Estimating Large-Scale Damages to Real Property

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Abstract

Estimating large-scale disaster damages is a difficult task since there is usually no up-to-date data on the value of property in the target area. For this purpose, it is necessary to have at disposal a methodology enabling estimation of potential damages/losses caused to real property as well as allowing quick estimation of real property value in the target area. Outputs obtained through the methodology are relevant especially during the investment decision-making process on the implementation of natural hazards protection measures, for insurance purposes and/or for urban planning. The aim of this paper is to discuss the potential of above mentioned type of methodology for hazards of windstorm and weight of snow and icing with regard to an existing methodology for floods.

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1. Introduction

The worldwide increasing frequency of occurrences of natural disasters and the intensity of their impact keep increasing the need of quickly estimating damage in the monitored territory. This estimation is necessary not only for determining the amount of actual damage caused as a consequence of a natural hazard, but also for evaluating the effectiveness of individual mitigation measures. Individual geographic regions are usually exposed to specific

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extreme risks, for example, the Caribbean Region faces hurricanes, mountainous areas are threatened by flash floods, avalanches, rock falls or debris flows, Central Europe is exposed to floods and windstorms, Japan to earthquakes.

Individual natural hazards differ from one another with their characteristics similarly to a significant difference in regions in which natural hazards are realized. For this reason, in most cases individual methods of damage estimation are only proposed, validated and applied for a selected natural hazard and a specific geographic region. This is caused by the fact that they are subject to many constraints and limitations. Such method is also the vulnerability loss curves system proposed for the flood risk in the Czech Republic. The aim of this paper is to discuss the potential of application of the above mentioned type of methodology for hazards of windstorm and weight of snow and icing with regard to an existing methodology for floods.

The paper is structured as follows: Firstly, the theoretical framework is outlined. Secondly, the methodology of estimating flood damage to property in a region is presented. Finally, the possibility of using the methodology for the needs of estimating damage caused by a windstorm and the weight of snow and icing is discussed.

2. Literature Review

Effective decision-making on implementation of individual structural risk mitigation measures should be based on a Cost-Benefit Analysis (CBA). The need of carrying out a CBA in this field is emphasized in many research studies, for example (De Loë & Wojtanowski, 2001; Holub & Fuchs, 2008; Nakano, Kajitani & Tatano, 2011; Okada, Mcaney & Chen, 2011; Papathoma-Köhle, Keiler, Totschnig & Glade, 2012). In this case the benefit is the difference between potential economic damage with and without structural protective measures, the costs are then connected mainly with the construction of these measures. However, the question is at what level of details CBA should be carried out. Nakano et al. regard the total economic damage as a sum of the cost of recovery + forgone profit (Nakano, Kajitani & Tatano, 2011). If also the social aspect is taken into consideration, then also, for example, the social costs of displacement (Hori & Schafer, 2010) can be evaluated as the consequence of a natural disaster. In the case of costs, then apart from costs connected with construction also costs for the maintenance of the built structures will arise. Costs of construction are dependent on the type of structural measure, since usually there are more applicable solutions that can also be combined, as is typical for flood risk (Schuster, Pfaffenwimmer, Hepp, Moussa, & Jugovic, 2012; Durechová, 2012). Besides, also mitigation measures of non-structural character can be implemented (watershed management, forestall measures).

The methodologies for estimating large-scale damage require a large amount of data to be collected (Liu & Xu, 2013) and they are often based on using modern technologies. Takashima & Hayashi used a city light distribution captured by satellite for identification of a metropolitan area, size of population and number of buildings with regard to an earthquake risk (Takashima & Hayashi, 2004). Boswell et al. point out in their hurricane study the need of using empiric data available from historical disasters over theoretical models based on an evaluation of the relationship between physical forces and the construction-technical characteristics of structures (Boswell, Deyle, Smith, & Baker, 1999). GIS systems are popular particularly for a flood risk assessment (Okada, Mcaney & Chen, 2011), satellite-based techniques were used for determining the extent of damage, for example, for a risk of tornado (Myint, Yuan, Cerveny, & Giri, 2008) or tsunami (Gillessie, Frankenber, Braughton, Cooke, Armenta, & Thomas, 2009). The output is then catastrophe (cat) models for insurance purposes (Keef, Tawn, & Lamb, 2013) or, generally, vulnerability curves showing the degree of loss corresponding to different process intensities (Papathoma-Köhle, Keiler, Totschnig, & Glade, 2012).

The methodologies for estimating large-scale damage in the monitored territory face a number of limitations which, to large extent, affect the quality of provided outputs:

- missing current information on the value of threatened/damaged property in a territory,
- different characteristics of a territory (regions and subregions),
- unavailable information on historical disasters including damage records,
- only selected characteristics of a natural hazard are taken into consideration,
- a limited number of hazard scenarios are evaluated,
• resistance of individual structures against damage are not evaluated,
• double counting of economic damage,
• non-existence of a price standard, or
• non-existence of a standard method for determining the value of property in a territory.

Estimation of economic damage is often related solely to a particular monitored territory and thus it cannot include all secondary economic damage associated with the risk realization (Sahin, 2011). In addition, the geographical limitation of global use of methodologies arises from a non-linear relationship between economic losses and the stages of economic development (Schumacher, & Strobl, 2011).

As there are general concepts for creation of vulnerability curves, the above-mentioned limitations predetermine, also for the future, the need of creating local methodologies for individual risks or at least groups of risks which may occur concurrently.

The outputs of these methodologies are widely applied in practice. Apart from evaluating the cost-benefit analysis of mitigation measures they can be used for insurance purposes, land planning, setting of appropriate technical requirements for structures or risk mapping and zoning (see e.g. approach to landslide and rock fall risk mapping presented by Pesevski, Jovanovski, Papic, Markoski & Milevski, 2012).

3. Methodology for estimating large-scale damage caused by floods

In order to be able to estimate the occurred loss by floods, an own method has been developed by the members of the research team of the Institute of Structural Economy and Management of the Faculty of Civil Engineering of the Brno University of Technology; this method consists of the following steps (Korytárová et al., 2007):

Specification of the territorial property valuation:
• Specification of property representatives in the territory.
• Estimation of property representatives.
• Specification of territorial category.
• Specification of territorial representative.
• Estimation of territorial property index in reproduction price level.

Evaluation of damage on the territorial property caused by floods:
• Specification of damage on the property representatives.
• Evaluation of damage ratio of the territorial representative formulated in %.
• Specification of damage on the territorial representative in reproduction price level.
• Specification of damage in the monitored territory in reproduction price level.

The output of the first part of the methodical procedure is determining the value of real property in the monitored territory in reproduction price level (CZK). This value is determined by a product of the actual territorial category area (m²) and the respective territorial property index (CZK/m²).

The area categories are specified in relation to the Regulation No. 501/2006 Coll. on general requirements for area utilization. A basic overview is presented by the Table 1.

| Marking | Area Category            |
|---------|--------------------------|
| A       | Residential areas        |
| B       | Recreational areas       |
| C       | Areas of civil infrastructures |
| D       | Green areas              |
The value of the Territorial Property Index represents the value of the real property in the area in CZK per 1 m² of the given area category (more in Korytárová & Hromádka, 2010).

The output of the second part of the methodical procedure is determining the amount of damage on real property in the monitored territory. Determination of expected damage on the property in the territory is based on the value of the territorial property index for the solved territorial representative or on the value of individual property representatives within the given representative of the considered territory. Losses on individual property representatives within the solved territorial representative are then determined as a product of the property representative value and the damage percentage. The damage percentage is dependent on the technical parameters of property representatives, it is a type of real estate property (e.g. a single family house), a type of the load-bearing vertical structure (e.g. masonry, bricked, made of blocks), building volume (m³), built-up area (m²), ratio (CZK/m³) and the anticipated parameters of the flood. The following relevant flood parameters were chosen: depth of water (elevation of the water column within the structure or in the terrain level) and duration (water on the surface of the structure). The combination of these criteria has been elaborated on the assumption of both flowing water reaching the speed up to 1.0 m/s and the load-bearing sub-grade.

Damage curves characterizing dependence of total damage on the real property in the territory were derived for the defined flood parameters using a regression analysis.

As an example a damage curve (see Figure 1) expressing dependence of the amount of damage on the real property is presented for A area category – Residential areas on the depth of flooding for load-bearing sub-grade and flood duration from 2 to 7 days. The regression equation has the following form:

\[ y = -263.2x^2 + 2491.9x \]  

where: \( x \) represents depth of water in meters and \( y \) represents amount of damage on property within territorial representative.
4. Discussion on the potential of application of flood methodology for the purpose of estimating large-scale damage to property caused by other natural hazards

In the Czech Republic, part from a flood risk, large damage to property is caused also by windstorms, hailstorms, lightning or the weight of snow and icing. It is therefore desirable to consider the possibility of application or transformation of the current methodology of estimating damage to property in a territory hit by a flood also for other territories and the needs of the above-mentioned hazards. This part of the paper deals with the possibility of application of the flood methodology to 2 types of natural hazards: windstorm and the weight of snow and icing.

Assuming that the methodology will be retained in structuring to two main parts 1) Specification of the territorial property valuation and 2) Evaluation of damage on the territorial property caused by a particular natural hazard, it is useful to discuss these parts separately.

It can be stated that the flood methodology can be fully used for the needs of estimation of territorial property index in reproduction price level. The necessary condition is updating the price data to the current price level, which, in the case of large-scale evaluation of property in large territories, can be solved by using building structure price change indexes. For the future it is necessary to continuously update the data to ensure compatibility of the methodology outputs of economic character with the actual prices in the affected territory. However, partial modification should be made in the field of structuring the property representatives for the needs of a specific hazard, because in the case of the weight of snow and icing or windstorm, the extent of damage to a structure will be significantly affected also by the type of the roof structure (roof pitch and roof covering material used).

On the other hand, in the case of the specification of damage in the monitored territory in reproduction price level the applicability of the methodology is limited significantly. Basically, this means solely taking over the basic methodology idea, but its content must be adjusted to a specific hazard. This adjustment consists particularly in determining the appropriate basic characteristics of the natural hazard, probability of an occurrence of the hazard in various scenarios in the monitored territory and an evaluation of the destructive action of the hazard on structures. Specification of damage in the monitored territory in reproduction price level can be carried out using the same
method as in the case of floods, but with different input data. The above-mentioned facts are clearly summarized in Table 2.

Table 2. Compatibility of the flood methodology for the needs of assessing the windstorm and the weight of snow and icing hazards

| Methodological steps                              | Windstorm                       | Weight of snow and icing |
|--------------------------------------------------|---------------------------------|---------------------------|
| Specification of property representatives         | Compatible, with minor modifications | Compatible, with minor modifications |
| Estimation of property representatives            | Compatible                       | Compatible                  |
| Specification of territorial category             | Compatible                       | Compatible                  |
| Specification of territorial representative       | Compatible                       | Compatible                  |
| Estimation of territorial property index in reproduction price level | Compatible                       | Compatible                  |
| Specification of damage on the property representatives | Non-compatible                    | Non-compatible               |
| Evaluation of damage ratio of the territorial representative formulated in % | Non-compatible                    | Non-compatible               |
| Specification of damage on the territorial representative in reproduction price level | Non-compatible                    | Non-compatible               |
| Specification of damage in the monitored territory in reproduction price level | Calculation process is compatible | Calculation process is compatible |
| Specification of damage in the monitored territory in reproduction price level | Calculation process is compatible | Calculation process is compatible |

To deduce damage curves for the windstorm and the weight of snow and icing hazards, it is necessary to determine mainly the selected characteristics of the natural hazard, to determine the probability of an occurrence of the phenomenon in the territory and to obtain information on historical disasters including damage records which are required for a regression analysis. The proposed characteristics of natural hazards, anticipated available sources for determining the probability of an occurrence of the phenomenon and for finding out historical data are shown in Table 3.

Table 3. Comparison of availability of input data and characteristics for assessing individual hazards

| Hazard                                | Flood                              | Windstorm                            | Weight of snow and icing |
|---------------------------------------|------------------------------------|--------------------------------------|---------------------------|
| Natural hazard characteristics         | Depth of water [m], duration (days) | Gust speed [m/s]                      | Height of snow cover (roof load) [kg/m²] |
| Occurrence of phenomenon in territory | Flood hazard mapping, GIS modelling | Windstorm hazard mapping              | Snow load mapping         |
| Historical data on disasters in territory | Insurance companies, public authorities | Insurance companies, public authorities | Insurance companies, public authorities |

Tab. 3 shows that when creating vulnerability curves for the windstorm and the weight of snow and icing hazards, it will be necessary to actively cooperate with the respective hydrometeorological institute, insurance companies and public authorities. The sufficient amount of empiric data obtained from these institutions directly affects the accuracy of vulnerability curves and thus also the accuracy and information capability of the methodology outputs.
5. Conclusion

Similarly to the other countries in Central Europe, the Czech Republic repeatedly faces a number of specific natural disasters. These are mainly floods, windstorms and disasters caused by the weight of snow and icing. In order to be able to estimate the occurred loss by floods, an own method has been developed by the members of the research team of the Institute of Structural Economy and Management of the Faculty of Civil Engineering of the Brno University of Technology. The purpose of this paper was to consider the possibility of how to use the elaborated methodology also for other natural disasters with a wider territorial impact.

The methodology worked out for quick determination of damage caused by floods is comprised of two parts. The first part deals with determining the value of the real property in the territory, the other deals with the potential damage to this property when specific parameters of the flood act. Based on a comparative analysis, see Tables 2 and 3, it is apparent that the first part of the methodology is applicable for estimating large-scale damage caused also by other natural disasters of territorial character.

From the other part of the elaborated methodology, the basic idea of the specification of damage in the monitored territory in reproduction price level is applicable and it can be achieved in the same manner as in floods, but with different input data.

In order to deduce damage curves for the windstorm and the weight of snow and icing hazards, it is necessary to set mainly selected characteristics of these hazards, to determine the probability of an occurrence of the considered phenomena in the territory and to obtain information on historical disasters including damage records which are required for a regression analysis.

The output should be again damage curves which will represent the dependence of the amount of damage on the real property in the territory and the specific parameters of the monitored hazard.

Quick estimation of damage caused by natural disasters is very necessary and important. In a short time, the public authorities must provide funds for renovation of damaged territories, the mayors of municipalities must be able to decide on the amount of damage in the territories administered by them and to apply for state subsidies in a reasonable amount. The methodologies being developed should help them in these situations efficiently.

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