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

Flood Risk Damage Assessment

Tanja Novaković
(Teaching Assistant, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia, tanjanovakovic@uns.ac.rs)
Jovana Bondžić
(Teaching Assistant, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia, jovanasimic@uns.ac.rs)
Đorđe Ćosić
(Associate Professor, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia, djordjecosic@uns.ac.rs)
Srđan Popov
(Associate Professor, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia, srdjanpopov@uns.ac.rs)
Miroslav Miškić
(Assistant Professor, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia, miroslav.miskic@uns.ac.rs)

Abstract

This paper elaborates the method for determination of direct material damage expected in the case of flooding. Presented method is based on the flood depth and damage factor estimation and monetary value (monetary equivalent) of the affected residential object determination. Proposed method was verified with example of the residential buildings located in the riverbed of the Danube in Novi Sad. Depth of flooding and age of residential buildings are variables that are tested during the method verification. Depth of potential flooding was determined by use of geoinformation technologies.

Key words: *Flood risk, Flood depth determination, Flood damage assessment, Insurance*

1. INTRODUCTION

Intense climate changes across the globe, in recent decades seriously affected sustainable development and community resilience which led to limited socio-economic development and increased poverty. Also, rising trend of natural disasters' consequences is evident both in developing and developed countries. The data provided by Munich Re Insurance company shows that the losses resulting from natural disasters are tripled between 1980 and 2016 [1]. In addition, the floods stand out as the most frequent natural disasters, which threatens a large part of the world's population. Over the last twenty years, flooding accounted 47% of all weather-related disasters, affecting 2.3 billion people [2].

The Republic of Serbia was affected by severe flood during the spring of the year 2014. According to the assessment results, the total damage from flooding in 24 municipalities in Serbia, was 1525 million euros. 57 % of total damage (885 million euros) represents the value of the destroyed material property, while 43% (640 million euros) refers to production losses [3]. Taking into account the remaining municipalities affected by the flood (total number of 38 municipalities), damage from flood reached 1.7 billion euros or more than 4% of GDP [3].

The consequences of floods in the Republic of Serbia in 2014 indicated increased socio-economic vulnerability of the population and the necessity of vulnerability reduction. An important mechanism for reducing the socio-economic vulnerability of communities to the impacts of natural disasters are financial instruments, among which the insurance stands out.

Insurance, as a financial instrument, ensures the financial security to the affected individuals and companies. By taking the risk within the insurance portfolio, the insurance company takes the responsibility for damages that might arise from the risk realization. However, it is necessary to keep in mind that insurance companies are not a social institutions. Insurance companies react on natural disasters (i.e. the increased exposure to risk of flooding in this reasrch) acording to principles of the market, which includes, among other things, designing the appropriate rates of insurance premium (risk price) which is proportional to the level of taken risk. In order to estimate risk adequately, determination of the expected damage is required. In that sense, the main goal of this paper is to point out:

- which parameters influence the damage rate in the case of the flood risk realization and
- the possibilities and importance of geo-informational technology utilization in the process of probable maximum loss (PML) estimation.

2. METHOD FOR THE EXPECTED DAMAGE ESTIMATION

In general, evaluation of the damage due to flooding is necessary to determine actions which can be taken to reduce the loss of flooding. In the (re-)insurance sector evaluation of the expected loss is necessary to calculate insurance premiums. To ensure business solvency, insurers have to estimate possible damage and the probable maximum loss (PML) for a risk.

Flood damage can be categorized as direct and indirect damage. Direct damages are those which occur due to the physical contact of flood water with humans, property or any other objects [4]. Indirect damages are induced by the direct impacts and occur – in space or time – outside the flood event [4]. Both types of damages are further classified into tangible and intangible damages, depending on whether or not they can be assessed in monetary values [5] [6]. Tangible damage is damage to man-made capital or resource flows which can be easily specified in monetary terms, whereas intangible damage is damage to assets which are not traded in a market and are difficult to transfer to monetary values [4]. The focus of this paper is on direct, tangible damage of residential buildings.

The basis for determination of damage from flooding to residential buildings includes the loss of structure's value due to the flood event. Damage to structure is strongly related to the depth of the flooding. Also, there are many other important parameters (flow velocity, duration, etc.), but depth describes the majority of the variance of damage when the structures are stratified by construction and use. There is a strong relationship between deeper depth and greater damage of a structure.

Presented paper is focused on the flood depth and age of residential buildings impact on direct, tangible damage. The damage dataset refers only to the structure of the flood-affected residential and no building content is included.

The general procedure for the estimation of direct, tangible physical damage involves: determination of flood characteristics; determination of maximum possible damage value; economic estimation of direct damage, mostly by applying depth-damage functions.

2.1 **Depth-damage function**

Damage functions represent a fundamental concept in the assessment of flood damage. They are internationally accepted as the standard approach to assessing urban flood damage [7]. These functions quantify, through mathematical equations, how the damage rate varies with the variation of flood parameter. Damage functions which include the water depth as the main determinant of direct damage are called depth-damage functions. Depth-damage functions are a particular type of stage-damage functions that are used to compute the probable damage from a given level of flooding.

In developing depth-damage functions, according to the kind of information which is used, two main types of such functions can be distinguished: empirical functions which use damage data collected after flood events and synthetic functions which use damage data collected via "what-if" questions and are based on hypothetical analyses and expert judgments.

In the presented research, the depth-damage approach is based on empirical function for residential buildings derived by German insurance companies, based on the historical data about flood consequences [5]:

$$y = 6{,}9 \cdot x + 4{,}9 \qquad (1)$$

This function represents the relationship between flood depth (independent variable x) and damage percentage (dependent variable y).

2.2 **Flood depth determination**

For the purpose of flood depth determination geoinformation technologies were used. Quantum GIS, as an open source software with a wide range of possibilities for the spatial analysis, was selected as a tool for digital model representation and testing of certain variables.

Variables that are necessary for the flood depth determination at a certain location are elevation and a water level of the high occurrence probability flood. Digital Elevation Model was obtained by topographic map vectorization and georeferencing. The water level of high occurrence probability flood was determined based on maximum water level measured for a long period of time. Subtracting elevation from flood water level it is possible to calculate flood depth.

2.3 **Residential value estimation**

To convert the physical structural damage to economic estimates of damage percentage, insight in the pre-disaster value of residentials at risk is required. Building values should be evaluated as an estimate of depreciated replacement value of the structure, not full replacement costs. Depreciated value reflects the value of a property at the time when the flood damage actually occurs.

Therefore, the depreciated value is used as the maximum possible damage value. The potential economic damage is expressed as a percentage of the maximum possible damage.

3. METHOD VERIFICATION

Method verification was conducted on the example of weekend settlement Kamenjar located in the riverbed of the Danube in Novi Sad. Due to the specific location, residential buildings in the settlement are particularly exposed to flooding. In order to estimate the monetary value of the expected damage in the case of flooding certain variables were examined: occurrence probability of flood, water level, elevation, flood depth, age of residential building, area of residential building, number of floors, cost of a residential building construction, depreciated value.

Based on the listed variables digital model of the observed situation was created by use of Quantum GIS software. Technological framework of model creation is divided into a few steps:

1. Import base map by OpenLayers plugin in QGIS. For the purpose of model creation Bing Aerial Map was used.
2. Import Digital Elevation Model of examined zone as a raster in QGIS project. MGI 1901/Balkans zone 7 was used as a Coordinate Reference System.
3. Determine water level of high occurrence probability flood for Danube river in Novi Sad. Water level of 78 m above sea level was calculated for 10-year flood [8].
4. By use of Raster Calculator create the vector of the potential 10-year flood from DEM (Figure 1).
5. Chose residential buildings that will be used for the method verification. Three houses located on different elevation were chosen and displayed on the separate vector layer by use of point geometry (Figure 2).
6. Organize attribute table joined to the vector layer displaying houses.
7. Calculate expected damage.

Steps 5, 6 and 7 of the model creation are based on selected example for method verification. The first object that is selected for method verification is located at an altitude of 74.611 m which is the lowest point that is exposed to the 10-year flood. The second object is located at an altitude of 77.724 m, which is the highest point exposed to the 10-year flood. The third object that is selected for method verification is located at an altitude which is within the selected extreme values (76.212 m). By subtracting the aforementioned altitude values of the selected objects from the characteristic value of the water level, the expected flood depths were determined.

To convert the physical structural damage to the monetary value of expected damage, insight in the pre-disaster depreciated values of each building is estimated. For method verification residential buildings have been classified into three categories, since building of the houses at the Kamenjar started in the late nineties:

1. Average age of residential buildings is 10 years,
2. Average age of residential buildings is 20 years,
3. Average age of residential buildings is 30 years.

According to the Law on Property Taxes [9], amortization rate is in the range from 1% for each year passed since the construction of a house, to the maximum of 40%. Accordingly, corresponding amortization rates for the analyzed types of residential buildings are 10%, 20%, and 30%, respectively.

Variables area of residential building, number of floors and unit price per square meter of the floor area are defined as constants, for the purpose of the method verification. The average floor area of the residential building in the research area is 40 m^2, while the unit price per square meter of the floor area is 775 euros [10]. Selected value, in this example, for a number of floors is one floor. Thus, the average value of a new residential building in the weekend settlement Kamenjar is 31000 euros.

Using the present method, the expected direct damage was estimated for different flood depths and different ages of selected residential buildings. The obtained values are shown in Table 1 and Table 2.

Table 1. Expected damage/loss for selected flood depths (10 years old residential)

Residential	***Flooding Depth (m)***	***Damage/Loss (€)***
Object 1	3,389	7891,24
Object 2	0,276	1898,32
Object 3	1,788	4809,12

Table 2. Expected damage/loss for selected residential age

Residential	***Residential Age (year)***	***Damage/Loss (€)***
Object 1	10	7891,24
Object 1	20	7014,43
Object 1	30	6137,63

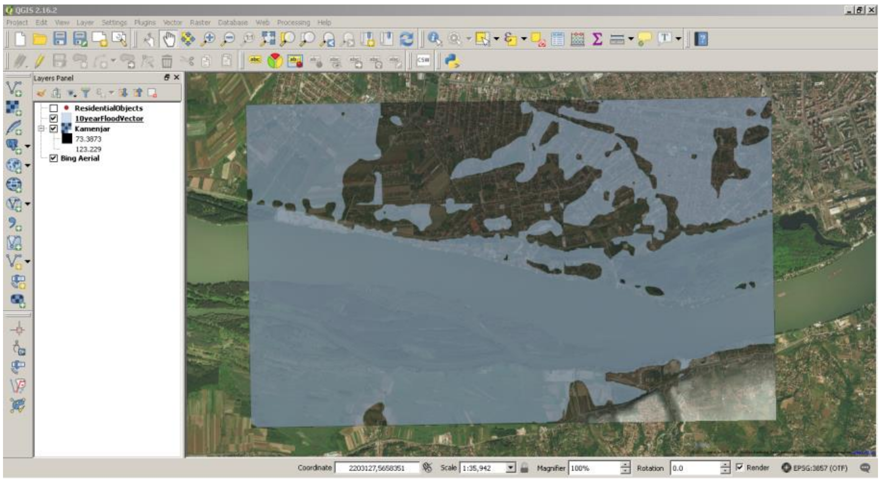

Figure 1. 10-year flood vector

StambeniObjekti :: Features total: 3, filtered: 3, selected: 0

	id	Example	Elevation	FloodDepth	y	Value10	Damage10	Value20	Damage20	Value30	Damage30
1	1	Object1	74.611	3.389	28.284	27900.00	7891.24	24800.00	7014.43	21700.00	6137.63
2	2	Object2	77.724	0.276	6.804	27900.00	1898.32	24800.00	1687.39	21700.00	1476.47
3	3	Object3	76.212	1.788	17.237	27900.00	4809.12	24800.00	4274.78	21700.00	3740.43

Figure 2. Vector layer displaying houses

5. CONCLUSION

Method verification indicated that expected loss (damage to structures) is strongly related to the depth of flooding and age of residential building. There is a linear relationship between both deeper depth and older building and greater damage of a structure. In that sense, the value of the expected damage represents the data necessary for designing the appropriate rates of insurance premium (risk price) which is proportional to the level of taken flood risk.

6. REFERENCES

[1] Munich Re, Nat-CatSERVICE, available at: http://natcatservice.munichre.com/ (accessed: 27 June 2017).

[2] Cred Crunch, „What is the human cost of weather-related disasters (1995-2015)?“, No. 42, available at: http://www.emdat.be/publications (accessed: 27 June 2017).

[3] Nacionalni program upravljanja rizikom od elementarnih nepogoda, available at: http://www.obnova.gov.rs/uploads/useruploads/Documents/Nacionalni%20program%20upravljanja%20rizikom%20od%20elementarnih%20nepogoda.pdf (accessed: 27 June 2017).

[4] Jongman, B. et al. (2012), *“Comparative flood damage model assessment: towards a European approach”* Natural Hazards and Earth System Sciences, Vol. 12, No. 12, pp. 3733–3752.

[5] Parker, D. J., Green, C. H., and Thompson, P. M. (1987), *Urban flood protection benefits: A project appraisal guide*, Gower Technical Press, Aldershot.

[6] Smith, K. and Ward, R. (1998), *Floods: Physical processes and human impacts*, John Wiley & Sons, Chichester.

[7] B¨uchele, B., Kreibich, H., Kron, A., Thieken, A., Ihringer, J., Oberle, P., Merz, B., and Nestmann, F. (2006), *“Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks”*, Natural Hazards and Earth System Sciences, Vol. 6, No. 4, pp. 485-503.

[8] Ćosić Đ. (2010), *“Razvoj integralnog modela osiguranja u cilju smanjenja rizika od hazardnih pojava”*, Faculty of Technical Sciences , Novi Sad.

[9] Law on Property Taxes, "Sl. glasnik RS", br. 26/2001, "Sl. list SRJ", br. 42/2002 - odluka SUS i "Sl. glasnik RS",br. 80/2002, 80/2002 - dr. zakon, 135/2004, 61/2007, 5/2009, 101/2010, 24/2011, 78/2011, 57/2012 - odluka US, 47/2013 i 68/2014 - dr. zakon

[10] Available at: www.nekretnine.rs (accessed: 27 June 2017).