XVII International Scientific Conference on Industrial Systems (IS'17)
Novi Sad, Serbia, October 4. – 6. 2017.
University of Novi Sad, Faculty of Technical Sciences,
Department for Industrial Engineering and Management
Available online at http://www.iim.ftn.uns.ac.rs/is17

Reinventing work study for lean manufacturing

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Abstract

Work Study, with its focus on method study and time measurement, has been integral part of Industrial Engineering since its inception. Both Work Study and Industrial Engineering were widely used during mass production era, helping companies like Ford to become more efficient, where specific role of industrial engineers has been recognized, along with manufacturing and product engineers. Work Study and Industrial Engineering also played significant role during the development of what we now know as kaizen and lean manufacturing. Training within industry, with its Job Method course, was embraced by early lean pioneers, and together with Shingo's P-Course influenced significantly the development of what would later become new manufacturing paradigm. On the other hand, lean changed the environment itself, requiring Work Study to change and develop in order to answer the requirements of the new manufacturing setting of working smarter, not harder. New roles for industrial engineers are imposed, with focus shifting from initiating changes to coaching and inspiring others to recommend changes. This paper seeks to examine this new role Work Study has in lean environment, and how this new role can be used to improve the efficiency of Serbian economy. The conclusions presented in this paper are drawn from literature review and authors' personal experience with the application of Work Study and Lean in companies operating in Serbia.

Key words: *efficiency, industrial engineering, lean manufacturing, work study*

1. INTRODUCTION

Work study is a discipline that aims at examining the way an activity is being carried out, simplifying or modifying the method of operation to reduce unnecessary or excess work, and setting up a time standard for performing that activity [1]. Work study has been at the forefront on industrial development since its inception. Early success of mass production owes a lot to pioneering work of Frederick Taylor and Frank and Lillian Gilbreth. In the beginning, Work Study dealt with the analysis of the existing work. Later, additional methods were devised that enabled the design of new work, which is why Work Study is sometimes called "methods engineering". Post World War II (WWII) industry saw the advent of Toyota Production System (TPS), and new manufacturing paradigm that would later become known as lean manufacturing. Although lean manufacturing can be considered an antithesis to mass production, it is often overlooked that TPS and lean development owe a lot to methods used in mass production. Situation with Work Study is no different. In fact, many of the methods, tools and techniques used in lean manufacturing can be traced back to pioneering work of Taylor and Gilbreths [2]. Obviously, Work Study has changed along with the changes in the manufacturing environment imposed by the development of lean manufacturing. This paper seeks to examine new role Work Study has in changed manufacturing environment, and what lies ahead of Work Study implementation in the future. In addition, the paper tries to describe how this new role a Work Study has can be used to improve the efficiency of Serbian economy.

2. WORK STUDY IN MASS PRODUCTION

Work Study has its main focus on time measurement and method study. Time measurement (also known as time study) is the a part of Work Study largely developed by Frederick Taylor, who sought to improve industrial efficiency, and was at the forefront of what is known as Efficiency Movement, especially during the Progressive Era between 1890s and 1920s. Most of his work is summed up in his book "The Principles of Scientific Management". Taylor was pioneer of applying engineering principles to the work done on the factory floor. He was the first man in recorded history who thought that work needs to be systematically observed and studied [3]. Taylor's time study, in addition to time

measurement and rate assessment, included the following: (i) division of work into smaller elements, their analysis and elimination of unneeded ones; (ii) analysis and improvement of equipment used during work; (iii) the design of best way to perform each element of work, based on measuring the performance of several workers; (iv) calculation of time allowances; (v) work elements systematization, so they can be combined and used for future work; and (vi) creating the foundation for improving the work of designers and for standardization. Taylor did also use motion study as a part of his technique, but gave more attention to materials, tools and equipment when improving work method [4].

Foundations for method study were set by Frank and Lillian Gilbreth. Gilbreths analyzed work methods in order to define "the one best way to do the work". In order to determine one best way, they have developed numerous instruments, such as process chart, 18 elemental motions used to study motion economy (therbligs), the use of cyclograph and chrono-cyclograph, etc. Although they relied to some extent to Taylor's scientific management approach, they were also helped formulate a constructive critique of Taylorism, stating the disregard of human factors as its main flaw.

Work Study (i.e. time measurement and method study) constituted much of the pre WWII Industrial Engineering (IE). Although it had relatively narrow focus (post WWII integration with operations research and systems engineering created IE as we know it today). IEs significance was recognized by Henry Ford though specialization of engineers. In addition to production engineers and product engineers, Ford introduced industrial engineers, whose main task was to, through application of Work Study, simplify and standardize work so it can be performed by unqualified workers. Their mission was to design tasks, parts and tools in a simplified way so they can be operated even by an unskilled worker [5]. This has been done in order to facilitate product standardization, which is considered to be one of Ford's main contributions to modern manufacturing.

Ford's extended use of Work Study and IE led to significant gains, such as shorter lead time, lower costs, increase in production volume etc. [5] However, Work Study as used in mass production had its drawbacks. It relied heavily on division of labor between managers and workers, as proposed by Taylor. This means that managers use scientific approach to plan design and plan the work, while workers perform the work as designed by managers. Work Study offered hierarchical driven fixed solutions designed by upper echelon staff [6]. The work was designed by industrial engineer with no direct experience of the work, and imposed to workers [7]. This led to alienation and confrontation among workers and managers. Tayloristic approach to Work Study deskilled a worker, making him unfit to face unpredictable situations.

3. WORK STUDY AT THE FOREFRONT OF THE NEW MANUFACTURING PARADIGM – TPS

TPS came out of necessity, because, for various reasons (such as lack of funding and limited and divergent demand) it was not possible to organize production based on principles of mass production. However, although considered an antithesis to Ford's production system, TPS owes much to tools and techniques used in mass production, particularly to Work Study and early IE.

This influence, according to Towill [2], stems from three sources: first is Frank Gilbreth and his lecturing to shipyard engineers immediately after WWI (one of his students will later become the director of Japanese Management Association – JMA whose significance will be described a little later); second is Lillian Gilbreth, with her travels to Japan and lectures (Robinson & Robinson [8] claim that Lillian Gilbreth is only two handshakes away from Toyota innovators); and the third is Taylor's scientific management approach and time study, where throughput increase advocated by Toyota comes from (at least to some extent) from time saved.

Toyota struggled significantly during the first years of car manufacturing. Although they had the willingness to improve, they lacked systematic approach to training people in order to prepare them to actively participate in improvements. In order to overcome this obstacle, Toyota opted for Training Within Industry (TWI), a program that has been successfully implemented in USA during WWII. TWI consisted of three programs: Job instruction (JI) taught participants how to train people properly in an effective methodical manner; Job methods (JM) taught participants how to make small improvements in their daily work; Job relations (JR) taught participants how to handle employee-related work problems using a four-step model. TWI is significant because it represents first structured program introduced to its manufacturing leaders (particularly supervisors) for the purpose of developing skill and making small improvements in daily work routines [9]. TWI JM course was particularly important. It follows simple four step methodology for making improvements (not too different from Gilbreth's four step approach), and it stresses the fact that the skill of improving work method can be learned. TWI JM's concepts such as developing improvement skills, breaking down job for purpose of study, elimination of unnecessary details, the use of 5W1H had great influence of later development on Kaizen courses.

TWI only lasted for a few years in Toyota. The reasons for discontinuation might be various, but one of the was certainly the lack of rigid knowledge needed to conduct improvements. In 1955 JMA developed Production Technology Course, also known as P-Course. P-Course was largely based on Frank Gilbreth's original lecture notes [2]. P-Course covered four topics: Time Study, Motion Study, Operation Analysis, and Process Analysis. Toyota sent an invitation to JMA to conduct P-course internally. The instructor was Shigeo Shingo,

now known as one of the innovators of TPS. Apart from introducing IE to Toyota, and describing TPS in great detail from IE point of view, Shingo is also considered to be the innovator of Single-Minute Exchange of Die (SMED), a method heavily based of Work Study aimed at rapid and efficient changeover. Content wise, P-Course was mainly based on developing industrial engineering skills needed to facilitate improvements. It was more successful than TWI JM program, and it lasted from mid 1950s till mid 1980s. In parallel with P-Course, Toyota developed Kaizen course. It was the extension of both TWI JM and P-Course, by borrowing from each of the preceding courses, while adding unique Toyota approach. As far as content of Kaizen course goes, it consisted of many topics covered previously by TWI JM and P-course, such as Motion Study, Process Study, Current Method Analysis, New Method Development, with the addition of topics such as leader development and team work. Kaizen course was used up until 1981, when it was replaced by combination of Kaizen course and standard operation course. Timeline of various Work Study based courses and in Toyota is presented in Figure 1.

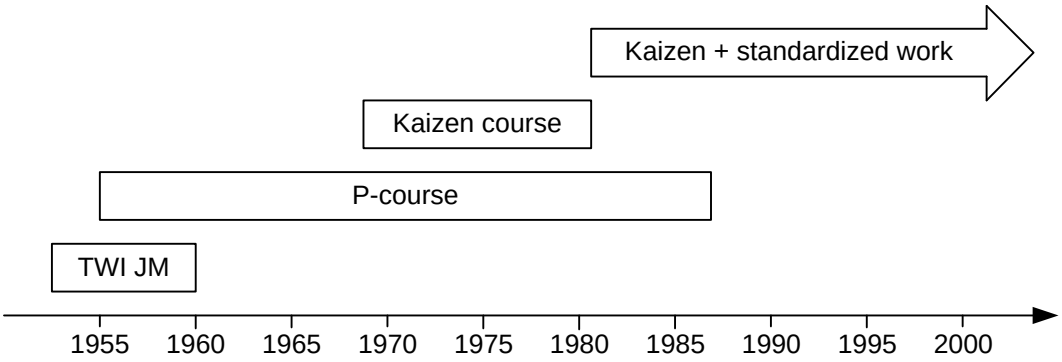

Figure 1. Timeline of Work Study related courses in Toyota (adapted from [9] & [10])

Standardized work played significant role in the development of TPS. Spear & Bowen [11] state that activities in Toyota are as rigidly scripted as in mass production. The difference is that they are at the same time flexible and adaptable by constantly being pushed and challenged to higher levels of performance. Adler [7] states that it is a common misconception to consider time and motion regimentation as something that constraints continuous improvement. In Toyota, standardized operation is not used to document work, but rather, although still being crafted IE technique, engages workers in making improvements in their work [12].

Work Study and IE background are often out of sight. Towill [2] states that one of the reason might be that shorter title of one of the most cited TPS related references is often used, namely “A Study of the Toyota Production System”, rather than its full version of “A Study of the Toyota Production System from Industrial Engineering Viewpoint” [10]. Other reason is identified by Shingo himself, where he states that most of the books about TPS were written by journalists or economists, and not by engineers, which is why the input of IE to TPS development is often downplayed. This is one of the reasons why he wrote his seminal book.

4. WORK STUDY FOR LEAN MANUFACTURING

Lean manufacturing (or often simply “lean”) is a systematic approach to waste (jap. *Muda*) elimination in order to increase productivity and create value for the customer [13]. In addition to waste, lean aims at eliminating other two sources of inefficiency, namely inconsistencies (jap. *Mura*) and overburden and irrationalities (jap. *Muri*) (the 3 MUs, or “the big three”). Term “lean manufacturing” has benn used for the first time by Krafcik [14] to distinguish between mass production (which he calls buffered manufacturing) and post-Ford production (i.e. lean manufacturing). In order to analyze the role of Work Study in lean manufacturing, it is beneficiary to see how contemporary IE is defined. Ishiwata [15] states that, simply put, IE can be defined as a group of techniques that can be used to eliminate waste, inconsistencies, and irrationalities from workplace in order to provide high-quality goods and services easily, quickly, and inexpensively. Waste elimination is not a new thing. In fact, Lillian Gilbreth published a book “The Psychology of Management: The Function of the Mind in Determining, Teaching, and Installing Methods of Least Waste” in 1914. Ishiwata [15] further states that IE techniques can be divided into method improvement techniques (motion study, process analysis, and conveyance and equipment layout, among others) and work measurement techniques (time study), same techniques that constitute Work Study. Both “Time” and “Motion” are specifically highlighted by Gilbreth through his “processing” and “transportation” waste elimination [2]. When IE definition is compared to lean definition, it can be seen that both lean manufacturing and IE strive for the same thing. Of course, lean manufacturing is more than just IE, but this definition stresses the central role IE and Work Study have in lean manufacturing.

Having in mind this central role, one might ask what is the difference between Work Study in mass production, and Work Study in lean manufacturing? The difference comes from who are the people who apply these

techniques, and the way they are applied. While in mass production Work Study and IE techniques were reserved solely for industrial engineers or upper echelon staff, now all levels of both factory and office workers study these techniques as a part of their improvement activities [15]. Work standards are not enforced, but rather developed by workers themselves. This doesn't mean that scientific management approach and Work Study are discarded, but rather that they have been transferred to workers [14]. In addition, perspective has changed, and it now encompasses product, information, capacity, and cash flows across work projects, entire business processes or supply chains [2].

In order to stress new roles Work Study has in lean manufacturing, it is necessary to compare Work Study in mass production to the one in lean manufacturing. Table 1 shows this comparison.

Table 1. Comparison of Work Study in mass production and lean manufacturing

Components	Mass production	Lean manufacturing
Focus	Narrowly specialized work place, with worker trained to perform small set of simple operations; Work study analyzes objects and processes in a work place that is a part of a wider manufacturing process; Time used as a measure of fitness and for production planning and control;	Workplace, work cell, entire manufacturing process, supply chain, etc., analyzed in its entirety; Multi-skilled and flexible workers; Focus on obtaining improvements quickly; Time used mainly as a measure for savings obtained through method improvement;
Approach	Mutually conditioned phases, with often reversion to previous steps for check; Approval of each phase; Thorough analysis and coordination between different phases that require a lot of time;	Simple approach which is easy to learn and apply; Less time spent on thorough analysis and coordination; The aim is to come to a solution that is better than the existing one, that will be further advanced through continuous improvement; Improvement projects are carried out autonomously by team members; Improvement projects action oriented, often lasting only a few days;
Organization	Managers make decisions, approve phases, and are responsible for implementation; Experts help managers with solving problems; Workers execute managers' decisions; Consultants are responsible for training experts and have counselling roles;	Managers create preconditions for work team to work on improvements; Experts serve as internal consultants; Workers are equal members of improvement teams who design, apply, and standardize improvement solutions, with the application of Work Study and Kaizen approach;
Instruments	Large number of instruments makes difficult to master them, choose between them and use them when and where appropriate; Both simple and more complex Work Study instruments at disposal;	Both Work Study and Kaizen instruments are used; Instruments divided into smaller groups in accordance to specific problems, which facilitates selection and implementation; Simple and more complex Work Study and Kaizen instruments at disposal;

Lean manufacturing has made Toyota leading car manufacturer in the world. Large part of this success comes from the fact that lean manufacturing is based on tried and tested efficiency improvement techniques, namely Work Study and Kaizen, but also adjusted to changed conditions on the market and supplemented with new set of knowledge. While keeping many of the tested Work Study techniques, lean manufacturing shows that relations based on enforcement and unwilling acceptance of enforced standards leads to dissatisfaction for both managers and workers, and that these relations can be replaced with relations of mutual respect and partnership while working on mutual goals. Teams, consisting of workers are bearers of all improvement activities, from the design, over implementation, to standardization of the solution, which eliminates the need for strict control and coordination.. What is evident is that Work Study in lean manufacturing has simpler approach (not unstructured, though), where the goal is shifted from coming up with the optimal solution to coming up with a good solution that will be bettered through continuous improvement. Work Study method in lean manufacturing is simplified, so workers can easily master it and apply it very quickly. Method study is at the forefront in lean manufacturing, while time is used for measuring the fitness of the method, so it can be said that both method study and time measurement are both used in lean manufacturing. Workers analyze the existing method and design new one, while industrial engineers serve as internal consultants and help and inspire workers to create changes.

5. WORK STUDY AND LEAN MANUFACTURING: OPPORTUNITY FOR SERBIAN ECONOMY

During the 1970s there were many IE and Work Study application projects in companies in Yugoslavia, with extensive participation of foreign and domestic consultants. In 1980s, foreign consultants left the country, while domestic consultants were engaged to a far lesser extents than in previous decade, and it was up to experts from companies themselves to continue with Work Study projects. However, that didn't happen. Results of research conducted between 1980 and 1985 show that Work Study was rarely used in domestic

economy [16]. Figure 2, created according to some of the results from the research, shows that method study has only been used in manufacturing, and only in 29% of the companies that participated in the research. Time study has been used in all of the companies that participated in the research. Figure 3 shows level of Work Study application, as perceived by the companies, on a scale of 1 to 5. The results show that average score for manufacturing is 3.14, while average score for administration is 1.

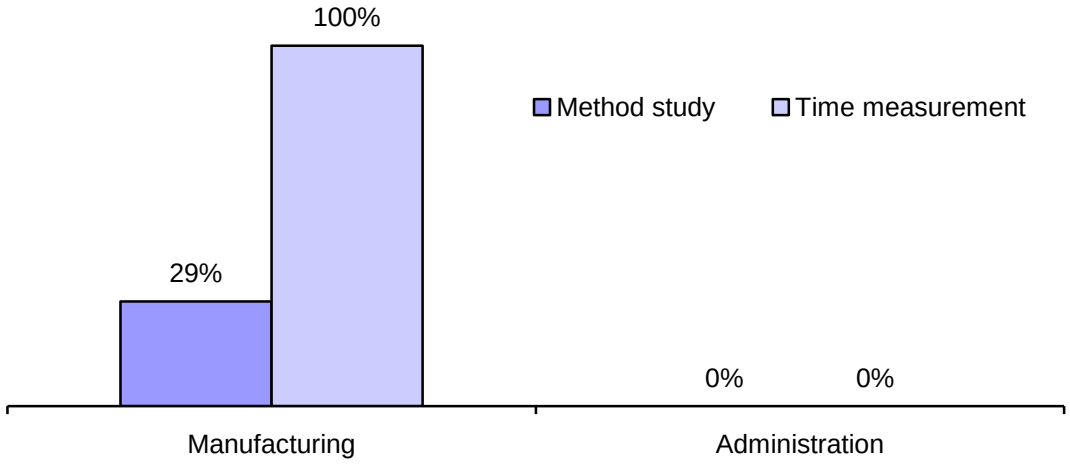

Figure 2. Frequency of Work Study application in companies in Serbia from 1980 till 1985

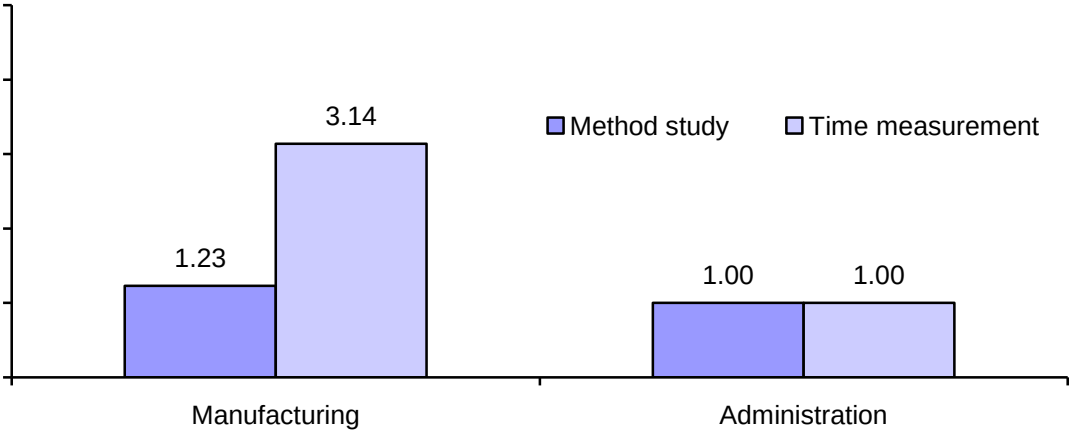

Figure 3. Average score of Work Study application in companies in Serbia from 1980 till 1985

In following decades, Work Study lost the priority it once had, an although there were no additional studies after the one conducted in the first half of the 1980s, subjective feel, based on authors' experience from the field, is that situation in Serbian economy regarding Work Study application is much worse.

Serbian economy is in position that resembles Toyota after WWII. Ohno said that this position (he called it "desperate position", but we will restrain from calling Serbian economy desperate) can be used as an advantage [17]. This means that companies should rely on their own knowledge and resources, and use simplified and action oriented approach to Work Study (as advocated by lean manufacturing) in order to make this position better. There are two problems that might hinder these efforts: (i) Managers, experts and workers are not motivated to make things better; and (ii) Managers, experts and workers lack information regarding possibilities for solving efficiency problems in production. Universities in Serbia have sufficient body of knowledge in the field of production rationalization, but this body of knowledge is not used enough in Serbian economy. Serbian economy could significantly benefit from cooperation with universities, where academians could serve as external consultants and transfer the knowledge to companies, and help them to establish system for continuous improvement. Since results are best motivators, it is recommended that improvement efforts start with a small scale improvement project that will yield some improvement in a few days, and that would not require investments but rather better utilization of the existing resources.

Based on our experience, most of the time standards in Serbian companies are obsolete and inaccurate, or many times nonexistent. This makes production planning and control difficult. In order to overcome this, we suggest that data needed for production planning and control should be obtained through analysis of manufacturing data from previous period. This doesn't mean that time study is not necessary, just that it will not be used to control workers but rather for measuring the fitness of work method. Through continuous

improvement, the efficiency of production increases, which means that norms could be gradually tightened.

Greatest obstacles to lean manufacturing based Work Study in Serbian economy nigh could be found in Organization component. As seen in Table 1, managers should create preconditions for work teams to work on improvements, but lack of knowledge might prevent them in doing so. Experts should serve as internal consultants and change agents. However, the problem is that majority of companies in Serbia don't have experts in the field of IE or work method improvement, so one of key tasks would be to train these experts. In addition, many universities in Serbia have programs for training experts in the field of IE, but it is necessary to make them more visible on the labor market, and to explain their role to the companies so they can understand the necessity of these experts. Workers are mostly unwilling to actively participate in improvements, although they are the ones who know the work best. They are not motivated and are often burdened with the heritage of the past where upper echelon staff were responsible to design work, while workers were responsible for the execution of the work. The key here, much like with managers, is motivation and education. Workers might not be willing to learn new things, and gain sharing system (a system where financial results of the improvement are shared between the company and the workers) might be used as a motivator for employees to accept new knowledge. When workers see that active participation in improvements will bring both improvements in work method and financial benefit, they will be more open to embrace new knowledge.

The new width Work Study and IE have in lean manufacturing should also be put to good use. Processes in Serbian companies are often fragmented, without the sense of mutual goal. This is why benefits of the Work Study should be extended to information flows and cash flows, and across entire business processes and supply chains.

6. CONCLUSION

This paper traced the evolution of Work Study, examined the role it had in mass production and lean manufacturing, and analyzed how lean manufacturing influenced further development of Work Study in order to adapt it to requirements of new manufacturing paradigm. Work Study has been used as primary efficiency improvement approach during the mass production era, and mass production owes much of its success to Work Study and IE. After the WWII, Work Study and IE knowledge, developed during mass production era, has been, through TWI JM and P-Courses, successfully transferred to Japan in order to help their economy to overcome inefficiency problems. Together with kaizen approach, Work Study has been used in changed conditions, where it was not possible to organize production based on principles of mass production. In addition to new knowledge, these changed conditions required changes in how Work Study is practiced, for the purpose of lean manufacturing. The main change is that Work Study is not performed by IE experts anymore, but by workers. Furthermore, the application process is simplified, which means that new knowledge is easier to accept and implement. This also changed the role IE experts have, from initiating changes to guiding changes and creating prerequisites (mainly in terms of knowledge) for changes to happen.

Serbian economy is in need for improvement. However, much of the knowledge it had has been lost in previous decades. Simplified approach to Work Study advocated by lean can be used to regain this knowledge, and action approach characteristic to lean can be used to obtain improvements in relatively short amount of time and with low costs. This will require for Serbian companies to embrace new set of knowledge. This knowledge exists in universities in Serbia, but it is of outmost importance to strengthen enterprise-academia connection in order to assure that right knowledge is transferred in the most efficient way.

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