Risk assessment of geological disaster in the region of Primorsko Municipality

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Abstract. Risk assessment methodology is described in detail and applied for assessing the geological hazard for potential landslides and earthquakes. This methodology follows the guidelines of ISO 31010 and the JRC recommendations, and is applied for the first time in Bulgaria. The obtained results have high practical applicability. The flexibility of the methodology allows the final result to be presented as either a risk matrix or risk profiles. It depends on the specific tasks, issues and scientific problems that need to be solved.

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INTRODUCTION

Bulgaria is located in an active orogenic zone with complex tectonic structure, a variety of geological formations and sharp relief changes, and the whole spectrum of destructive and hazardous processes are present. Most popular European and world practices for risk assessment are incorporated in the present research. The main aim is to present an enhanced complex method for risk (multi-risk) assessment of natural hazard which incorporates the most used applications and practices (*i.e.*, Inter-American Development Bank, World Bank, United Nations International Strategy for Disaster Reduction, Joint Research Center – European Commission).

Primorsko Municipality (Fig. 1) occupies the southern part of the Bulgarian Black Sea coast (Burgas District). It is a resort and tourism center. The relief is mostly hilly, with a dense network of ravines. The main drainage arteries are the Dyavolska and Ropotamo rivers. The average altitude is 16 me-

ters above sea level. The relief is low in the coastal zone and mountainous in the Strandzha Mountain zone. The climate is continental, influenced by the Black and the Mediterranean seas. The summer is sunny and warm, with refreshing winds in daytime and relatively high night temperatures. The average temperature in July is 23–24 °C. The maximum temperature rarely reaches over 32–33 °C. The vegetation has strongly manifested Mediterranean characteristics.

From a regional point of view, the area of Primorsko Municipality is a part of the Srednogorie tectonic zone (Dabovski *et al.*, 2009). Upper Cretaceous sediments and volcanic rocks (*e.g.*, tuffs and trachytes) predominate (Petrova *et al.*, 1992). North of the town of Primorsko, a fragment of an intrusive body of syenites and quartz-syenites (*i.e.*, the Rosen pluton) occurs. The Neogene is represented by sandstones, limestones and clays (Galata Formation). The Quaternary deposits cover mainly river valleys, estuaries and the Black Sea coast. Lake-

Fig. 1. Location map of Primorsko Municipality (map sourced from Google Earth).

swamp (sands, clays, peat), alluvial (gravel, sands, clays) and modern sea deposits (beach sands) are observed within the considered area.

According to the map of geological hazards in Bulgaria (Iliev-Broutchev, 1994), the risk in the area of Primorsko Municipality can be divided into several classes by the natural hazard-triggering threats (geological and meteorological) as follows: 1) low level – erosion, salt water intrusion (salinization), coastal depositions, abrasion; 2) middle level – heavy rains, winds, blizzards hails; 3) high level – storm surges, flash floods and especially earthquake effects and landslides, which are under investigation in the present paper.

METHODOLOGY USED FOR THE RISK ASSESSMENT PROCESS

Risk is the probability of harmful consequences or expected losses (deaths, injuries, damages of properties, livelihoods and environment economic activity disruption) resulting from interactions between natural or human-induced hazards and opportune

conditions. It refers to the expected losses from a specific hazard to a given element at risk over a specified time period in the future. The first definition was given by Blaikie *et al.* (1994), according to which risk is the product of hazard potential and vulnerability. According to UNISDR (2002) and UNDP (2004), risk is a function of hazard, vulnerability and coping capacity, whereas, according to JRS recommendations (see Poljansek *et al.*, 2021), it is a function of hazard, exposure and vulnerability.

Risk assessment is a disaster preparedness activity and a main tool for the risk management of natural disasters (Fig. 2). The relationship between vulnerability, hazards and coping capacity are presented in Table 1 and Fig. 3.

Hazard is usually expressed by the probability of occurrence for a specific time period (UNDP/DMTP, 2002). Vulnerability has the following aspects: economic, social, environmental, physical and demographic. While vulnerability focuses mainly on the communities and people, the coping capacity is a measure of prevention, mitigation, preparation, response, rehabilitation and reconstruction (IADB/GTZ, 2003, UNISDR, 2004; IADB, 2005).

Fig. 2. Risk assessment (UNDP, 2004).

Table 1
Relationship between vulnerability and coping capacity (after Frantzova, 2017)

Vulnerability	Coping capacity				
	Very low	Low	Medium	High	Very high
Very high	Very high	Very high	High	Medium	Medium/Low
High	High	High	Medium/High	Low/Medium	Low
Medium	Medium	Medium	Low/Medium	Low	Very low
Low	Low	Low	Very low	Very low	Very low
Very low	Very low	Very low	Very low	Very low	Very low

Very high	6 (102,255,255)	7 (188,112,0)	8 (255,87,91)	9 (184,0,0)	10 (133,39,113)
High	5 (0,102,0)	6 (93,174,255)	7 (254,127,0)	8 (255,139,142)	9 (255,51,0)
Medium	4 (234,228,0)	5 (108,254,68)	6 (67,130,193)	7 (255,178,101)	8 (255,183,185)
Low	3 (255,175,255)	4 (255,255,102)	5 (124,154,0)	6 (47,47,255)	7 (255,221,125)
Very low	2 (255,255,255)	3 (255,221,255)	4 (255,255,204)	5 (51,204,51)	6 (0,51,153)
Hazard/Vulnerability	Very low	Low	Medium	High	Very high

Fig. 3. Risk matrix (Schmidt-Thomé, 2004).

RISK ASSESSMENT METHODOLOGY APPLIED FOR PRIMORSKO MUNICIPALITY

According to the landslide zoning of the Bulgarian Black Sea coast, Primorsko Municipality falls into the southern landslide zone and the subzone of landslides southern from Burgas (Konstantinov *et al.*, 1992; Bruchev *et al.*, 2007; Frangov *et al.*, 2011; Dobrev *et al.*, 2013; Berov *et al.*, 2016, 2020; Ivanov *et al.*, 2017b, 2020). The main destabilizing factors are sea erosion, erosion and fluctuations in groundwaters. Data for local and regional seismicity are taken from the works of Rangelov (2011), Solakov *et al.* (2014), Simeonova *et al.* (2006), as well as from the seismic zonation of Bulgaria (NIGGG, 2009), and seismic codes. The evaluation of geological risk itself is preceded by a number of other geological assessments: susceptibility, vulnerability and hazard (Lakov *et al.*, 2002; Ivanov *et al.*, 2017a; Bruchev, 2018).

The Inter-American Development Bank and Deutsche Gesellschaft für Technische Zusammenarbeit (IADB/GTZ, 2003) methodology was chosen for the risk assessment for Primorsko Municipality because of its flexibility and adaptability. It uses four risk factors (*i.e.*, hazards, exposure, vulnerability and coping capacity) and is fully compat-

ible with the United Nations, World Bank and Joint Research Center recommendations.

Developed and adapted methodology for risk and multi-risk assessment

The newly developed and adapted herein methodology for risk and multi-risk assessment includes five risk factors: hazards, exposure, vulnerability, coping capacity and risk perception (Fig. 4). Therefore, the risk profile for the given selected area is expressed as:

$$R = wH + wE + wV + wRP - wCC,$$

where H, E, V and CC are the values of the hazard, exposure, vulnerability and coping capacity, and RP is the risk perception; $H_1, H_2, E_1, E_2, V_1, V_2$ and CC_1, CC_2 , respectively, refer to the scaled values of the indicators; w_i is the weighting coefficient. The total sum of the weighting coefficients must be equal to 100.

The total number of indicators used to assess the risk profiles are over 70, including climate change and Global Change Syndromes (WGBU, 1998), specific to particular natural hazards for selected areas. Five classification characteristics associated with risk perception are included as indicators for risk assessment.

Fig. 4. Adapted methodology (Frantzova, 2017).

RESULTS

The risk profile for Primorsko Municipality is expressed as:

$$R = 0.32 \times H + 0.35 \times E + 0.34 \times V + 0.34 \times RP - 0.35 \times CC.$$

The weighting coefficients vary for the different factors (hazard, exposure, vulnerability, coping capacity and risk perception). It is assumed that some of them have a greater importance in risk assessment and require the greatest attention. The general algorithm for multi-risk assessment is a set of consecutive operations described by Frantzova (2017). Result and risk levels are presented in Figs 5, 6 and Table 2. The risk from landslides and earthquakes is very low due to very low hazards and exposure. Risk levels are defined in Table 2.

Confidence level

Assessments of confidence are based on the expert's judgment and should provide supporting evidence and references for each conclusion. Confidence is expressed qualitatively and ranges from low confidence (inconclusive evidence or disagreement among experts) to very high confidence (strong evidence and high consensus). Confidence levels are reported even when they are low. Confidence should not be interpreted probabilistically, as it is distinct from statistical likelihood. The four confidence levels used herein are: 1) very high: strong evidence (established theory, multiple sources, consistent results, well-documented and accepted

Fig. 5. Landslide risk profile (Primorsko Municipality).

Fig. 6. Earthquake risk profile (Primorsko Municipality).

Table 2
Description of risk levels

Risk levels	Description
Very low (33–46)	No casualties, damages to buildings, facilities or infrastructure are expected.
Low (47–60)	No casualties or injuries are expected; non-structural damage to buildings; 0.05% up to 0.08% expected economical losses from the municipal budget.
Medium (61–73)	Up to 0.5% affected population (not death toll or severely injured population expected); non-constructive damage to buildings and facilities; local disruption of critical infrastructure; up to 1.2% expected economical losses from the municipal budget; necessity of medical care (up to 0.2% of affected population); loss of household income.
High (74–86)	Strongly affected population more than 0.3%; necessity of medical care and temporary shelter; structural and non-structural damage to buildings; cascading disruption of infrastructure; financial losses (economic damage); up to 5% expected economic losses from the municipal budget.
Very high (87–100)	Victims and severely injured population (more than 0.5% of the population); cascading disruption and failure of critical infrastructure; destroyed buildings and facilities; loss of household income; necessity of medical care and temporary shelter; financial losses (economic damage) more than 5% of the budget.

methods, etc.), high consensus; 2) high: moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus; 3) medium: suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought; and 4) low: inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts (<https://science2017.globalchange.gov>).

CONCLUSIONS

The present report describes a methodology for natural disaster risk assessment put in practice for Primorsko Municipality. Real scenarios derived from

empirical data and analyses have been used. The final result shows low and very low risk levels; no death tolls are expected in case of the occurrence of landslides and earthquakes. Low and very low risk levels are due to low hazard and vulnerability levels and high coping capacity resources.

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