METHODOLOGY OF FLOOD RISK ASSESSMENT ON THE MAIN ROAD NETWORK IN THE FEDERATION OF BOSNIA AND HERZEGOVINA

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Abstract

Climate change in Bosnia and Herzegovina is mainly manifested through the increasingly common occurrence of rain with a significant amount of precipitation in one hour, which causes floods. Floods cause great material and intangible damage per population and often endanger human lives. The road network in such situations has crucial importance to take urgent intervention measures and rescue people, animals and material goods. This paper is focused on the natural flood disaster and its influence on road infrastructure and presents the risk assessment methodology and determines critical road sections of main roads in the Federation of Bosnia and Herzegovina, analyzing data on 100-year floods.

Keywords: climate change, road network, risk assessment, flood

1 Introduction

Road infrastructure is permanently exposed to climatic conditions over time. Thus, rains, droughts, very low and high temperatures affect the life of road infrastructure as well as their way of designing, applying materials, and road assets dimensioning. The increasing occurrence of extreme weather conditions and natural disasters have exacerbated this impact and further shortened the life of road infrastructure. Floods as natural disasters are one of the most common causes of traffic crashes. In order to respond to such weather conditions, it is necessary to act ade-quately both before and after the disaster [1]. Therefore, there was a need to adapt the rules, standards, guidelines and legislation for the design, construction, reconstruction and maintenance of roads to the new projected climatic conditions to prolong functionality and resilience to expected climatic conditions.
The first task is to identify potential risk road sections on the existing network to prioritize interventions rationalizing budget investments.

2 Climate change in Bosnia and Herzegovina

The Earth's climate has permanently changed and will change in the future. However, in the last 100 years, the climate has been changing much faster than before, primarily due to anthropogenic factors. Climate change means changes in the variability of climate variables that last for decades and longer [2].
According to the most recent climate models, the climate is changing and is expected to continue changing rapidly in the following decades. It will cause the long-term change of average temperature, frequency and precipitation levels and severity of extreme weather events. Climate change projections will impact the long-term security and functionality of the road network and road planning, design, operation, maintenance, and management [3].

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Significant climate change is likely to occur in the future in Bosnia and Herzegovina's territory, notably if climatic scenarios do not include the implementation of effective mitigating measures. Based on IPCC (Intergovernmental Panel on Climate Change) predictions, the change in mean annual temperature by the end of this century ranges from 2.4 to 4°C, depending on the selected scenario and the area of the territory in the period 1961 to 1990. Changes in mean annual cumulative precipitation range from 0 to -30 % over the same reference period, with a negative anomaly affecting the majority of the territory.
Figure 1 depicts the rise in mean annual temperatures throughout the three-time horizons of 2011–2040, 2041–2070, and 2071–2100, as well as the three observed scenarios RCP8.5, A2, and A1B.

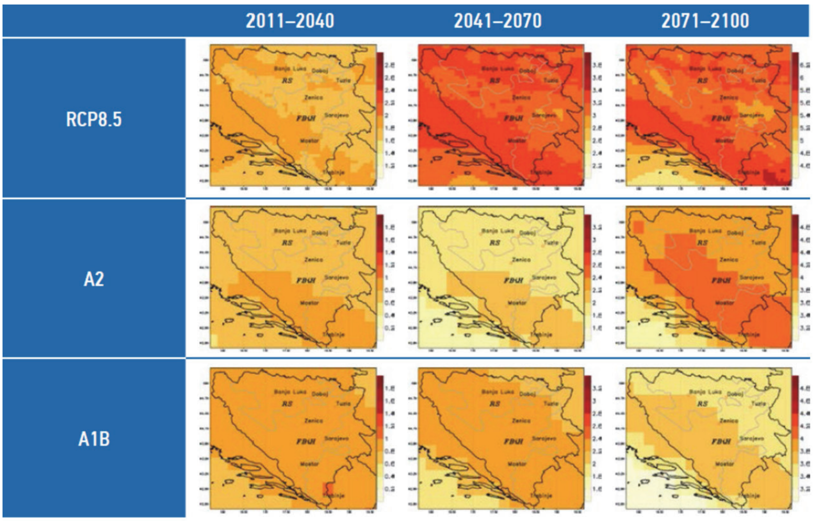

Figure 1 Changes in annual temperatures for the scenarios RCP8.5, A2 and A1B, for future periods 2011 – 2040, 2041 – 2070 and 2071 –2100 in relation to the reference period 1971 – 2000.

By the end of the twenty-first century, all three scenarios predict a continual rise in temperature in Bosnia and Herzegovina's territory. According to the RCP8.5 scenario, the temperature rises between +1.6 and +2°C in the first thirty years, and +5.4 to +5.6°C in the last thirty projected years. Under scenarios A2 and A1B, the temperature rise is less.

3 Main road network in Federation of Bosnia and Herzegovina

The road network of Bosnia and Herzegovina, and thus the FB&H, is part of the regional transport network and has international strategic importance in the Western Balkans region due to its inclusion in the SEETO comprehensive network (Figure 2). SEETO is a regional transport organization that was established in 2004 by a Memorandum of Understanding for the development of the Core Regional Transport Network by the Governments of Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro and Serbia and the United Nations Mission in Kosovo and the European Commission (Dec. 2013)

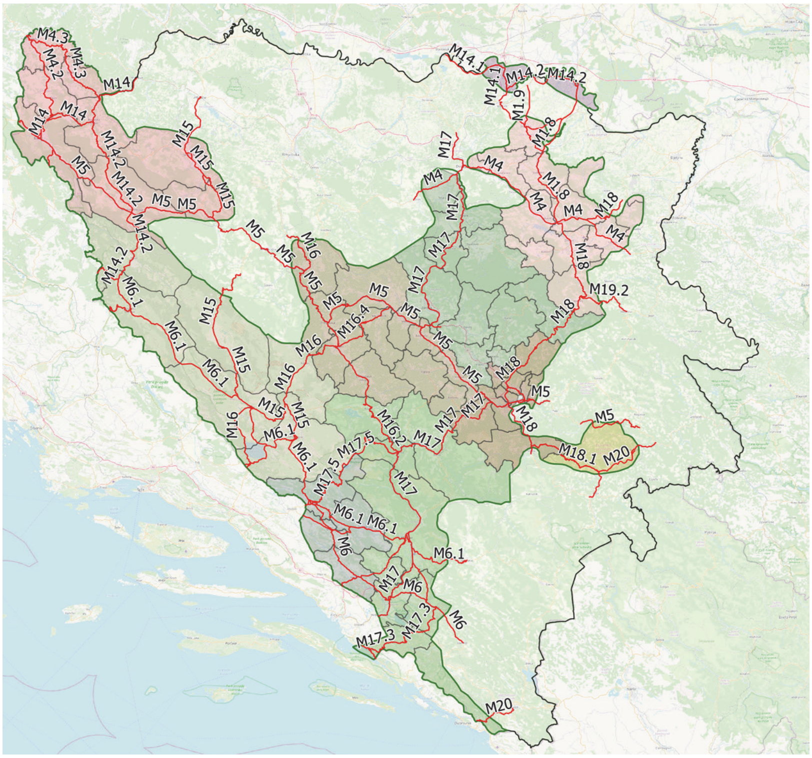

Figure 2 Main road network in Federation of Bosnia and Herzegovina

The main road network in FB&H spans 2, 331 km and divided into 373 sections. Some of the sections are very short, locating in junction areas. Out 2, 331 km, approximately 2, 255 km are paved, and 76 km unpaved (Table 1) [4].

Table 1 Main road network in FB&H

Pavement type	**Length** [km]
Bituminous	2, 255.5
Portland cement concrete	0
Unpaved roads	75.6
Total	2, 331.1

3.1 The role of road infrastructure during natural disasters

Transport networks support economic activity by enabling the movement of goods and people. During extreme weather events, traffic infrastructure can be directly or indirectly damaged, posing a threat to human security and causing significant disruptions and related economic and social impacts. Floods, especially due to heavy rainfall, are the dominant cause of interruptions in the transport sector. Existing approaches to assessing the disruptive impact of floods on road traffic do not record interactions between floodwaters and the transport system.

3.2 Consequence of flooding on road infrastructure

Reliable transport systems are valued for their safety, cost, travel time and regularity of service. Maintaining the volume of traffic flow, whether it is public transport or private, is crucial for production, logistics and business. Floods affect this in several ways, with direct impacts (e.g., physical damage to transport infrastructure) and indirect impacts (e.g., disruption of traffic flow, disruption of operations, increased emissions) (Figure 3).

Figure 3 Consequence of flooding on road infrastructure (Source: jpdcfbh.ba)

4 River basins in FB&H

Water resources in Federation of Bosnia and Herzegovina consist of two river basins: the Black Sea Basin (38 719 km²) and the Adriatic Sea Basin (12 410 km²) [5] (Figure 4).

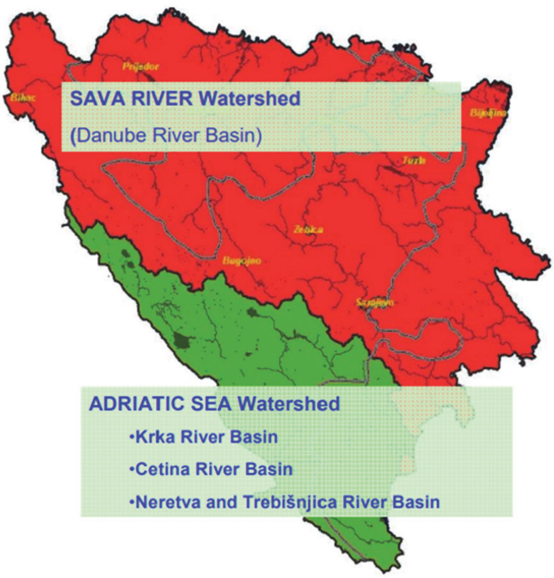

Figure 4 Watersheds in B&H (Source: unece.org)

The largest renewable water resources per capita are in the area of the rivers Neretva and Trebišnjica, around 29, 060 m^3/resident/year. The most vulnerable is the basin of the river Bosna with an available amount of water 2, 820 m^3/resident/year.
Despite Bosnia and Herzegovina having significant water resources, it estimates that as many as 57 % are left unused, with the quality of drinking water increasingly worsening. It is assumed a negative impact of changes in temperature and rainfall on water resources. Water systems are directly exposed to climate factors, so the increase in temperature and reduction in the amount of precipitation in the summer months lead to the appearance of drought. In opposite, another extreme will occur during the autumn, floods appear. The period of such conditions is predicted every 5 to 10 years [6].

5 Methodology of flood risk assessment

In order to analyze the flood risk on the main road network of FB&H, in the first step, relevant data were collected from competent institutions [7]. With the help of the collected data, by overlapping the layers of hazard and elements exposed to risk, the identification of critical segments of each section on the main network of FB&H was performed using QGIS software. Based on the performed analysis and created files, the chainages of the beginning and end of each previously defined critical segment were determined. In the next step, the comparison of elevation levels of identified critical segments of road sections with flood lines elevations was performed, and a risk assessment got as a result.
In criticality, assessment risks are divided into five categories, as described in the Table 2.

Table 2 Categories of risks

Category	Symbol	Water elevation
Very High		>1.0m
High		0.8 m – 1.5 m
Moderate		0.3 - 0.8 m
Low		0 - 0.3 m
Very low / None		<0 m

5.1 Case study section M16.2 Bugojno - Jablanica

The main road, M16.2, is 71, 858 km long. There is a possibility of flooding along the river Vrbas on this road. After overlapping the "shape" files of the section and the flood lines using QGIS software, several critical segments with a total length of 907 m were located. Detailed analysis and calculation based on the elevation of the beginning and end of the critical segments and the elevation of the floods showed that not all critical sections obtained in this way through QGIS are indeed critical.
The following table shows the risk analysis results obtained by comparing the altitudes of the beginning and end of critical sections and floods (Table 3).
The length of the critical segment with medium risk is 89 m, the length of critical segments with high risk is 259 m, and other segments that are not risky, according to the analysis, have a total length of 559 m. (Figure 5 and Figure 6).
Although the total length of critical segments is relatively small compared to the observed section of the main road, the 348 m of risky segments is enough to cause catastrophic consequences, from the impact on human safety to material damage and traffic suspension.

Table 3 The results of analysis

Section	Esp [m]	Eep [m]	Efl [m]	Efl – Eep [m]	Level of risk
1	643.54	644.02	594.95	-49.07	
2	647.93	649.00	599.95	-49.05	
3	652.43	652.46	599.95	-52.51	
4	652.84	653.00	599.95	-53.05	
5	653.39	655.56	599.95	-55.61	
6	654.43	654.43	604.95	-49.48	
7	693.93	693.93	694.95	1.02	
8	693.93	693.93	699.95	6.02	
9	693.93	693.93	704.95	11.02	

Esp – elevation of section start point, Eep – elevation of section end point, Efl – elevation of floods

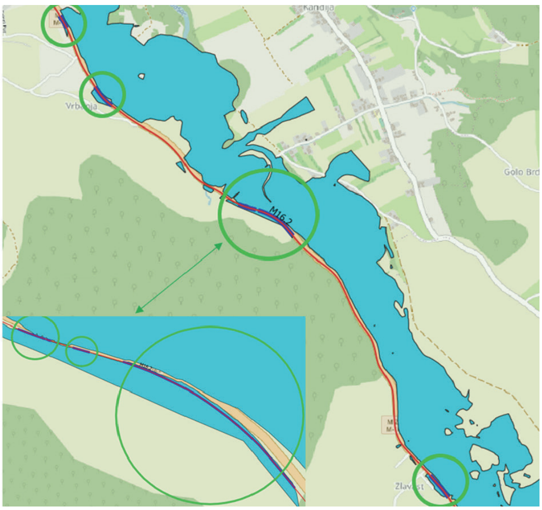

Figure 5 Segments with very low or no risk on the main road M16.2

Figure 6 Medium and high-risk segments on the main road M16.2

5.2 Protection measures

Flood risk analysis for road networks allows plans to be carried out in an appropriate manner, allocating resources for prevention, mitigation, and restoration [8]. Flood risk management to reduce flood risk is carried out through the implementation of the so-called flood protection measure, which according to different criteria, has several types, but the most common division is into:

- preventive,
- measures at the time of flood and
- remedial measures.

Previous protection measures are further divided into:

- non-construction and
- construction measures for flood protection.

6 Conclusion

Floods are natural disasters that, in intensity and magnitude, can endanger the health and lives of people, material goods and the environment. Floods occur everywhere and cause more damage than any other type of natural disaster and cause significant damage and losses that are often permanent, including road infrastructure. Road infrastructure has one of the most important roles during floods and other natural disasters. That is why it is necessary to have data on traffic size, road capacity, road construction, intersections with other modes of transportation, and the necessary geospatial data and maps.

Flood management plays a crucial role in protecting the population and their property. Although it is not possible to eliminate the risk of floods in most cases, efforts are focused on reducing and mitigating the damage caused by floods through flood defence, evacuation and rescue measures, and finally, the remediation of flood consequences.

The paper presents the methodology of flood risk assessment on the main road network of FB&H. This methodology was applied through the case study on the main road M16.2, section Jablanica - Bugojno, where a flood is possible along the Vrbas River. Critical sections identified using QGIS software were analyzed in more detail by comparing the altitudes of the critical segments and flood lines. In this way, a flood risk assessment was performed for each critical segment. Based on the assessment, it is possible to recommend various protection measures and thus reduce the consequences of floods as much as possible. It is important to emphasize that for the implementation of such and similar methodologies, up-to-date geospatial databases are of great importance so that the assessment is accurate and the envisaged measures are adequate and efficient.

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