allows us to lock the load inside the system and evenly distribute it between the bearings, the load remains unchanged within acceptable limits and does not depend on external energy sources. The loading limits are limited only by the design of the spring. However, in this case, the ability to purposefully change the load during testing is lost. If necessary, such a loading system with minimal changes in the design can be replaced by a system with external loading using a pneumatic or hydraulic cylinder. Load control is carried out according to the degree of compression of the spring. The radial load is created using a kind of pneumostatic bearing. Load

control is carried out by air pressure in the system. The maximum created load on one bearing is 588,6 N (60 kg), with an air pressure in the system of 0,49 MPa (5,85 kgf/cm2).
Lubrication is carried out with the help of a jet of oil supplied through jets separately to each bearing (supply is carried out into the gap between the separator and the inner ring of the bearing). Oil outlet from bearings - common through fitting.
Lubrication system - closed, circulating, separate for the tested bearings and multi-plier bearings. The oil temperature is controlled by thermocouples at the inlet to the bearings and at the outlet of the bearing block housing. There is no forced oil heating. The oil is cleaned with a 10 μm filter. The bearings were lubricated with Turbonicoil 210A or IPM-10 synthetic hydrocarbon grease.
The bearing housing 8 is blown by air entering through the fitting 6. The supplied air allows additional cooling or heating of the bearings. It is possible to control the heat flow from the bearings through the bearing block housing by the temperature difference between the incoming and outgoing air. Temperature control is carried out by thermocouples. The air blowing system of the bearing housing is independent of the radial load system.
The temperature of the outer rings of the bearings is controlled by thermocouples 11.
The speed control of the shaft of the installation is carried out using an inductive sensor 17. Two additional inductive sensors 16 allow you to record the vibrations of the shaft.
The block of tested bearings is installed in the housing 1 roller bearings 5, which allows you to directly measure the moment of resistance in a pair of bearings under study. Clamps 15 prevent axial movement of the outer rings of the bearings.
The drive of the block of tested bearings is carried out from the electric motor 1 through the multiplier 2 (Figure 3). Achievable speed - up to 40,000 rpm.

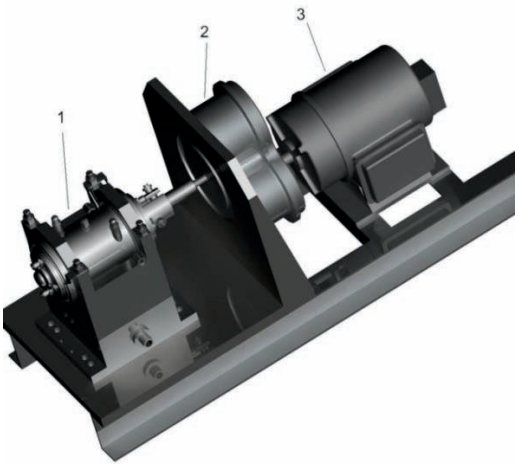

Figure 3: Bearing test facility: 1 - block of tested bearings; 2 - multiplier; 3 - electric motor

3. RESULTS

Thus, the developed setup allows testing of angular contact rolling bearings in the presence of radial and axial loads, external cooling or heating.
In the process of testing, control and measurements are carried out (Dotsenko, et. all, 2023):

- temperature of the outer ring of the bearing;
- oil temperature at the inlet and outlet of the bearings;
- air temperature at the inlet and outlet of the unit;
- rotational resistance moment for a pair of bearings;
- oil flow through the bearings.

Carrying out comparative tests of hybrid bearings and conventional serial aircraft bearings with metal balls provides for the solution of the following tasks:

- determination of heat dissipation in bearings under the same operating conditions (load, lubrication, ambient temperature) by determining the temperature of the outer rings of bearings;
- determination of the degree of wear of bearings under the same operating conditions for a period equal to the designated service life for a serial aircraft bearing;

• determination of friction losses by determining the moment of resistance, heat removal to the oil and through the housing to the blowing air when testing a pair of hybrid bearings and a pair of conventional bearings;

• determination of optimal lubrication conditions that ensure minimum friction losses and optimal cooling of hybrid bearings;

• creation of recommendations on the expediency of using hybrid bearings;

• creation of recommendations for the use of hybrid bearings, namely: methods for determining the optimal lubricant consumption, the optimal radial clearance of the bearing (based on thermal conditions and taking into account the special physical and mechanical properties of the bearing materials).

4. CONCLUSIONS

In the paper, the analysis of the support units of high-speed rotors with plain and rolling bearings made of steel and ceramic materials was carried out in terms of the possibility of their use for modern and advanced turbines of diesel engines. Possible advantages and disadvantages of ceramic or hybrid (steel and ceramic) rolling bearings and the ambiguity of the literature data on their characteristics are noted. Design of an experimental setup for conducting comparative tests of steel and ceramic bearings and a methodology for their implementation have been developed. The developed setup will be used to study the performance characteristics of bearings with ceramic rolling elements for diesel engine turbines.

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MATURITY MODELS FOR THE USE OF ARTIFICIAL INTELLIGENCE IN ENTERPRISES: A LITERATURE REVIEW

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Abstract: *Artificial intelligence is a promising technology for companies to leverage optimization potential and remain competitive. Nevertheless, studies show that only a few companies use this technology. Maturity models can contribute to self-assessment and help to implement this technology. In this paper, capability, readiness and maturity models are presented based on a literature review and a qualitative analysis. Overall, the results show that the models can serve as a tool to assess and improve AI readiness and maturity. However, in order to fully exploit their potential from a user perspective, it is essential to further develop these models specifically for AI domains, ensure transparency in their design, draw clear conceptual boundaries and incorporate user-friendly assessment mechanisms. Furthermore, recommendations for action are made on the basis of this information.*

Key words: Artificial Intelligence, Maturity Model, Adoption, Literature Review

1. INTRODUCTION

The impetus for this paper arises from the recognition that there have been several preliminary works and literature reviews on this subject. However, either these works did not adequately consider specific artifacts that are important to the topic AI maturity models, or the explanations regarding these artifacts were not sufficiently detailed. Consequently, there exists a gap in the literature regarding a comprehensive investigation of these artifacts within the context of the examined subject. Through a systematic approach and comprehensive analysis, we endeavor to offer valuable insights that enrich the scholarly discourse on this subject matter. The detailed explication of these artifacts will contribute to a more nuanced and well-founded understanding of their relevance and potential implications for maturity models.
This paper commences with an introduction and an elaborate presentation of the fundamentals of maturity models. Within this introduction, relevant theoretical concepts and methodological approaches are introduced to provide readers with a comprehensive context for the subject matter. In the second chapter, an overview of existing models follows, which were identified on the basis of a literature review, then reduced, structured and sorted. In the third chapter follows the evaluation of the maturity models and presentation of the results. The paper ends with the discussion and conclusion.

1.1 Fundamentals of maturity models

Many AI technologies and applications developed in recent decades have reached market maturity and are now being sold commercially in digital products and services (Schmid et al., 2021). Maturity models serve as a kind of tool that makes it possible to determine the positioning of one's own organization and to identify development prospects (Becker et al., 2009a). Although various types of maturity models exist, they share common characteristics. They include a set of indicators or process areas in multiple maturity levels, with a description of the required performance of the indicators at these levels (Fraser et al. 2002). According to (Mettler, 2010), the implementation of the components into a maturity model is done in various ways in practice. In the literature, a basic distinction can be made between two types of maturity models. (Mettler, 2010) distinguishes in his work between optimization models and evaluation models:

1. Optimization models try to specify an idealized development path in order to achieve an improvement for the object under consideration (Paulk et al. 1993).
2. Evaluation models also aim at the continuous improvement of the object of observation, but the focus is rather on the aspect of comparison. Often, no explicit development path is specified, but it is rather implicitly contained in the models (Winter et al. 2016).

Another distinction often made in the literature is according to the typology of maturity models, which manifests itself in the design of the maturity model. Maturity models can be divided into three basic types (Fraser et al., 2002):

1. Maturity Grids (maturity grids, maturity tables): Grid models use a grid structure in which each activity in each maturity level is represented by textual descriptions. As a result, these models have lower complexity and usually consist of only a few pages of text.
2. Capability Maturity Model-like models (CMM): models based on the CMM approach have a more structured but also more complex form, where each stage is described by a specific sequence of measures and activities addressed to specific goals. Although there are general descriptions of maturity for each level, there are no individual descriptions for each activity at each maturity level.
3. Likert-like questionnaires: The Likert-like questionnaire, when constructed in an appropriate manner, can be considered a simple form of a maturity model. In this type of model, the "question" simply represents a statement of "good practice" by the object of assessment and rates the relative performance of the organization on a scale from 1 to n. It should be noted that this type of questionnaire becomes a checklist when n=2.

The aforementioned characteristics of maturity models primarily pertain to their formal content. While the fundamental objectives and structure of the models have been elucidated, the further assessment of these models necessitates a more profound examination of their characteristics. Particularly, evaluating maturity model attributes requires a deeper analysis (Jording, 2018). The classification of these characteristics are based on the work of (Jording, 2018), (Mettler, 2010) and (Ahlemann et al. 2005). (Mettler, 2010) distinguishes the characteristics of maturity models into general characteristics, construct-specific characteristics, and model-specific characteristics. Jording (2018) differentiates the characteristics into general attributes, attributes related to conceptualization, attributes related to operationalization, retention attributes, and framework attributes. The following sections are based on these characteristics of maturity models and present a compilation of relevant attributes for the evaluation.

1.1.1 General Attributes

The novelty value refers to the extent to which the model draws upon existing solutions, meaning it either addresses an existing problem in an alternative way (variant or version) or provides a completely new problem-solving approach (innovation) (Mettler, 2010).
The institutional background in addition to individual authorship describes, if there is an overarching institutional affiliation or connection (Jording, 2018). A distinction is made between four attributes. The model was developed by researchers affiliated with universities or institutional research establishments. The model was created by one or more individuals who are not associated with scientific institutions or the organizations mentioned here and work independently. The model was created by one or more individuals who are not associated with scientific institutions or the organizations mentioned here and work independently. The model was developed by a company or directly commissioned by a company. In many cases, these may be consulting firms. Since models from consulting firms were not considered in the literature review, so this characteristic indicates that the examined model is based on previous work by a consulting company. As the last and fourth attribute, when model was devised by an association, society, or similar organization. The model was developed by a government institution or directly commissioned by such an organization (Becker, 2009b).
The model's breadth defines the scope within it was designed and determines whether it is a sector-specific or none-sector-specific-model. The target group specifies the perspective from which the maturity model is viewed, either from a management-oriented or technology-oriented standpoint (Mettler, 2010).
Regarding accessibility, three distinct variants are distinguished: freely accessible, cost-based, and consulting services (Jording, 2018). In the course of the research, the access was free of charge, whereas external individuals have to bear costs. For this reason, the accessibility of a model, even if associated with only a minor expense, was classified as fee-based.
Within the context of priorisation, the examination of the models assesses whether they conduct an evaluation of their contents. It takes into account that not all content underlying the evaluation contributes equally to the performance of the evaluated object (Jording, 2018). Additionally, the model is

evaluated regarding its adaptability to individual users, where specific questions or evaluations can be excluded or modified (Ahlemann, 2005; Jording, 2018). In terms of the geographical scope, the assessment determines whether the maturity model considers a geographical reference during its validation or application (Jording, 2018).

Table 1: General Attributes

Characteristics		Parameter Value				
General Attributes	Institutional Background	Science	Individual	Company	Association or Society	Government Organization
	Novelty Value	Innovation		Variant		Version
	Accessibility	Freely Accessible		Cost-based		Consulting Services
	Priorisation	Priorisation possible		Priorisation Proposal		Adaptability
	Target Group	Management-oriented		Technology-oriented		
	Geographical Scope	Yes		No		
	Breadth	Industry-agnostic		Industry-specific		

Source: Adapted from (Jording, 2018; Mettler, 2010)

1.1.2 Model-Specific Attributes

In regard to the conception of the model, the purpose of use and the Definition of maturity levels were taken into account. The purpose of use defines whether the model was primarily developed for optimization or evaluation purposes (Mettler, 2010). The definition of maturity levels can be approached either through a Top-Down or Bottom-Up approach (De Bruin et al., 2005). The determination of the approach for deriving maturity levels is specified in the maturity level definition (Mettler, 2010). Unless explicitly stated, as in the work of (Alsheiabni et al. 2019), that a Bottom-Up approach was used, it will be assumed that Models aligning with the design frameworks of (de Bruin et al., 2005) or (Becker, 2009a) are based on a Top-Down approach, as they implicitly follow a Top-Down approach (Mettler, 2010).
Regarding the application of the maturity model, further differentiation is made based on the data collection method. The data used to assess the maturity can be gathered through either self-assessment or external assessment. Depending on the maturity level of the subject under consideration and the complexity of the maturity model, professional assistance may be required. An essential component of the data collection method is the data collection technique, which determines the specific means through which the data is gathered. This could include methods such as interviews, surveys, observations, or document analyses. The chosen data collection technique significantly influences the format and structure of the collected data. Finally, the tools provided to facilitate data collection are specified. These tools could include handbooks, checklists, or software tools that support the data collection process (Mettler, 2010).

Table 2: Model-Specific Attributes

Characteristics		Parameter Value			
Model-Specific Attributes	Data Collection Technique	Interview	Survey	Observation	Document Analysis
	Assessment	Self-Assessment	Supported by Third Parties		Assessment by Third Parties
	Tools	None	Document-based		Computer-assisted
	Maturity Level Definition	Bottom-Up		Top-Down	
	Purpose of Use	Optimization		Evaluation	

Source: Adapted from (Jording, 2018; Mettler, 2010)

1.1.3 General condition

The examined maturity models differ in terms of their empirical foundation. According to (Ahlemann et al. 2005), this characteristic can be interpreted as a quality indicator of a maturity model and is defined and differentiated as follows:

1. Models have no or no documented foundation.
2. Models are explained and motivated based on case studies, making the results understandable based on individual cases.
3. Models have an empirical foundation based on a broad empirical analysis involving a large number of experts in the construction of the model.

Regarding the third point, it can be added that in the study of (Jaaksi, 2018), which was conducted through 11 expert interviews, it is stated that the results are not generalizable due to the low number of interviews. In this Paper, a supporting number of more than 20 expert interviews is assumed as a basis for an empirical foundation.

Table 3: General Condition

Characteristics		Parameter Value		
General Condition	Empirical Foundation	No/Not documented	Case Studies	Empirical Foundation

Source: Adapted from (Jording, 2018; Mettler, 2010)

1.2 Objective of the paper and Research Questions

The objective of the paper is the identification and application areas for maturity models. The research questions (RQ) are as follows:
RQ 1: Which maturity models exist in the literature and how do they differ?
RQ 2: What are the application areas of these maturity models?
RQ 3: What various terminologies are used in relation to indicators within models and the model itself, and how can be categorized?

2. RESEARCH METHODS AND LITERATURE OVERVIEW

The research questions are answered with a literature search and subsequent qualitative evaluation. For this purpose, a general overview of the topic was first made and the research questions were refined before starting the actual search. For the research process, the works of (Snyder 2019; Webster & Watson 2002) were consulted and guided by their research process. The systematic process of (Wright et al., 2007) was also used in the literature search. The authors divided the steps of the systematic review into: (1) research question, (2) research protocol, (3) literature search, (4) data extraction, (5) quality assessment, (6) data analysis and results, and (7) interpretation of results.
After establishing the research questions, a continuation protocol was established to help systematically identify papers in the literature review. The procedure in a research protocol can be described as an iterative process with four steps: (1) search, (2) screening, (3) data extraction, and (4) data analysis. For step 1, the database was selected and keyword chains were created. Scopus (www.scopus.com) was used as the database because many economics papers are indexed there. The next step was to select the keywords for the research topic. Key terms were varied according to both synonyms and abbreviations. The search period for the articles was from December 2022 till March 2023. After the relevant papers were selected, data extraction and analysis took place. The relevant papers are presented in the following.
The universal maturity model by (Burgess, 2018) has six maturity levels. This is intended to enable assessment of the entire organization, but can also be applied to individual areas of the company. Burgess takes a solution-oriented approach in which AI applications are assigned to the desired solution area in a matrix. The assessment of maturity levels is subjective and is done through interviews. After developing the AI maturity matrix, Burgess' next step is to create a heat map. The heat map provides a top-down perspective on areas where AI solutions are desirable, economically viable, and/or technically feasible and is intended to identify the types of AI applications that could be applied in each area to achieve the desired goals. Using the combination of the maturity matrix and the heat map, business areas can be assessed against 4 main factors and their sub-indicators. How these are to be assessed is not apparent.
(Jaaksi, 2018) identified five indicators that influence the maturity level in an organization in his study by means of 11 expert interviews, but points out that the maturity model cannot be generalized due to the small number of interviews. The development of the maturity model follows the development framework

of (Bruin et al., 2005) and (Becker et al., 2009a). The maturity model was designed as a matrix with four unnamed maturity levels and the five relevant indicators. An assessment approach is proposed using either qualitative descriptions or a quantitative alternative. For the latter, the use of a Likert scale is proposed. It is not clarified in the paper how the proposed assessment alternatives can be applied.

(Seger et al., 2019) develop a maturity model framework specifically for intergovernmental organizations in their study. The maturity model describes a series of evolutionary stages that are passed through during their AI transformation and it consists of 5 maturity levels. The maturity levels are described. Essential influencing factors for AI application implantation are presented in the paper, but there is no indication of how they should be applied to each maturity level. Furthermore, it is not apparent how the individual maturity levels are to be evaluated in the course of determining maturity.

A maturity model was developed by (Alsheiabni et al., 2019) to assess the maturity of organizations that have already implemented or partially adopted AI. Therefore, according to the authors' own statement, the paper represents an attempt to develop an AI maturity model at the organizational level. The indicators were identified by the authors through an analysis of the general maturity model literature. The maturity model follows the design principle of (Becker et al., 2009a). It is represented by a matrix and includes 5 maturity levels and the corresponding 4 indicators identified from the literature. According to the author, an expert survey will be conducted in the future to validate the maturity model and, based on this, the maturity model will be further refined with case studies. Through further research in the scientific literature, it was not possible to determine whether this has already been implemented. No recommendations for action are given as to how the next maturity level can be reached.

(Gentsch, 2019) pursues the goal of developing a universally applicable maturity model based on an AI framework. The AI framework functions as an approach that captures the success factors and drivers of AI in companies and transfers them to operational applications. Building on this framework, a maturity model was developed that includes four maturity levels and five indicators described at each maturity level. The maturity model is intended to help companies assess their progress in AI based on the selected indicators and defined maturity levels. However, it does not provide details on how to evaluate these indicators, nor does it offer specific recommendations for action to reach a particular maturity level.

The maturity model of (Saari et al., 2019) was developed based on the maturity index of the Finnish Artificial Intelligence Accelerator (FAIA), an organization specializing in AI progress. Originally, the AI maturity index was first published in the 2018 Finnish Digibarometer. The resulting maturity model has been further developed and consists of five maturity levels described by six indicators. Each maturity level represents a prerequisite for the next. The questionnaire developed for the assessment assigns two questions with five response alternatives to each indicator, which are intended to reflect the maturity level.

The approach of (Kreutzer et al., 2019) is based on an AI maturity map. This maturity map serves as a tool to determine the maturity level and enables a clear distinction between the basic AI competencies and the specific application areas of AI in a company. The AI fundamentals are analyzed based on four indicators: AI goals, AI staff, AI systems, and AI budget. These indicators serve as guidelines to assess the current maturity level with respect to AI fundamentals. At the same time, the AI maturity map provides the flexibility to define the relevant application areas specifically for each company, as these may vary depending on individual requirements and goals. The five maturity levels are divided into percentages from 0% to 100% to show progress in terms of AI maturity. The indicators are evaluated equivalently by a percentage assessment from 0% to 100%. The advantages and disadvantages of self-assessment and third-party assessment are described in overview. Although the indicators are described roughly, the model does not explicitly specify how these indicators affect the individual maturity levels and how they should be evaluated as a result.

(Ellefsen et al., 2019) focus in their approach on how companies can successfully implement AI solutions in the areas of production and warehousing. In doing so, they propose to combine the maturity levels of AI with the maturity models of Logistics 4.0 in order to identify the relationship between the actual maturity level of logistics and the readiness of companies to implement AI solutions. The basis of the maturity model is a maturity model from the consulting firm Ovum, which places its focus on communications and media companies. The authors see great potential for applying this model to their problem, but do not substantiate this in the following. The model was adapted to meet the requirements of logistics and the use of AI in production and warehousing. Part of the work consisted of developing a questionnaire that was used to collect relevant information to determine the maturity level of companies. In total, the questionnaire includes 49 questions, but only 12 of them are presented in the paper. A case study was conducted in Norway and Poland and was based on direct interviews with the

companies. The exact way of this maturity determination was not explicitly presented in this thesis, nevertheless the results were discussed.

(Lichtenthaler, 2020) proposes an AI management framework with five maturity levels in its maturity model, which is based on the five stages of autonomous driving. These allow consideration in terms of the degree of automation, which range from no automation to full automation. The AI management framework is intended to highlight untapped potential and unrecognized opportunities in virtually all companies by seeking to solve the additional opportunities of AI with the creation of an integrated intelligence architecture. The maturity model includes a total of 5 maturity levels, ranging from 1 to 5, and has been expanded to include the introduction of a "zero" maturity level and a higher-level future-oriented maturity level, but these are not explained in detail. The maturity levels are described. The three indicators: the different types of AI, the multiple aspects of human intelligence, and meta-intelligence are described, but not brought into the context of the individual maturity levels. No explicit approach to maturity assessment is presented.

(Yams et al., 2020) focus their work on how AI can and will change and support different aspects of innovation management. In developing the maturity model, the authors were guided by the development framework of (Bruin et al., 2005). The maturity model was designed as a matrix and consists of five maturity levels and six interrelated and interdependent indicators. To allow a more precise definition of the indicators, they were further specified by sub-indicators. The selection of indicators is based on the AI index developed by the consulting firm Gradient Descent. Although the model is described in detail, it does not include a specific scoring system for assessing AI maturity. The authors suggest that the development of an assessment tool could be considered in the future. According to the authors, this would serve to support the maturity model to enable a systematic assessment of a company's current AI maturity level. Through further research in the scientific literature, it could not be determined whether this has already been implemented. Furthermore, it should be noted that the authors do not provide any concrete recommendations for action on how to reach the next maturity level.

(Holmström, 2021) presents a comprehensive readiness framework designed to support the assessment of an organization's AI readiness. Four key indicators are defined that are used to assess the current situation and future expectations related to these indicators. The assessment is done through a self-assessment by employees, where they rate two statements per dimension using a Likert scale from 0 to 4. It is important to note, however, that the primary purpose of this maturity model is to perform an assessment and not to provide specific recommendations for action to achieve a particular maturity level.

(Limat, 2021) focuses in his research paper on the identification of corporate capabilities and characteristics that are relevant for the design of AI initiatives. The goal is to transfer these findings into a holistic maturity model. For this reason, a maturity model has been developed that enables a structured analysis of AI integration efforts at the enterprise level, based on different design domains. The development of this maturity model is based on the development frameworks of (Bruin et al., 2005) and (Becker et al., 2009a). A total of 18 sub-indicators were identified, which were subordinated to 7 main indicators. The description of the individual dimensions was done deliberately without weighting them. The focus is rather on a holistic assessment of the situation in order to comprehensively capture the integration of AI at the company level. The maturity model consists of 5 successive maturity levels, which are not discussed in detail. The indicators are not described at all levels.

In their research approach, (Mikalef et al., 2021) focus on identifying the organizational resources that companies need to develop their AI capabilities to achieve performance improvements. In doing so, they draw on the foundations of resource-based theory to determine an organization's AI capability. Through an in-depth analysis of existing academic studies and conducted interviews, the authors identify relevant technical and non-technical indicators that are critical to developing a company's AI capability. The identified indicators are divided into three categories and described in detail. Questions are defined that serve as measures to gauge a company's AI capability. The work of (Mikalef et al., 2021) focuses specifically on the impact of these indicators on business performance and creativity. It should be noted that the authors primarily address the identification and description of the indicators in their work and do not present a maturity model.

In their work, (Jöhnk et al., 2021) derive from scientific and practical literature the factors that influence a company's AI readiness and define relevant indicators for this AI readiness. Through this thorough analysis, they identified a total of five main indicators, which are in turn subdivided into 18 sub-indicators. These indicators are assigned AI characteristics and company-specific requirements. Maturity levels are not defined. The authors note that a comparison of organizational readiness factors for different technologies based on their underlying technological characteristics was not included in their work, but

point out the benefits of such research. Furthermore, they suggest further research into the specific characteristics of organizations for AI adoption.
(Fukas, 2022) pursues the goal of an integrated management framework that combines insights from maturity model research with those from a comprehensive AI management perspective. In the development process of the maturity model, a systematic literature review was conducted at the beginning of the thesis and relevant indicators were defined. Furthermore, these indicators were assessed by experts by means of a questionnaire and a new model was created, which should cover all relevant aspects. The author is guided by (Becker et al., 2009a) in creating his maturity model. The nine indicators of the model are described in detail, but not in terms of the individual five maturity levels. The maturity model follows the design of a grid matrix and functions as an assessment model used to evaluate the state of an organization in terms of its AI capabilities. Control questions are designed to assess the state of the organization with respect to its handling of AI. Both the control questions and the associated assessment system are currently under (further) development and have not yet been fully elaborated. No concrete recommendations for action are given as to how the next maturity level can be reached.
The maturity model, developed by (Noymanee et al., 2022), focuses on maturity assessment of government organizations. The development process of the model involved a systematic literature review to identify relevant indicators. The model was designed according to the approach of (Becker et al., 2009a). It consists of 5 maturity levels and 5 main indicators presented in the form of a matrix and described at each level. The indicators are further subdivided into sub-indicators. However, no information is available on how the maturity level is determined for each indicator. No information will be provided on how to determine an overall maturity level. Furthermore, no concrete recommendations for action are given to achieve a higher level of maturity.

3. RESULTS

In accordance with SADIQ et al. (2021) Table 4 serves as a summary of the models, elucidating the key parameters. The table provides an overview of the Stages and associated indicators derived from the examined models, offering a consolidated and informative perspective on the factors considered for evaluating readiness-, capability- and maturity levels.

Table 4: Summery of the Models

Autor/s	*Number of Stages*	*Terms of the Stages*	*Number of Indicators*	*Terms of Indicators*
Alsheiabni et al. (2019)	*5*	*Initial, Assessing, Determined, Managed, Optimized*	*4*	*AI functions, Data Structure, People, Organizational*
Burgess (2018)	*6*	*Manual processing, Traditional IT enabled automation, Isolated basic automation attempts, Tactical deployment of individual automation tools, Tactical deployment of range automation, End-to-end-strategic automation*	*5*	*AI-Capabilities, Benefits, Existing Challenges, Strategic Objectives*
Ellefsen et al. (2019)	*4*	*AI novice, AI ready, AI proficient, AI advanced*	*5*	*Strategy, Organization, Data, Technology, Operations*
Fukas (2022)	*5*	*Initial, Assessing, Determined, Managed, Optimized*	*8*	*Technology, Data, People & Competences, Organization & Processes, Strategy & Management, Budget, Products & Services, Ethics & Regulations*

Gentsch (2019)	*4*	*Non-Algorithmic, Semi-Automated, Automated, Intelligence Enterprise*	*5*	*Strategy, Staff, Decisions, Data, Analysis*
Holmström (2022)	*5*	*None, Low, Moderate, High, Excellent*	*4*	*Technologies, Activities, Boundaries, Goals*
Jaaksi (2018)	*4*	*1, 2, 3, 4*	*5*	*Workforce, Data management, Process, Organization status, organizational maturity*
Jöhnk et al. (2021)	*N/A*	*N/A*	*5*	*Strategic alignment, Resources, Knowledge, Culture, Data*
Kreutzer & Sirrenberg (2019)	*5*	*0-20%: missing; 20-40% selectively present; 40-60% in individual areas, but not yet networked; 60-80% in many areas, networked to some extent; 80-100% completely networked in terms of content and structurally anchored in the company*	*4*	*Four Dimensions of AI-Basics: Objectives, Budget, Staff, Systems*
Lichtenthaler (2020)	*5 (+2)*	*(Isolated ignorance), initial intend, independent initiative, interactive implementation, interdependent innovation, integrated intelligence, (intuitive ingenuity)*	*N/A*	*Not available*
Limat (2022)	*5*	*1, 2, 3, 4, 5*	*7*	*Data, Culture, Competences, Strategy, Regulation, Customer behavior, Compatibility*
Mikalef & Gupta (2021)	*N/A*	*N/A*	*3*	*Tangible Resources, Human Resources, Intangible Resources*
Noymanee et al., 2022	*5*	*Rookie level, Beginner level, Operational level, Expert level, Mastery level*	*5*	*Strategy, People & Organization, Decision Making, Data and Analysis*
Saari et al. (2019)	*4*	*AI as part of identity, Integrated AI, Initial AI, Awareness of AI*	*6*	*Data, Technology, Internal Process, Product and Services, Competences, AI as a resource*
Seger et al. (2019)	*5*	*Unaware or risk averse, Aware and resourceful, Fully developed strategic plan, AI harnessed at scale*	*N/A*	*Not available*
Yams et al. (2020)	*5*	*Foundational, Experimenting, Operational, Inquiring, Integrated*	*6*	*Strategy, Ecosystem, Mindset, Organization, Technology, Data*

Source: Adapted from (SADIQ et al. (2021))

Following the analysis of the models, 102 different indicators and sub-indicators were identified. In accordance with Hizam-Hanafiah et al. (2020), an attempt is made to categorize these indicators into their main thematic areas. Indicators were considered for categorization when they exhibited differences in terminology and phrasing. The primary thematic categorization areas identified are Technology, Data,

People, Strategy, Management/Leadership, Organization, External Influences, Resources, and not assignable indicators. The indicators were either assigned to categories based on the Description in their model or were implicitly categorized when explicit classification was not evident. Table 5 shows the allocation of all indicators to their respective domains.

Table 5: Concentration of the Indicators

Indicators	*Number*	*Assigned Indicators*
AI-Capabilities, AI functions, Technology, Analysis, AI as a Resource, AI-Systems, Scalability, Robustness, Democratization, Capability, Infrastructure & Technology, Digital Transformation	*12*	*Technology*
Data Management, Data Structure, Data, Data Readiness, Data Strategy, Data-driven Decisions, Data Quality, Integrated Data management, Data-Governance	*12*	*Data*
Workforce, People, Personal, Competences, AI-Employees, People & Skills, Technical Skills, Business Skills, AI Awareness, Upskilling, People & Competences	*11*	*People*
Strategic Objectives, Strategy, AI-Objectives, Vision, Value Creation, Governance, Goals, Commitment & Ownership, Imbedded Vision, Key Figures, Strategic alignment, AI-business potentials, Customer AI readiness, Top Management Support, AI-process fit, Data-driven decision making, Strategy & Management	*18*	*Strategy*
Product & Services, Operations, Mindset, Leadership, Change management, Process	*5*	*Management / Leadership*
Organization status, Organizational maturity, Organizational, Internal Process, Organization, Ecosystem, Collaboration, Communication, Impact, Innovation, Growth, Structure, Processes and operation aspects, Culture, agility, Innovation & Fault Tolerance, Talent, Training, Partner Network, Inter-departmental Coordination, Organizational Change Capacity, Risk proclivity, Innovativeness, Collaborative work, Organization & Processes	*25*	*Organization*
Existing Challenges, Boundaries, Regulation, Regulatory, Compliance & Ethics, Customer Behavior, Acceptance, Predictability, AI ethics, Ethics & Regulation	*10*	*External Influences*
Basic Resources, Resourses, Financial Budget, IT Infrastructure, Budget, AI-Budget, Staff	*7*	*Resources*
Decisions, Activities	*3*	*Not assignable*

Source: Adapted from (Hizam-Hanafiah et al. (2020))

Table 6 presents a comprehensive summary of the attributes discussed in the first chapter, providing a holistic view of their key characteristics and implications. In some of the examined models, the attributes were not explicitly stated. When possible, these characteristics were either implied or evaluated through subjective judgment. This was done to the best of our knowledge and judgment. If the evaluation of a particular characteristic was not feasible, it was omitted. In the case of combination of two characteristics, both were considered to emphasize their interrelatedness and significance. The information of the Design Principle (Top-Down, Bottom-UP) and the attribute assessment is based on the content of the respective sources from which the maturity models were extracted. Therefore, the table does not indicate whether the assessment method is possible, but rather how it is described. The evaluation of Design Principle is based on structure of the scientific work. That means, if the Indicators were defined before the maturity stages the model was evaluated as Bottom Up. Furthermore, it should be noted that only the maturity models contextually relevant to this study were evaluated and compared on a comparative basis. This means that certain maturity models might not have been accessible or were

authored in a language different from the defined search-strings, and therefore. The assessment of novelty value is based on a subjective judgment and requires further elaboration. (Burgess, 2018) has been categorized as an innovation due to its chronological precedence as the first model of its kind. (Saari et al., 2019) was classified as an innovation because it introduced the first assessment system of its kind. In the case of (Mikalef et al., 2021), although they not define a specific model, it stands out as the only study that conducted a thorough investigation of the indicators.

Table 6: Attributes of the Models

Characteristics		***Parameter Value***	*Burgess (2018)*	*Jaaksi (2018)*	*Seger et al. (2019)*	*Alsheiabni et al.*	*Gentsch (2019)*	*Saari et al. (2019)*	*Kreutzer & Sirrenberg*	*Ellefsen et al. (2019)*	*Lichtenthaler (2020)*	*Yams et al. (2020)*	*Holmström (2022)*	*Limat (2022)*	*Mikalef & Gupta*	*Jöhnk et al. (2021)*	*Fukas (2022)*	Noymanee et al.,
General attributes	*Institutional Background*	*Science*		x		x					x		x	x	x	x	x	x
		Individual	x				x		x									
		Company								x		x						
		Association or Society			x													
		Government Organization						x										x
	Novelty Value	*Innovation*	x					x							x			
		Variant								x		x						
		Version																
	Accessibility	*Freely Accessible*		x	x			x		x	x	x	x	x	x	x	x	x
		Cost-based	x				x		x									
		Consulting services																
	Priorisation	*No Priorisation*	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
		Priorisation possible													x			
		Priorisation Proposal												x	x			
		Adaptability																
	Target Group	*Management-oriented*				x		x		x	x	x	x	x		x	x	x

		Technology-oriented	x	x	x		x		x									
	Geographical Scope	*Yes*						x		x								
		No	x	x	x	x	x		x			x	x	x	x	x	x	X
	Breadth	*None-industry-specific*	x	x		x	x	x	x				x	x	x	x	x	
		Industry-specific			x					x		x						x
Model-specific Attributes	*Data Collection Technique*	*Interview*	x	x	x		x			x	x	x						
		Survey						x	x					x				
		Observation																
		Document Analysis																
	Assessment	*Self-assessment*	x	x				x	x		x		x	x				x
		Supported by third parties							x	x								
		Assessment by third parties																
	Tools	*None*	x		x	x	x		x	x	x	x		x			x	x
		Document-based											x		x	x		
		Computer-assisted						x										
	Maturity Level Definition	*Bottom-up*	x			x	x				x			x	x	x	x	
		Top-Down																x
	Purpose of Use	*Optimization*	X															
		Evaluation		x	x	x	x	x	x	x		x		x	x	x	x	x
General condition	*Empirical Foundation*	*No / Not documented*	x		x	x	x	x	x	x	x	x	x	x			x	x
		Documented, but no Case Studies		x											x	x		
		Case Studies								x								
		Empirical Foundation																

Source: Summary presentation of the results based on the sources mentioned above.

4. DISCUSSION

The comprehensive description and evaluation of the maturity models provide a solid information foundation, serving as a starting point for the discussion. The insights gained facilitate an examination of the various attributes and indicators of the maturity models.

4.1 The models in general

To ensure the relevance for the considered object, various approaches exist that allow for the step-by-step development of new maturity models (Akkasoglu, 2014). Many of the presented maturity models are based on the design frameworks proposed by (de Bruin et al. 2005), (Becker et al., 2009), and (Mettler, 2010). In his work, (Akkasoglu, 2013) critically examines existing approaches to the development of maturity models and questions their applicability to other domains. Akkasoglu argues that (Bruin et al., 2005) present a framework for creating maturity models in the context of process and knowledge management, and the transferability and applicability of this framework to other domains is unclear. Following this argument, the transferability to the field of AI should be discussed in the future. Additionally, the design framework proposed by (Becker et al, 2009) offers only limited support for the modeler of a maturity model. Both approaches do not provide a specifically developed maturity model, which makes validation more challenging or less transparent (Akkasoglu, 2013; Pöppelbuß et al., 2011).
Regarding the design of maturity models, (Sadiq et al., 2021) argue that the models use a bottom-up approach more often because artificial intelligence (AI) is no longer a new technology and is being used in various organizations. According to (Sadiq et al., 2021), this could explain the popularity of the bottom-up approach in the development of AI maturity models. A bottom-up approach, however, is characterized by the calculation of quality criteria or graphical interpretation. This allows potential maturity levels to be identified. The significant advantage of this approach, the high transparency and verifiability of the proposed developmental stages, is not evident in the maturity models (Winter et al., 2016).

4.1.2 Maturity Stages

The decision on the number of levels is mainly determined by weighing two factors. A small number of levels would have clear advantages for the model construction. Fewer levels mean less complexity and allow for a clearer definition of the developmental path. On the other hand, a large number of levels offers clear advantages for the application of the model. Many levels can achieve a broad differentiation, leading to a distinct differentiation between high-performing and low-performing organizations. This can be useful in the practical application of the model to enable a more precise and differentiated assessment and comparability. Most maturity models use 5 maturity levels, which can be seen as a compromise between these considerations. The labeling of maturity levels complicates or does not allow for adaptation and weighting possibilities within the practical applicability of a maturity model (Jording, 2018). Even when focusing on a specific application domain, it cannot be assumed that maturity levels in different maturity models precisely represent the same concepts (Maier et al., 2011).

4.1.3 Recommendations for action

Regarding the assessment of maturity levels and the associated recommendations, mainly descriptive models were identified, and only two of the examined maturity models included an assessment tool. (Saari et al. 2019) and (Holmström, 2022) are the only two maturity models that include an assessment tool, enabling the evaluation of maturity levels. In both maturity models, two questions are used for determining the maturity level for each dimension and stage, but they differ in the type of assessment. Holmström (2022) employs a quantitative approach using a Likert scale, while Saari et al. (2019) uses pre-defined answers. In this context, the appropriateness of an assessment system based on a few questions to comprehensively evaluate a complex system comes into question. No information was found in the literature to assess the breadth and depth of a questionnaire. It can be argued that such a system may provide initial insights, but it might not be able to adequately capture all relevant aspects. (Ellefsen et al., 2019) mentioned a developed questionnaire in their work, but it is not fully disclosed in the publication.

4.1.4 Geographical Scope

Regarding the geographical scope, specific geographic restrictions are generally not taken into account during the development process. The scope is primarily defined by the framework of the empirical

investigation (Jording, 2018). (Saari et al., 2019) developed their maturity model for Finland, while (Ellefsen et al., 2019) applied their maturity model in Norwegian and Polish companies. In both models, no dependency on geographical factors is apparent.

4.1.5 Terminology

(Sadiq et al., 2021) delve into the terminologies used in the models and how they differ across various models. In this context, the focus is on the terminology used in the models in general, considering their overall terminology and not specific to any particular model. Both readiness models and maturity models have been presented. The definitions of terms used in these models require thorough clarification to ensure a clear understanding. According to (Holmström, 2021), "readiness" is defined as the "capability" to implement AI in the organization. Readiness is defined in the literature as the question of whether the company is "ready" for AI deployment in its operational environment. Therefore, the concept of readiness is context-dependent. To achieve readiness, the AI system must be validated against user requirements (Tetlay et al., 2009). In their work, (Jöhnk et al., 2021) follow this approach and are able to clearly differentiate the concept of readiness. The introduction of AI requires a thorough understanding of relevant AI readiness factors and a tailored alignment between the organization's current AI readiness and the intended purpose of AI adoption. In (Saari et al., 2019), readiness appears to assess maturity, in turn determining readiness itself. Based on this statement, it could be inferred that the concept of "maturity" is embedded within the concept of "readiness" (Tetlay et al., 2009). In contrast, according to (Ellefsen et al., 2019), the assessment of readiness takes place before the actual development process to examine whether the prerequisites for the maturity process are met. On the other hand, the maturity assessment occurs during the maturity process to capture the current state of development and evaluate progress. According to (Tetlay et al., 2009), maturity involves the evaluation within an iterative process and occurs before readiness. This implies that the system must first be fully "mature" before it can be considered "ready" for deployment. To address these challenges and enable cross-sector and cross-domain initiatives related to AI, it is important to establish common terminologies and definitions. A shared terminology and understanding of key concepts can serve as a foundation for communication and collaboration in the models (DIN, DKE, 2022).

4.1.6 Relevance and Applicability

A crucial influencing factor for achieving reliable maturity models is the maturity of the object under consideration. However, this aspect is often overlooked, impacting the usability of the maturity models. The newer the domain of the object under consideration, the more significant the uncertainty in practical application, and the higher the need for a maturity model. Conversely, the newer the domain, the less widespread it is, which is reflected in the reliability of a maturity model (Mettler, 2010). In the future, a technological roadmap for AI developments could play a significant role in aligning technological advancements with requirements and needs. This involves fostering the establishment of solution spaces (e.g., catalogs) for patterns of requirements and creating the possibility of a framework for classifying AI methods. Additionally, semi structured application scenarios could be formulated, from which potential AI methods can be derived to address and consider these use cases in the maturity levels (DIN, DKE, 2022).
(Kreutzer et al. 2019) oppose the enterprise prerequisites to the AI applications in their maturity model. (Gentsch, 2019) takes these aspects into account by comparing technologies and AI methods with use cases. (Burgess, 2018) contrasts AI applications with enterprise benefits and hurdles. However, the impact of requirements on the maturity levels is not apparent. In the future, the innovative concept of AI engineering could create a modular approach that provides clear definitions and establishes conditions under which AI solutions are appropriately applicable (DIN, DKE, 2022).

4.2 Indicators

When considering the evolutionary development of indicators in maturity models, it becomes evident that over time, more and more influencing factors have been taken into account. Additional indicators, such as ethics and regulations, have been introduced as the field progressed. The number of indicators varies significantly across different maturity models. While a comprehensive analysis of all indicators is is not the scope of this paper, two specific indicators were selected: data and costs. This selection is based

on their significance in the maturity models themselves and their frequent mention in the general literature on AI applications.
The indicator "data" was chosen because it was identified as one of the most commonly used indicators in the analyzed maturity models. The effective implementation of data analytics tasks is significantly influenced by the methods and algorithms used. These algorithms often have specific requirements for the data, which should be appropriately considered within the framework of a maturity model. All maturity models focus on a holistic implementation of AI. Therefore, the "data" indicator is seen more as a means to an end, which is considered from various perspectives in the maturity models. However, none of the examined maturity models sufficiently analyze the specific requirements placed on the "data" indicator from the perspective of AI applications (Bernerstätter, 2019). By initiating the ISO/IEC-5259 standard series, which is still in development, a common framework is established in the field of data quality for AI to describe terminologies and data quality management processes across sectors (DIN, DKE, 2022).
The second indicator "Costs" was selected due to its frequent mention as a hindrance in the literature. In an extensive literature analysis conducted by (Merkel-Kiss et al., 2022), numerous publicly available studies were examined to identify hindrances related to maturity models. Taking various factors into account, it was found that the human factor, including skilled labor shortage and lack of competencies, along with the aspect of effort, particularly in terms of costs, were the most commonly mentioned obstacles. The indirect consideration of costs is achieved by incorporating financial resources (Jöhnk et al., 2021). Although the maturity models by (Kreutzer et al., 2019) and (Fukas, 2022) do not explicitly introduce a cost indicator, this aspect is implicitly described through the indicator of the budget. However, during further research, no scientific work was found that specifically examines the costs of common AI applications. Despite the lack of explicit cost indicators in the mentioned maturity models, works like (Seger et al., (2019) have proposed a factor called "Return on Artificial Intelligence," which aims to compare the benefits of AI with the associated costs. It is not evident how this factor is incorporated into the model or how it can be assessed.

4.2.1 Reflective vs. formative characteristics

In the examined maturity models, the formative and reflective characteristics of the indicators are not explored. (Mikale et al., 2021) do not define a maturity model in their work, but they made a distinction of the indicators based on their formative and reflective characteristics. The reflective model specifies the effects and impacts of a model on its indicators. On the other hand, the formative model specifies the indicators as causes of a model (Bollen et al., 1991). In the maturity models, it is not evident whether a change in the indicators leads to a change in the maturity level or vice versa (Jarvis et al., 2003). The maturity model proposed by (Yams et al., 2020) emphasizes the mutual dependency of the indicators, but an investigation of these dependencies is not presented in their work. Similarly, in the work of (Noymanee et al., 2022), the dependence of the "Data" indicator is evident but not mentioned or explored. If mistakenly reflective indicators are used, it does not result in an incorrect model, but rather a significantly restricted model. This means that the substantive content of the construct is narrowly defined. Only the simultaneous changes in drivers are tested for their impact on success, leaving the question of whether individual drivers make independent contributions to success unanswered (Albers et al., 2006).

4.2.2 Prioritization and weighting of the indicators

The independence of individual indicators not only serves as a basis for their weighting but also allows for separate evaluation and potential customization of the maturity model (Jording, 2018). It is advisable to differentiate the indicators based on their relevance to the defined goal of the maturity model. This can be achieved through weighting the indicators, with higher weights assigned to those that are particularly significant for achieving the model's objective (Akkasoglu, 2013). Among the examined maturity models, the concept of weighting the indicators is only present in the work of (Mikalef et al., 2021). To enhance the robustness and practicality of maturity models, further research should be dedicated to exploring different approaches to determine indicator weights based on their significance and impact on the overall assessment. It is not to be assumed that all the factors underlying the assessment of an object make an equal contribution to the performance of the object. Furthermore, it should be considered that the significance of the assessed content may vary depending on the specific circumstances and conditions of the organization (Jording, 2018).

5. CONCLUSIONS

Overall, this paper demonstrates that maturity models can serve as an instrument for assessing and improving AI readiness and maturity. To fully leverage their potential from the user's perspective, these models could be further developed specifically for AI solutions, designed transparently, and include a user-friendly assessment approach. With these improvements, maturity models can contribute to further advancing AI implementations in businesses and pave the way for effective and responsible utilization of AI technologies.
In his work, (Akkasoglu, 2013) critically examines existing approaches to the development of maturity models and questions their applicability to other domains. Akkasoglu argues that Bruin et al. (2005) present a framework for creating maturity models in the context of process and knowledge management, and the transferability and applicability of this framework to other domains is unclear.

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CHALLENGES OF IMPLEMENTING THE SUPPLY CHAIN DIGITIZATION PROCESS IN THE REPUBLIC OF SERBIA

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Abstract: *By using modern technologies, traditional supply chains are transformed into smart ones that need to face challenges in the digital era. Traditional supply chains exhibit numerous shortcomings in terms of security, safety, visibility, losses, delays. To tackle these challenges, companies need to apply the latest technological advancements. Technological innovations such as the Internet of Things, Cloud computing, Blockchain and others guide organizations towards the digitization of supply chains, making them sustainable, flexible and efficient. Despite the numerous benefits they bring, companies encounter obstacles in implementing new technologies, particularly regarding security risks in information exchange. The aim of this paper is to review relevant literature and demonstrate which digital technologies are significant for supply chain management and how these technologies have led to optimizing operational costs, performance, profits, and growing needs of customers. Additionally, it will explain how companies can enhance the process of information exchange as a key component of supply chain management. The paper will present the current state of digitalization of the supply chain in the Republic of Serbia. It will identify indicators of limitations for implementing digital solutions and present measures and guidelines for further development. The paper should provide guidelines for further theoretical and empirical research.*

Key words: Digital transformation, digital technologies, supply chain management, information security, sustainability.

1. INTRODUCTION

Digital technologies have transformed consumer behavior as well as the operations and activities of companies, which in turn affects the way society approaches information exchange. The quality and accuracy of information play a crucial role and serve as a link that unities all participants.

It has been shown that the traditional supply chain is not prepared to respond to dynamic changes and uncertainties that appear in the market (NegruÈ, 2022; Li, & Song, 2022). Authors (Bancal, & Ray, 2022; Rizou, Galanakis, Aldawoud, & Galanakis, 2020; Aung, & Chang, 2014) note that the exchange of information among participants is not at a level that would enable supply chain management to react timely in terms of business optimization and meeting customer needs. The traditional supply chain is rigid, lacks transparency, exhibits weak cross channel connectivity and shows a lack of digitization (Talal, Kazmi, Joyia, & Naz, 2022). In order to achieve success through the concept of the 7Rs, which implies the right product, right quantity, right conditions, right place, right time, right customer and right price, the transformation of the traditional supply chain into a modern digitized chain based on contemporary IT technologies is necessary.

The application of digital technologies should lead to better processing and utilization of data, contributing to improved performance in both the public and private sectors and enhancing communication and collaboration among state, businesses and the population. In order to increase competitiveness and successfully respond to global social challenges it is crucial to encourage the digital maturity of Serbian companies. The digitalization of the supply chain in the Republic of Serbia lags behind EU countries. A small number of manufacturers, transportation companies and retailers use this type of technology for various reasons (high initial implementation costs, lack of modern IT technology, lack of trained personnel, etc.).

2. THEORETICAL BACKGROUND

Digitalization of the supply chain represents progress towards a fully integrated set of solutions that facilitate and accelerate data flow while also affect the overall chain's security. Attaran (2020) identifies 8 technologies as drivers of the digital supply chain.

2.1 Cloud computing

Cloud computing technology is based on the concept of making all necessary data available to the user at any given time. Cloud computing starts with the idea of resource sharing and on-demand availability, providing users with the ability to plan capacity according to their needs (Chen, & Ma, 2011). The three key contributions of cloud computing are connectivity, which establishes a network between suppliers, vendors, and customers. The second contribution is cognitive intelligence, which influences proactive decision-making and predictive analytics, which mitigates potential risks. The third contribution is scalability, which leads to efficiency, flexibility and cost optimization. By moving to cloud computing organizations can gain better access to resources and information, increasing flexibility and the ability to adapt to market conditions (Botta, De Donato, Persico, & Pescapé, 2016).

2.2 Big Data (Advanced analytics)

Advanced analytics in supply chains starts from the application of sophisticated techniques and tools that enable the processing and analysis of large amounts of data, making plans and forecasts and based on the achieving better business outcomes (Simonetto, Sgarbossa, Battini, & Govindan, 2022). Methods such as statistical modeling, machine learning, data mining, etc. are used to extract insights from complex data sets, providing information for decision-making. Big data analytics includes five dimensions: volume, velocity, variety, veracity and value. Based on these dimensions, advanced analytics is a powerful tool that enables companies to proactively monitor key performance indicators and make decisions based on valid data, which has proven critical in business optimization, risk management and overall supply chain sustainability.

2.3 Internet of Things (IoT)

The concept of the Internet of Things (IoT) is based on the use of a virtual platform that connects and enables communication among devices (RFID tags, barcodes, wireless sensors, GPS, etc.), leading to automation and faster information exchange within the supply chain. Business processes and devices connected in the IoT can be remotely controlled to facilitate easier and quicker data management (Gubbi, Buyya, Marusic, & Palaniswami, 2013). The system identifies real-time changes and demands, monitors inventory levels and promptly sends information to all participants. The Internet of Things reduces the time gap between data collection and decision-making, enabling faster response and adaptation to changes, thereby increasing agility and efficiency among supply chain participants.

2.4 Advanced Robotics

Robots have emerged as a result of the need to elevate the level and speed of service, improve distribution processes and optimize workers' working hours. Robots are used for performing manipulative and routine operations in production facilities and warehouses (Attaran, 2020). They contribute to increased productivity, efficiency, safety, accuracy and speed of operations, while also reducing risks and errors. Cobots (collaborative robots) are the outcome of recent technological advancements designed to work autonomously in physical interaction with humans in a shared workspace (Simonetto, Sgarbossa, Battini, & Govindan, 2022). The purpose of using robots is to replace manual vehicles, ensure safe, efficient, cost-effective material movement and enable employees to engage in value-added activities.

2.5 Additive Manufacturing (3D printing)

Additive manufacturing refers to hybrid machines that transform traditional production systems into intelligent ones. 3D printers are next-generation production tools that operate based on laser or inkjet printer principles, converting digital media products into solid three-dimensional objects with a "layered" structure defined as "additive manufacturing" (Paksoy, Koçhan, & Ali, 2021). The main reasons why companies use 3D printing technology are to produce smaller quantities of materials and more cost-effective parts in a shorter timeframe. Additionally, product prototypes can be designed and created in a faster and more flexible manner than before. The result of implementing 3D printers is lower costs and increased productivity in the supply chain.

2.6 Blockchain Technology

Blockchain represents a digital database consisting of interconnected blocks. Each block contains and stores data about various types of transactions. The four main characteristics of Blockchain are: 1) immutability, 2) decentralized system, 3) consensus mechanism, 4) transparency (Paksoy, Koçhan, & Ali, 2021). The application of Blockchain Technology positively impacts the supply chain by increasing transparency, ensuring transaction integrity and validity (Dursun, Birinci, Alptekin, Sertkaya, Hasekioglu, Tunaboylu, & Zaim, 2022). This technology reduces administrative tasks, provides quick access to relevant information and prevents potential fraud. Blockchain Technology contributes the most to information security (Nurgazina, Pakdeetrakulwong, Moser, & Reiner, 2021). The combination of Blockchain with other technological solutions encompassed by the concept of Logistics 4.0 brings numerous advantages, such as the integration of the physical and virtual world, enhanced speed and secure information exchange, contributing to sustainability across all segments of the supply chain.

2.7 RFID (Radio Frequency Identification)

RFID is a wireless information transmission technology used for locating and identifying individual items through radio waves. The components of RFID include tags, readers and controllers/ software. RFID technology is used in various fields where tracking and data processing are required. The application of RFID in supply chains is primarily associated with automated data collection and real-time information availability, which enhances traceability, control and efficiency to a higher level.

2.8 Augmented Reality (AR)

Augmented Reality (AR) is a simulation model that allows the combination of digital elements, such as text, images and sounds, with the real world, providing additional information, visualization and interaction with physical objects and processes. The application of AR in supply chains leads to improved operational efficiency in the area of warehousing by displaying information about inventory, order status, optimal routes and other relevant data, facilitating decision-making and reducing the time required for searching and handling goods (Angela, Lee, Pledger, Cendejas, Mannemela, & Awwad, 2021). In the field of employee training, AR technology enables simulations, virtual training and the display of complex processes in an interactive manner. Employees can be trained through virtual scenarios that depict real-life situations, helping them acquire the skills and knowledge necessary for efficient job execution.

3. METHODS

3.1 The Objective of the Research and Research Hypotheses

The aim of the empirical research is to analyze the constraints and advantages of implementing and applying digitalization processes in supply chains in the Republic of Serbia. Additionally, the importance of the research lies in determining the correlation between the adoption of digital technologies and the business performance (profitability) of the supply chain. Based on the defined research framework, the following research hypotheses can be formulated:

H1 - Constraints for implementing digitalization processes significantly influence the decision to adopt them in the supply chain in the Republic of Serbia. The first research hypothesis tests whether the existing constraints in the supply chain have a statistically significant impact on the supply chain management's decision regarding the adoption of intelligent digital systems.

H2 - The benefits of implementing digital solutions in the supply chain significantly influence the decision to introduce them in the Republic of Serbia. This hypothesis aims to test whether the expected benefits of digital solutions statistically influence the management's decision regarding their implementation.

H3 - The implementation and application of digital technologies are statistically significantly associated with the business performance (profitability) of the supply chain. The third research hypothesis tests whether the introduction of digital technologies has a positive or negative implication on the profitability and overall business performance of the supply chain.

3.2 Research Variables

A literature review indicated the limitations of traditional supply chains and potential advantages of modern supply chains. Indicators of constraints and advantages that directly impact the implementation and sustainability of supply chain digitalization processes have also been identified. Supply chain participants, including manufacturers, transportation companies, wholesalers and retailers were selected

as the independent clustering variable. The indicators of constraints and advantages for the adoption and implementation of digitalization processes in supply chain business activities were ranked as the independent measurement variables. The business performance (profitability) of the supply chain was chosen as the dependent variable.

Authors (Wang, Chaudhry, Li, & Li, 2016; Gubbi, Buyya, Marusic, & Palaniswami, 2013; Končar, Vučenović, & Marić, 2020; Granjal, Monteiro, & Sá Silva, 2015; Bedekar; Luthra, Garg, Mangla, & Berwal, 2018; Al-Fuqaha, Guizani, Mohammadi, Aledhari, & Ayyash, 2015; Whitmore, Agarwal, & Da Xu, 2015) list the following indicators as constraints or barriers: 1) lack of awareness about the importance of digitalization, 2) changes in the business model, 3) lack of financial resources, 4) underdeveloped infrastructure, 5) lack of qualified workforce, 6) user security, 7) standardization and lack of legislation.

Ranked indicators of advantages include: 1) integrated planning of production, transportation and distribution, 2) inventory level optimization, 3) lower transportation costs, 4) reduced errors and product returns upon delivery, 5) better utilization of warehouse capacity, 6) monitoring quality parameters and storage and handling safety conditions of products (Attaran, 2020; Abdel-Basset, Manogaran, Mohamed, & Gunasekaran, 2018).

3.3 Research Sample and Data Analysis Methods

The sample consists of business entities that differ in terms of their size, profitability and field of operation. The research includes employees in the manufacturing and processing sector, physical distribution, wholesale and retail. Descriptive statistics method is used to present the obtained results, while the research hypotheses are tested through one-way analysis of variance and multiple regression analysis. A standard Likert scale (1 - not important, 5 - crucially important) is used for ranking the provided indicators. The collected data is sorted and processed using the statistical package SPSS 20.

4. RESULTS & DISCUSSION

The research results show that the major obstacles for the efficient implementation of digitalization processes in supply chain management are the lack of financial resources, changes in the business model and the shortage of skilled workforce. On the other hand, the confirmed indicators of advantages, ranked as most significant by the respondents for the digitalization of the supply chain process, include integrated planning, inventory optimization and better utilization of storage capacity. Hypotheses H1 and H2 are accepted, concluding that the identified indicators of limitations and advantages significantly influence the decision to implement and apply digitalization processes in the supply chain. Furthermore, the research confirms a direct connection between the implementation of digital solutions in the supply chain and business performance (profitability). In this way, research hypothesis H3 is confirmed. The given research should serve as a guide for supply chain managers to understand which indicators need to be optimized in order to reduce limitations and barriers to the implementation of digitalization processes. Digitalization of the supply chain in the Republic of Serbia should encompass much more than just introducing new technologies into business, it requires fundamental changes in the way organizations think and perceive their operations. In other words, the digitalization of the supply chain should be viewed and understood as a continuous process of business transformation involving investments in projects, people, infrastructure, networks and information technologies, which entails the intertwined work of people, systems and business processes. Improvement directions for the digital supply chain should include financial incentives, employment incentives and security measures. All participants, including processors, manufacturers, distributors, wholesalers, retailers, customers and consumers, should be equally involved in this process. Enhancing the digitalization process would result in better visibility, transparency and product availability at every moment along the entire supply chain, leading to faster responses to end-user needs, increased flexibility, lower costs and corrections in shorter time intervals.

5. CONCLUSIONS

Republic of Serbia like other countries in the region, is undergoing a period of intense change due to geopolitical, economic, public health and environmental challenges. In order to successfully respond to these challenges in the coming period, it is necessary to harness the power of digital technologies, which if properly managed enable the creation of a sustainable economy and society. Recent experiences during the pandemic have shown that countries with a higher degree of digitalization had lower decline rates compared to those with lower digital maturity, indicating that digitalization not only strengthens the

economy but also provides greater resilience in times of crisis. The government should recognize and finance digital transformation projects that offer opportunities to increase competitiveness in the global market.

We can conclude that the state of digitalization in the supply chains in the Republic of Serbia is in a growth phase with significant room for improvement. Some companies have recognized the importance of digitalizing the supply chain and have actively worked on implementing digital solutions related to inventory management software tools, electronic data exchange, transport tracking and process automation. The most significant limitations for successful supply chain digitalization in the Republic of Serbia are considered to be the current digital infrastructure, limited financial subsidies and incentives, lack of tax and credit incentives, absence of subsidies for new jobs, free training for employees, etc. Additionally, an important prerequisite for supply chain digitalization is the change in administrative and legislative frameworks. Efforts and initiatives need to be directed by the state sector accordingly. On the other hand, the task of company management, both large and small is to raise awareness of the importance of changing the business model and based on that changing the way human resources are managed. Consequently, the national strategy should focus on redefining the existing education system and continuous improvement of educational programs that must be closely linked to the economy. Continuous training is increasingly seen as mutual protection for both the company and employees, and it also contributes to better competitiveness of the country in the global market.

The objectives of digital transformation in the Republic of Serbia in the coming period should focus on improving the necessary infrastructure, digitalizing business processes and services and enhancing digital competencies in all segments of society. To achieve these desired objectives, active collaboration among all key stakeholders from the public and private sectors, associations and the academic community is necessary to achieve synergy between knowledge, human capital and sources of funding. Very few academic research studies, especially in the domestic market, are dedicated to the issues of supply chain digitalization and this paper would fill the research gap in the given field.

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APPLICATION OF PERFORMANCE-BASED MAINTENANCE IN LEAN PRODUCTION SYSTEMS

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Abstract: *Over the past several decades maintenance became a critical contributor towards achieving the strategic objectives in a typical industrial company. Traditionally, outsourced maintenance services are delivered transactionally, meaning that company pays for services provided. Emerging trend is to change from cost of maintenance services to value and performance. Performance-based maintenance is a concept where the performance measures are defined related with structured monetary incentives rather than the process to achieve results. By this performance-based maintenance approach motivates service providers to implement effective maintenance practices to achieve results at lower cost. The paper clarifies the application of performance-based maintenance in performance-oriented companies such as lean production systems. Furthermore, paper outlines global industry trends enabling more widespread application of performance-based maintenance: servitization, industrial digitalization, and circular economy.*

Key words: performance-based maintenance, servitization, industrial digitalization, circular economy

1. INTRODUCTION

Industrial companies are facing increasing challenges in terms of operating costs optimization, innovative technologies implementation and more demanding environmental regulations. Together with product commoditization and the competition from low-cost economies it becomes very difficult to maintain competitive advantages.

Over the past several decades maintenance has become a critical factor to meet business objectives and maintain a competitive edge. To maximize productivity companies must achieve the right performance from their production equipment. At the same time, companies are focusing on their core business activities, increasingly requiring maintenance services suppliers to provide more comprehensive solutions rather than individual service offering.

Traditionally, outsourced maintenance services are delivered transactionally, meaning that company pays for services provided. While some companies are sensitive to maintenance services costs for others such as lean production systems achieving performance outcomes is the top priority. In these companies there is an understanding that the costs related with premature or unexpected failures, such as lost production, loss of reputation, and penalties for late deliveries, are usually much larger than the actual repair costs of the failure.

Performance-based maintenance emerged as a new maintenance concept and received much attention in performance-oriented companies. With this approach performance results are contracted instead of paying for the materials and labor consumed in a maintenance process. At the same time service providers are incentivized to achieve performance goals at lower cost by decreasing the equipment total cost of ownership.

The paper clarifies the application of performance-based maintenance in performance-oriented companies such as lean production systems. Furthermore, paper outlines global industry trends enabling more widespread application of performance-based maintenance: servitization, industrial digitalization, and circular economy.

2. MAINTENANCE IN LEAN PRODUCTION SYSTEMS

Lean principles and practices application including lean approach to maintenance are considered a necessity for success in today's competitive marketplace. Even companies focus more on the production optimization by applying lean principles, lean approach to maintenance should be considered as a prerequisite for lean manufacturing.

Lean maintenance is defined as "*a proactive maintenance operation employing planned and scheduled maintenance activities through total productive maintenance (TPM) practices using maintenance strategies developed through application of reliability centered maintenance (RCM) decision logic and practiced by empowered (self-directed) action teams using the 5S process, weekly Kaizen improvement events, and autonomous maintenance together with multi-skilled, maintenance technician-performed maintenance through the committed use of their work order system and their computer managed maintenance system (CMMS) or enterprise asset management (EAM) system. They are supported by a distributed, lean maintenance/MRO storeroom that provides parts and materials on a just-in-time (JIT) basis and backed by a maintenance and reliability engineering group that performs root cause failure analysis (RCFA), failed part analysis, maintenance procedure effectiveness analysis, predictive maintenance (PdM) analysis, and trending and analysis of condition monitoring results*" (Smith, 2004).
Effectively operating total productive maintenance is identified as the foundation of lean maintenance (Smith and Hawkins, 2004). It is also noted that implementing lean maintenance without total productive maintenance as a foundation would be difficult. However, authors also identified foundation elements of successful maintenance which should be implemented to achieve lean maintenance including planning and scheduling, documentation, work order system, computerized maintenance management system, predictive maintenance, and the root cause failure analysis.
Total productive maintenance program is driven by the concept of overall equipment effectiveness, which requires strict attention to the measurement and quantification of the major losses. According to that in lean production systems there is a strong focus on performance measures.
During the years different roadmaps are proposed to apply lean thinking in a maintenance processes (Sherif et al., 2015), as well as industry case studies of the lean maintenance methodologies application (Clarke et al., 2010). Even competitive advantages gained from successful lean principles and practices application in maintenance processes are easily justified it still seem like a daunting task.
Successful lean maintenance implementation depends on a comprehensive set of knowledge and skills, such as maintenance strategy development, spare parts optimization, or maintenance procedure effectiveness analysis. Predictive maintenance and operator inspection programs requires right technologies, together with processes and trained employs.
Considering all the above mentioned it becomes obvious that lean production systems are suitable for performance-based maintenance application. They need support from maintenance services providers, equipped with right technologies, processes and people for successful lean maintenance implementation and on the other hand they have clear performance indicators aligned with the strategic objectives throughout the whole organization.

3. PERFORMANCE-BASED MAINTENANCE

Maintenance is defined as "*combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function*" (BS EN 13306, 2018). Based on the definition maintenance can be performed in two major types: corrective maintenance undertaken after a breakdown, and preventive maintenance which is further divided on periodic time-based maintenance and condition-based maintenance. All traditional maintenance types are widely used in practically all industrial companies.
Performance-based maintenance emerged as new maintenance concept and received much attention in performance-oriented companies. Despite the examples of successful performance-based maintenance implementation in defense and aerospace industries (Kim et al., 2007), and in some manufacturing industries (Hypko et al., 2010) its widespread application remains in an early stage.
In general, maintenance service contracts could be divided in two main categories: resource-based contracts and performance-based contracts. Traditionally maintenance services are performed transactionally under the resource-based contracts. In this approach service providers are paid each time maintenance service is performed. Three types of resources-based contracts are commonly used in practice: fixed-price contract under which the maintenance service providers are paid with a fixed fee for labor and materials consumed, cost plus fixed fee under which customers pay for all resources consumed with a negotiated fixed fee added and cost-plus incentive under which customers are willing to provide some gain sharing. Maintenance service providers are often not well motivated to improve their services under resource-based contracts, and instead they usually focus on how to minimize the costs and to increase the profits.

Emerging trend is to change from cost of maintenance services to value and performance provided. Performance-based maintenance is a concept where the performance measures are defined related with structured monetary incentives rather than the process to achieve results.
The goal of performance-based maintenance is to design and implement effective maintenance service program to incentivize the supplier to achieve predefined performance results and decrease the total cost of ownership while ensuring the reliability and availability of the equipment (Jin, 2018). With this approach equipment user define the performance measures related with company's strategic objectives. Service provider is focused to achieve predefined performance measures at lower cost, and motivated to even exceed performance goals as this relates with increased revenue.
Together with increased focus on total cost of ownership under the performance-based maintenance the responsibilities between service supplier and the equipment user are changing, with transferring more responsibilities to service supplier (Jin et al., 2022).
Performance-based maintenance service program can have different starting points and goals (Figure 1):

- product performance including product selection, application engineering services, root cause failure analysis or technical upgrades,
- asset performance including technical assessments, application or design reviews, maintenance and lubrication products, condition monitoring products, remote monitoring, remanufacturing services, and trainings or
- plant performance including assessment and benchmarking, plant reliability improvement, programs, maintenance best practices implementation, spares and inventory management and optimization.

Figure 1: Contracting performance starting points and goals

Performance-based maintenance provides benefits compared to traditional transactional approach to maintenance services contracting. The concept motivates maintenance service providers to implement effective maintenance policies to attain performance goals at lower cost by bringing their extensive experience and latest technologies.
Nevertheless, it can be challenging to develop and implement performance-based maintenance since both contracting sides should adapt to this significant shift compared to traditional maintenance services contracting. Developing effective maintenance program capable to achieve performance results could take time. In practice, it can take years of traditional cooperation before the relationship such as performance-based maintenance is mutually acceptable.

4. ENABLING GLOBAL INDUSTRY TRENDS

Ongoing global industrial trends fundamentally changes the conditions for maintenance service providers when developing and delivering innovative maintenance services. Following section will outline recent global industry trends which are having profound effect on increasingly widespread application of performance-based maintenance: servitization, industrial digitalization, and shift towards circular economy.

4.1 Servitization

Servitization can be defined as the process of creating value by adding services to product offerings (Vandermerwe and Rada, 1988). The concept can be explained as a movement towards integrated systems of products and services to become more competitive.

Over the last decades across manufacturing industries there is a growing interest to integrate products and services (Annarelli et al., 2021). This can be explained with increased customer focus on the function of the products rather than the products itself.

Many manufacturing companies have been focusing on adding services to their products to gain competitive advantage. Those newly developed integrated product-service solutions are creating additional value and make it more difficult for low-cost competitors to compete due to the lack of additional knowledge.

Between a pure product manufacturer and a pure service provider, various business model options exist, in which products and services are combined to varying degree. Between the pure product and pure service integrated product-service offering could be product focused, use oriented or result oriented (Tukker, 2004).

The type and scope of products and services packages are limited only by the ingenuity and technological capabilities. SKF integrates the products, the technologies, and various services into an integrated Rotating Equipment Performance business model (Figure 2).

Figure 2: SKF product-service integration model

The objective of Rotating Equipment Performance business model is to maximize the reliability, performance of the machinery, and the production process tracked thru clearly defined key performance indicators. With access to application information, along with the integrated knowledge, technology products and service capability, this results-oriented approach purpose is to prolong the useful life of equipment while reducing the total cost of ownership.

4.2 Industrial digitalization

The ongoing "digital transformation" of manufacturing industries is influencing nearly every aspect of business. The maintenance function needs to take advantage of new developments in digital technology and the opportunities brought by industrial digitalization. Even though industrial digitalization is growing, most condition monitoring data is still collected manually for multiple reasons. This important fact indicates that there is still a lot of possibilities for further digital technologies adaptation.

SKF concept of digitalization in industrial maintenance applications can be broken down into four steps:

- connect: measuring or acquiring the right production equipment condition data, at the right rate, and then connecting to a host software,
- detect: establish a trend of data that describes normality and identify anomalies or alarms and its severity using automated algorithms and/or human expertise,
- inform: insights presented in dashboards or reports on the possible consequences of the diagnosis and when the failure may occur,
- improve: working together with the equipment user to act on resolving the issue, and avoid repeating, through a range of mechanical engineering technologies and services.

Condition monitoring is all about measuring physical parameters on an asset, that provide information about its physical condition. We need to have a range of data-acquisition devices: portables, wired and wireless installed systems, capturing condition data that indicates rotating asset health. Then establishing what is normal for that asset and detecting deviations from normal. The machine health alerts that are the output of this process are then combined with other data and information. The data then needs to be managed, analyzed, and actionable information produced. That information then is shared, reported, and visualized, often in a key performance indicator (KPI's) dashboard (Figure 3).

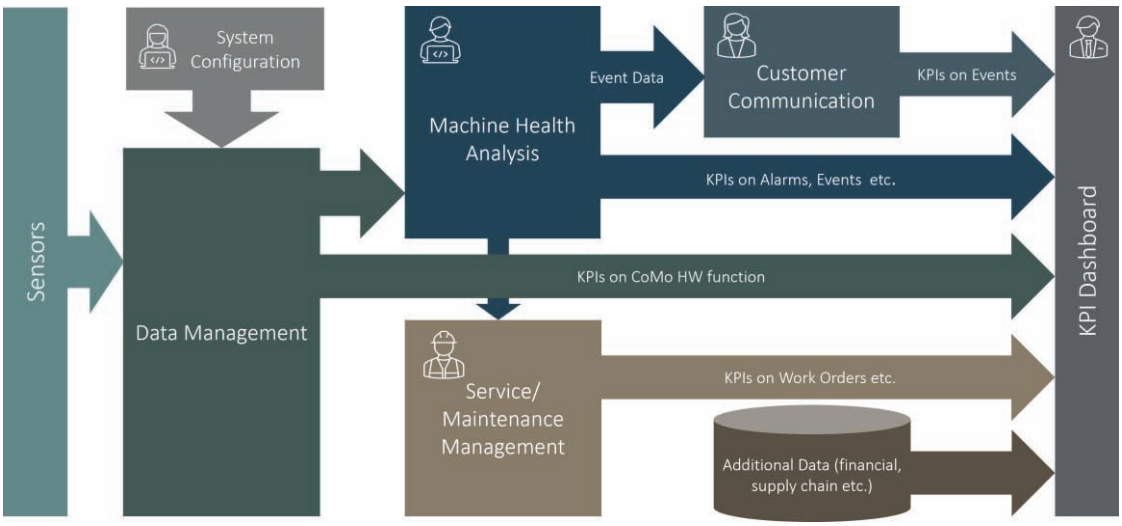

Figure 3: From sensors to dashboards

Ability to corelate equipment condition parameters measured by sensors with the company's key performance indicators will support more widespread application of performance-based maintenance in practice. Accordingly, ongoing industrial digitization should be considered as one of key enablers for performance-based maintenance.

4.3 Circular economy

Economy today has the major problems with that increased revenue also implies increased sales of products and use of resources. In a circular economy, there is no conflict between economic growth and environmental protection. The circular economy is gaining interest due to potential to align business and societal goals as it offers the opportunity to focus simultaneously on economic value creation and on the mitigation of impact on the environment.

All newly developed maintenance program should include maintenance services that recover resources, avoid generating waste, and provide the best quality and reliability to the customer.

SKF conduct two types of reconditioning services that help customers meet their climate goals and reduce their negative impact on the environment:

- remanufacturing of bearings which manages to reduce the carbon footprint compared to manufacturing a new one, consumes less energy and at the same time it is often the fastest way to replace a bearing due to failure and guarantees the same quality as the manufacturing process for new products,
- reconditioning of industrial lubrication oils offering reusing the same lubricating oil repeatedly while maintaining its essential additives, reducing the need for new oil, and by that reducing both costs and environmental impact, and generating emissions savings compared to the conventional process.

Reconditioning services are increasing the lifetime of production equipment, lowering the consumption of spare parts, and reducing energy consumption. Performance-based maintenance is supported by reconditioning services, as the total implementation cost for the service provider is lower. By that the concept is incentivized by business practices aligned with the principles of the circular economy, such as encouraging material resources circularity.

5. CONCLUSIONS

The paper identifies performance-oriented industries, especially lean production systems as suitable candidates for performance-based maintenance application, since they strive to implement lean maintenance approach and have clear performance indicators aligned with the strategic objectives throughout the whole organization.

Performance-based maintenance provides benefits compared to traditional transactional approach to maintenance services contracting. The concept motivates maintenance service providers to implement

effective maintenance policies to attain performance goals at lower cost by bringing their extensive experience and latest technologies.
The paper reviews topics of servitization, industrial digitalization, and circular economy, which are enabling and bringing new opportunities for more widespread application of performance-based maintenance.
Finally, it is important to state that performance-based maintenance program development could take time. In practice, it can take years of traditional cooperation before the relationship such as performance-based maintenance is mutually acceptable.

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IMPORTANCE OF DEMAND PLANNING PROCESS ON DIFFERENT SUPPLY CHAIN PERFORMANCE INDICATORS

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Abstract: *The main purpose of this paper is to present and explain how specific demand data can influence on the performance of the company in certain business areas. Every company depends on how required information is received from the market (customers) and how this information is being interpreted internaly before alignment within the company is done. Situation on the market changed significantly in the last few years, availability of goods has been and still is disrupted. Supply chains had to change dramatically in order to provide requested service levels, which in some industries was very difficult or even not achievable. Timely information sharing between companies has become of increasing importance not only for regular business but also for bare survival in very competitive environment. For managing effectively there has to be a clear process of gathering, evaluating and distributing information to all relevant stakeholders. Communication of decisions made in this process has crucial importnace on the company's business performance in the short and mid-term. This paper will present an impact analysis on the specific supply chain performance indicators over a certain time period where the process of data gathering has been evaluated and improved.*

Key words: Demand planning, Supply chain, Performance, Logistics

1. INTRODUCTION

The term supply chain was first encountered in the literature in 1982, in the controversy whether there is a difference in the impact of logistics management and supply chain management on the creation of value for the end user and their impact on the company's profitability. What supply chains are? Turban and King in 2003 said that a supply chain is a combination of different organizations and flows of materials, money and information that support the execution of different activities. However, there are several definitions for supply chain and we will list some of them:

Council of Supply Chain Management Professionals (CSCMP): "A supply chain is a global network used to deliver products and services from raw materials to end customers through an engineered flow of information, physical distribution, and cash"(Council of Supply Chain Management Professionals (CSCMP), 2023).

The Global Supply Chain Forum (GSCF): "A supply chain is a sequence of processes and flows that take place within and between different stages and combine to fill a customer need for a product" (Global Supply Chain Leaders Group (GSCLG), 2023).

The Chartered Institute of Procurement & Supply (CIPS): "A supply chain is a network of entities, directly or indirectly interlinked and interdependent in serving the same consumer or customer. It comprises organizations, people, activities, information, and resources involved in moving products and services from suppliers to end-users" (The Chartered Institute of Procurement & Supply (CIPS), 2022).

The aforementioned definitions highlight the common characteristics and key aspects of the supply chain, emphasizing more its mutual nature, involving multiple stakeholders, and the flow of products, information and resources through the various stages.

A supply chain connects many companies, it implies the exchange of materials and information in logistics processes that extend from the collection of raw materials to the delivery of finished products and services to the end user. We would distinguish two definitions that the supply chain consists of a series of companies that are involved in satisfying the needs of consumers (directly or indirectly).

Based on the definitions, we can see the importance of the supply chain in today's economy. It was especially emphasized during the Covid virus pandemic when the supply chains assumed the obligation to ensure that all customers are supplied with the necessary product. The most important participants in the supply chain are: buyers, manufacturers, suppliers, retailers, wholesalers and distributors. In addition to

the participants, each supply chain has its own activities. Supply chain activities begin with customer orders and end when a satisfied customer pays for the purchased good or service (Balfaqih, Hasan, et al, 2016).
Supply chain management requires planning and monitoring of a high number of activities. Demand planning on which supply chain operations are based is providing a signal or warning about the status of a particular product or service. Planning managers need to have access to the most relevant information that drives the supply and demand system available at any given moment. The data obtained by the management should be based on real time and by planning the demand for certain products, it allows the decision maker to act in a timely manner and with a true or approximate forecast of demand trends. To maximize profitability, supply chains must be as efficient as possible. Accurate demand planning is critical to ensuring supply chain efficiency for inventory and, ultimately, revenue.

2. IMPORTANCE OF DEMAND PLANNING ON SUPPLY CHIAN KPI's

In today's fast-paced and highly competitive business landscape, an efficient and well-organized supply chain is vital for a company's success. One of the key pillars that underpin an effective supply chain is the demand planning process. Demand planning involves forecasting customer demand for products or services and aligning it with the necessary resources and production capabilities to meet that demand in a timely and cost-effective manner. This process is crucial for optimizing supply chain performance and ensuring business sustainability. Here are some reasons why demand planning holds such importance:
Anticipating Customer Needs: Demand planning involves analyzing historical data, market trends and customer behavior to anticipate future demand accurately. By gaining insights into consumer preferences and buying patterns, companies can proactively align production, procurement, and distribution efforts to ensure the right products are available at the right time and in the right quantity. This proactive approach minimizes the risk of stockouts and excess inventory, allowing businesses to meet customer demands efficiently.
Enhancing Supply Chain Efficiency: Demand planning facilitates the smooth flow of goods along the supply chain. When demand projections are accurate, procurement, production, and distribution activities can be coordinated seamlessly, reducing lead times and improving order fulfillment. Moreover, streamlined processes minimize operational disruptions, enabling businesses to respond swiftly to market fluctuations and capitalize on new opportunities.
Cost Reduction and Resource Allocation: Accurate demand forecasting allows companies to allocate resources more efficiently. By knowing what and when to produce or purchase, businesses can negotiate better contracts with suppliers, take advantage of volume discounts, and optimize production schedules. Consequently, cost savings can be channeled into product development, customer service, or innovation, further boosting supply chain performance.
Optimizing Inventory Management: A robust demand planning process enables organizations to strike a balance between stock levels and customer demand. Excess inventory ties up capital and incurs storage costs, while inadequate inventory leads to missed sales opportunities and dissatisfied customers. By accurately forecasting demand, companies can optimize inventory management, reducing carrying costs and minimizing the risk of obsolescence.
Strengthening Customer Relationships: Meeting customer demands promptly and consistently is vital for building strong customer relationships and loyalty. A reliable demand planning process ensures that companies can fulfill orders accurately and on time, leading to increased customer satisfaction and positive word-of-mouth. Satisfied customers are more likely to become repeat buyers and brand advocates, which can significantly impact a company's bottom line.
Demand management process is all about predicting customer demand and balancing with supply chain capabilities, so demand is fulfilled. There are six main sub-processes or activities which have a goal to make efficient operational system for balancing demand and supply:

- Determine demand management goals and strategy
- Determine forecasting procedures
- Plan information flow
- Determine synhronization procedures
- Develop contingency management system
- Develop framework of matrics

With a clearer understanding of demand patterns and customer behavior, companies can make informed choices about product development, market expansion, and investment in new technologies.

3. RESULTS

Based on the research goal, data was gathered and analysed. Example is from a domestic company and their experience with one foreign company, which is thier strategic customer. Company name will not be revealed due to data protection purposes. After observed problems, forecast accuracy has been adressed and its impact on transportation cost and inventory levels, as some of the most important performance parameters.

Company has quite sophisticated system of receiving forecasted quantities from this customer. They are ordering multiple products for different production lines. There were both internal and external factors that influenced on their actual performance. However, our focus was more on the performance and activities done in the domestic company. Internal analysis of this forecast in the local company was not done and no quite clear rules in cooperation with customer have been communicated. After implementing changes from september 2022., some KPIs (key performance indicators) have been established and monitored on a regular base. Actual forecast accuracy (FA) results were calculated and are shown in table below:

Table 1: Forecast accuracy development for 2022.and 2023

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	45.3%	42.7%	51.4%	56.1%	52.3%	64.3%	52.4%	41.0%	42.3%	47.8%	62.1%	71.3%
2023	48.2%	68.7%	75.4%	84.6%	86.4%	88.2%						

After implementing more detailed analysis, some facts became obvious:

- Very low forecast accuracy among two companies (B2B), where it should be much higher
- Very unstable FA (demand), variations per month are significant and trend is very unpredictable
- No clear rules communicated internaly how to work with the customer on this topic
- Forecast received is much shorter vs lead times (LT) for some important and expensive materilas

Inacuracy of shared forecast and longer period of lower actual results vs plan led to a further process deterioriation, which impacted on transportation costs and inventory levels.

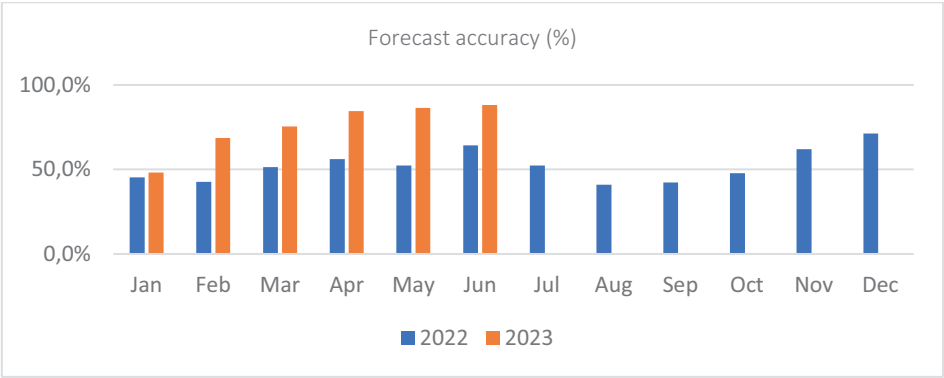

Figure 1. Forecast accuracy development

In period May – July 2022. forecast accuracy was still on a low level. Expectation was that quantities will not be taken as in previous period, but oposite happened. This influenced from one side on higher transport cost due to more deliveries which had to be done. On the other side, production was not able to keep up with the demand due to lack of resources, which was also one factor which was not planned correctly. First, there were not enough people enganged in the production process. This is an activity that has to be done much sooner, so pople can be trained and be utilised in the process once expected. Sedond, there was not enough materilas since planned output was much lower and suppliers were not informed about additional needs.

Table 2: Overview of transport costs per month in 2022. and 2023 (kEUR)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	37	51	29	31	109	109	163	26	42	37	42	18
2023	124	42	38	22	45	60						
YTD 2022	37	88	117	148	257	366						
YTD 2023	124	166	204	226	271	331						

In period from september 2022. there was a stable growth of forecast accuracy due to better data analysis. However, in the begining of the 2023., due to previous year low results in Q1-Q2 period, significalntly higher inputs were not expected and validated, which led to a lower accuracy result. And this was real example where you have to consult and align with the customer in order to avoid potential issues in operations. After observing what happened, taking all negative consequences on the performance, process was revised and better allignment with the customer was established. Better internal communication and alignment of all sectors on what should be done caused FA result to continously rise. This led to a much better results in a different business areas. Transport cost and inventory levels will be observed with more details.

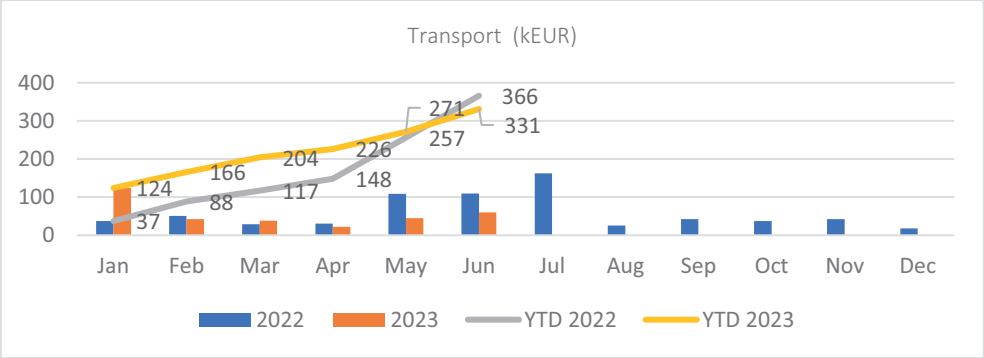

Figure 2. Transport cost development per month

Transport cost from Aug till Dec 2022. was significantly lower. Increase of transport cost in jan 2023. was a direct consequence of wrong internal decision that customer will not take forecasted quantities and all internal operations were set on a lower output. In period May – June 2023. there was an increase of transport cost but this had different, produciton related causes.

There are different factors that influence on inventory levels and demand inputs are one of the main. Demand data and analysis of actual performance in the past are crucial for future planning of all activities, inluding stock management. In this case stocks in Q1 2022. were very high due to much higher forecasted inputs vs what was actual realisation. Due to very long times some materials were ordered and delivered based on the original demand and kept on stock for much longer time than what was initially planned. If demand / sales happened as planned, stock would be lower.

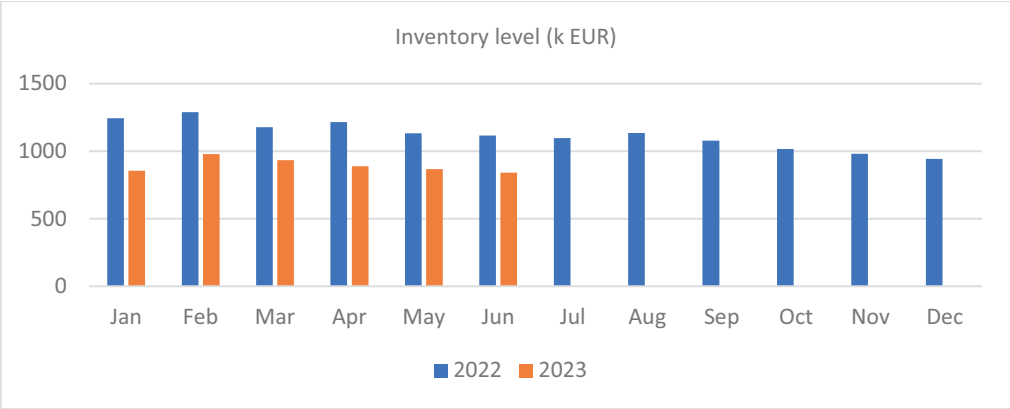

Figure 3. Inventory level per month

Having this in mind corrective activities have been introduced. Some alternative materilas with shorter lead times were implemented. Better stock monitoring has been in place and faster decision making regarding all references on stock that are potentially not usable. Claim process with suppliers has been revised and strucured, which resulted with improvement in supplier management.
Better structure of stock has been defined in order to prioritize some products which are esencial for sales and revenue point of view. This provided more stabile production process with less stoppaged due to lack of materials.

4. DISCUSSION

Demand planning process was not considered as important part of the activities which seriously contribute to the performance of majority of sectors in the company. Consequently it had effect not only on the logistics business acumen (inventories, transport cost,..), but on the total supply chain (procurement, production,…). Not to mention negative financial effect on the company as a whole.
One of the most important improvement actions was to establish demand planning process in order to define steps how to improve input data coming from the customer. Awareness of the problem is the first step in starting resolving it. Understaning what influence on the input data, how to interpret them, and what decisions are made based on them, together with communication with internal stakeholders is considerabely impacting companies performance.
Some decisions made in the past, based on previous negative experience when customer was not performing as expected, without informing customer, had huge negative impact on company financial result. As we could see, there was a repeated unclear behaviour in the beginning of 2023. when a similar situation happened. Doubt was present and the situation with high stocks and low turnover was something to be avoided (Ka, Jagan Mohan Reddy, 2019) .
Regular communication with customers has been introduced in order to foresee what are they planning in the short / mid term, so all relevant operiations can be organized accordingly. Additional step was better internal alignment based on the decisions made regarding demand inputs. Once everybody starts communicate one plan and align priorities per sector in line with this plan, things become clearer and more transparent. It is not easy but eventually improvements are visible in different areas. There are still some other processes to be corrected and improved, but this is topic for some other study.

5. CONSLUSION

The demand planning process serves as a crucial foundation for supply chain performance and overall business success. Accurate demand forecasting empowers companies to optimize inventory, streamline operations, reduce costs, and enhance customer satisfaction. By anticipating customer needs and aligning resources accordingly, organizations can remain agile and responsive in a dynamic market, gaining a

competitive advantage over their peers. Embracing a robust demand planning process is not just an option; it is a necessity for any business looking to thrive in the ever-evolving landscape of modern commerce.

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Exploring a Methodological Approach to Assessing the Potential Impact of the Implementation of Circular Economy Strategies on Regional Economies Through Environmentally Extended Input–Output Tables

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Abstract: *This article is part of a research stream that aims to evaluate the impact of circular economy policies on greenhouse gas (GHG) emission reduction and the industrial structure of specific regions. Building upon previous research that generates a linear representation of GHG emissions along industrial value chains using environmentally extended input–output tables and employment data pertaining to the region's industrial structure, the study analyses GHG emissions and employment in a three-dimensional space defined by the following axes: 1) productive sectors as homogeneous blocks of the market and technologies/products, 2) value chains as a set of interrelated and dependent activities involved in circular economy implementation and 3) the position of emissions in the value chain. The employed methodology aims to provide a framework to characterise both productive sectors and value chains, offering valuable insights into emission and employment dynamics. This approach facilitates a comprehensive understanding of the potential implications of circular economy initiatives on the overall structure of regional economies.*

Keywords: *circular economy, input–output, greenhouse gases, employment*

1. INTRODUCTION

According to a study conducted by the Instituto Nacional de Estadística (INE, 2020), the manufacturing industry accounted for a substantial portion (25.8%) of the total greenhouse gas (GHG) emissions in Spain in 2020. This empirical evidence underscores the significant environmental impact of the manufacturing sector in terms of carbon emissions. To devise effective GHG reduction programmes, it is imperative to classify emissions into distinct tiers, namely tier 1, tier 2, and tier 3 emissions, as proposed by Ranganathan (2001).

To evaluate the environmental consequences of economic activities, environmentally extended input–output tables (EEIOTs) have emerged as a frequently employed methodology like in Park et al. (2022). Although input–output analysis is considered to possess a degree of imprecision compared to process analysis, it offers a comprehensive lens by integrating detailed major production data (Peters et al., 2010).

To achieve a climate-neutral and circular economy, it is necessary to transform industrial sectors and all value chains, and this will take a generation. Together with industrial strategies, a new circular economy action plan will help modernise the EU's economy and lead to benefits from the opportunities provided by a circular economy both domestically and globally (European Commission, 2019).

The 9R framework, as proposed by Kirchherr et al. (2017) and derived from Potting et al. (2017), is an instrumental tool for circular economy assessment. This framework delineates the transition from recovery loops to refusal loops, with the extent of circularity contingent on the goals ambition pursued. The transformation of society to a circular economy will certainly depend on assessing environmental, economic and industrial factors while, in addition, addressing factors such as labour practices, human rights and community well-being, which have been peripherally and sporadically integrated into the circular economy concept (Mies and Gold, 2021). To achieve a truly sustainable alternative to the current economic system, a more balanced integration of the social sustainability dimension is essential. Public institutions must take into consideration the social aspects of the circular economy, including employment, to ensure the well-being of citizens. At different levels of governance, it is necessary to be able to assess the impact that circular economy projects have on the economies of each region or geographical environment.

Given the difficulties in analysing the interconnections between economic sectors, the goal of this research is to introduce a methodological approach aimed at addressing two fundamental inquiries. First, it seeks to learn how the employment effects of circular economy initiatives on regional economies can

be effectively evaluated. Second, it aims to provide insights into how to prioritise projects that optimise the reduction of GHG emissions while concurrently minimising the potential impact on employment. By addressing these critical areas, this research aims to offer valuable guidance in circular economy implementation, ensuring that both environmental sustainability and socioeconomic factors are taken into account.

The impact that emission reduction measures will have on a given territory depends on the distribution of emissions across value chains and on the overall industrial fabric of the region. This study examines the distribution of GHG emissions within the industrial sector in Spain and offers information to qualify the sectors and value chains. To do this, GHG emissions are analysed along a triple axis: 1) the axis of the productive sectors as homogeneous blocks of the market and technologies/products, 2) the axis of the value chains as a set of interrelated and dependent activities in the implementation of the circular economy and 3) the axis of the position of the emissions in the value chain that will condition the relevance of the different loops of the circular economy. In this three-dimensional space, different variables, such as GHG emissions and employment, are analysed using the results of a previous study (Retegi et al., 2023) that configures a linear model of intersectoral relations that covers 94.5% of industrial emissions. By employing this methodological framework, the research endeavours to provide valuable insights by simultaneously considering both levels of emissions and employment dynamics, facilitating a comprehensive understanding of the potential implications of circular economy initiatives on the productive fabric.

2. METHODOLOGY

This study uses secondary data from the latest available version of the input–output economic tables for Spain obtained from the Organisation for Economic Co-operation and Development (OECD, 2021), as well as data on greenhouse gas emissions (INE, 2020) and Spanish firms and employment (INE, 2023). The methodology developed in this research is based on a previous article by the authors (Retegi et al., 2023) in which, based on environmentally extended input–output tables, they studied GHG emissions (CO2-eq) along industrial value chains and represented their dependency links linearly as the first step in assessing the GHG-reducing potential of the circular economy. The result of this previous research was a set of intersector relations (links) arranged based on their belonging to various value chains and their position within these value chains. Each link is assigned a quantity of GHG emissions obtained by the average values of each sector. The sectors included in this research correspond to the statistical classification of economic activities (NACE) codes 10–43 at a 2-digit level of detail, with some groupings of NACE branches of activities due to the availability of data on GHG emissions.

Based on the outcomes of the research conducted in Retegi et al. (2023), a series of E_{ijk} data is available, consisting of the emissions of the activities of sector i in value chain j and in position k, constituting a three-dimensional space configuration. The index k represents a backwards classification of the position of the link within the value chain (link x), from the final demand to basic suppliers. Based on the available data, the new variable J_{ijk} is defined, which represents the employment corresponding to the economic activity of sector i in value chain j and in position k.

The allocation of employment associated with each link is proportionally determined, considering the amount of economic exchange that this link represents in relation to the totality of the exchanges of each sector. In this context, we define a value chain as the necessary economic activities and prior relationships between different sectors required for a sector to provide its products or services to meet the final demand.

3. RESULTS AND DISCUSSION

This section presents the key results obtained by this research. Table 1 presents the emissions associated with the productive sectors, each sector's percentage of the total emissions, their corresponding employment contribution, emissions per job, and the number of value chains in which they are incorporated.

As can be seen in Table 1 above, the NACE 35, NACE 23 and NACE 19 sectors account for 65% (39%, 16% and 10%, respectively) of the total emissions captured within the model. These three sectors exhibit significant participation in a large number of value chains (19, 16 and 10, respectively). Furthermore, these three sectors are characterised by a large amount of emissions generated per job (1,487, 216.7 and 1,574, respectively).

Table 1: Sectors and their corresponding emissions (E_i and J_i)

NACE Code	Emissions (TCO2-eq)	% of Total	Employment	Emissions/Job	Number of VC
NACE 10–12	6,310,613	4%	478,096	13.2	1
NACE 13–15	438,035	0%	119,473	3.7	1
NACE 16	137,539	0%	52,292	2.6	1
NACE 17-18	3,949,863	3%	109,154	36.2	3
NACE 19	14,827,271	10%	9,416	1,574.7	10
NACE 20	13,858,895	9%	97,594	142.0	15
NACE 21	838,595	1%	54,911	15.3	1
NACE 22	200,112	0%	95,453	2.1	1
NACE 23	23,602,326	16%	108,929	216.7	16
NACE 24	10,386,656	7%	60,842	170.7	7
NACE 25	166,167	0%	241,227	0.7	1
NACE 26	27,494	0%	25,476	1.1	1
NACE 27	159,221	0%	67,416	2.4	1
NACE 28	758,468	1%	104,932	7.2	1
NACE 29	509,285	0%	123,217	4.1	1
NACE 30	149,440	0%	43,034	3.5	1
NACE 31–33	173,795	0%	200,743	0,9	1
NACE 35	59,135,046	39%	39,762	1,487.2	19
NACE 36–39	12,758,870	8%	145,719	87.6	12
NACE 41–43	3,140,910	2%	1,049,335	3.0	1

Within the analysed model, only 13 of the 20 sectors were found to be present in a value chain. This indicates that these sectors are vulnerable to implementation decisions based on circular economy strategies focused on specific value chains aimed at the elimination of GHG. For instance, the NACE 10–12 sector will be influenced by decisions or trends within the food value chain but will be unaffected by decisions made in other sectors.

Table 2 presents the GHG emissions associated with specific value chain activities, the percentage of total emissions, the associated employment and the number of emissions per job. The value chain of electricity, gas and steam and the value chain of coke and refined petroleum products have a high level of emissions per job. The electricity, gas and steam value chain in response to final demand accounts for 23% of all emissions and has an emissions rate per job of 1,487 TCO2-eq/job. Moreover, the value chain associated with oil refining emits 12% of the total emissions, which represents 1,337 TCO2-eq/job.

Table 2: Value chains and their corresponding emissions (E_j and J_j)

Value Chains	Emiss. (TCO2-eq)	%Total Emissions	Employment	Emissions/Job
Basic metals	8,250,795	5%	43,800	188
Chemical products	12,106,511	8%	72,515	167
Coke and refined petroleum products	17,801,734	12%	13,310	1,337
Computer, electronic and optical products	27,494	0%	25,476	1
Construction	17,389,108	11%	1,109,713	16
Electrical equipment	2,108,818	1%	75,451	28
Electricity, gas, steam and air conditioning	34,612,812	23%	23,273	1,487
Food products, beverages and tobacco	12,628,448	8%	519,220	24
Machinery and equipment	2,476,234	2%	112,677	22
Metal products	7,060,732	5%	274,819	26
Motor vehicles	5,629,701	4%	143,087	39
Other nonmetallic products	10,369,551	7%	44,177	235
Other transport equipment	377,918	0%	43,187	9
Paper products and printing	4,176,070	3%	83,207	50
Pharmaceutical products	1,710,931	1%	58,584	29
Repair and instal. of machines equipment	1,245,060	1%	207,868	6
Rubber and plastic products	2,649,689	2%	104,857	25
Textiles, apparel and leather products	997,382	1%	120,821	8
Water supply and waste management	9,448,896	6%	98,502	96
Wood products	406,373	0%	52,473	8

As can be seen in Table 2, the three value chains with the highest emissions per job are basic metals, chemical products and other nonmetallic products.

It is interesting to note that some value chains that are high emitters of GHG also integrate a significant number of jobs within their activities. For example, construction accounts for 11% of total emissions but,

due to the high number of jobs generated in this sector, has an emissions ratio of just 16 TCO2-eq/job. Similarly, the value chain of food products, beverages and tobacco accounts for 8% of total emissions but produces only 24 TCO2-eq/job.

Table 3 presents the emissions related to the activities of each value chain, distributed according to their position in terms of proximity to the final demand. First, it can be observed that value chains vary considerably in terms of their length. For some value chains, there are up to six levels of precedent intersectoral relationships, representing a significant level of GHG emissions (e.g. construction, electrical equipment, machinery and equipment, metal products, motor vehicles, and repair and installation of machinery and equipment), while other value chains are short or their precedent activities do not produce a high number of emissions (computer, electronic and optical products; electricity, gas, steam and air conditioning; other nonmetallic mineral products; other transport equipment; and wood products). The length of value chains impacts the feasibility of establishing circular loops and, consequently, affects the potential for differential effects based on the level at which these loops are implemented within the value chain.

Table 3: Emissions per value chain, intersectoral link position and corresponding emissions (E_{jk})

Value chains	Link 6	Link 5	Link 4	Link 3	Link 2	Link 1	Final Demand
Basic metals		0.1	145	7,963	194,560	3,404,068	4,644,204
Chemical products					54,720	2.287.565	9,764,226
Coke and refined petroleum prod.			21	1,121	19,777	3,700,885	14,079,951
Computer/electronic/optical products							27,494
Construction	0.01	22	1,286	37,813	1,733,327	12,475,771	3,140,911
Electrical equipment	0.01	18	1,001	24,455	475,954	1,448,187	159,221
Electric, gas, steam & air cond.							34,612,812
Food products, beverages and tobacco		6	643	21,879	672,730	5,622,519	6,310 ,677
Machinery and equipment	0.01	21	1,176	28,745	526,485	1,161,360	758,468
Metal products	0.04	83	4,635	116,141	2,092,988	4,680,801	166,167
Motor vehicles	0.01	29	1,598	42,257	942,145	4,134,416	509,285
Other nonmetallic products						933,424	9,43,127
Other transport equipment						228,478	149,440
Paper products and printing			18	1,865	55,091	1,235,754	2,883,360
Pharmaceutical products				2,624	109,693	760,019	838,595
Rep. install. of machin. & equip.	0.003	6	390	10,034	206,908	85,933	173,795
Rubber and plastic products		0	39	5,609	235,965	2,208,003	200,112
Textile and leather products				825	34,510	524,012	438,035
Water and waste management				1,051	55,373	976,808	8,415,664
Wood products						268,834	137,539
TOTAL	0.1	185	10,952	302,382	7,410,226	46,904,837	96,846,083
% TOTAL	0.00%	0.00%	0.01%	0.20%	4.89%	30.9%	63.94%

Second, overall, the percentage of emissions produced in the final phase of value chains and in the immediately preceding phase by another sector accounts for 94.90% of total emissions. Of the remaining percentage (5.1%), 4.89% is emitted in the intersector relations of link 2. Thus, 99.79% of the emissions included in the model are emitted in the immediate response to final demand and in the two preceding phases.

Third, value chains can be assigned to two differentiated categories: those that concentrate most of the emissions in the last stage of response to final demand and those that induce upstream emissions in other sectors. In the first category, it is worth mentioning electricity, gas, steam and air conditioning; other nonmetallic mineral products; paper products and printing; coke and refined petroleum products; chemicals and chemical products; water supply and waste management; basic metals; and computer, electronic and optical products. The rest of the value chains can be placed in the second category.

4. CONCLUSIONS

As part of a research stream with the ultimate goal of defining a methodology to assess the impact that the circular economy can have on the productive fabric of a region, the objective of this paper is to propose a framework to assess the susceptibility of sectors and value chains to be affected by the implementation of the circular economy. For this purpose, a quantitative method based on EEIOT was used and expanded to incorporate the employment variable. Data processing was used to construct a

three-dimensional space based on three axes: value chains, productive sectors, and the position of each sector according to its distance from the final demand of intersectoral relations. In this space, emissions and employment corresponding to the activities retained in the model developed by Retegi et al. (2023) have been identified.

According to the data analysis, it can be observed that, in 10 of the 20 value chains analysed, most of the emissions are generated in the last phase of providing the final demand. For other value chains, most of the emissions are carried out in the immediately preceding phase (link 1). The outcomes of this study enable the classification and qualification of production sectors based on the following criteria:

- Number of value chains in which they are present
- The intensity of emissions per job
- The proximity or distance of the participation in value chains from the final demand

Sectors with participation concentrated in a limited number of value chains, coupled with a high level of emissions per job and a considerable distance from the final demand will be more vulnerable to the implementation of circular economy principles. Furthermore, considering the findings, value chains can be classified based on the following:

- The number of sectors involved and the length of the chain
- The phase during which emissions occur
- The level of emissions and the induced employment

These classifications of sectors and value chains will offer valuable insights that can inform conclusions regarding circular economy policies and, ultimately, their regional impact. For instance, the value chain of electricity, gas, steam and air conditioning exhibits the characteristics of a short chain, a high emission intensity per job, and a significant proportion of total emissions. In this case, the circular economy strategies to emphasise would range from the R0 refuse strategy to the R2 reduce strategy (Kirchherr et al., 2017). Another example is the construction value chain, which accounts for a substantial number of emissions, with fewer emissions in the final phase and many jobs. Considering the challenges associated with recycling construction materials, achieving effective emission reductions would necessitate demand reduction strategies or technological approaches involving material substitutions that facilitate recycling and reuse.

This research is part of a broader line of inquiry aimed at assessing the vulnerability of the productive fabric within a geographical context to the implementation of circular economy strategies. To achieve this objective, further research is needed in areas such as sector qualification that takes into consideration all the above-mentioned factors, incorporates the value added of activities as a key variable alongside employment, conducts qualitative analysis that integrates the specific characteristics and the trends of each value chain (e.g. technological, local vs. global) and assesses vulnerability from a geographic industrial fabric perspective.

As mentioned in the introduction, the use of environmentally extended input–output tables (EEIOTs) inherently presents limitations associated with a certain level of imprecision. However, it provides a more comprehensive perspective compared to tools based on life-cycle analysis. The level of detail in the available information and the use of sector averages do not allow for precise differentiation within the same sector. Nonetheless, the validity of the conclusions may be sufficient to identify priorities among sectors as well as areas requiring further investigation.

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RELEVANCE OF ADEQUATE INDICATOR UNDERSTANDING FOR BUSINESS PERFORMANCE

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Abstract: *Key performance indicators (KPIs) present relevant, quantifiable measurements of achievement for specific objectives during a certain period. Setting KPIs is crucial in ensuring teams and individuals support higher overall organizational goals. These indicators are set throughout the organization, across different sectors, teams, and for various individuals. Often, achieving some KPIs may have an opposing effect on others. However, the ultimate expectation is to balance their impact and fine-tune their effects to reach optimal company performance. The disruptive environment in the last few years has affected supply chains in all industries, emphasizing the relevance of sharing information and team alignment more than ever before. A proper understanding of those KPIs and their impact on business results is of utmost importance. Establishing a proper KPI monitoring system and making necessary adjustments when needed is another step in assuring that goals are achieved. Based on the author's experience, this paper will present some actual cases of how a proper understanding of KPIs impacts performance results.*

Key words: People management, Performance, Indicators, Supply chain

1. INTRODUCTION

Key performance indicators (KPIs) refer to a set of measurable indicators used to monitor the success of a company's operations. KPIs play an essential role in determining strategic, operational, and financial achievements, acting as a compass, especially when compared with other companies in the same industry.

Many people wonder when it is necessary to start defining and monitoring KPIs in a company. At the very beginning of a company's development, KPI structure is not very much developed or even doesn't exist at all. However, after a certain period of time and operation growth, when the company has defined its goals and strategy, it becomes necessary to introduce a system for monitoring the success of goal execution, i.e., KPIs (Marr B., Gray D., 2012; Patrick Mutabazi, 2022).

Key Performance Indicators (KPIs) represent crucial indicators of success or performance that are chosen in advance to set, monitor, and evaluate activities in different phases and based on results, determine possible corrective measures. They must be measurable, achievable, relevant, specific, and time-framed. The primary purpose of KPIs is for the organization to reach its set goals and achieve targets, enabling timely recognition of any deviations and successfully organizing appropriate corrective activities. An important factor in choosing indicators is the reliability of the source. Relying on pre-developed templates and sources might have been viable twenty years ago, but today, due to the rapidly changing business landscape, constant work on new or updated sources is practically necessary.

It is not enough to merely define KPIs and monitor their achievement; all employees must understand the KPIs and their specific implications for their work. Without defined KPIs, employees may rely on instincts, personal preferences, or hypothetical criteria that often lack confirmation in reality. This approach can be hazardous for business because relying on intuition alone can lead to misunderstandings and significant problems in the mid and long-run. Tracking KPIs is crucial for understanding why certain situations occur, enabling better decision-making.

The use of KPIs in companies is the primary means of motivating employees and thus enhances productivity and employee performance evaluation based on results. This collective effort contributes to the achievement of strategic goals (Acupower LTD., 2022).

However, it's important to note that the mere existence of defined KPIs doesn't guarantee improved staff performance. As demonstrated in the example of a company operating in Serbia, if employees do not

understand or choose not to understand the KPIs and do not actively work towards achieving them because they perceive them as unattainable, performance may decrease.
As Endru Lang said: "Most people use statistics like drunkards use a bottle, more to mask a problem than to come to enlightenment. The real power of KPIs lies in your ability to interpret data and draw actionable conclusions, which can help you improve your business. With them, you can achieve long-term success by consistently taking optimal actions.".

2. UNDERSTANDING KEY PERFORMANCE INDICATORS

How to overcome the problem when employees do not understand the importance of KPIs for their business and the company's success? How to deal with negative employee reactions when introducing a performance monitoring model? In this paper, we will show a case of how one company succeeded and the results were achieved.
The first step is for management to convey to employees the information that KPIs offer a reward system for achieving specific goals and implementing well-defined processes within these goals. Employees should not only understand that such an approach is beneficial for them but also see the criteria for evaluating the efficiency of their work after the system's implementation. However, changes that impact working conditions and especially salary conditions may cause natural resistance among employees.
The emergence of fear and concerns in this case is a normal process, and the manager needs to address this issue and conduct targeted employee training simultaneously with the implementation of the KPIs. Effective communication with employees is essential in this process.
In the introductory part, we touched on what KPIs are and their significance for successful business operations. In the subsequent sections, we will prospect into the theoretical foundations of KPIs to provide a better understanding of their importance for the company's successful operation.
When attempting to improve a company's operations or foster its growth, finding a starting point can be challenging. The company operates to achieve its mission, vision, and goals and carries out various activities, processes and operations accordingly. To assess which activities, processes, and operations lead to the achievement of set goals, the company requires measurable indicators. Not only are measurable indicators necessary, but their selection is crucial to obtain a balanced measurement of success. It is essential to include all business performances and define KPIs that serve as success factors for achieving set goals. The company should monitor KPIs at both the high level (company level) and the low level (within each of the company's functions, departments, services, etc.) or all business processes. When discussing the lower level of KPI monitoring for the company, it is preferable to monitor KPIs by processes, utilizing a process-oriented approach instead of monitoring by departments (Müllner A., 2007). The reason is that certain processes occur across multiple organizational departments, services, and plants, leading to overlapping or unmonitored KPIs because one organizational unit assumes that another will take care of it, etc.
Based on this, we can divide KPIs into two groups:

- KPIs at the company level
- KPIs that are monitored for each organizational unit (e.g., procurement, sales, marketing, human resources, production, etc.)

KPIs should be seen as a guide, indicating the direction in which the company is heading and how far it has progressed towards fulfilling its business goals. When choosing KPIs, it is essential to ensure that they lead the company in the right direction. Some KPIs will have oposed effect on different sectors, departments, or can be even oposed within the same secotor or department. However, real success is to make the right balance in achiving them, do proper prioritization and align all stakeholders.
When defining KPI, it is necessary to answer the following questions:

- Why is this goal important?
- How will we measure progress?
- How can we influence the outcome?
- Who is responsible for the business result?
- How do we know that we have achieved the desired results?
- How often we must analyze the achieved results?

Successful companies have KPIs that all employees focus on, aligning their work with the company's strategy. KPIs can determine and measure how well each individual is performing, helping the company

identify necessary changes to improve productivity and overall success (Addison, R., Haig, C., & Kearny, L., 2009).

3. RESULTS

This thesis will explore real-life examples and what impact those changes made for the company. Solely, this information would be not complete and that is why research papers concerned with different influence factors on business performance will also be assessed to provide a more holistic picture and a greater acceptance of the proposed KPIs.

Based on the problem and the goal of the research, data was analyzed in a foreign company operating in Serbia. For the sake of data protection, we will not specify which company is the subject of the research. The mentioned company has defined KPIs for all its business processes, however, the set goals were not achieved. The reason for the poor fulfilment of the set goals is the employees' familiarity with KPIs and their importance for the company's operations. During the data analysis, it was observed that many employees knew they have defined personal KPIs, but they never looked at them, tried to understand them, let alone tried to achieve them. The reason for this is that the employees were not aware of the KPI relevance and the management has not explained to them what it means for the company (Parmenter D., 2015).

After the observed problems and certain changes in the management of the company, KPIs monitoring and the achievement of the goals were approached more seriously. The management organized several training sessions with employees where everyone was familiarized with the KPI and where they could give their suggestions for improving the KPI. KPIs were no longer just numbers on paper. In this paper we will analyze several segments of logistics operations in the company, performance achievement and the definition of KPIs in business processes.

Following business processes were observed and relevant set of KPIs were established:

- Level of service to customers (KPI - Service rate development)
- What is the number of process mistakes toward customer (KPI - Number of justified customer complaints)
- Order fulfillment process review from suppliers (Number of justified complaints to suppliers)

First, we observed the achievement in cooperation with customers and level of service that was provided to them before and after familiarizing all employees with the goals and KPIs by which those goals are measured, and the motivation of employees based on the measurement of the fulfilment of the set goals for each KPI. The changes took place in May 2022.

Table 1: Service rate development for 2022. and 2023.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	23,7%	27,8%	25,4%	31,8%	24,3%	26,5%	44,2%	59,6%	42,2%	57,9%	22,3%	59,4%
2023	42,2%	11,4%	77,3%	93,4%	92,8%	93,6%						

Data analysis (Table 1) shows the percentage of fulfilment of the set KPIs that were monitored in 2022 ranged from 23.7% in January to 59.4% in December. The changes that occurred in the implementation of the KPI in May began to give the first results in July when the fulfilment was 44.2%. Growth trend was recorded until the end of the year, except in November, when there was a decline in performance with a realization of only 22.3%. The reason for this were problems in the company's operations and effect was expected and known to all relevant stakeholders.We can see really improved results only in 2023 when the result reached the level of 93.6%, which was in June.

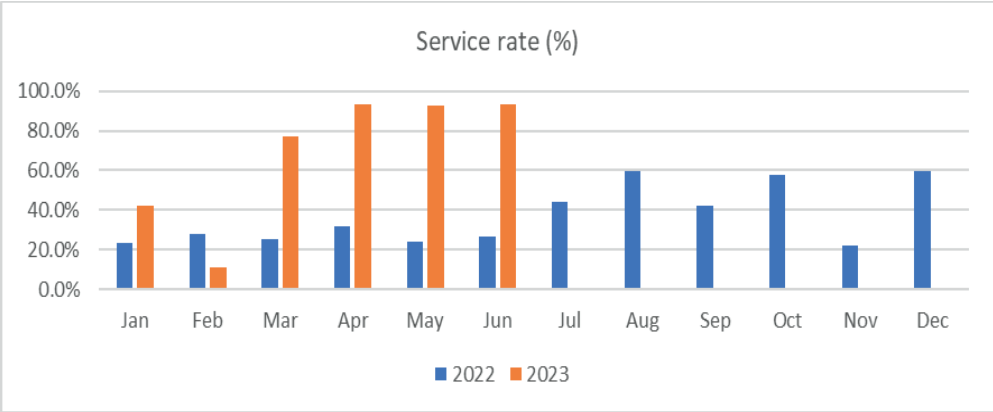

Figure 1. Service rate development

The quality of the service has increased, and we will see if this is reflected in the other logistics processes of the business through the findings of the number of justified complaints from customers and to suppliers.

We saw in the previous part that the service rate increased from July 2022 until the end of the year (apart of Sept and Nov). In the case of justified complaints, there was a declining trend(in May there were 85, and then they decreased to 15 in October and 20 in December).

Table 2: Number of justified customer complaints in 2022 and 2023

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	4	12	16	16	85	55	54	18	24	15	23	29
2023	12	20	29	12	18	24						
YTD2022	4	16	32	48	133	188	242	260	284	299	322	352
YTD2023	12	32	61	73	91	115						

If we compare 2023 vs 2022 (Figure 2), it is visible that number of complaints is lower in 2023. Figure 2 shows the number of justified complaints by month and the cumulative number of complaints for 2022 and 2023 by June for both years. Total number of complaints until end of June 2022. was 188, and by end of June 2023 that number was 115, more than 30% less.

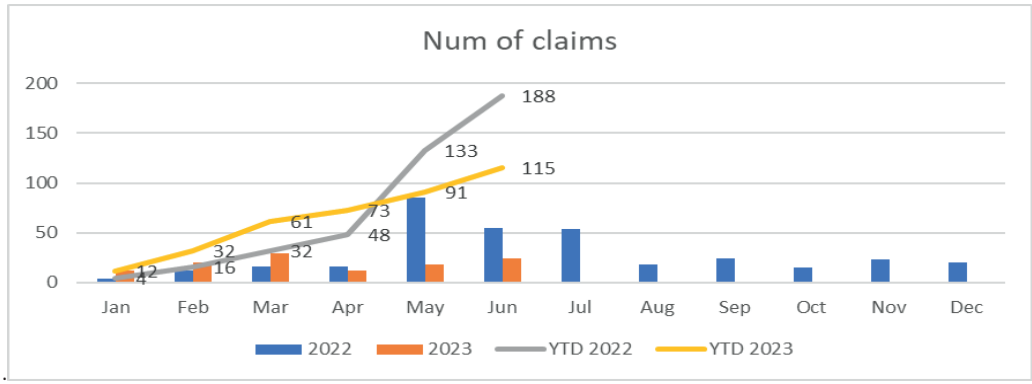

Figure 2. Number of justified customer complaints in 2022 and 2023

In addition to the number of justified complaints, we analyzed the number of justified complaints to suppliers. Achieving the set goals requires the quality of raw and other materials used in production. The analysis shows the number of complaints in 2022 to suppliers was in the range of 1 to 3 complaints per month. By increasing the fulfilment of stated goals and involving all employees in the creation of KPIs, the number of justified complaints to suppliers has also increased. Employees increasingly noticed the poor performance in suppliers' behavior when providing materials to the plant, which had a direct efect on the lower results in production efficiency, causing often stoppages and plan changes. The number of justified complaints in 2023 ranged from 3 to 5 complaints per month. The number of complaints is small because

the company itself does not have many suppliers, but the purpose was to establish a proper way of cooperation where all obligations will be respected and all parties will be satisfied.

Table 3: Number of justified complaints to suppliers in 2022 and 2023

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	1	1	2	1	2	1	1	0	1	1	2	3
2023	3	4	2	5	4	4						
YTD2022	1	2	4	5	7	8	9	9	10	11	13	16
YTD2023	3	7	9	14	18	22						

When the cumulative data is analyzed, we see that in 2022 there were 16 complaints to suppliers, and in 2023, until June, the number of complaints to suppliers was 22. Looking at the same period for both years (Jan – Jun) in 2022. there were 8 compaints vs 22 in the same period in 2023., which is almost three times more.

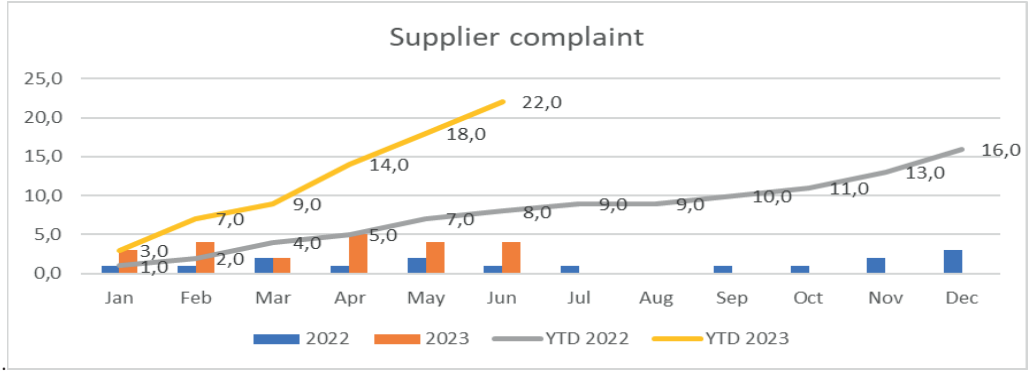

Figure 3. Number of justified complaints to suppliers in 2022. And 2023.

The connection and interdependence between the increase in the fulfilment of set goals and KPIs and justified complaints from customers and to suppliers will be presented in the next part of the work, i.e. the discussion.

4. DISCUSSION

Poor performance from the supplier side which was caused by a few factors, but not adressed as a serious issue, had a negative impact on production efficiency and consequenlty on product availability. For understanding purposes, only one delay of material for a few days could disturb customer supply for more than a month. This led to an increased number of negative effects (more customer compleints and higher associated costs, higher transportations cost, prolonged weekly production shifts,…). Better follow-up and improvement actions led to better performance results.
In the given case KPIs have been established but monitoring, route causes analysis and corrective activities were not conducted. The culture of setting KPIs was there but not as a process of running operational activities, tracking them, finding out what has an impact on them and how this can be improved. We can say that the form has been fulfilled but the essence was missing.
When KPIs were properly explained, the monitoring system was established and mutual correlation recognized, it was easier to move forward by involving more people and setting the whole process as it should work.

5. CONCLUSIONS

To improve business and advance the development of the company, we need to find a clear starting point. Every company in the world monitors its work through certain set goals and monitors their achievement. To evaluate the activities that need to be carried out to achieve these goals, the company needs measurable business indicators, which are known as key performance (business) indicators or KPIs.

Selecting and monitoring KPIs is the best way to begin to discover what is working and what is not working in a company's business. There are many KPIs but only the right ones prove to be effective if carefully selected.

In addition to this, KPIs can determine and measure how much each individual participates in achieving the specific goals of the business. In addition, KPIs will help the company determine what changes need to be implemented to improve productivity and success. This is probably the most important reason why companies set and track KPIs. In our example, we saw what changes the observed company made to improve its business and what results were achieved.

When we have defined KPIs and when we know that they represent key indicators for a successful business, we should know that each KPI is only worth as much as it inspires employees to achieve it. Companies often adopt KPIs and then wonder why those KPIs do not reflect their business results and do not effect any positive change. One of the most important, and often interchangeable, that we saw in the observed company is communication. All employees should be familiar with KPIs what they bring to them and how they can help in achieving them. The employees must understand the KPIs and react according to them. It is necessary for employees to understand the business strategy based on which the KPIs were formulated and to understand what the organizational goals are, how to plan their achievement and how it can affect their work and motivation.

KPIs are useless if not communicated properly. How will the employees who are tasked with implementing the company's business vision implement it, if they don't know what they are? Or even worse, if employees don't know what the company's KPIs are, then they alienate them from their goals and make them frustrated because they don't see the direction in which the company is going and should go. KPIs need to be communicated effectively. This can only be achieved if it is explained to all employees what we measure, and why we do it. If we fail to do that, KPIs will become just numbers that have no meaning for either management or employees.

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ACHIEVING SYNERGY: AN INTEGRATED APPROACH TO PROJECT AND QUALITY MANAGEMENT IN PROJECT-ORIENTED ORGANISATIONS

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Abstract: *Projects play a pivotal role in realizing organizational objectives. In today's dynamic work environment, organizations increasingly rely on projects as an integral part of their operations to successfully accomplish their goals. The stringent regulations and prerequisites pertaining to the knowledge economy and the contemporary industrial model have resulted in a shift from the traditional 'quality management' approach to one focused on 'managing quality.' This paper aims to showcase the beneficial outcomes resulting from adopting an integrated approach to project and quality management in project-oriented organizations. The research conducted for this paper involved an international sample of 124 organizations renowned for their high levels of quality and excellence. By embracing this integrated approach, organizations can establish a strong foundation that empowers them to reach the desired levels of success they strive to achieve.*

Key words: project management, quality, excellence, project-oriented organizations (POOs)

1. INTRODUCTION

Achieving effective project management at the organizational level extends beyond mere software applications or the utilization of a particular tool. To successfully adopt this, it is crucial to foster acceptance and a positive attitude toward the project approach across all organizational levels. Subsequently, establishing robust, enduring processes and capabilities becomes essential, enabling the implementation of this approach and ensuring excellence and favorable results.

By examining both project and quality management through the lens of customer focus and continuous improvement, it becomes evident that project-oriented organizations uphold quality principles by implementing a structured project management methodology (Orwig and Brenan, 2000). Kerzner (2017) emphasizes that organizations today are increasingly recognizing the need to implement project management approaches. However, the question arises about how this approach is being applied and to what extent, as well as how it is connected to organizational performance.

This study demonstrates the positive impact of adopting an integrated approach to project and quality management on the overall business performance of such organizations. In the second chapter, both the project and quality management perspectives, as well as an integrated approach, are described. The third chapter provides evidence of high-performing and excellent project-based organizations, focusing on the relevance of project management. The fourth chapter presents a discussion of the results, while the conclusion remarks and future implications are described in the fifth chapter. Finally, a reference list is provided at the end.

2. PROJECT AND QUALITY MANAGEMENT: AN INTEGRATED PERSPECTIVE

2.1 Project management perspective

Project management plays a crucial role in the contemporary business landscape as it encompasses an approach that fosters ongoing enhancement through diverse project endeavors, ultimately resulting in enhanced organizational performance (Radjuković & Sjekavica, 2017).

One of the leading authors in this field, Rodney Turner (2009), defined a project as a temporary organization assigned resources to perform work that delivers beneficial changes. Each project has its project life cycle, which represents the process that transforms vision into reality – from initiating the

initial idea with potential for performance improvement to delivering results that enable the realization of benefits (Turner, 2009).
Project management is a significant process for all organizations, regardless of their size, type, and/or industry. Efficient project management allows organizations to complete their tasks on time, within planned costs, and with satisfactory high-quality results (Ebbesen et al., 2013).
Bredilet et al. (2013) state that as much as 20% of global economic activity is conducted through projects, with this percentage reaching up to 30% in certain growing economies. Today, it is common for businesses to be managed through projects, which applies to project-oriented organizations (POOs) as well as those that are not.
POOs can be defined as organizations that conduct the majority of their activities according to project principles and prioritize project dimensions over functional ones in terms of their structure and processes (Sydow et.al, 2004) in order to fulfil quality requirements in all aspects.

2.2 Quality management perspective

The notion of quality is interconnected with all domains of human activity and can be examined from various perspectives: organizational, process-related, technical-technological, sociological, and other aspects that relate to people, the environment, processes, products, or services.
Juran (1994) defines quality as fitness for use in terms of design, conformance, availability, safety, and field use. While a high level of quality is desired, specific requirements vary among individuals and organizations, and these may evolve over time.
For that reason, it is important for organizations to fulfil quality requirements throughout the entire business and implement the Total quality management (TQM) approach. TQM focuses on improving organizational effectiveness, efficiency, and responsiveness to customers and other stakeholders. It does so by actively utilizing the skills and competencies of employees, with the ultimate goal of achieving sustained organizational performance improvement and excellence through quality (Sader et al., 2019).
Anticipating the quality of a process, product, or service is one of the major challenges of the contemporary era – determining whether what is being created today will deliver value to users in the future. The main objective of project management is to fulfil the requirements of customers and other stakeholders while meeting the quality standards that satisfy their needs (Digehsara, 2018).

2.3 An integrated approach

Project management is no longer seen solely as an internal system within organizations, but rather, it represents a competitive tool that enables the achievement of higher levels of quality and enhances opportunities for delivering additional value to customers and other stakeholders (Silva et al., 2021).
Undoubtedly, quality stands as a pivotal outcome for every project. The consensus among professionals is that project performance is inherently linked to three key factors: time, cost, and, most importantly, quality. Hides (2000) has proven that project management plays a significant role in the successful implementation of the total quality management approach.
Project management is an approach that promotes continuous improvement through projects, leading to enhanced organizational performance and outcomes (Radujković & Sjekavica, 2017). Josef Juran, one of the founders of the quality management concept, emphasized that improvements within an organization are carried out project by project (Juran, 1994).
Managing quality in project-oriented organizations includes three main steps (PMI, 2013):

- Quality planning involves the identification of quality requirements and standards for a project and its deliverables. It entails documenting how the project will exhibit adherence to quality and meet the specified criteria.
- Performance quality management includes conducting audits on the quality requirements and evaluating the outcomes derived from quality control measurements. This process ensures the utilization of appropriate quality standards and operational definitions.
- Control quality encompasses the monitoring and recording of results obtained from implementing quality activities. It involves assessing the performance against established benchmarks and recommending any essential modifications.

Bryde and Robinson (2007) concluded that adhering to quality management steps and principles helps organizations maintain effective project management, especially in areas of customer service delivery,

preventing business failures, fostering employee professional development, and promoting strong leadership.
According to Basu (2014), every project-oriented organization must critically assess its project management's effectiveness in delivering the required longer-term outcomes and benefits to sponsors and end users.

3. ACHIEVING SUCCESS THROUGH INTEGRATED PROJECT AND QUALITY MANAGEMENT: EVIDENCE ON HIGH-PERFORMING PROJECT-BASED ORGANIZATIONS

All organizations that participated in the research were recognized or awarded as excellent by the European Foundation for Quality Management (EFQM). Business excellence principles are based on total quality management principles, and the research has shown that the companies that obtained certification with the ISO 9001 standard achieved higher scores in the EFQM model compared to those that were not certified (Fonseca, 2015). Accordingly, it is considered that organizations with a certain level of recognition and awards for business excellence demonstrate the highest levels of quality achieved in their processes and results.
Using these organizations as examples, it was examined to what extent project management is prevalent and integrated into the overall system, which has already been confirmed to deliver quality processes and results.

3.1 Research methodology

Data collection was initiated in January 2021 and persisted until March 2021. The distribution of the questionnaire took place in electronic format, utilizing the Google Forms platform, targeting organizations that have received recognition and awards for their business excellence. Out of the total participants involved in the research, which amounted to 130, six individuals had missing data, resulting in a final count of 124 participating organizations with a response rate of 10.05%.

3.2 Results

The majority of respondents were employed in top management positions, constituting 37.90% of the participants, followed by middle management comprising 27.42%, and project management with 11.29% representation. The research included organizations from 27 different countries which operate in both service and manufacturing industries.
When it comes to business excellence, the majority of organizations are recognized as being dedicated to excellence, with four stars (24.19%), one star (19.35%), five stars (16.94%), or two stars (15.32%). The attained level of recognition and awards for business excellence is defined according to the categories established by the EFQM organization (EFQM, 2013). The criteria relate to three groups of business excellence levels, further divided into seven sub-levels.

Table 1. Organizations according to the level of recognition or Awards for Business Excellence

	Category	Number	Percentage (%)
Business Excellence level	Committed to Excellence	24	19.35
	Committed to Excellence 2 stars	19	15.32
	Committed to Excellence 3 stars	12	9.68
	Committed to Excellence 4 stars	30	24.19
	Committed to Excellence 5 stars	21	16.94
	EFQM Finalist	10	8.06
	EFQM Award/Prize winner	8	6.45

The participants completed a questionnaire consisting of 39 questions and one of the questions for organizations was whether project management is identified as a separate process. This question aims to determine whether excellent organizations that have demonstrated quality in their activities and results have established project management as a distinct process. It is important to note that in the assessment of business excellence, there is no mandatory part related to project management. Therefore, this research attempted to examine the correlation between these two aspects.

The responses of the organization representatives to this question are shown in Figure 1.

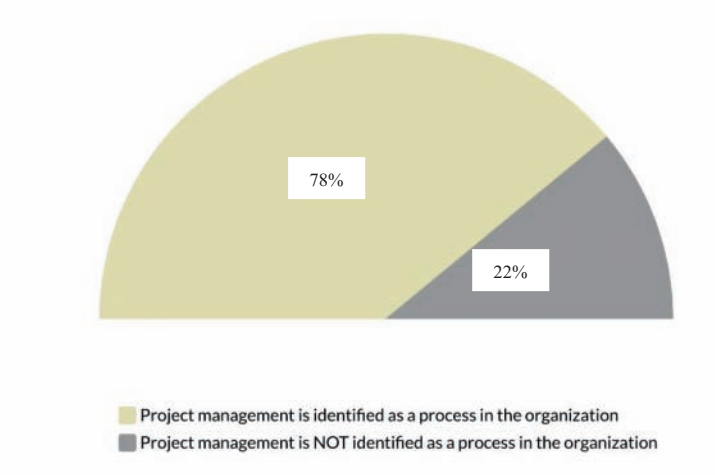

Figure 1: The systematization of project management as a separate process

Project management is systematized and identified as a separate process in 78% of organizations, while it is not identified as a separate process in 22% of organizations.
In addition, there was a question that examined the extent to which project management is integrated into the business, i.e., whether it is connected with all functions, whether only specific aspects are used as needed, or if there is an approach to total project management.
Figure 2 illustrates the response structure of the organizational representatives.

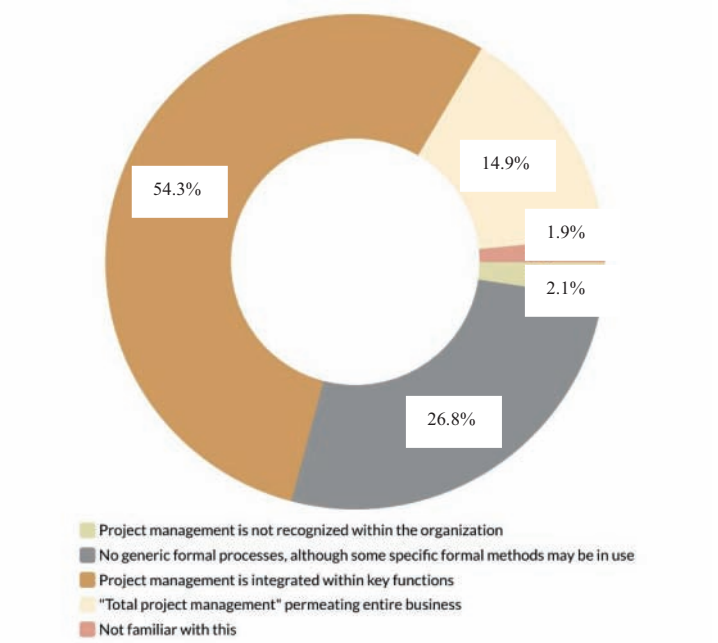

Figure 2: Integration of project management within the organization

In the previous graph, it is shown that 54.3% of organizations have integrated project management within their key business functions, while 26.8% of organizations stated that they do not yet have formalized project management but use some specific methods for this purpose. 14.9% of organizations reported applying a total project management approach, which means that this approach is integrated into all business functions and aspects. Only 4 % of excellent organizations indicated that project management is not recognized in their organization or that they are not familiar with it.
The next chapter will present a discussion of the obtained results.

4. DISCUSSION

The previous chapter presented the results of the conducted research, which establishes the significance of the relationship between quality management and project management. All participating organizations have demonstrated excellence in their operations and achieved remarkable results, indicating the highest levels of quality they attain (Fajsi, 2022).

Among the sample of 124 organizations, it was shown that over 3/4 of these organizations have established project management as a separate process (78%). This further implies that project management is recognized as a significant means to achieve quality and excellence in all business domains. The systematic approach to project management was previously solely associated with the application of accepted methodologies or the existence of a project management office or department. Over time, the specificities of organizations have been increasingly considered and placed in the context of project management, resulting in a series of adapted and modified approaches and methodologies to systematize project management within these organizations.

When examining the level of project management integration across all key business segments, more than 50% of organizations responded that they have an integrated approach that involves linking project management with procurement, finance, planning, and other departments. Project-oriented organizations applying this approach are typically structured as strong matrix organizations, where project management is to some extent formalized. A significant percentage of organizations indicated that they haven't established project management in this way but apply specific elements as needed, while 14% of organizations stated that they implement total project management, meaning their business is entirely based on the project principle. All of the above points to a strong correlation between the implementation of a project management approach and the achievement of quality in business operations and results.

5. CONCLUSIONS

The findings from this study provide empirical evidence that demonstrates a positive correlation between project management and enhanced quality, subsequently leading to the attainment of business excellence. Organizations in which the approach to project management is systematized achieve higher levels of quality, excellence and performance compared to organizations where project management is not systematized.

Project management is no longer a methodology exclusively confined to the industry; instead, it has become integrated into other sectors such as education, public administration, politics, and culture. This implies that an increasing number of sectors will adopt project management methodologies and approaches to address complex tasks arising in the ever-changing market and technological environment.

For future research, it is suggested to empirically investigate the impact of project management on specific aspects of quality management, such as customer and employee satisfaction, leadership, and continuous improvement, with the aim of achieving better organizational performance and competitiveness.

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MODEL FOR ACCEPTANCE OF PATIENTS DURING A PANDEMIC USING SPACE SEARCH OPTIMIZATION

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Abstract: *Resource allocation is one of the major problems in a healthcare system. The problem gets worse during a disaster situation like a pandemic. The demand is high, and the resources are limited, this puts a question on which patient should be admitted. This research focuses on increasing the number of patient admissions by deciding who should be admitted based on the patient's severity and length of stay. In the research, the patient has a fixed length of stay and if a patient is rejected, he/she is rejected forever. The research focuses on one critical resource, and it needs to be available to admit the patient. The daily capacity of resources is fixed. The demand during the pandemic is dynamic, so this research solves the problem using space search optimization which is one of the techniques of dynamic programming. The research uses depth-first and breadth-first space search algorithms. The experiments with randomized data were executed to see the effect of available capacity on the number of admitted patients. This research shows that space search algorithms are useful techniques for the optimization of resources and patients during a pandemic.*

Keywords: pandemic, optimization, healthcare resources, space search

1. INTRODUCTION

A pandemic is a situation when a disease outbreak spreads to large areas, such as several countries or continents or the whole world ("WHO | What Is a Pandemic?" n.d.). There are approximately 1.7 million viruses that can infect humans from animals and birds, and, according to some scientists, the next pandemic can be around the corner ("Why Scientists Are Rushing to Hunt Down 1.7 Million Unknown Viruses | Live Science" n.d.). Situations like pandemics can disrupt almost every part of human life, but the most affected is the healthcare system.

The healthcare systems get overwhelmed with the patients' load due to limited resources (Emanuel et al. 2020), (Baheti and Nayak 2022). Resources being limited means that not everyone can get treatment. This raises a lot of ethical questions as to who should be treated and how fair allocation can be made (Emanuel et al. 2020). During Covid-19 doctors' moral ethics were tested as they had to make decisions on who needed to be taken out of the ventilator so that it could be provided to other patients. Various researchers have done studies on what should be criteria for admissions and some have suggested age should be a priority. But there is not much done in creating a model for patient admission (Emanuel et al. 2020)

This research focuses on patient admission during situations like a pandemic. In the research, a patient's length of stay and day of arrival are known and the decision is to be made on who should be admitted to increase the overall number of patients taken in a given period. This research uses space search optimization to solve the patient admission problem.

This research is important in several ways: a) it provides hospital managers with a model to decide who to admit and who not to admit, and b) The research uses space search algorithms to solve the presented problem, space search has not been used in literature to solve patient admission problem. Section 2 provides a brief literature review of relevant research. Section 3 presents the problem statement. The solution methodology is given in Section 4, and its implementation in Section 5. The paper ends with conclusions in Section 6 and used references.

2. LITERATURE REVIEW

The literature on the pandemic generally focuses on the resource allocation problem, meaning how resources can be distributed to increase the number of patients taken. The research generally uses operation research techniques such as mathematical modeling or simulation to solve these problems. Prieto and Gomez solved the resource allocation using a risk-based algorithm. The authors' objective was to distribute patient and resources among hospitals to minimize the spread. The authors model detects

which locations needs to be prioritized to minimize the spread of pandemic (Prieto and Gomez 2021). Chen et. al. used the prediction to find the resource flow during a pandemic and then based on the predictions optimally allocated the resources in different regions (Chen, Sun, and Han 2022). Rico et.al did research on allocation of nurses in a hospital during influenza outbreak. The authors' objective was to find the optimal number of nurses to increase the number of patients taken. The authors used simulation to create various scenarios to find the optimal number of nurses in a hospital (Rico, Salari, and Centeno 2007).

Singhrova created an intelligent healthcare system to allocate the movable resources such as ventilators, ambulances among hospitals to increase the number of patients getting treatment during Covid-19 (Anu and Singhrova 2022). Mbah and Gillian showed that applying quantifiable strategies such as using treatment measure and reproductive number may provide fair treatment to everyone. They said that fair treatment to everyone can minimize the spread (Mbah and Gilligan 2011). Sun demonstrated through mathematical model that in pandemic resource sharing and patients among hospitals can reduce the patient load and overall burden on hospitals. The author said that it is important to share resources and patients during such overwhelming situations. The author's model has two objectives: first is to minimize total travels distance by patient to hospital and second is to minimize the maximum distance patient travel to a hospital. The author's model also predicts the resource shortage and optimizes the resource allocation when they become available, the allocation is done based on patients' cost to access care, minimizing travel distance and burden. The authors showed through their model that patient and resource allocation can reduce the overall burden during such crisis (Sun 2011).

Vaccine distribution is equally important to control the spread of the virus. Venkatramanan et al. showed that optimal vaccine allocation reduces the spread of influenza outbreak (Venkatramanan et al. 2019). Tuite et.al studied the effects of vaccines to control the spread of H1N1 virus. The authors used simulation to create various strategies to optimally allocate vaccines and found that regardless of the age if the vaccines are allocated to high severe patients it can decrease the morbidity and spread of the virus (Tuite et al. 2010).

Sormaz and Malik proposed a mathematical model for the patient admission to find out who should be admitted to increasing the number of patients taken. The patients in their model had priority based on the severity of the patient. The author's model has capacity as a constraint and studied the number of resources required to increase the number of patients (Sormaz and Malik 2023). Fattahi et. al. created a multi-stage stochastic program model for the distribution of resources and patients in a pandemic. The authors' model is multi-stage model and uses stochasticity to capture the uncertainty in demand and resource requirement during pandemic. Since, the situation in pandemic is dynamic, meaning the demand and resource requirement continuously change over time and is not linear. To address this issue, they used the approach of rolling horizon, to make their model closer to the real-world problem The authors' tested their model on two real world case studies, in one case study they focused on distributing resources and the other they focused in both resources and patients distribution. The authors concluded that resource distribution and patient sharing can increase the number of patients getting treatment (Fattahi et al. 2023).

Liu et. al. used integer programming to solve the resource allocation problem during pandemic dynamically. The authors' objective was to minimize the total cost of logistics of medical resources. Their problem concentrated on transshipment of resources from supplier to distribution centers and from distribution centers to hospitals and found that dynamic models are more effective for resource distribution during pandemic (Liu and Li 2022). Space search optimization has not been explored much for optimization of resources and patient distribution during emergency like situations such as pandemic. But the technique has been proven to be useful in allocating resources. Costa Filho et al. used the depth search technique with heuristics to allocate the physician in a healthcare setting. The problem they solved has constraints such available hours of physicians, number of days a physician works. The authors' objective was to efficiently allocate human resources to increase the overall number of patient treatments. The authors used combination of heuristics such as minimum remaining values, grade heuristic to solve their problems and found that their method is effective in distributing the resources and minimizes the cost at the same time increases the patients getting treatment (Costa Filho et al. 2012).

Space search is a problem-solving technique where a search space is being explored to find the solution (Luger 2005). The space search uses blind or informed search algorithms to make decisions on patients in a period when the capacity is a constraint. Space search is an artificial intelligence technique that uses search algorithms to find the optimal solution (Cortes et al. 2017). To our knowledge this is the first research that explores the methodology of space search on patient admission during methodology. The research will help in understanding the use of space search algorithms in solving problems of improvement and optimization of health systems operations.

3. PROBLEM STATEMENT

This research proposes a solution to the problem of patient admission in situations where resources are limited. The research uses random data of patients, where patient length of stay and day of arrival is known to the hospital managers in advance. If a patient is rejected, the patient is rejected forever in current research. To illustrate the problem, let us consider ad sample data shown in table 1 there are four patients and five days. The arrival of patients P1 and patient P2 is day 1 and they are going to stay for four and three days respectively. The arrival of patient P3 is on day 2 and he/she stays for 3 days, while patient P4 arrives on day 5 and stays only one day. Since the capacity is two and if we take patient P1 and P2 on day one, we cannot take patient P3 on day 2, or we can take one of the two patients on day 1 and take patient P3 on day 2. All four patients cannot be taken, since in days 2 and 3 we have demand for 3 units of the resource, but we have capacity of only 2. In day 5 we cannot utilize all capacity.
So, in the current problem the focus is given in periods when the capacity is a constraint for who should be admitted, if we take a patient today then this decision might decrease the overall number of patients in a whole period. Thus, the objective is to find the best combination of patients based on the capacity to increase patients taken. We will consider this problem as a sequence of one day problems, where for every day we need to make a decision on which patients to admit, which is suitable for the space search algorithms. The objective will be to maximize the number of patients for given capacity constraints.

Table 1: Description of sample data

Patients	Day 1	Day 2	Day 3	Day 4	Day 5
P1	1	1	1	1	
P2	1	1	1		
P3		1	1	1	
P4					1
Total Patients	2	3	3	2	1
Capacity	2	2	2	2	2

The search algorithm creates combinations of patients based on the number of available capacity and makes decisions based on it.

4. METHODOLOGY

This research uses the space search technique to solve the patient admission problem. The search algorithms uses the graph theory and graph representation of the problem space and traverse through nodes of the graph to solve the problem (Luger 2005). The following subsections will describe state representation and transition, breadth-first algorithm and depth-first algorithm as applied for the presented problem.

4.1 State Representation and Transition

State representation reflects the decisions made by the hospital for any given day in operation. It carries the following details: current day, current patients and provides method for state transition and evaluation. The state space search transition for the example in Table 1 is shown in Figure 1. In Figure1 the arrows going out of a node (represented as a circle) are the resulting states for decisions from a current state or node. The root of the state space search graph is start and its resulting children according to capacity two on day 1 are (none), P1, P2, or (P1,P2) where P1 and P2 for various choices at day one. Based on choice the appropriate capacity will be reserved for patients for day 1, but also for future days. That means if we choose the state (P1,P2), then in day 2 we cannot choose P3, since there is no available capacity. After day one we expand each state based on the day 1 decisions. The children of none nodes are P3 and (none) – patients P1 and P2 are lost, as we can still have none patients on day 2. Similarly children of node P1 are none, P1 and (P1,P3). Children of P2 are (none and P2), (P2 and P3). The children of the (P1,P2) state are (none) as there is not enough capacity. This expansion then continues until the end of the whole period of operation. In the end, the solution in the path from start to goal which admits the most patients. In our

example it would be with admitting three patients, three alternative solutions, S1(P1,P2,P4), S2(P1,P3,P4), S3(P2,P3,P4). For larger problems it is not trivial to come with those solutions.
The search algorithms are applied on the state space graph to find the optimal or a good solution. The research uses two types of space search algorithms to solve this problem: breadth first algorithm and depth first algorithm.

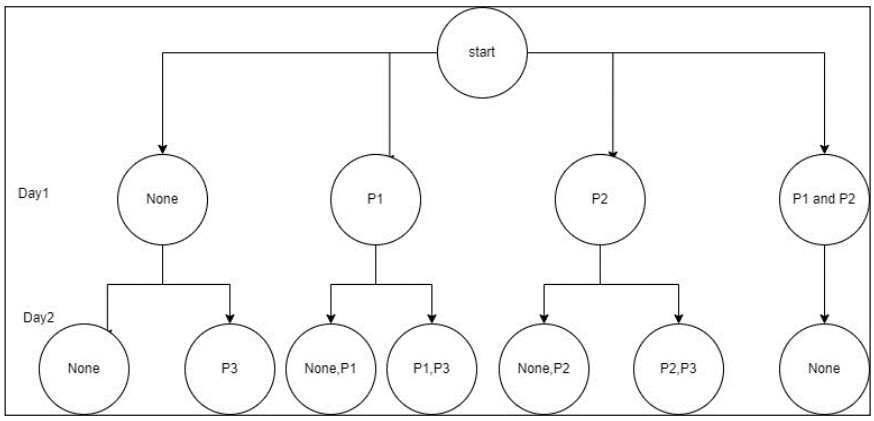

Figure 1: State transition diagram

4.2 Breadth First Algorithm

The breadth first algorithm traverses the graph nodes level by level. If there are no more states to investigate in a level, it advances to the next level (Luger 2005).The breadth first algorithm for Table 1 example would start by examining the start state, which is start, according to the breadth first approach. After visiting this stage, it will be closed, which means it will not be examined or explored further. The open states are the offspring of the start state, which are none, P1, P2, and P1,P2, where P1, P2 represent the patients in this problem. It would next visit state none and add its children in the queue of open states. The algorithm explores states in a systematic way, moving through them level by level. It doesn't stop until it has examined all possible states.

4.3 Depth First Algorithm

The depth first method adheres to the principles of last in, first out, and the search space becomes deeper as it explores in length. The backtrack algorithm is then used to discover the solution(Luger 2005). The depth first algorithm for the Table 1 example would start with the start node and then investigate it. The open states would be the start node's children (none, P1,P2, and P1,P2). The program would then investigate (P1,P2) and place it in a end states. (none,P1,P2, none) is the open state. The solution will then investigate the none state and place it in the close state ((P1,P2), none) because it has no children; the open state will remain unchanged.
The following state would be P2, and the open state would add its children (none, P1,(none,P2), and (P2,P3). (P2, P3) is the next state to be visited. The solution would continue to go deeper and would come to an end after visiting all the states or after finding the goal state.

4.4 State Evaluation

As it was mentioned, the objective in our probelm i sto maximize number of admitted p[atiens, which is equivalent to minimize teh number of rejected patients. When loking teh the state transition explaind in section 4.1, four possible choices on day 1, namely (Npone), P1, P2, adn (P1,P2) have 2, 1, 1, and 0 rejected patients respectively. Therefore, it would be beneficial to introduce informed search and expend states with minimal number of rejected patietns first.
The search termination happens when we reach the last day of the whole period (in our example day 5) or when there is no chance to further improve. In this paper we just report teh blind search, so termination happens at teh end of the whole period.

5. IMPLEMENTATION

In this section we present the current implementation of the space search algorithm within SpaceSearcher tool developed in previous work. We include a brief introduction to SpaceSearcher, and then details of implementation for this research.

5.1 SpaceSearcher for Patient Admission

The proposed space search procedure has been implemeted within the framework of *SpaceSearcher*, java based tool for exectuion and visualization of problem-solving algorithms (Sormaz, Dusan and Rajaraman, Srinivas 2003). The tool has been applied on variety of problems in manufacturing (Šormaz and Rajaraman 2008). The tool implements generic search algorithms while problem specific state transition and evaluation has to be done for each problem model for patient This research imports the SpaceSearcher library into its worksapce to use the algorithms, but it provides state representation, state trnasition, and state evaluation metohds.

5.2 PeriodicProblem Implemetation

Implementation inlcude two classes: *Patient*, to represent the data about each patient who comes to the hospital and *PeriodicProblemDay*, which extends *ComparableSpaceState* from *SpaceSearcher*, to implement state represetation, state transition, and stateevaluation methods needed by *SpaceSearcher*.
The following methods are created in the model to solve this problem:

- main *Method:* This method creates the current state and goal state of the problem. The method calls the SpaceSearcher and graphically displays the results of the algorithms being used.
- createPatients *Method:* This method uses the *Patient* class. The Patient class provides information about the patients, the class has constructor that creates objects of patient with length of stay , name of the patient and their arrival day. The *createPatients* method uses this class and stores the information of the patients based on the data provided in a map or from a file. The method sorts patients on a daily basis and groups patients who come on the same day into one list in the map.
- makeNewStates *Method:* This method creates new states based on the current state of the problem. The code for *makeNewStates* method is shown in Figure 2. The method runs as follows, in the beginning of the method a set of searchable states, list of patients "newStPat" and nextDyPat are being created.

The nextDyPat stores the information of the next day patients. The code begins with the for loop on the decisions that resulted in the current state of the search, if the patient in the current state is staying over nextday , the code then add this patient in the newStPat and in the states which stores the information of the resulting states from the current state. This ensures that the patients that are staying over next day are added in the resulting state from the current state decisions.
Once the patients from previous states are added in the current state, the method then check there are patients on next day of the problem and is there is enough capacity.
If both are true , it then runs the creates the combinations on the number of next day patients based on the group of remaining capacity. The combinations are created by calling createCombinations method. The combinations are then added in the nextDayComb list. A new list of patient is created that carries the patients from the previous decisions, the elements from the combination list are then added in the new patient list created and finally added in the states. The states are then returned as the result of the method.

```
public Set<Searchable> makeNewStates()
{

    Set<Searchable>  states=  new HashSet<Searchable>();
    ArrayList <Patients> newStPat= new ArrayList <Patients> ();
    ArrayList <Patients> nextDyPat= map.get(currentDay+1);
    for (Patients p2 : statePat)
    {
        if(p2.isStayingDay(currentDay+1))
        {
            newStPat.add(p2);
        }
    }
    states.add(new PeriodicProblemDay(this,newStPat,currentDay+1));
    if (nextDyPat !=null)
    {
        int nextDayCap= nextDayCap();
        if (nextDayCap>0)
        {
        List<Patients> nxtDyPatIter = nextDyPat;
        List<List<Patients>> nextDayComb=new ArrayList <>();
        try {
            for (int i=1;i<=nextDayCap;i++)
            {
            List<List<Patients>> combinations = Comb.createCombinations(nxtDyPatIter, i);
            nextDayComb.addAll(combinations);

            }
        } catch (Exception e) {
            e.printStackTrace();
        }
        for (List<Patients> ndi :nextDayComb)
        {
            ArrayList <Patients> allNewPat= new ArrayList <Patients> (newStPat);
            for (Patients i : ndi )
        {
            allNewPat.add(i);
        }
            states.add( new PeriodicProblemDay(this,allNewPat,currentDay+1));
        }
    }
    }

    return states;
```

Figure 2: The code for makeNewStates *method*

5. RESULTS

The model was run on a randomly generated data. The input data is shown in *SpaceSearcher* GUI in the Figure 3 in the left side of right panel. According to the table patient one comes on day 1 and stay for three days, patient two come on day 1 and stay for two days and so on. The capacity is two. This is the shortened versionj of the problem in Section 3 inorder to show completion of algorithms runs. The model has also been run on models with 20 patients and 10 days. The results of the algorithms are described below:

- Breath First Alorithm: Based on the capacity and patient arrivals, the states are created and each state creates its children states. The algorithm was run and the goal state in this case was the number of days defined in the data set. Figure 3 shows the breadth first search, the left side of the figure shows the expansion of the state space after every satet is explored. Integre numbers in brackets ([1], [3], [4], [5], etc) show the order of state expansions. State transitions are shown as children nodes for a given node, with color codes as: red are the states that have been already explored, magenta is the current state, blues are the children or decisions for each state that have not been explored yet. . Accoding to breadth first, it first investigated state number [3]. Decision number three takes no patients on day one, thus if it takes zero patients on day one, it can accept zero or patient number three who arrives on day two.

The search then moves on to the state [4], where patient one is taken, therefore children from this state would be patient one on the second day as it stays for another two days and does not take anyone else, or it can admit patient three. The algorithm currently runs until the number of days indicated in the objective state is completed. The state tree shown visually how breadth first expands level by level (in our problem day by day) before moving to the next day. The highlighted state [24] shows the one of best states which will be explored in the next round of the algorithm. The panel on the far right shows the current patients in this state, P3 and P4 (It does not show P2, since that patient has already left).

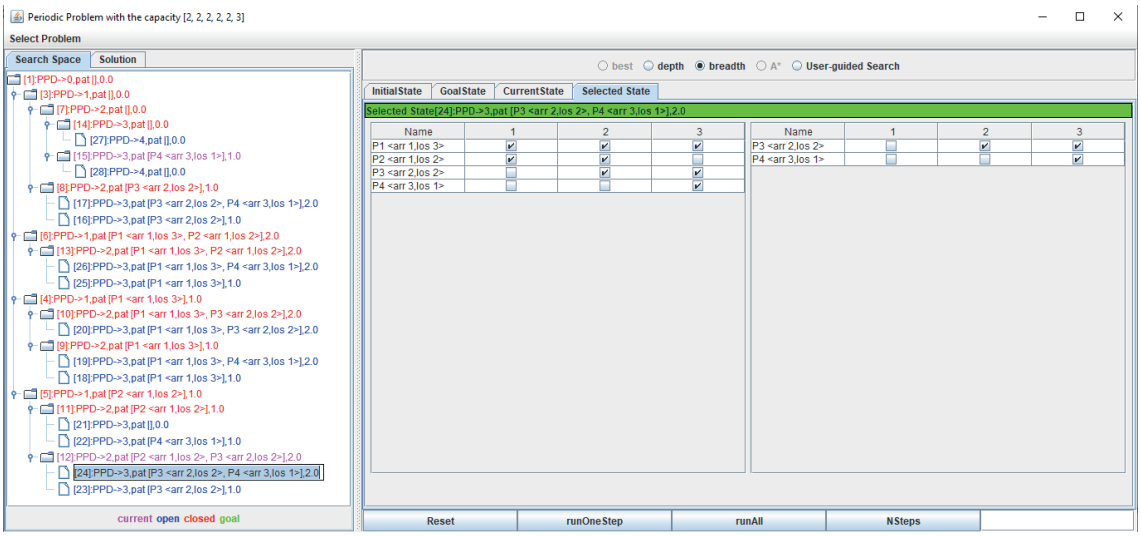

Figure 3: Breadth First Algorithm Result

Depth First Algorithm: According to the depth first algorithm it first explores state [6], which means taking patients one and two. The total patients count is 2 as shown in the Figure 4. After this, it explores state [7], where it can not take new patient P3, then state [9] where Patient P2 is gone, and in the next step I twill explore state [10] and take patient P4. The total patient count is 3. Then it explores state 10 . In state 10 the day is three and patient 4 comes the total patients in the system currently is 2 (patient 1 and patient 4). The states continue to explore until day 3. The state tree on the left shows the depth first behavior in which only one state in each day has been explored so far. The panel on the far right shows the current patients in this state, P3 and P4 (It does not show P2, since that patient has already left), the same as in breadth-first algorithm.

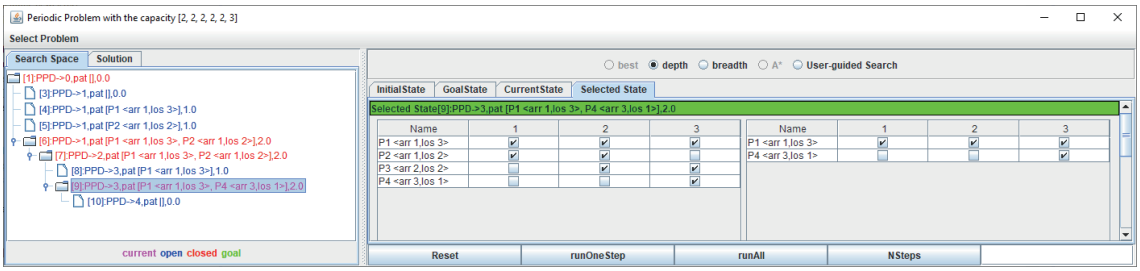

Figure 4: Results of depth first algorithm

According to the current scenario the maximum number of patients taken would be 3, as shown in the both algorithms. The algorithm shows combinations of patients based on the capacity and shows successfully the patient that needs to be taken to maximize the result. Running algorithms further wwoudl also detect other optimal states as mentiond in Section 3.

6. CONCLUSION

This paper presents the initial results of an ongoing research. The research explores the applications of space algorithms in creating models for patient admissions. The research shows that space search algorithms can be used in making decision on patient admission when capacity is the constrained. The future work in this research includes the implementation of state evaluation method and search termination criteria that would avoid the exhaustive search, The future work also includes running the data sets with larger number of patients and days and experimentation and optimization on real data.

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ACCELERATING BUSINESS TRANSFORMATION: UNLEASHING POTENTIALS FOR CHANGE AND CONTINUOUS IMPROVEMENT THROUGH AGILE PROJECT MANAGEMENT

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Abstract: *Withstanding challenges constantly emerging in today's ever-evolving business environment, organizations are facing the need to accelerate their business transformation more than ever before. Embracing agile project management practices appears to be among the possible solutions to unlocking the full potential for change and continuous improvement at all levels leading organizations towards better performance. Thus, this paper explores how agile project management serves as a catalyst for driving business transformation and aims to provide valuable guidelines for organizations seeking to accelerate their business transformation by adopting agile project management practices and leveraging the potential of agility. By doing so, organizations can seamlessly integrate and adapt to frequent and intense changes, harnessing the power of agility and delivering long-term value through short-term and successive iterations. The paper also acknowledges that certain industries, such as ITC, may already be well-versed in agile project management, while others, like manufacturing, face unique challenges in implementing this approach effectively, but the focus remains on all organizations tending to become more agile and responsive to changes regardless of the sector and activity.*

Keywords: business transformation, agile project management, change management, continuous improvement, organizational agility

1. INTRODUCTION

As markets rapidly evolve and technology advances at an unprecedented pace, being agile in change is not always an easy task. The ability to adapt, innovate, and drive transformation has become essential for organizations aiming to stay ahead of the curve, and there is no one-size-fits-all approach for achieving impactful and sustainable change (Ćirić et al., 2016). Therefore, agile project management, traditionally associated with the realm of IT companies and software development projects, has transcended its narrow boundaries, and evolved into a powerful tool for embracing change in all industries. Recognizing the imperative role of agility in driving growth and performance, businesses are now compelled to explore how agile values and principles can be applied to foster continuous improvement, enhance operations, and disrupt markets by delivering innovative products and services. Accordingly, this paper aims to explore the transformative potential of agile project management in accelerating business transformation and provides an overview of main aspects of its broader application in the context of building change awareness and continuity.

The paper is comprised of six independent sections, including introductory and methodological ones, and tends to explain essential elements of business transformation in an agile way. Thereby, the aim of the paper is to compensate the lack of systematic literature reviews in the field of business transformation, change, and continuous improvement naturally fostered by agile approach.

2. METHODOLOGY

To examine business transformation in the context of agile project management and its change and continuous improvement practices, we have been using systematic review approach. The idea is to gradually introduce three main stages of agile transformation – deploying organizational agility, harnessing agile project management benefits, and sustaining change in the long term, and increase transparency and clarity in transformation studies. The first step was to identify key research that provide relevant findings on business transformation, agile project management, or both combined, and we have been using databases like Scopus or Web of Science as well as literature published by Elsevier, Emerald

Publishing, and Springer, prominent international publishers, and the focus was on papers published in the past five years, periodically broadening to a ten-year publishing scale. The main criteria in selecting papers and books for this research were their accuracy, citing score, publishing journal, actuality, and innovativeness. We have also provided comprehensive quality assurance and peer-to-peer review prior to submitting the paper.
Note that this paper is introduction to agile transformation research and aims to collect basic data on matter-related topics thus ensuring support for further research covering application of empirical studies, grounded theory approach, and practical implementation of transformational project.

3. ORGANIZATIONAL AGILITY AS A CATALYST FOR CHANGE

Organizational agility has transcended its association solely with IT firms and has emerged as a vital strategic approach for embracing change and remaining competitive in dynamic and volatile business landscape (Ciric et al., 2018; Nejatian et al., 2019). Many authors consider organizational agility a key factor influencing growth and performance, thereby understanding all-important role of organizational agility in driving change and continuous improvement remains crucial to overcoming challenges and achieving business transformation (Appelbaum et al., 2017). However, although resistance to change seems to be a matter of the past, it is still an imperative to foster organizational agility and ensure alignment of processes and operations with change-friendly agile practices.
Recent research shows that the readiness to learn, create, innovate, and adapt, especially regarding new technologies and digital transformation, depends to a significant extent on organizational agility (Rafi et al., 2022; Puriwat & Hoonsopon, 2022; Liu et al., 2023, Nagy et al.,2019). This stems from the built-in incremental approach that harmonizes planning, developing, testing, and refining activities within consecutive iterations, thereby ensuring the acceptance of changes and the delivery of exceptional products and services to customers and other stakeholders involved (Grebic, 2019; Kurniawan et al., 2021; Puriwat & Hoonsopon, 2022). Therefore, organizational agility enhances quality and reduces risk exposure, with change responsiveness and adaptiveness remaining consistently present rather than being sporadic and ad hoc activities (Dakovic et al., 2020).
Appelbaum et al. (2017) state that "increased organizational agility increases the ability to respond proactively to unexpected environmental changes" confirming that organizational agility is gaining more importance today. Moreover, increasing technology turbulences (e.g., the rise of artificial intelligence) and sustainability concerns (e.g., climate changes) spur broader adoption and deployment of organizational agility at all levels. With this in mind, we can observe a growing emphasis on organizational agility across enterprises of all sizes, industries, geographical locations, and more.
It is equally important to highlight that organizational agility influences both the strategic and operational facets of an organization. Yildiz and Aykanat (2021) discovered that organizational agility has positive effects on company's performance and innovation, and they position agility as a strategic management tool for gaining a competitive advantage. On the other hand, Carvalho et al. (2020) combined operational excellence and organizational agility to demonstrate their aligned impact in addressing challenges and ensuring survival in these unpredictable times. In line with these perspectives, organizational agility emerges as a catalyst that empowers change at all levels of an organization, transcending hierarchical and bureaucratic boundaries.

4. LEVERAGING AGILE PROJECT MANAGEMENT TO DRIVE CHANGE AND CONTINUOUS IMPROVEMENT

Agile project management has fundamentally changed the way change is managed and is usually considered a revolutionary approach that encourages early acceptance of changes and enables project teams to derive benefits from them (Arefazar et al., 2019; Franklin, 2021). Nowadays, there are dozens of agile project management methodologies and frameworks and all of them have the same in common – welcoming changes at all stages of a project and simultaneously shifting between the ever-changing requests of stakeholders and the internal needs, constraints, and capacities of the teams employed (Gandomani et al., 2013; Grebic, 2019; Albuquerque et al., 2020). For instance, Scrum, a widely used agile framework, assumes executing projects through multiple iterations of equal duration which include predefined planning, review, and introspection sessions, as well as continuous developing, testing, and delivering activities, thus allowing changes to be observed as positive events that improve quality rather

than negative events that consume resources. Considering this, along with agile values and principles, it becomes evident that agile change management serves as both a mean and strategy for driving change and transformation in the modern business context (Arefazar et al., 2019; Grocholski, 2022).

Franklin (2021) highlights that agile project management encompasses two essential elements that uphold effective change implementation: iterations and processes. Firstly, breaking the change lifecycle into iterations enhances the likelihood of change to be carried out successfully and enables it to be seamlessly integrated within the project or even treated as an independent project. Secondly, by establishing a continuous change management practice along with processes required to cope with change in agile manner, we facilitate its delivery and provide justification for the change within an organization. Therefore, agile project management helps changes to be recognized as a necessity for maintaining business continuity, i.e., remaining competitive and meeting expectations of both internal and external stakeholders. Additionally, agile practices challenge project (or work) scope imposing frequent refinements and rapid change implementations which are crucial for handling uncertainty and avoiding uncontrolled changes (Marnada et al., 2022).

Despite the prevailing belief that agile project management is primarily suited for software development projects and IT companies, numerous authors emphasize the imperative of adopting agile approach to change for businesses striving for continuous improvement, operations enhancement, and market disruption through the delivery of innovative products and services (Ciric et al., 2018). Alawairdhi (2016) asserts that when a more comprehensive change management approach is required, agile methods should be embraced due to their proactive nature and ability to align with specific requirements, solutions, and circumstances. There is also a significant potential for implementing agile project management in the manufacturing sector as digital transformation emerges as a strategic goal for many companies operating in this field; thus, agile methodologies are increasingly becoming the new usual across industries, including construction, energy, automotive, etc., at least within the context of the digital transformation and development of the matter-related software (Edwards et al., 2018; Savkovic et al., 2022; Ågren et al., 2022). Consequently, agile approach to change is being applied on a large scale and its deployment tends to increase in the following years.

Building on the previous findings, we can draw the conclusion that agile project presents itself as a suitable approach for building sustainable, adaptable, and flexible ecosystems, regardless of an organization's field of play or its level of readiness for change. Additionally, the readiness for change significantly improves when agile project management is implemented, typically leading to an overall performance enhancement. Consequently, agile project management, with its integrated proactive change management, remains a prominent practice for delivering value accurately and with high quality delivery to both customers and the organization itself.

5. SUSTAINING CHANGE THROUGHOUT THE TRANSFORMATION PROCESS AND BEYOND

Sustaining change may arise as a challenge for many organizations undergoing the change, thereby, seizing the opportunity of the continuity in change appears to be a proper solution for today's ever-evolving business environment. Building a capacity for change is usually seen as a main factor influencing organizations' ability to recognize and harness change potential and it is inseparable from the organizational development, organizational learning, and organizational structure, with all of them being pillars of the change, transformation, and performance (Hodges & Gill, 2015). Agile project management itself promotes change awareness and may be perceived as a kind of roadmap for continuous change and incremental improvements thus creating environment for change to be accepted and implemented even when everything works smoothly. Therefore, agile project management supports transformation process and encourages further changes and transformative initiatives.

Reinventing conventional business process management to become more adaptive and adjustable is also considered a great advantage of agile project management (Badakhshan et al., 2019). Using agile project management, especially in the field of change management, assist companies and organizations in optimizing processes and boosting performance, and it usually serves as a starting point for initiating organizational changes aiming to build resilience and improve responsiveness to risks and challenges constantly emerging (Petrillo et al., 2018). Additionally, applying agile approaches, methods, and practices may result in increasing flexibility, enhancing quality, simplifying communication, reducing costs, and strengthening collaboration, that is beneficiary for sustaining change and achieving organizational

excellence (Wipfler & Vorbach, 2014; Lloyd et al., 2019). Therefore, agile project management, with its proactive and highly effective change management practices, naturally facilitates continuous change and enables transformation to be realized.

However, embracing agile project management does not imply the exclusion of traditional project management, it enables organizations to tailor their approaches to change based on specific goals, requirements, and the dynamics of their industry, market, and environment. This grants organizations a more comprehensive view and deeper insight into their needs, capabilities, and the external factors influencing them, which is essential to sustaining a continuous state of change.

6. DISCUSSION

This paper aimed to provide a step-by-step overview of how agile project management impacts business transformation through change management and continuous improvement practices. The purpose of the paper is achieved by analyzing relevant and up-to-date sources that encompass various aspects of this topic, particularly organizational agility, the application of agile project management, and sustaining change throughout transformation process.

Based on the literature review, the first step in accelerating business transformation should be to establish leadership, workforce, and organizational capabilities that support and integrate agile project management practices; these are collectively seen as an organizational agility, enabling and empowering change. Therefore, organizational agility has numerous dimensions, but the one focused on continuous improvement and the pursuit of excellence may be considered the most significant in the context of business transformation. Furthermore, agile project management, with its tools, methods, and frameworks, introduces new possibilities for managing change and creating value, representing a revolution in the modern business environment. Breaking beyond the boundaries of the IT sector, agile project management has become somewhat a generally accepted change practice that provides guidelines for both driving and managing change, positioning itself as an approach that supports organizations in fostering innovation and achieving a competitive advantage. Bearing this in mind, agile project management encourages growth and performance enhancement, making it often regarded as an indispensable facilitator of business transformation.

However, there are limitations to this approach, including to some extent unclear distinction between change and transformation, as well as difficulties in effectively maintaining continuum of change. To address these challenges, additional research that connects the elements of managing change and transformation in the agile landscape should be undertaken. This would also reduce the limitations of this research, which focuses on theoretical aspects of accelerating business transformation by employing agile project management.

Further development in this area can be achieved by examining agile transformation from the perspective of people, processes, and organization, encompassing a wider range of literature, and conducting comprehensive empirical research. Additionally, agile transformation should be viewed in the context of leadership, employee performance, organizational learning, and organizational culture, all of which are crucial for understanding specific changes in behavior and approaches to value creation brought about by agile project management. Lastly, connecting agile transformation with creativity, innovativeness, and disruptiveness can yield both theoretical and practical benefits for any organization undergoing or intending to undergo business transformation in an agile manner.

7. CONCLUSION

This paper emphasizes the significance of employing organizational agility and agile project management practices in driving change and business transformation. Organizational agility is proven to be a vital catalyst for growth and performance, providing the essential adaptability to overcome challenges and achieve transformation. Agile project management, through its iterative and change-friendly approach, ensures that changes are embraced and integrated seamlessly within projects, yielding exceptional results, and encouraging transformative initiatives. As technology and sustainability concerns continue to shape the business landscape, the importance of organizational agility and agile project management will become even more pronounced. Looking ahead, further research can explore the long-term sustainability of change initiatives under agile project management, as well as the integration of traditional and agile project management approaches to address specific organizational needs. Additionally, investigating the

impact of agile practices on different industries and their overall performance would provide valuable insights into the broader adoption and benefits of agile change management.
In summary, we can highlight two significant, slightly nuanced, states that can describe the tremendous impact of agile project management: 1. Agile project management changes the way change is managed; and 2. It's not just about being agile, it's about being agile in change.

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EMPOWERING CONTENT CREATION WITH GENERATIVE AI IN METAVERSE

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Abstract: *Metaverse platforms have garnered substantial attention as collaborative virtual environments serving diverse purposes. This paper introduces an extension to the VoRtex Metaverse Platform for Gamified Collaborative Learning, incorporating a generative artificial intelligence (AI) tool to streamline content creation within virtual worlds. Leveraging advanced AI technologies such as GPT-4, GET3D, and stable diffusion, our objective is to tackle the chicken-and-egg problem by facilitating the development of captivating virtual environments for early adopters. The integration of the generative AI tool into the VoRtex platform empowers users to effortlessly generate diverse and immersive content, eliminating the need for extensive technical expertise. The AI tool aids in the creation of virtual objects, characters, scenarios, and interactive elements, thereby enhancing the overall learning experience. This paper highlights the potential impact of AI-powered content creation on platform development and user engagement. Our research findings underscore that the integration of AI-powered content creation tools represents a significant stride toward enriching educational experiences within metaverse environments. Moreover, the implications of AI-assisted content creation in fostering collaborative learning are notable, offering insights into the potential challenges and future directions for integrating generative AI tools into metaverse platforms.*

Key words: *metaverse, Artificial Intelligence (AI), collaboration, development, platforms*

1. INTRODUCTION

The emergence of metaverse platforms has revolutionized virtual interactions and collaboration. These platforms cater to various purposes, including education. However, creating engaging content in virtual worlds is challenging and time-consuming. To address this, this paper introduces an extension to the VoRtex Metaverse Platform, incorporating a generative AI tool. By integrating the generative AI tool, users can effortlessly create diverse and immersive content. This AI-powered approach enhances the learning experience and enables the development of interactive educational content (Classe, 2023).
Firstly, the paper explores AI-powered content creation in the metaverse, including technologies like GPT-4, GET3D, and stable diffusion. The advantages and challenges of integrating AI tools into metaverse platforms are discussed. Secondly, the VoRtex Metaverse Platform is showcased, including its design principles, features, and the necessity of AI assistance in content creation. Thirdly, an explanation is provided on how the generative AI tool in VoRtex empowers users to effortlessly create diverse and immersive content. The capabilities and user benefits of the tool are discussed. In the subsequent section, a comparative analysis will be conducted, examining various metaverse platforms that have been enhanced using AI tools. Lastly, the paper discusses future directions, advancements in AI technologies, and strategies for the widespread adoption of AI-powered content creation in the metaverse.

2. METHODS

To assess the impact of AI-generated content on metaverse platforms, the researchers adopted a mixed-methods research approach. They conducted a generative literature review to explore existing literature on AI-powered content creation in the metaverse. Data collection involved interviews, surveys, and observations of platform development processes. The researchers then utilized statistical techniques to quantitatively analyze the impact of AI-generated content on platform development, focusing on metrics

such as user engagement and satisfaction. In addition, qualitative evaluations through interviews and focus groups provided in-depth insights into the experiences of developers and users. Finally, case studies of selected metaverse platforms that integrated AI-generated content were conducted to gain a better understanding of the practical outcomes of implementing AI in content creation.
To quantify the impact of AI-generated content on the development of metaverse platforms, the following formula was used:

$$\text{Impact} = (X / Y) * 100.$$

The formula measures the improvement achieved by incorporating AI-generated content (X) compared to the baseline or platforms without AI-generated content (Y). It calculates the percentage improvement, indicating the impact of AI-generated content on platform development. A higher value signifies a greater impact of AI-generated content.

3. AI-POWERED CONTENT CREATION IN THE METAVERSE

In recent years, the integration of artificial intelligence (AI) technologies into various domains has significantly transformed the way digital content is created and interacted with. Within the context of metaverse environments, the utilization of AI-powered content creation has emerged as a promising solution to the challenge of developing engaging and immersive virtual worlds. This section explores the concept of AI-powered content creation within metaverse environments, including an examination of the underlying technologies and a discussion of the advantages and challenges associated with the integration of AI tools. The foundation of AI-powered content creation in the metaverse lies in advanced AI technologies that enable the generation of virtual content. Key generative AI technologies for the metaverse include GPT-4, which generates accurate and ethical text by understanding language and adapting to specific tasks. GET3D utilizes machine learning to create realistic and diverse 3D environments through procedural generation, image synthesis, and reinforcement learning. Stable diffusion algorithms play a crucial role in ensuring stable animations and interactions, enhancing the overall user experience (Baidoo-Anu, 2023). Integrating these AI tools democratizes content creation, enhances creativity, and enables the efficient development of expansive virtual worlds.

4. THE VORTEX METAVERSE PLATFORM FOR GAMIFIED COLLABORATIVE LEARNING

In this section, an overview of the VoRtex metaverse platform for gamified collaborative learning is provided. The concept of a virtual world is discussed, emphasizing the need for content creators, including 3D designers, NPCs (Non-Player Characters), voice actors, and other building blocks within the VoRtex platform (De Felice, 2023). The platform's significance in the field of educational technology (EdTech) and collaboration within the metaverse is highlighted (Rangel-de Lázaro, 2023).
Virtual worlds are digital environments that simulate reality and provide users with interactive and immersive experiences (Figure 1.). These environments can be accessed through various platforms, allowing users to explore, interact, and engage with the virtual environment and other users within it. Virtual worlds provide a unique opportunity to transcend physical limitations, enabling individuals to connect, learn, and collaborate in ways that were previously unimaginable. The VoRtex Metaverse Platform aims to harness the power of virtual worlds for gamified collaborative learning. By integrating education and gaming elements, the platform creates an engaging and interactive environment that promotes active learning and knowledge acquisition. Users can participate in educational activities, solve challenges, collaborate with others, and experience the benefits of social learning within the metaverse (Jovanović, 2022).

Figure 1: Virtual world (Jovanović, 2022)

The VoRtex platform represents a significant advancement in the field of educational technology (EdTech). It offers a unique and immersive learning environment that blends educational content with gamification elements (Hwang, 2023). By providing interactive challenges, collaborative activities, and real-time feedback, the platform promotes active learning, critical thinking, and problem-solving skills. Furthermore, the VoRtex platform facilitates collaboration among users within the metaverse. It enables students, educators, and professionals from different locations to interact, share knowledge, and work together on projects or tasks (Jovanović, 2023). The platform's collaborative features foster teamwork, communication, and the exchange of ideas, enhancing the social learning experience and preparing individuals for collaborative work environments (Figure 2.).

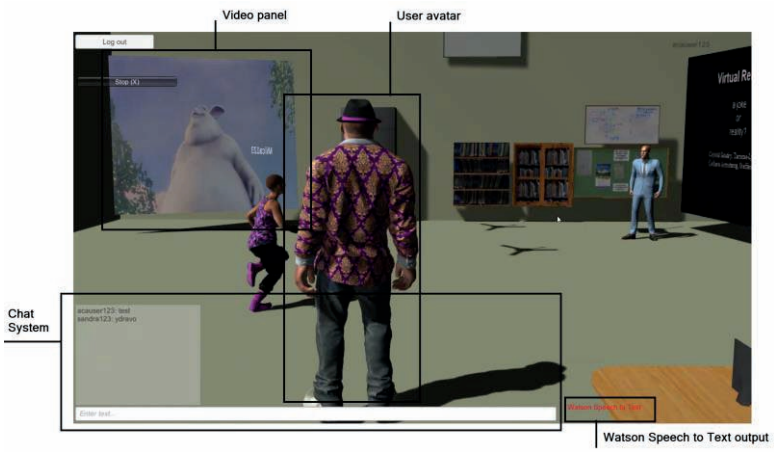

Figure 2: VoRtex user interface (Jovanović, 2022)

The VoRtex platform relies on diverse content creators for a vibrant metaverse. 3D designers create visually captivating virtual environments. NPCs interact with users, adding gamification and interactivity. Voice actors bring characters and narratives to life, enhancing immersion. These content creators contribute to engaging and dynamic collaborative learning experiences within the VoRtex platform.

5. EMPOWERING USERS WITH AI-GENERATED CONTENT

AI-driven content creation refers to the utilization of artificial intelligence technologies to automate or enhance the process of generating virtual world content. By leveraging advanced AI algorithms and models, content creation tasks such as designing objects, characters, and interactive elements can be streamlined, reducing the need for extensive manual work and technical expertise.

InWorld AI combines AI with immersive virtual worlds, offering interactive experiences and dynamic NPC interactions (InWorld, 2023). It enables AI-driven NPCs to respond to voice inputs, enhancing realism and engagement. In games like Code Alkonost and InWorld Origins, InWorld AI has successfully created intelligent virtual characters that understand and respond to player voice commands. In the VoRtex Metaverse Platform, AI-generated content, such as teacher NPCs, can provide personalized guidance and

adapt to individual learner needs. This integration enhances engagement and knowledge acquisition. In the game InWorld Origins, NPCs' emotions can be manipulated based on player voice input, adding interactivity and immersion. Voice and emotion recognition technologies analyze player voice characteristics, allowing NPCs to dynamically adjust their emotional responses. This feature enhances gameplay immersion and creates unique experiences. Overall, InWorld AI enriches educational and gaming experiences in the metaverse (TechGameWorld, 2022). AI can be used in the VoRtex platform to create AI-generated avatars as virtual teachers, enhancing the learning experience. These avatars utilize advanced AI technologies like natural language processing and machine learning to analyze user queries and provide personalized responses. They adapt their teaching style and content delivery based on individual learner preferences. The integration of AI-generated avatars as teacher NPCs promotes learner engagement and personalized learning. Students receive immediate feedback, individualized instruction, and the ability to learn at their own pace. The VoRtex platform empowers users with educational resources and interactive learning experiences that enhance knowledge acquisition and collaboration (Zahedi, 2023). The integration of AI technologies in content creation enables a personalized and adaptive learning environment within the metaverse (Hwang, 2022). When developing an AI model for NPC teachers within platforms like VoRtex, it is important to consider several factors related to relevant content (Jovanović, 2022). These considerations include incorporating a diverse range of educational materials such as textbooks and research papers to provide a solid knowledge foundation for the model. Additionally, exposing the model to curated dialogues between teachers and students facilitates meaningful interactions and improves contextual understanding (Baidoo-Anu, 2023). Subject-specific information is also crucial, as providing datasets relevant to specific subjects helps the model gain deeper insights and deliver more accurate responses (Rangel-de Lázaro, 2023). Including case studies and problem-solving exercises enhances the model's ability to handle specific use cases and real-life scenarios. Furthermore, continuous feedback collection and iterative training processes contribute to refining the model and enhancing its responses (Chen, 2023). Finally, ethical and inclusive practices should be considered to ensure that the content provided aligns with principles of fairness, diversity, and sensitivity (Rangel-de Lázaro, 2023). By incorporating these content considerations, the AI model can effectively create NPC teachers in the VoRtex platform, offering engaging and informed educational experiences in the metaverse (Wang, 2023).

6. RESULTS

The option for generating content using AI could solve the chicken-and-egg problem faced by metaverse platforms (Wei, 2023). This problem refers to the challenge of attracting users to a platform that lacks sufficient content, while simultaneously struggling to attract content creators to generate content for the platform. By incorporating AI-powered content generation tools, metaverse platforms potentially can provide a diverse range of immersive content right from the outset (González Vallejo, 2023). This content can include virtual environments, objects, characters, and interactive elements. As more users join the platform, the demand for content increases (Lee, 2023). AI-generated content creation tools can address this demand by enabling users, who may not have specialized skills in content creation, to generate high-quality content effortlessly. This reduces the barrier to entry for content creation and encourages user participation in generating content. By facilitating the creation of content through AI tools. The availability of content attracts users, and as more users join, the platform becomes more attractive to content creators. This cycle of content creation and user engagement helps overcome the chicken-and-egg problem by kickstarting the growth and development of the platform (Jovanović, 2019).

In Table 1, the results of the case study are presented, quantifying the impact of AI-generated content on the development of three metaverse platforms: Decentraland (Decentraland, 2023), Roblox (Roblox, 2023), and VoRtex. The baseline metric (Y) represents the performance or user experience without AI-generated content, while the AI-Generated Metric (X) represents the improvement achieved by incorporating AI-generated content. The Impact (%) column calculates the percentage improvement achieved by integrating AI-generated content into each platform. Decentraland is a decentralized virtual world platform where users can create, explore, and trade virtual assets using blockchain technology. Roblox is a user-generated content platform that allows users to create and play games across various genres.

Table 1: Analysis of Generative AI in Metaverse

Metaverse Platform	Baseline Metric (Y)	AI-Generated Metric (X)	Impact (%)
Decentraland	80	95	18.75
Roblox	70	90	28.57
VoRtex	65	85	30.77

According to analysis, the integration of AI-generated content had a significant impact on the development of metaverse platforms. In Table 1, it can be seen that Decentraland experienced an improvement of 18.75%, while Roblox saw a greater impact with a 28.57% improvement. However, VoRtex demonstrated the highest impact with a substantial improvement of 30.77% (Jovanović, 2019 and 2022). These results suggest that incorporating AI-generated content positively contributes to enhancing user experiences and platform performance within the metaverse. It should be noted that the specific metrics used in the analysis may vary depending on the platforms and the objectives of the study. Nonetheless, the table provides a comparative view of the impact achieved by AI-generated content across the selected metaverse platforms, highlighting the potential benefits of leveraging AI in content creation for platform development. The findings presented in these results extend beyond the realms of external sources, delving into the empirical experiences of the authors as active users of the VoRtex Metaverse Platform. In the context of this study, the authors assumed multifaceted roles as platform users, effectively bridging the roles of content creators and consumers within this innovative virtual environment. This immersive engagement provided the authors with a distinctive vantage point, enabling them to assess the concrete implications stemming from the integration of generative AI tools and thereby offering invaluable insights into how such integration profoundly enhances the overall user experience. The authors' firsthand experiences within the platform have unveiled a transformative narrative, wherein users, regardless of their prior technical proficiencies, now possess the capacity to harness AI-driven capabilities. The collaborative synergy between users and AI-driven tools, as elucidated through the authors' experiences, lays the foundation for a metaverse ecosystem characterized by inclusivity and enriched creative expression.

7. CONCLUSIONS

The authors of this paper have ventured into the emerging domain of AI-powered content creation within the metaverse ecosystem. While the VoRtex Metaverse Platform has been utilized as a demonstrative case study, the crux of their work revolves around the synthesis and interpretation of existing research and insights. They acknowledge the imperative need for a more explicit delineation of their distinctive contributions in the context of this scholarly endeavor. The authors' comprehensive inquiry has encompassed a wide array of AI technologies, including prominent entities such as GPT-4, GET3D, and stable diffusion. Through this, they have elucidated the potential of these technologies to effectively address critical challenges faced by burgeoning startups while concurrently elevating user engagement within metaverse environments. Importantly, it must be underscored that this paper serves as an integrative conduit, harmonizing and meaningfully interpreting diverse findings gleaned from heterogeneous sources. The primary objective of this synthesis has been to underscore the transformative capacity inherent to AI-generated content within the metaverse landscape. The authors' evaluative endeavors spanned the spectrum of AI integration within platforms like Decentraland, Roblox, and VoRtex, culminating in the quantification of tangible enhancements in user experiences and platform performance.

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