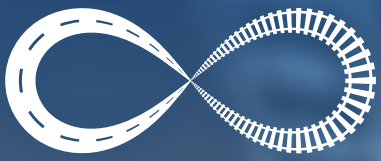

CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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CLIMATE CHANGE IMPACTS ON ROADS IN BOSNIA AND HERZEGOVINA

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Abstract

Safe and efficient transport system are essential in the functioning of business and society at large. The consequence of extreme weather events due to climate change are usually interruption of road network and inaccessibility to urban and economic areas. In Bosnia and Herzegovina climate change manifested itself by gradual changes in climate parameters in the last ten years. So, changes go unnoticed but still have effect on durability and functioning of road infrastructure, like continuous temperature rise, changing of ground water levels, extreme rainfall events, higher maximum temperature and higher number of consecutive hot days, drought (consecutive dry days), extreme wind speed, foggy days, heavy rain for longer periods. As with many hazards, the best way to avoid damage caused by climate change are prevention and preparedness. This paper presents impacts of climate change on roads in Bosnia and Herzegovina, and measures for mitigation and adaptation of road network.

Keywords: climate change, resilient roads, road infrastructure

1 Introduction

As the impacts of climate change become more apparent, climate change adaptation is emerging as an important part of the international climate change agenda. In the road sector, the floods that affected Bosnia and Herzegovina (B&H) in May 2014 caused collapse to several bridges and road sections. Total damages and losses in the transportation sector were estimated about € 348 million [1]. The devastating floods highlighted the need for increased investment in road infrastructure and policies that will help the country mitigate expected impacts from a shifting climate and shield the most vulnerable from natural disasters. The climate change resilient road focuses on ensuring adequate service levels of the road network under extra weather conditions. Innovation themes will address adaptation of road operations and management to the effects of extreme weather to such extent that adequate service levels are ensured [2]. The resilient road will adapt itself to the impacts of extreme weather conditions and climate change.

2 The climate of Bosnia and Herzegovina

The climate of B&H varies from a temperate continental climate in the northern Pannonia lowlands along the Sava River and in the foothill zone, to an alpine climate in the mountain regions, and a Mediterranean climate in the coastal and lowland areas of the Herzegovina region in the south and southeast (Figure 1).

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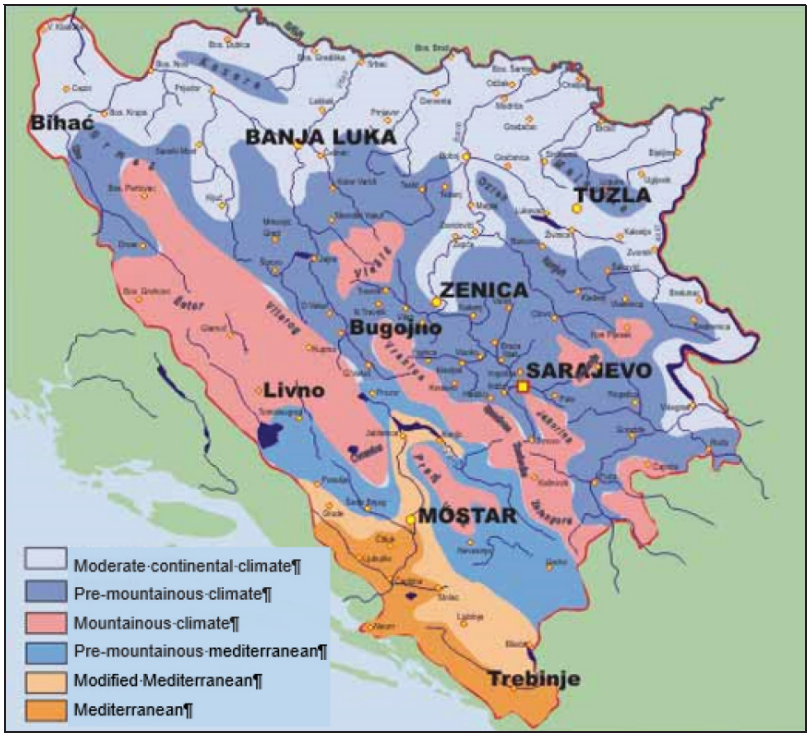

Figure 1 Climate map of Bosnia and Herzegovina

On the basis of temperature characteristics, the territory of Bosnia and Herzegovina may be divided into three temperature zones: warm, moderate and cold [3]:

- The warm zone corresponds to the Adriatic coast and lowland Herzegovina. In lowland Herzegovina, summers are hot and winters are very mild. Mean winter temperatures are above 5 °C, whereas summer temperatures reach 40 °C. Mean annual temperatures have the value of above 12 °C.
- Moderate areas include plain and hilly regions in the central part of the country. Summers are warm and winters are moderately cold. Mean winter temperatures are around 0 °C and summer temperatures reach 35 °C. Mean annual temperature ranges between 10 °C and 12 °C, whereas in the area above 500 m, it is below 10 °C.
- Cold regions refer to mountainous areas where summers are fair (days moderately warm and nights chilly), while winters are very cold. During at least 3 months of the year, these regions have a mean temperature lower than 0 °C.

2.1 Projections of Future Climate Change in B&H

To determine the impact of climate change on road infrastructure, climate events have to be forecasted. The results of the coupled regional climate model EBU-POM for future climate change scenarios, obtained by the method of dynamic scaling of results from two global climate models of atmosphere and ocean – SINTEX-G and ECHAM5. In this paper, the focus is on the results from the IPCC (Intergovernmental Panel on Climate Change) SRES (Special Report on Emissions Scenarios) scenarios A1B and A2 [4]. Model results were analysed for two intervals: 2001-2030 and 2071-2100. The Communication focuses on changes in two basic meteorological parameters: air temperature at 2m and accumulated precipitation. Changes in these parameters are shown with reference to the mean values from the so-called base (standard) period of 1961-1990. (Figure 2 and Figure 3)

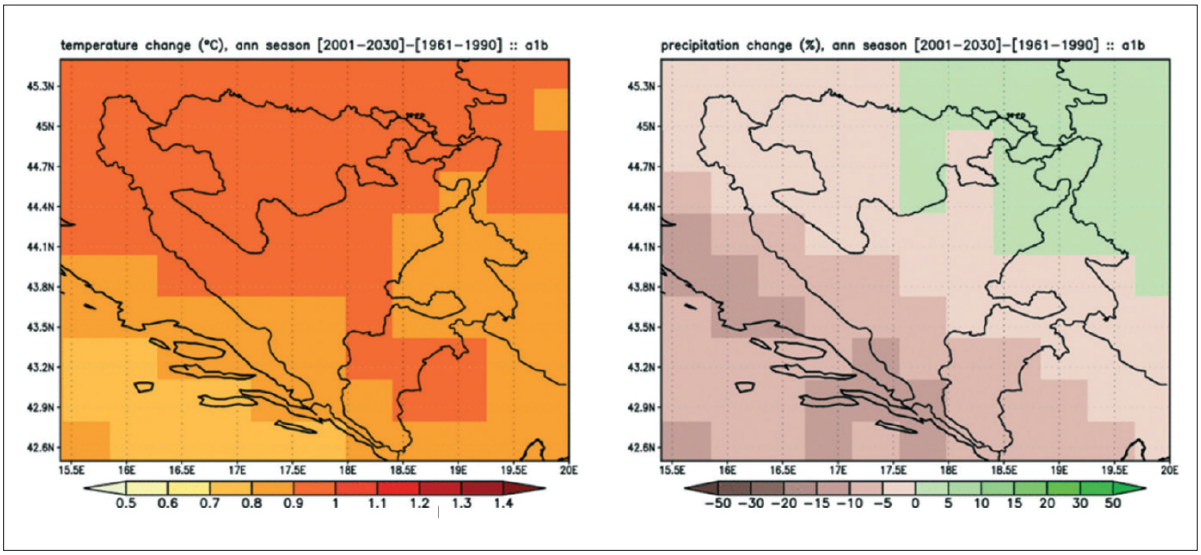

Figure 2 Average annual temperature change in °C (left) and precipitation change in % (right) 2001-2030

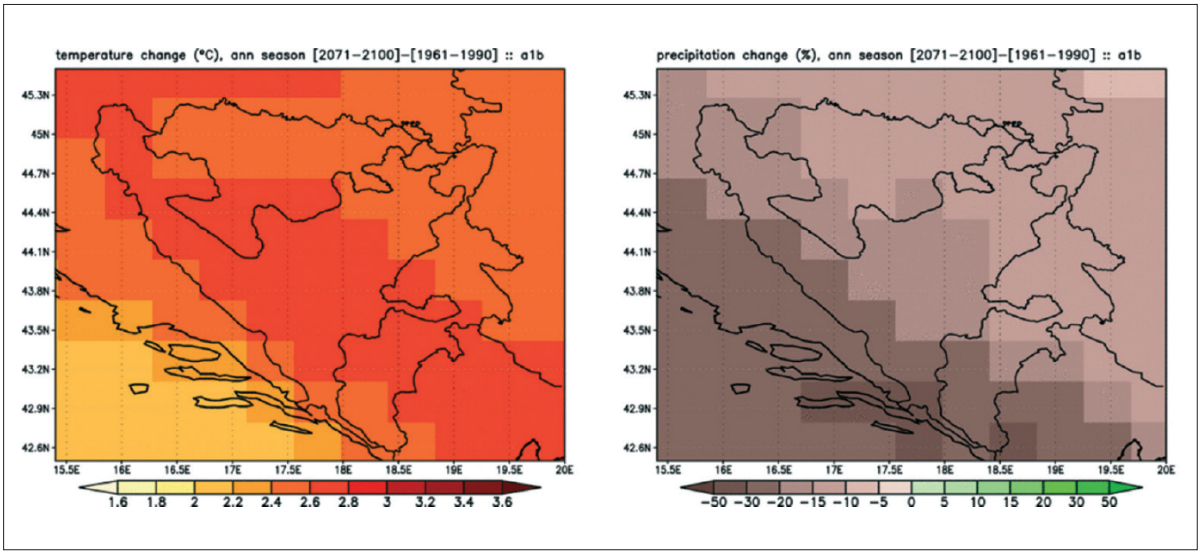

Figure 3 Average annual temperature change in °C (left) and precipitation change in % (right) 2071-2100

According scenario A1B for projection interval 2001-2030, annual temperature changes range from 0.8 to 1 °C, with higher values in the north and in the west of the country (Figure 2). Annual precipitation change is negative for the entire territory (ranging from 0 to -10 %) with the exception of the northeast, where precipitation is expected to increase by up to 5 %. For the same scenario and projection interval 2071-2100, annual temperature changes range from 2.4 to 2.8 °C, with greater values in the south and in the west of the country (Figure 3). Annual precipitation change is negative in the entire territory, ranging from -30 to -10 %. The results for scenario A2 and projection period 2071-2100, are as follow: temperature changes range from 3.4 to 3.8 °C, whilst annual precipitation change is negative throughout the entire territory, ranging from -15 to 0 %. Although the annual changes in precipitation negative in all scenarios, there are seasonal changes in precipitation that are positive. Positive changes in precipitation are in the MAM (March, April, May) season, about +5 % in the north and northeast.

3 Road Infrastructure in Bosnia and Herzegovina

According to the 2016 data, B&H has 23,119 km of roads of all categories (Figure 4), which is 6.65 % more than in 1991 when it had about 21,677 km.

Figure 4 European routes in Bosnia and Herzegovina

The most important road routes in Bosnia and Herzegovina which are connecting to the network of international routes are as follows (Figure 4):

- E–73 B. Šamac – Doboj – Zenica – Sarajevo – Mostar – Metković;
- E–761 Izacic – Bihac – Jajce – Travnik – Sarajevo – Višegrad – Vartište;
- E–762 Sarajevo – Foča – Hum;
- E–661 Gradiška – Banja Luka – Jajce.

These are the main routes that have to mainstream on climate resilience risk in road management.

4 Potential Impacts of Changing Climate on Transport Infrastructure

Transport infrastructure faces two major types of climate related risks:

1) Long-term changes in the climate, particularly temperature and precipitation; and
2) "Shock events" such as flooding and landslides.

According to the forecasted climate change related to changes in temperature and precipitation in Bosnia and Herzegovina, some of the potential risks to the road network are outlined below:

Precipitation changes, flooding

Flooding either through precipitation or potentially rapid snow/ice melt in some regions and some of the associated effects such as:

- Operational disruption, reduced network availability and blockages.
- Bridge scour, inundation of tunnels and landslides.
- Saturation of the unbound layers, resulting in loss of fine material, settlement and failure.

- Saturation of the subgrade causing a reduction in strength.
- Intense rainfall events causing erosion or landslides on embankments and in areas with reduced vegetation, would intensify erosion.

Air temperature, drought

- Hotter, drier summers leading to a reduction in sub-surface water, causing shrinkage of the sub-surface and inducing cracking. The cracks are the result of exceeding stress to the tension under asphalt layers [5]. Increasing changes in sub-surface water can cause soil to shrink and expand significantly, causing the overlying pavement layers to heave and subside.
- In periods of hot weather, asphalt surface layers can become susceptible to rutting and deformation. In addition, high temperatures can make newly laid asphalt remain workable for an extended time, making it difficult to maintain profile during compaction.
- Thermal gradients can create uneven internal stresses, giving rise to curling or warping in concrete pavements.
- Reduction in vegetation due to higher temperatures (wildfire) and drought, and/or higher wind speeds could increase erosion processes on embankments, leading to them becoming unstable.

Climate change is projected to concentrate rainfall into more intense storms. Heavy rains may result in flooding, which could disrupt traffic, delay construction activities, and weaken or wash out the soil and culverts that support roads, tunnels, and bridges. Exposure to flooding and extreme snow events also shortens the life expectancy of highways and roads. The stress of water and snow may cause damage, requiring more frequent maintenance, repairs, and rebuilding [6].

Figure 5 Landslide, Locations: Nemila, Main road M17, Topcic polje -Lasva km 3+880 (after floods in May 2014.)

In some locations, warmer temperatures are projected to cause more winter precipitation to fall as rain instead of snow. Winter flooding could occur more frequently if the frozen ground cannot absorb precipitation. Landslides and wash-outs could also occur more frequently, as saturated soils are exposed to more rainwater. Drought in some areas could increase the likelihood of wildfires that reduce visibility and threaten roads and infrastructure.

5 Adaptation options

Considering significant impacts from climate change there is the need to determine how road transport infrastructure will adapt to the inevitable changes. This will affect design, construction, maintenance and operation of new and existing road infrastructure. As with many hazards, the best way to avoid damage caused by climate change are prevention and preparedness. So, the adaptation options are:

1) More accurate and timely weather prediction and communication of storm warnings in real time to those potentially in harm's way have to be more important. Projected increases in extreme weather and climate underscore the importance of emergency response plans in vulnerable locations and require that transportation providers work more closely with weather forecasters and emergency planners and assume a greater role in evacuation planning and emergency response.
2) Monitoring infrastructure conditions, particularly the impacts of extreme climate changes, offers an alternative to preventive retrofitting or reconstruction of some facilities. Greater use of technology enable infrastructure providers to monitor and receive advance warning of potential failures due to water levels and currents, wave action, winds, and temperatures exceeding what the infrastructure was designed to withstand. As the climate changes, many countries have experience new climate induced weather patterns. So, identifying the best practices and sharing information as the climate changes is the way for adaptation measures.
3) Conditions such as temperature, freeze–thaw cycles, and duration and intensity of precipitation determine subsurface and foundation design, choice of materials, and drainage capacity. Many infrastructure components are currently designed for the 100-year water level, but projections indicate that what is today's 100-year precipitation event is likely to occur every 50 or perhaps even every 20 years by the end of the current century. The development of appropriate design standards to accommodate climate change is one of several possible adaptation strategies. Developing new standards is a time-consuming process. Thus, there is a need for a selective, risk-based approach to making changes in standards that focuses first on long-lived facilities, such as bridges and large culverts.
4) Transportation planners are not currently required to consider climate change impacts and their effects on infrastructure investments, particularly in vulnerable locations. One of the most effective strategies for reducing the risks of climate change is to avoid placing road infrastructure in vulnerable locations.

Key design parameters corresponding to vulnerable infrastructure identified based on the literature and studies related to the climate event are shown in the Table 1.

Table 1 Key design parameters corresponding to vulnerable infrastructure

Infrastructure element	Design parameters needing consideration
Road and pavement	Camber to quickly remove surface water Stiff bitumen to withstand heat or workable in winter Soil moisture and maintenance planning
Bridge	Flood estimation, return period, design discharge High flood level Length of waterway Design load, wind load Foundation, river and bank protection
Tunnel	Flood estimation, return period, design discharge
Drains	Discharge estimation (return period) Size and shape of drain Drain slope
Culvert	Discharge estimation (flood return period) Size and discharge capacity Cross slope
Side slope	Slope protection work Subsurface drains Catch drains

6 Conclusion

Bosnia and Herzegovina is subject to natural hazards such as flooding, landslides, snowfall and droughts. It is expected that the frequency and magnitude of these events will increase as a result of climate change, making infrastructure damage and travel disruption that will affect the country's economic development.
Engineers are taught that water is the greatest enemy of transport infrastructure, and unfortunately climate change is leading to an increase in floods and storms.
Adaptation to climate change means anticipating the effects of climate change and taking appropriate action to prevent or minimise the damage they can cause. Early action will save on damage costs later. Adaptation strategies are needed at all levels of administration, from the local to the international level.
In Bosnia and Herzegovina, the legislation absolutely does not cover the methods, techniques, and tools for project management in application measures for adaptions to climate changes [7]. So, one of the main steps in the fight against the impacts of climate changes on road infrastructure is the adoption of legal regulations that will treat this area. Facing this situation road authorities need to be supported with appropriate strategies to ensure reliability, availability, maintainability and safety (RAMS approach) of road infrastructure.

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