URBAN DEVELOPMENT CONSEQUENCES OF THE RIVERINE FLOODS IN THE WESTERN BALKANS: ANALYSING BELGRADE

SANTIAGO LEMA-BURGOS | DIVISION OF RISK MANAGEMENT AND SOCIETAL SAFETY | LTH | LUND UNIVERSITY, SWEDEN

Urban development consequences of the riverine floods in the Western Balkans: Analysing Belgrade

Santiago Lema-Burgos

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Abstract
Rapid urbanisation coupled with unplanned development create the perfect recipe for a disaster, the risk of which has increased with climate change-related uncertainties. Belgrade's high population growth rate and exposure to riverine flooding presents such a case. This study aims to provide insight into the relationship between urban development and riverine flooding in Belgrade and thereby induce a raised level of resilience in relation to riverine flood risk. To achieve this aim, this thesis seeks to answer: What are the effects of urban development in Belgrade on the riverine flood hazard? In this context, urban development is seen as a combination of urbanisation and spatial planning.

The research question is answered using three different methods: (1) a literature study to understand the effects of urban development on flooding, (2) a secondary data analysis to guide the description of Belgrade's riverine flood risk and urban development situation, and (3) semi-structured interviews with open questions. The results show that urban development processes undoubtedly produce both positive and negative environmental changes. The effects are found to be mixed in Belgrade: Urban development plans have been poorly implemented in Serbia, but signs of improvement have been visible over the past few years. For instance, the Serbian Government has designed hazard-based land use plans and a new strategy for disaster risk management.

Riskhantering och samhällssäkerhet
Lunds tekniska högskola
Lunds universitet
Box 118
221 00 Lund

http://www.risk.lth.se

Telefon: 046 - 222 73 60

Division of Risk Management and Societal Safety
Faculty of Engineering
Lund University
P.O. Box 118
SE-221 00 Lund
Sweden

http://www.risk.lth.se

Telephone: +46 46 222 73 60

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Summary

In 2018, 55% of the world's population resided in urban areas and this number is expected to increase to 68% by 2050. In areas already exposed to different geophysical or weather-related natural hazards enhancing societal resilience is vital for reducing vulnerability, protecting lives and ensuring development. Factors including rapid urbanisation, increasing population density and the growth of unregulated housing, have resulted in the converse outcome by increasing vulnerabilities and raising exposure to natural hazards. Within the diverse natural hazards affecting the Western Balkan region, riverine flooding is the most common, with all six countries facing high risk levels. As the region's largest city and due to its high flood risk level, Belgrade is the most distinctive case.

This thesis contributes towards the understanding of the relationship between flooding and urban development in fast-growing cities. The study's main objective is to specifically focus on the positive and negative effects of urban development over the riverine flood risk. By understanding the connections between urban development and riverine flood risk, this thesis contributes with the generation of knowledge that can be used to augment the city's resilience, and research focusing on the identification of means to reduce riverine flood vulnerability. To achieve this aim, this thesis seeks to answer: What are the effects of urban development in Belgrade on the riverine flood hazard? For a more structured answer, the thesis answers two sub-question: (1) what has been the nature of the urban development process in Belgrade?; and (2) in what way urban development contributes towards vulnerability in terms of riverine flooding? This question was answered by using three different methods: (1) a literature study to understand the effects of urban development on flooding, (2) a secondary data analysis to guide the description of Belgrade's riverine flood risk and urban development situation, and (3) semi-structured interviews with open questions.

The literature demonstrated that urban development always produces landscape and environmental changes. It is critical to tailor urban development plans to the context and region in which they will take place in order to maximise their benefits and to reduce risks as much as possible. A well-formulated urban development process in a flood-prone area can serve to reduce the people's vulnerability and exposure to hazards by (1) helping to control the flow of water through water channels, and (2) enhancing water storage through infiltration.

Despite the different positive effects of urban development, urbanisation mostly increases flood risk (Hollis, 1975). The direct results of urban development, such as the concentration of population and infrastructure, raises vulnerability to flooding. The most significant negative effects are: (1) alteration of the water cycle by altering the relationship between the precipitation and runoff processes; and (2) increased frequency of flooding, resulting from impermeable surfaces impeding water infiltration, the obstruction of natural paths affecting

water flow to streams and channels, and from the production of solid waste, debris or sediments that can obstruct and clog drainage and channel systems. The natural hazard spatial distribution map (Figure 7) shows that a vast area of the city's urban space is considered flood-prone. The two central urban cores, would be profoundly affected by flooding and heavy precipitation. The two cores are, in the east bank, the 'Old City' (compound by Stari Grad, Savski Venac and Vračar municipalities) and in the west bank, Novi Beograd (also known as the New Belgrade).

Interviewees state that Belgrade's recent urban development plans have been poorly implemented. For instance, many of the buildings constructed within the city did not satisfy legal requirements, such as terrain adequations and the use of appropriate materials. The region with the highest concentration of these illegal buildings is the area on the northern bank of the Danube, which is heavily exposed to riverine flood risk. Thus, it is identifiable as an area that requires more robust measures to reduce the flood risk and inhabitants' vulnerabilities. It is important to mention that the city's disaster risk management (DRM) systems have been gradually improving in recent years; however, there is still significant scope for improvement. The interviewees note that some additional systems for flood protection (e.g. drainage) are old, insufficient in some parts of the city, and are often non-existent, especially in the Old City.

Interviewees also state that the urban development plans have been mismanaged and poorly implemented previously. This situation, in conjunction with other factors, such as rapid population growth, migration and rushed development in the post-war period, have caused buildings and infrastructure to be constructed without adherence to adequate safety standards. However, the city's urban development has been slowly improving over recent years. Building codes have been established and enforced, and activities related to DRM and climate change adaptation have been integrated into the country's urban plans. Nevertheless, there is still scope for improvement.

Recently, the Government of Belgrade has sought to improve this situation and protect its citizens. The recent urban development plan of the city, the Master Plan of Belgrade (MPB), was developed after considering risk assessments. It aims to satisfy the needs of the increasing population whilst reducing the various hazards affecting the city. This goal is aided by the production of land use maps, which mark areas according to their possible uses and prevent construction in some areas based on their terrain types and exposure to natural hazards.

The Government of Belgrade is starting to act proactively by designing and implementing various artificial infrastructural protection measures (e.g. retention basins) and non-structural protection measures (e.g. DRM laws and hazard-based development plans). These measures aim to tackle the multiple natural hazards threatening the city and reduce associated vulnerability. However, much more could be implemented to further increase the city's resilience.

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BBB	Build Back Better
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EU	European Union
EWS	Early Warning System
GFDRR	Global Facility for Disaster Reduction and Recovery
MPB	Master Plan of Belgrade
NBS	Nature-Based Solution
NGO	Non-Governmental Organisation
UHI	Urban Heat Island
UN	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction

1. Introduction

In 2018, 55% of the world's population resided in urban areas (UN DESA, Population Division, 2018). By 2050, this number is expected to increase to 68% (UN DESA, Population Division, 2018). In areas already exposed to different geophysical or weather-related natural hazards enhancing societal resilience is vital for reducing vulnerability, for protecting lives and for ensuring development (GFDRR, 2019; UNISDR & World Bank, 2008). However, factors including the rapid urbanisation of regions, ineffective infrastructure maintenance, increasing population density and growth of unregulated housing, among many others, have resulted in the converse outcome by increasing vulnerabilities and raising exposure to natural hazards (UNISDR & World Bank, 2008; World Bank, 2018). If not conducted with due regard for mitigating natural hazards, urban development becomes a vicious circle, not only by concentrating large groups of people within hazard-exposed areas but also by worsening the effects of those hazards. Human activity can, for instance, destroy protective barriers and natural buffer zones (World Economic Forum, 2019).

According to the UN DESA (2018) projections, the Western Balkans' urban population is expected to increase as well. For example, a UN DESA (2018) report shows that, in 2010, the percentage of Albania's population residing in urban areas was 52.2, but that this figure is projected to increase to 78.2 by 2020. Furthermore, this report estimates similar increases in urban populations for other Western Balkan countries. The Western Balkan[1] region is affected by different natural hazards, such as earthquakes, extreme temperatures, droughts, forest fires, windstorms, and floods (UNISDR & World Bank, 2008). Within these diverse natural hazards, riverine flooding is the most common, with all six countries facing high risk levels (GFDRR, 2019; UNISDR & World Bank, 2008). For instance, in highly exposed areas, there is a high probability that a potentially-damaging flood will occur once every 10 years (GFDRR, 2019), thereby regularly affecting the people living in the nearby municipalities.

Worsening this situation, the ongoing effects of climate change and rapid urbanisation processes are increasing people's vulnerability to riverine flooding in the region (World Economic Forum, 2019). To find the best approach for increasing societal resilience and therefore protecting human lives in the region, it is necessary to understand the regional urban development process, whilst devoting special attention to how this process affects both the floods' frequencies and consequences.

As the region's largest city and due to its high flood risk level, Belgrade is the most distinctive case. This thesis therefore considers the specific case of Belgrade, to understand the urban

[1] In this thesis, the Western Balkans region is considered to consist of Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia and Serbia, such that Balkan member countries of the European Union (EU) are not included. This region is grouped upon the basis of similar geographies, climate and weather conditions, as well as historical and economic linkages.

development consequences on the riverine flood hazard. This section starts by explaining the primary research objective and questions to be analysed, followed by the case background.

1.1. Purpose and objectives

This thesis contributes towards the understanding of the relationship between flooding and urban development in fast-growing cities. This study focuses on a single case. However, the findings can be used to analyse other similar contexts, in particular other Western Balkan countries due to the presence of shared environmental contexts. The study's main objective is to specifically focus on the positive and negative effects of urban development over the riverine flood risk. In doing so, it analyses the challenges present in implementing disaster risk management (DRM) activities with regards to the city's land use planning and urban development plans. By understanding the connections between urban development and riverine flood risk, this thesis contributes with the generation of knowledge that can be used to augment the city's resilience, and research focusing on the identification of means to reduce riverine flood vulnerability, as well as embrace, strengthen and replicate positive effects across the region.

1.2. Research questions

This study aims to answer the following research question: *What are the effects of urban development in Belgrade on the riverine flood hazard?* Answering this question helps to achieve the thesis' purpose and objectives mentioned previously. Additionally, the following sub-questions are considered in order to provide a more structured and robust result: (1) *What has been the nature of the urban development process in Belgrade?*; (2) *In what way urban development contributes towards vulnerability in terms of riverine flooding?*

This study employs an inductive research logic, an approach that requires to gather data about predetermined characteristics to, therefore, draw specific conclusions and generalisations (Blaikie, 2010; Creswell, 2013). This process is further explained in the methodology section.

By answering these questions, the thesis provides an understanding of the link between urbanisation and flood risk. The results will help to plan for future risks that emerge from the interaction between two major issues in contemporary societies: climate change and demographic change.

1.3. Regional background

Flooding in the Western Balkan region is caused by different factors, mostly related to the region's location and geography, which is marked by dramatic mountains and extensive coastlines, ensuring that the region is subjected to both cold winters and warm summers (UNISDR & World Bank, 2008). Heavy rainfall, which occurs mostly between March and May, can cause sudden floods with high flows, possibly accompanied by landslides (UNISDR & World Bank, 2008). This was the cause of the flood that affected Bosnia and Herzegovina, Croatia and Serbia on May 23, 2014. It was the heaviest flood to hit Bosnia and Herzegovina, and Serbia since records began, affecting around 39% of the Bosnian population and 22% of Serbians (ACAPS, 2014). Climate change is also worsening this situation with precipitation levels projected to increase by 10% every 10 years in mountainous areas (Vuković & Vujadinović, 2018). The following subsection provides more information about the Serbian context.

1.4. Serbian background

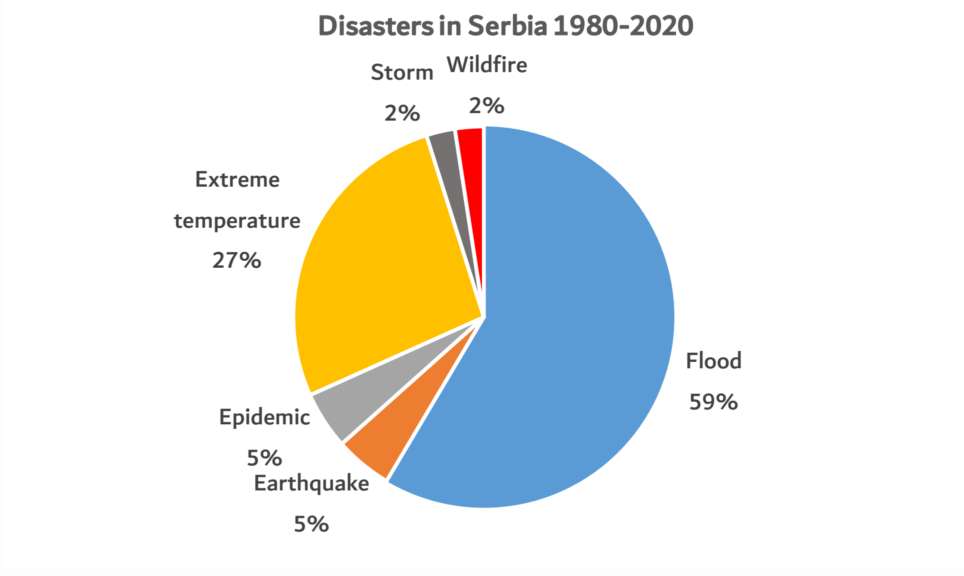

Figure 1. Natural disasters in Serbia 1980-2020.
Data source: EM-DAT: The Emergency Events Database - Université Catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium (2020).
Note. From 1990 to 2006, the data shown is for the unified state of Serbia-Montenegro.

Considering the specific case of Serbia, Figure 1 provides a visual demonstration of the flood hazard weight relative to other natural hazards affecting the country. The figure shows that 59% of the disasters affecting Serbia between 1980 and 2020 were flood related. Compared to other disasters in the same period, floods doubled in percentage the second most common disaster, extreme temperature.

The population information gathered from the UN DESA (2018), shown in Appendix A – Population data and trends in the Western Balkans, demonstrates that Serbia has the highest population in the Western Balkan region, with an estimated 8,704,000 inhabitants in 2020. Serbia's large population more than doubles the second most populated country, Bosnia and Herzegovina, which has an estimated population of 3,498,000. Additionally, the UN DESA (2018) trends show that 63.7% (5,041,000 people) of the total Serbian population will be living in urban areas by 2040, thus representing an increase of 15.8% on the total population residing in urban areas in 2010.

Riverine flood risk maps collected using the 'ThinkHazard!' web tool from the Global Facility for Disaster Reduction and Recovery (GFDRR) (2019) mark the five most populated cities in each country using information obtained from the most recent national census (see Appendix B). Figure 2 shows that the three largest Serbian cities—Belgrade, Novi Sad and Niš—are considered as 'high-risk', meaning that the majority of the country's urban population is exposed to a devastating riverine flood once every 10 years. Therefore, it is important to consider the case of Belgrade, as being Serbia's largest city.

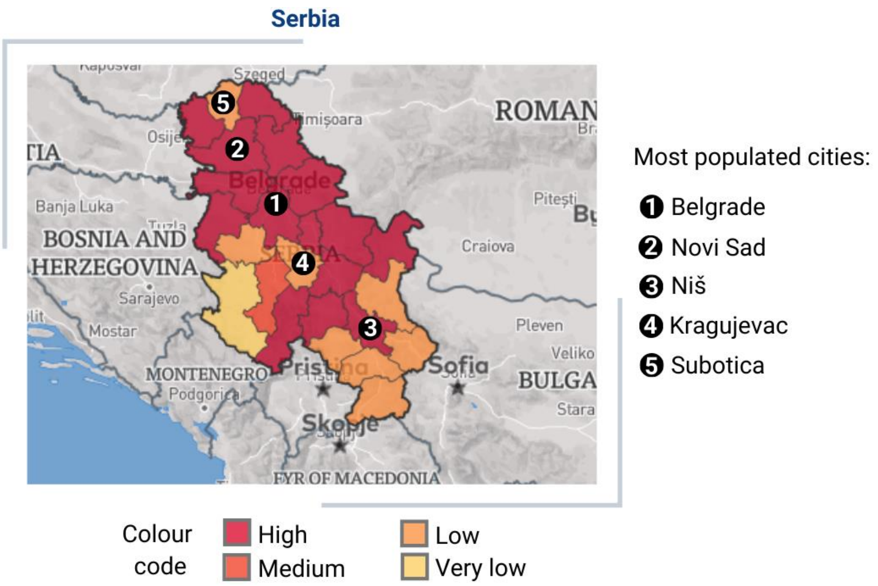

Figure 2. Riverine flood risk map of Serbia pointing the five most populated cities.
Note. Adapted from GFDRR (2019).

1.5. Belgrade background

Belgrade is the most distinctive case from the country of Serbia, and the whole Western Balkan region. It has the highest population in the region, with 1,166,763 inhabitants (Statistical Office of the Republic of Serbia, 2014), which is more than double that of Skopje, the second-largest city in the region, with 506,926 (Republic of Macedonia State Statistical Office, 2005). Both the population data and the riverine flood risk levels, as noted in Appendices A and B, make Belgrade the most appropriate case for the analysis of urban development effects on flood risk. Moreover, it provides a mechanism for relating these effects to other countries within the Western Balkan region, considering the extensive regional similarities.

One of the main reasons why Belgrade is subject to a high riverine flood risk is the city's geography. Belgrade is located at the confluence point of the Danube and Sava rivers, with the Danube flowing from north-west to south-east and the Sava flowing from south-west to the north (New World Encyclopedia, 2019). Figure 3 provides a visual satellite view of Belgrade, displaying both rivers, in which the Danube river appears as 'Dunavac', and a portion of the Sava as 'Savsko Jerezo'. Although the central part of the city is slightly elevated, most of the urban terrain is flat as part of an alluvial plain, with the highest peaks lying south of the city's outskirts (New World Encyclopedia, 2019).

Figure 3. Map showing the location of Belgrade, Serbia.
Source: Google Earth (2019) Belgrade, Serbia. 44°47'34.77" N 20°29'55.87" E, Eye alt 23.27 km.

The river banks in Belgrade cover around 200 km long of the city's urban area, representing a significant proportion of the city's territory (New World Encyclopedia, 2019). This combination of flat alluvial terrain and river banks, and the bordering mountainous territory, which is mostly covered in snow during winter due to the region's continental climate, increases the city's exposure to riverine floods. However, these are not the only causes of high riverine flood risks in the city, as human activity has direct effects on the degree of exposure and vulnerability, which are discussed in the following sections.

2. Conceptual framework

This section clarifies the main concepts used throughout this thesis. Some concepts are taken from direct sources, whereas others are combined from two or more official sources. These concepts have been interpreted differently across disciplines. Hence, a conceptual framework was deemed necessary to clarify the stance of the thesis in relation to these concepts. In this thesis, these concepts serve to analyse the results, discussion and conclusion.

The primary concepts used are *urban development*, *riverine flood*, *vulnerability* and *resilience*. These concepts are not just defined independently, since the relationship between each is also presented. The specific relationship between the concept of urban development and the riverine flood is also highlighted in the results regarding the case of Belgrade.

2.1. Urban development

Although the concept of urban development might invoke differing conceptions, for instance, economic, social or cultural development (UN DESA, Population Division, 2019), this thesis considers urban development from the perspective of urban population growth rate, stating the concept as a combination of urbanisation and spatial planning. Urbanisation is the increase of people living in urban areas (Geographical Association, 2020), and spatial planning is the attempt to influence and control the use of land (FAO, 2015). Urban development is defined as a complex system which integrates the different sectors involved in the process of transformation of the built environment as residential expansion and the creation of cities, converting rural areas into urban spaces (UN DESA, Population Division, 2019).

The urban development process also includes renovation activities to redevelop failing or decaying regions. Amongst the sectors included within urban development processes are civil and design engineering, architecture, project management and environmental planning. Other relevant aspects that shape the urban development process are the investments of both public and private sector actors and their associated priorities (UN DESA, Population Division, 2019).

Structural changes within a society heavily influence the process of urban development. These changes include economic and political shifts, migration patterns, globalisation and the surge of new technologies (Schneider-Sliwa, 2015). A significant structural change reforming society is the increase in the world's urban population, either by natural growth or by people migrating from rural areas. Because of these changes, adequate urban development processes are now more vital than ever before in order to satisfy present and future needs. One approach to achieving manageable urban development is by combining it with a sustainable development approach (WCED, 1987).

Insufficient urban development planning could have direct negative impacts on the degree of exposure and the vulnerability of communities to natural hazards. These impacts could vary for different peoples (Anguelovski, et al., 2016; Rumbach & Németh, 2018). In some cases, it could even expose the area to new hazards not previously present by, for instance, damaging natural hazard buffer zones and barriers (PreventionWeb, 2015). If the urban development process is undertaken rapidly, informally, or is poorly planned, and within the context of extreme poverty, the situation will likely worsen (PreventionWeb, 2015; UN DESA, Population Division, 2019). All of these factors could lead to an increase in disaster risk and create new risks (Rumbach & Németh, 2018). Therefore, in order to reduce the negative effects of urbanisation efficiently, it is necessary to incorporate DRM strategies into urban development plans.

However, in order to generate a comprehensive plan, it is essential to first understand the urban growth trends of the region, which provides information about the current situation and the areas of greatest need, as well as understand the hazards affecting the region, from where these risks stem and how to reduce the level of associated vulnerability and exposure (UN DESA, Population Division, 2019).

2.2. Riverine flood

Flooding can have different sources and effects. Therefore, in order to ensure proper flood risk management, it is critical to understand which type of flood hazard must be controlled and the factors that convert flood hazards into disasters, to implement resilience measures accordingly. Floods can be caused by meteorological events, like heavy rainfall, coastal storms, or snowmelt, by geophysical events, such as earthquakes, which can cause tsunamis, or by human activity, such as from infrastructure damage (i.e. a dam or sewage-system failure) (Rudari, 2017).

In part due to their range of sources, of all the natural hazards floods are the most common, possessing both the highest frequency and the most extensive geographical distribution (Rudari, 2017). Some of the most common types of floods are riverine, flash, urban, fluctuating lake levels, and coastal floods (Rudari, 2017; Wright, 2007). This thesis focuses on riverine flood hazards, since this is the most common type of flood event in the world (Wright, 2007) and the one affecting the Western Balkans region, specifically Serbia, the most.

Riverine flooding, also known as fluvial flooding, as its name indicates, originates in rivers and water streams. This type of flooding occurs when the natural or artificial banks of a stream or river are overflown due to a sheer excess of water volume, either from upstream flows or water surface runoff. Exceeding the channels' capacity, water then flows into adjacent low-lying areas (Wright, 2007). The timing, depth and magnitude of riverine flooding varies according to the source, location and geography.

Riverine flooding tends to inundate an area for days or even weeks in flat and low-lying areas, since floodwaters move slowly due the lack of steed terrain to continue the water flow (Wright, 2007). Such floods are generally worse in urban areas covered with artificial materials, as this reduces water absorption. This situation is the case of when Belgrade is flooded.

2.3. Vulnerability

Vulnerability is defined as a specific characteristic and circumstance of a community, system, asset, individual or any other entity, that makes it susceptible to the potential destruction, damage, disruption or any other form of negative impacts of a hazard (Coppola, 2011; UNDRR, 2017; Wisner, Blaikie, Cannon, & Davis, 2004). Therefore, vulnerability is the inability to anticipate, withstand, cope with, and recover from both specific external and internal hazards (Twigg, 2004).

Vulnerability is a complex characteristic, composed by a mix of physical, social, economic and environmental factors or processes. These factors derive primarily from class, gender or ethnicity, resulting in some human groups to be more vulnerable than others (Bankoff, Frerks, & Hilhorst, 2004; Coppola, 2011). Specifically speaking about people's vulnerability, it is tightly related to the individuals' perceptions and knowledge (Bankoff, Frerks, & Hilhorst, 2004). Hence, it is essential to understand why people exhibit certain behaviours and how they act in different circumstances, to reduce vulnerabilities and augment resilience.

2.4. Resilience

Resilience is a heavily debated concept (Alexander, 2013). Although the concept was initially developed within the field of ecology around fifty years ago (Djalante, Holley, & Thomalla, 2011; Goldstein & Brooks, 2006), it has since been employed in different contexts (Alexander, 2013). In the context of hazards three important conceptualisations have emerged that understand resilience as: (1) an ability to bounce back to the equilibrium point after any disturbance situation occurs; (2) a buffering capacity, related with how much pressure the system, society or community can sustain before it shifts from one stable state to another, finding a new equilibrium-point; and (3) an ability to adapt after any disturbance, therefore having a constant adaptive change instead of a single equilibrium point (Becker, 2014; Pendall, Foster, & Cowell, 2010). This thesis follows the third definition provided, merged with the one used by the United Nations Office for Disaster Risk Reduction (UNDRR) (2017). Therefore, resilience is considered here to be: the ability of a system, community or society to anticipate, recognise, adapt to and learn from the effects of any disturbance to which the system is exposed, ensuring the reach of the equilibrium point through a time-efficient risk management approach. This thesis's systems consist of the city of Belgrade, looking to augments the system's resilience to manage urban flooding risks.

3. Methodology

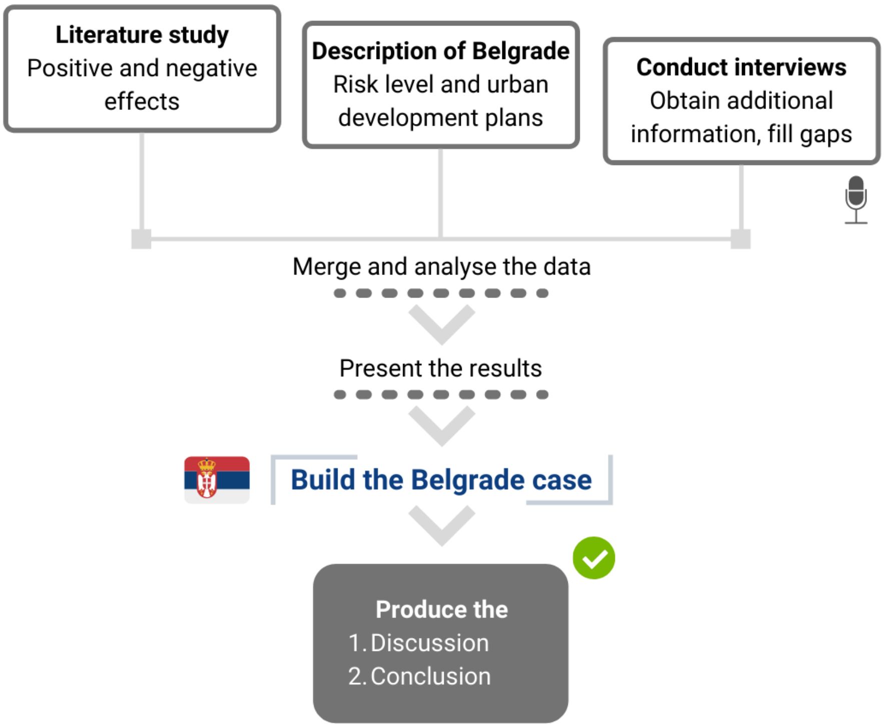

Figure 4. Representation of the research flow.

This thesis follows the inductive logic of inquiry which aims to build new theories from observations and analysed data, rather than testing existing theories (Blaikie, 2010; Creswell, 2013). Hence, the inductive approach requires the gathering of data on predetermined characteristics to draw specific conclusions (Blaikie, 2010). Additionally, this is a qualitative study. The methodology used in this thesis is presented in this section. Figure 4 provides a visual representation of the research process.

A literature study was undertaken in order to observe and understand the positive and negative effects of urban development for the riverine flood hazard. Relevant literature was found through online searches (Google and LUBsearch) using combinations of keywords—mainly 'urbanisation and floods', 'effects of urbanisation in flooding', and 'consequences of constructions in river basins'. From the various results, the title was used as a first filter to determine which were going to be preselected. To make the final selection, the abstract of each preselected document was read. The chosen literature was selected according to its source, prioritising sources like peer-reviewed articles, government documents and United Nations (UN) or Non-Governmental Organisations (NGO) reports. Both scientific and grey literature were used aiming to find as much information as possible, looking to achieve the saturation of data. The information gathered from this documentation process was categorised into two groups—the positive and the negative effects.

Following the literatures analysis, a description of the situation in Belgrade was formulated with two distinct focuses: the city's riverine flood risk and urban development situation. For the former, maps showing the elevation of the city and natural hazard risks were obtained from official sources. For the latter, secondary data about ongoing and future urban development plans were gathered. Two urban development plans were collected from the Master Plan of Belgrade (MPB). Both were in Serbian; however, they were translated into English by this study's author. To complement the maps, and to obtain extra information and corroborate zoning structures, a visit to the city was undertaken. The information collected on both the flood hazard risk and the urban development plan was merged to identify which areas of the city are most at risk and to inform final findings.

Next, semi-structured interviews with open-ended questions were carried out. Two key informants, members of the United Nations Development Programme (UNDP) were interviewed. One interviewee working for the Serbian Country Office and the other in the Regional Office for Europe and Central Asia. These participants were selected to obtain different perspectives from the local to the regional level. Given the opportunity, more stakeholders would have been interviewed, but paucity of time was something that had to be considered. Appendix C provides an interview guide, detailing the questions asked, and providing interviewees' information. The interviewees are experts in climate change adaptation and DRM, and posses a vast experience working in the region. The interviews were conducted after forming the description of Belgrade. Therefore, interviews were intended to complement the research rather than heavily rely on them, fill existing gaps and corroborating information gathered.

The literature study, the analysis of Belgrade and the interviews are used to build a comprehensive and robust picture of the situation in Belgrade. The discussion section presents some recommendations useful to tackle some of the identified vulnerabilities to riverine flooding, and therefore increase the city's resilience. These are not an exhaustive list, but constitute some important ways of moving forward on DRM.

Both the interviews and the secondary data analysis are chosen as methods of analysis as they develop an in-depth picture of the case (Creswell, 2013) and supply higher-quality data than individual research given the wealth of resources available (Blaikie, 2010). Note that the main data collection method is secondary data analysis, while the interviews were complementary. The data collected is qualitative in nature. Following Blaikie (2010) and Creswell (2013), conventional content analysis is used because of its usefulness in analysing qualitative data across sources, including official documents, secondary sources and interview transcriptions, which form the main data collection methods of this thesis. This data analysis method was selected since using multiple sources helped to triangulate the information.

Conventional content analysis allowed the data to be fragmented into different themes, which are subsequently categorised and compiled into a matrix. The matrix provides a structured overview of the data and assists in the analysis and comparison of data. Furthermore, the conventional content analysis matrix can summarise large amounts of information (Blaikie, 2010; Creswell, 2013), and identifies the most crucial aspects. This method's bottom-up approach was helpful in the identification of themes and combining these with the conceptual framework.

Three significant limitations of the approach used in this study were encountered. The first relates to the use of secondary data, much of which, including urban development plans, was in Serbian, making the translation of materials necessary. Nevertheless, the author's knowledge of the Cyrillic alphabet and the use of web-based tools helped with this translation process. The second limitation was the availability of the possible interviewees and their willingness to be interviewed. While numerous possible interviewees were approached, only a few answered positively to the first communication attempts, but stop answering back, since most were responding to the novel COVID-19 pandemic. Therefore, it was necessary to use the UNDP's network in order to obtain input from interviewees. Two interviewees were obtained using the UNDP's network. The last limitation relates to the time constraints in obtaining data (including the collection of secondary data, conducting site visits, and arranging interviews), analysing information, and producing tangible results before the deadline. This problem was addressed by organising a clear structure for conducting the study.

4. Results

This section presents the results obtained following the methodology outlined in the previous section. This section begins by presenting the findings of the literature study, which aims to provide an understanding of the positive and negative effects of the urban development process regarding the riverine flood hazard. The findings demonstrate the relationship between these concepts, rather than identifying circumstances in a specific city or region. The data obtained from the literature review concerns only the direct impacts of urban development over the flood hazard, and not indirect effects produced by other macro-level processes (e.g. climate change).

The rest considers how the information obtained is used to develop a description of Belgrade's riverine flooding vulnerability and urban planning. In order to provide a comprehensive and structured description of the current situation, the data obtained from the documentation and personal visit is divided and presented in various subsections explaining the uneven exposure to flooding, the most vulnerable sectors to flooding within Belgrade, and the implementation or urban development plans.

The second and third parts of this section present the information obtained from the interviews. This information is used here to complement and support the case. The interviews also provide new information from the one obtained for the description of the city.

4.1. Effects of urbanisation on flooding

This section is informed by the analysis done using literature findings. While analysing the effects of urban development or urbanisation on the flood hazard, the literature generally notes negative effects.

4.1.1. Positive effects

Urban development always produces landscape and environmental changes. It is critical to tailor urban development plans to the context and region in which they will take place in order to maximise their benefits and to reduce risks as much as possible. A well-formulated urban development process in a flood-prone area can serve to reduce the people's vulnerability and exposure to hazards. The following categories of benefits were identified during the literature study.

a. *Controlling the flow of water through water channels.* One way in which urban development positively influences the flood hazard is through the management of water channels and streams within the urban area. Multiple sources clearly state that adequate drainage and channelling systems are essential to reduce flood risks significantly (Booth & Jackson, 1997; Huong & Pathirana, 2013; Konrad, 2003; Leopold, 1968; Mukherjee, 2016). The efficiency of the existing natural channels and streams could be increased with artificial structures, such as by straightening or deepening channels, as this raises the water discharge speed and aids debris flow (Booth & Jackson, 1997; Konrad, 2003). It is therefore critical to weigh up the benefits from these structural measures against the risk of influencing flooding risks downstream (Konrad, 2003).

For the channels approach to work efficiently, some vital aspects should be considered. These aspects include the periodical maintenance of the drainage system, the cleaning of debris clogging the system, the designing of well-defined paths, consideration of underground paths when necessary and the materials' infiltration capacity, among other aspects (Mukherjee, 2016). Some channels, according to their design and location, could work as temporary storage spaces for runoff excess (Leopold, 1968), balancing the water flow across the whole drainage system. Comprehensive urban development processes could also include flood storage spaces, such as water reservoirs, upstream in order to reduce flood peaks by extending the water flow period (Leopold, 1968).

b. *Enhance water storage through infiltration.* Proper urban development plans help to control the amount of runoff ending up in water streams. These plans increase infiltration capacity, by promoting water storage in underground terrain and avoiding the bursting of streams by reducing, as much as possible, the surface area of impermeable materials (Konrad, 2003). Higher infiltration can be achieved by using adequately designed artificial materials—for example, permeable pavements being used in open spaces such as car parks and roads (Konrad, 2003). Other solutions for increasing infiltration consider the use of soil amendments and infiltration trenches, which complement the use of permeable materials (Konrad, 2003).

c. *Risk* assessment. Comprehensive urban development plans based upon accurate risk assessments which identify the hazards affecting the studied area, their sources and their possible consequences, allow the design and implementation of measures that increase the area's resilience (Huong & Pathirana, 2013). Risk assessment could also pinpoint the flood-prone areas, which could decrease the flood risk of adjacent areas. These flood-prone spaces should be used as parks, playgrounds, or other natural and open spaces which can tolerate seasonal flooding (Konrad, 2003).

If the identified flood risk is too high, other structural measures are useful and should be considered for reducing risk. These measures include the construction of floodwalls, levees, detention basins and high-flow bypass channels (Konrad, 2003). However, it should be noted that before implementing any hard-structural measure, it is crucial to analyse their possible effects on the landscape, the environment and the population.

4.1.2. Negative effects

Despite the main three categories of positive effects of urban development mentioned previously, urbanisation mostly increases flood risk (Hollis, 1975). The direct results of urban development, such as the concentration of population and infrastructure, raises vulnerability to flooding (Huong & Pathirana, 2013). This situation worsens when the urban development process is undertaken rapidly and is unplanned, while attempting to satisfy the needs of a fast-growing urban population (Huong & Pathirana, 2013). Urban development does not affect only large streams with already existing flooding intervals, but even transforms small streams, potentially making these high risk streams for flooding (Jha, et al., 2011). The most significant negative effects are presented below.

a. *Alteration of the water cycle.* Urban development unquestionably has a substantial impact on the water cycle (Huong & Pathirana, 2013; Leopold, 1968). Urban development can diminish the efficiency of the water cycle system within the urban area and its surroundings (Booth & Jackson, 1997) by altering the relationship between the precipitation and runoff processes (Huang, 2019; Huong & Pathirana, 2013). Even small-scale urban development causes a significant degradation in water bodies (Booth & Jackson, 1997).

b. *Increased frequency of flooding.* The further categorises how does the urban development has negative impact through, impermeable surfaces, obstruction of natural paths, generation of solid waste debris, and elimination of vegetation. The literature states that, in general, the combination of flood seasons, urbanisation, a high percentage of impermeable material coverage and climate change effects, increase both the magnitude and frequency of the riverine floods, affecting the surrounding communities (Mukherjee, 2016; Pattison & Lane, 2012). Urban development can also raise the possibility of flooding events even after low-intensity precipitation (Huang, 2019). Moreover, in some river basins, it is expected that in covering 30% of the river basin's natural floor, the frequency of small floods will increase tenfold and the magnitude of large floods may double (Hollis, 1975).

The reason behind this frequency and magnitude increase is that natural permeable soils are replaced by *impermeable artificial surfaces*, which impede water infiltration, thereby lessening the natural water storage capacity and prompting runoff into water channels (Booth & Jackson, 1997; Hollis, 1975; Huang, 2019; Jha, et al., 2011; Konrad, 2003; Leopold, 1968; Mukherjee, 2016; Pattison & Lane, 2012).

The percentage of coverage by impervious materials, the runoff speed and the volume directed to channels and streams are considered to be principal factors governing the riverine flood risk (Leopold, 1968). On one hand, the drainage network might augment the flood risk within an urban area, as dense and complex drainage and sewage networks reduce the distance that the excess water must travel to reach the main streams and channels, and therefore increase the flow speed (Hollis, 1975; Konrad, 2003). Drainage networks could also elevate the stream water level until the point that the maximum capacity is exceeded (Hollis, 1975).

On the other hand, even from small rainstorms, the runoff excess translates into stream level elevation and faster flow speeds compared with pre-urbanisation averages. It therefore causes the stream to rapidly reach capacity and increases the flood risk, especially for flash floods (Hollis, 1975). Furthermore, this issue with runoff excess and high speeds does not only affect the urban area, but also alters the downstream flows (Jha, et al., 2011), possibly raising the riverine flood hazard in adjacent regions, which, in most of cases, houses rural populations.

The impermeable artificial surfaces that impede water infiltration, including roads, car parks, pathways and construction sites, reduce underground water storage (Hollis, 1975; Konrad, 2003; Mukherjee, 2016). These surfaces do not only limit water infiltration because of their impervious nature but, since they cover the naturally permeable soil and land depressions used for water storage, they also dramatically lessen the land's capacity to absorb, retain and manage rainfall and snowmelt (Hollis, 1975; Jha, et al., 2011; Konrad, 2003; Mukherjee, 2016). Figure 5 shows the relationship between the percentage of impervious surfaces, infiltration and runoff levels.

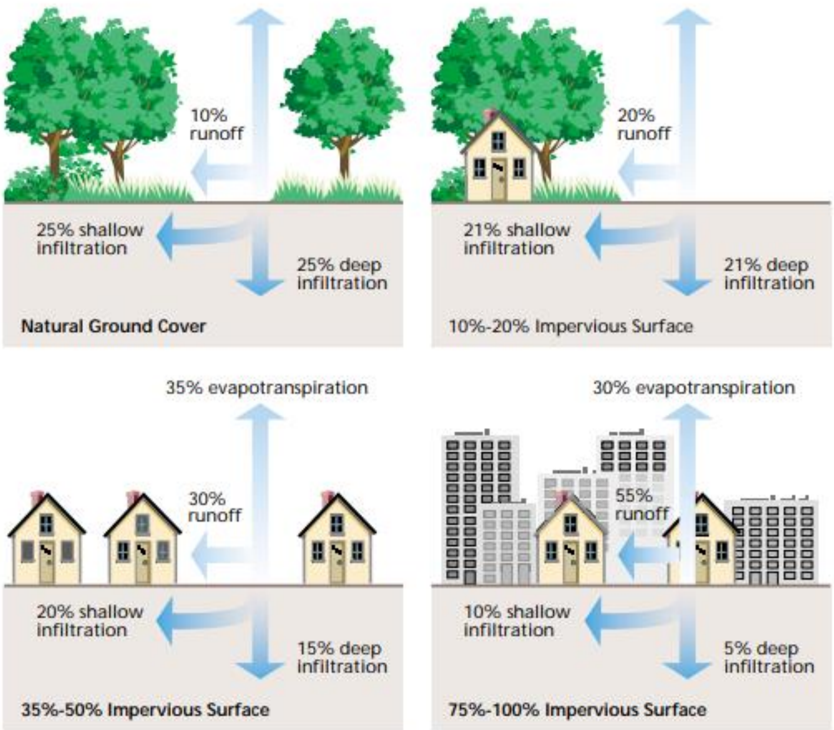

Figure 5. Relationship between impervious cover and surface runoff.
Source: Federal Interagency Stream Restoration Working Group—FISRWG (1998).

Even slightly reduced perviousness rates imply an increase in runoff levels and a rise in overland flow (Hollis, 1975; Jha, et al., 2011; Konrad, 2003; Mukherjee, 2016). Figure5 shows that between 10 and 20% of impermeable surface produces double the amount of runoff compared to the natural state. This situation worsens with more significant urbanisation rates: with 75 to 100% impermeable surface coverage, the runoff is five times greater. Figure 5 also shows that a percentage of the rainwater evaporates. However, the literature asserts that this process is intermittent within urban areas (Huang, 2019); hence, runoff rates might be higher than those presented in the figure, depending on the season. Additionally, the remaining uncovered soil is, to some extent, trampled, flattened, squashed and compacted, thereby lessening its natural infiltration capacity and increasing runoff (Booth & Jackson, 1997; Pattison & Lane, 2012).

The runoff alters as well, with the *obstruction of natural paths* by the construction of infrastructure*,* like transportation networks and buildings, affecting water flow to streams and channels (Jha, et al., 2011). New development impacts the channels negatively, primarily when it occurs alongside the stream and floodplains (Konrad, 2003). This development could narrow the streams' amplitude, modifying, and perhaps restricting, its capacity to contain water flows, by, for instance, raising the water level or the channel's flow resistance (Jha, et al., 2011; Konrad, 2003).

The channel's capacity is also affected by *solid waste, debris or sediments* that result from the urban development process and could end up in water bodies (Booth & Jackson, 1997; Huong & Pathirana, 2013; Konrad, 2003; Leopold, 1968). These materials can obstruct and clog drainage and channel systems, thus increasing the riverine and urban flood risk (Booth & Jackson, 1997; Huong & Pathirana, 2013). Therefore, it is possible to affirm that urban development significantly alters the stability of channels.

An additional factor in this regard is that urbanisation can *eliminate both the streamside and water bank vegetation* (Booth & Jackson, 1997; Huong & Pathirana, 2013; Konrad, 2003; Leopold, 1968). The removal of the natural canopy by the streamside caused by the urban development process limits the water retention abilities of the river basin (Jha, et al., 2011; Konrad, 2003), increasing runoff and raising the riverine flood risk. Moreover, if the water bank vegetation is removed, water resistance is diminished, increasing the streamflow velocities and, thus, the riverine flood risk downstream (Booth & Jackson, 1997; Konrad, 2003). Higher velocities mean more significant sediment transportation, transforming the river basin and streams in the long-term (Konrad, 2003). It is essential to highlight that the adverse effects of urban development tend to be more noticeable in small river basins, since they are easier to accommodate and transform in order to satisfy human needs (Konrad, 2003). Hence, the urban development process can entirely change the landscape of a small river basin, altering the natural cycles in the area.

c. *Effect on the microclimate*. In addition to the physical effects of the urban development process on river systems, the literature notes that this process has substantial effects on local weather and climate patterns (Huong & Pathirana, 2013; Jha, et al., 2011; Konrad, 2003). Urban development also produces hydrometeorological changes, by affecting local microclimates (Huong & Pathirana, 2013)—for example, via the strengthening of the urban heat island (UHI) effect, where urban areas become warmer than their surroundings (Shishegar, 2014). Greenhouse gas emissions and energy consumption increase temperatures in these areas. The absence of vegetation decreases evapotranspiration volumes, limiting the extent to which water vapour cools the surrounding air (Shishegar, 2014). Furthermore, artificial materials used in construction absorb heat, and a high density of buildings prevents wind flows from freshening the area.

Additionally, the UHI effect induces changes in local rainfall patterns, mostly increasing rainfall levels in cities' neighbouring areas, directly increasing the flood risk (Huong & Pathirana, 2013; Jha, et al., 2011). Studies have noted increases—as high as 25% in some cases—in the precipitation levels within these downwind neighbouring areas (Huong & Pathirana, 2013; Shepherd, Pierce, & Negri, 2002). Also, climate change, which is evidently caused by human activities, is altering precipitation patterns. Therefore, the global water cycle is likely to be accelerated, resulting in less predictable weather, more torrential rainfall and a raised likelihood of extreme weather events and storms (IPCC, 2012).

It is worth noting that both the positive and negative effects listed in this section should not be considered exhaustive, as other aspects influence the relationship between urban development and riverine floods. However, these only represent the most prominent effects mentioned by the reviewed literature. In order to avoid these adverse effects to the greatest extent possible, it is essential to first understand the context to provide adequate focus, and aptly tailored solutions and recommendations. The next section provides a more in-depth description of the city of Belgrade, providing a better understanding of the study's context, which is necessary for tackling the city's riverine flood risk.

4.2. Urbanisation's effect on flooding: The case of Belgrade

This section presents the findings of the description of Belgrade, particularly regarding the factors that shape exposure and vulnerability to riverine flood risk. The findings are based on secondary data and interviews undertaken. They are presented under the following subsections.

4.2.1. Uneven exposure to flooding

As mentioned in the background section, flooding is the most common disaster experienced by Serbia. The city of Belgrade is at high risk of riverine flooding; however, this risk is not homogeneously distributed throughout the city's territories. Some parts of the city, such as areas next to the Danube and Sava rivers, are more exposed than others. This high exposure level is not caused merely by proximity to water bodies, but by the regions' elevations. Figure 6 demonstrates the elevation of the different areas. It is noteworthy that almost all of the city is located in low-lying areas, compared to the elevation of the river.

The areas north and west of the Danube river, coloured in light blue, are the lowest-lying land areas at approximately 84 metres above sea level—the same elevation as both rivers.

Therefore, these areas are the most heavily exposed to riverine floods. Similarly, the far west and the central areas, coloured in dark blue, are low lying at 104 metres. Figure 6 shows that most of the city has an elevation of around 145 metres (marked in lilac); however, these areas are not significantly elevated above the rivers' height, thus ensuring that they are also exposed to riverine floods. Moreover, they are bordered by hills in the south, increasing the flood risk after heavy rainfall due to the high-volume and high-velocity runoff from these hills.

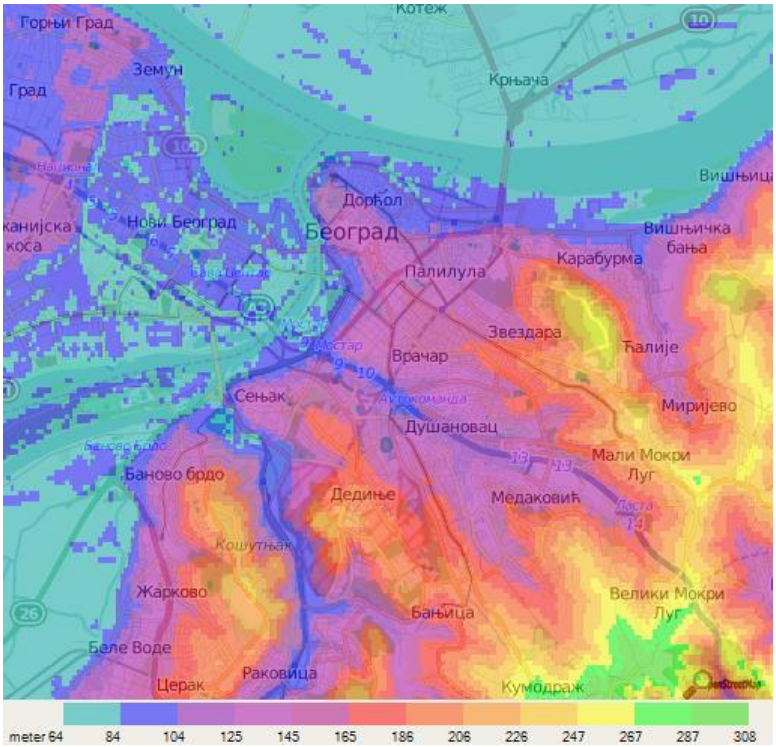

Figure 6. Elevation map of Belgrade.
Source: Flood Map (2020).

4.2.2. Flood-prone areas

The Government of the City of Belgrade, through its Secretariat for Environmental Protection, and in conjunction with the German Corporation for International Cooperation (GIZ), developed the city's '*Climate change adaptation action plan and vulnerability assessment*' (City of Belgrade, 2015). As part of this action plan, both agencies designed a map of the administrative territory of the Belgrade municipality showing the spatial distribution of natural hazard impacts and considering the effects of climate change (see Figure 7).

Following the scope of this thesis, from the map above[2], only the flood-prone areas, as shown in light blue and lilac, are considered. The main urban area, which is the focus of this study, is denoted by the dashed square. Further explanation of the city's urban distribution is provided later. Figure 7 shows that a vast area of the city's urban space is considered flood-prone. This representation accords with the distribution provided in Figure 6. Additionally, under the portion of Figure 7 dedicated to future climate change impacts, it is noted that both the built

[2] Note that this map represents the administrative area of Belgrade and associated rural areas.

environment and industry will be affected by heavy precipitation and floods. The two central urban cores, marked by the two largest grey circles located either side of the Sava river and south the Danube, would be profoundly affected by these natural hazards. The two cores are, in the east bank, the 'Old City' (compound by Stari Grad, Savski Venac and Vračar municipalities) and in the west bank, Novi Beograd (also known as the New Belgrade).

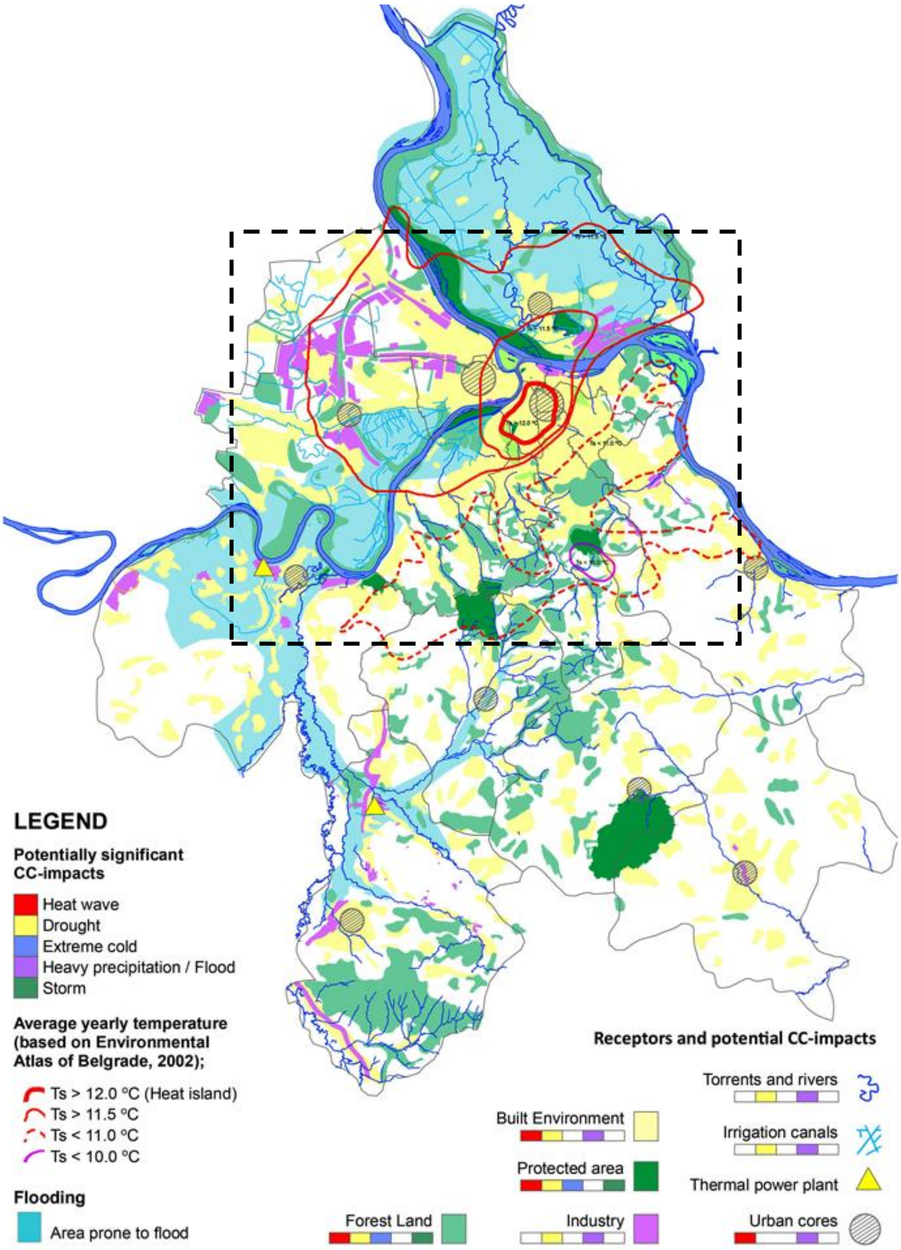

Figure 7. Natural hazards spatial distribution within Belgrade's territory.
Source: City of Belgrade (2015).

Analysing both maps together, the two central urban cores, and another smaller one located north of the Danube, are at low elevations, and one of the leading reasons for the urban centres' high level of exposure. Following subsections, which show information regarding the sectors vulnerability levels to flooding and Belgrade's urban planning clarify further the reasons behind these cores' vulnerability.

4.2.3. Sectors vulnerable to flooding

Table 1. Vulnerability levels by receptor.

VULNERABILITY LEVELS TO HEAVY PRECIPITATION/FLOOD		
Receptor	**Description**	**Vulnerability level**
Population	Public health	High
	Vulnerable groups	High
Infrastructure	Transport	High
	Electricity and heating services	High
	Water supply and sewage	High
	Social infrastructure	Low
Built environment	Building stocks and materials	High
Economy	Tourism	Low
	Industry	High
	Retail	Low
Natural resources	Green spaces	Medium
	Water resources and quality	Medium
	Air quality	High
	Agriculture	High
	Forests	Medium
	Biodiversity and ecosystems	Medium

Note. Adapted from City of Belgrade (2015).

The City of Belgrade's action plan and vulnerability assessment (2015) presents the current vulnerability levels of receptors to the natural hazards identified in Figure 7: heatwaves, droughts, extreme cold, heavy precipitation or flooding, and storms. These levels are identified by linking the receptors' exposure and their adaptation capacities, and by analysing past events and future trends. This vulnerability assessment includes an analysis of extreme weather events occurring in Belgrade between 1995 and 2014, focusing on their consequences, and response and recovery activities. The vulnerability level is either low, medium or high. Table 1 compiles information on only the heavy precipitation/flood hazard risk from the City of Belgrade's action plan and vulnerability assessment (2015). It is possible to see in Table 1 that the most vulnerable sectors are population and infrastructure.

The population's vulnerability level is high because various factors, such as the people's exposure and their lack of preparedness for managing floods, which produces a low adaptation capacity (City of Belgrade, 2015). For instance, the potential effects of riverine flooding on the population include possible casualties and the spread of infectious diseases caused by contaminated water.

The majority of infrastructure vulnerability levels are rated as high due to their exposure level and their potential to generate significant negative impacts on the country. Some of the city's busiest transport routes run alongside rivers (City of Belgrade, 2015). Damage to these routes would stimulate high rebuilding costs and severely disrupt day-to-day life in the city. For example, the E70 highway, which is not only strategic to Belgrade but to the whole country, spans Serbia, running from the Croatian border to the Romanian border, passing through Belgrade along the Danube in a marked flood-prone area. Additionally, busy traffic intersections, such as Slavija Square and Republic Square, as well as public transportation systems, such as Belgrade's central railway station, are located in flood-prone areas. Damage to these networks would affect thousands of people.

Electricity production, and water supply and sewage systems are particularly vulnerable to riverine flooding. Energy and industrial facilities are located in flood-prone areas, such that flooding could cut the electric service across entire regions of Belgrade, as observed in the 2014 floods with the disruption on the Nikola Tesla power plant in Obrenovac (City of Belgrade, 2015). Floods do not only cause damage to water distribution systems but also reduces the quality of drinking water, directly affecting people's health. The 2015 City of Belgrade's vulnerability assessment identifies the Old City as the most critical area, since this area lacks rain drainage, augmenting its exposure to flooding. Other critical areas without stormwater sewer systems include parts of Dedinje, Kaluđerica and Banovo Brdo, which are also within the flood-prone area identified in Figure 7.

The built environment's high vulnerability level is explained by the potential direct damage that would be caused by riverine flooding, especially for residential and commercial buildings, alongside other pieces of key urban infrastructure. The same is true for industry. The highly vulnerable locations identified in the assessment (City of Belgrade, 2015) include the Nikola Tesla power plant, the mining zone in Lazarevac, and major road and rail transportation corridors within the city. Some economic sectors, such as tourism and retail, are assumed to be more flexible in the aftermath of a riverine flood, making them less vulnerable than other receptors noted in Table 1.

Within natural resource receptors, agriculture is identified as the most vulnerable sector. Agriculture is highly exposed to the effects of climate change, via alterations in the growth cycle, asset damage and soil pollution (City of Belgrade, 2015). Additionally, the agricultural sector in Belgrade possesses an inadequate adaptation capacity for overcoming these problematic changes. The negative consequences in the agricultural sector do not only affect the people working directly within the sector but also the food industry and food availability in general (City of Belgrade, 2015). For other natural resource receptors, such as green areas and forests, medium vulnerability ratings stem from potential damage caused by riverine flooding. However, as they are part of the ecosystem's natural cycle and form a major part of the environment's ability to recover, it should be expected that these areas will recover.

4.2.4. Belgrade's urban planning

In Serbia, 'Master Plans' define long-term spatial development projections for each city. These plans delineate areas for construction, the land use type, roads and other aspects within the city's urban area (Serbia Construction, 2020). Additionally, the master plans state capacities for transportation, power supply, and water management, and mark the zones with generalised construction rules (Serbia Construction, 2020). The master plans are both strategic and operative, indicating that they must be directly implemented (Serbia Construction, 2020). The urban development plan of Belgrade is presented in the MPB, which covers only the city's built territory. The MPB for the year 2021 was developed by the Urban Planning Institute of Belgrade and adopted by the City Assembly on 7 March 2016 (Beoland, 2016).

The MPB 2021 consists of a set of nine city maps concerning different aspects. These maps present and outline: (1) plan border and different city zones, (2) existing land use, (3) land use plans, (4) general traffic, (5) general solutions, (6) durable goods, (7) water surfaces, (8) urban development limitations, and (9) areas of further planning. Following this study's scope, the maps analysed are numbers 3 (land use plans) and 8 (urban development limitations), since these cover the current urban setup and the planned future usage of different zones within Belgrade. The English translations of these maps are presented in Figure 8 and Figure9.

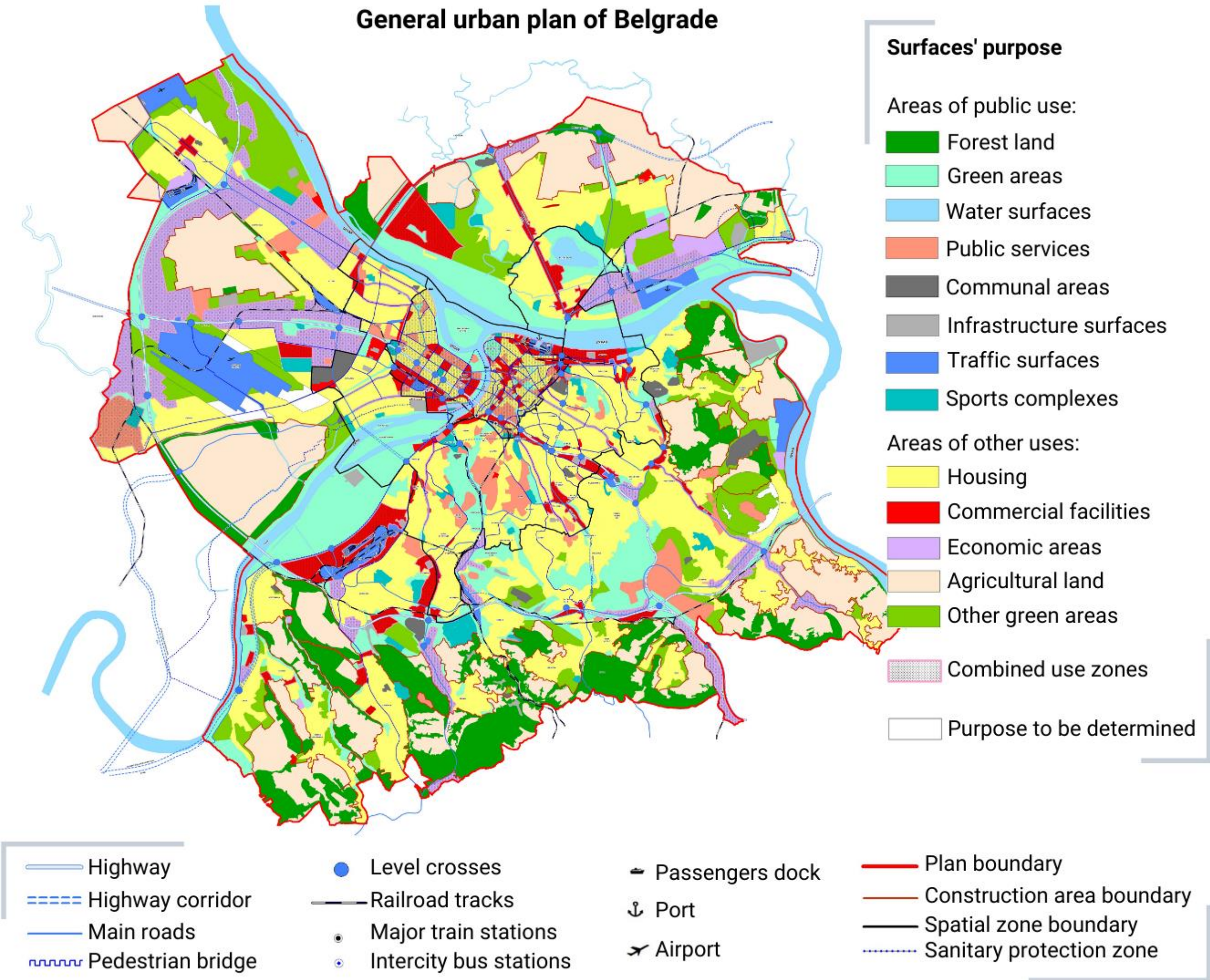

Figure 8. MPB number 3—Land use plan.
Source: Belgrade Land Development Public Agency (Beoland, 2016) (translated into English).

It is noticeable in Figure 8 that most of Belgrade's space is dedicated to housing; however, this is not surprising, since it is the most populated city in the Western Balkan region. The areas earmarked for housing are relatively centralised, with some exceptions in the west and south. Commercial and economic/industrial areas are more evenly spread throughout the city's territory. Commercial facilities, marked in red are located mostly in the city's cores, with some exceptions, such as a large zone in the west, next to the Sava river, which surrounds the Belgrade marshalling yard—the largest railway station in the country (marked in dark blue). The two primary urban cores identified in Figure7, which lie either side of the Sava river, are combinations of housing, commercial and public services zones.

Green areas are lacking in both city cores; nevertheless, large green spaces can be found in areas north of the Danube and east of the Sava. Moreover, there are other green spaces within other zones, providing a balance against the built environment. Additionally, forest land and other green areas are prevalent in the city's outskirts, especially in the southern and eastern zones. It is noteworthy that these spaces are generally located adjacent to rivers, especially in the city centre and the Danube's southern bank. The land use plan also marks areas dedicated to agricultural land, which mainly surround built zones, particularly in the north and west.

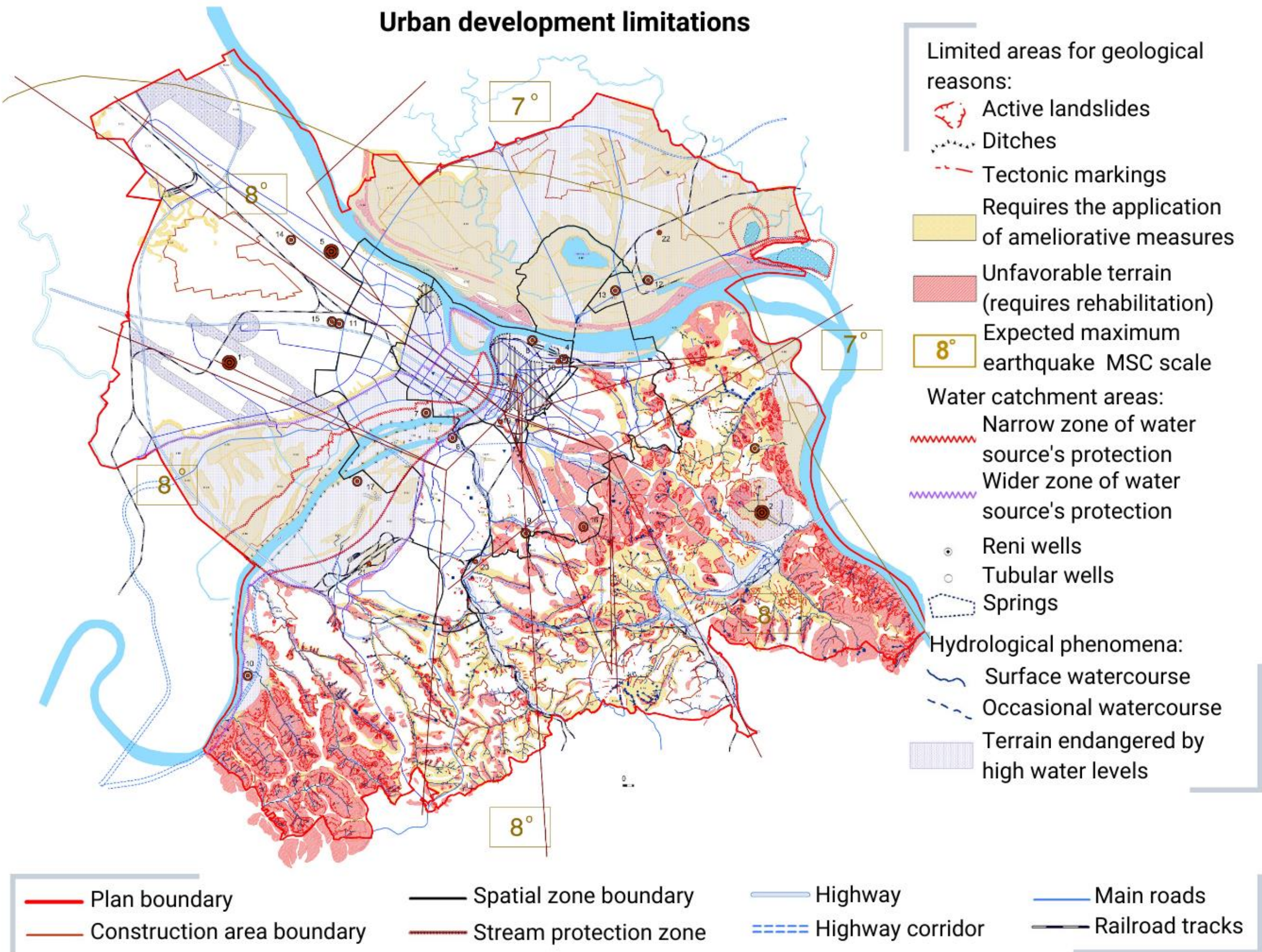

Figure 9. MPB number 8—Urban development limitations.
Source: Belgrade Land Development Public Agency (Beoland, 2016) (translated into English).

Figure 9 provides a comprehensive map of Belgrade's geographic boundaries. The map identifies areas of the city that require special consideration due to their particular circumstances, which include terrains that require rehabilitation for construction, zones in which measures for water protection should be applied and areas exposed to natural hazards (including landslides, earthquakes and floods). The south and east of the city are made up of complicated terrains that require specific measures for construction (marked in yellow and red). The map makes clear why this zone mostly consists of forest land and green areas, as shown in Figure 8.

Areas both sides of the Sava river and the north side of the Danube are marked by blue-grey shading, representing terrain endangered by high water levels. This limitation is particularly relevant because buildings and infrastructure in this area are highly exposed to the effects of riverine flooding. This information accords with Figure 7, which displays the risk of natural hazards across the municipality of Belgrade. Structures in these areas should be ready to withstand such hazards, and the government should lower exposure levels by implementing adaptation measures. It is noteworthy that both city cores are located in this highly exposed area.

Two broad areas are marked to represent the space in which measures to protect the Sava river should be implemented. These measures should aim to reduce extent of the river's pollution. Such sanitary measures are critical, since the Sava river is an important water source for the city, with most of the city's wells located along its banks. These water protection areas are within the narrow zone, marked with a red zigzagged line, and the wider zone, marked with a lilac one. Protection measures in the narrow zone should be more substantial and be further reinforced than those in the wider zone due to its proximity to the river.

4.2.5. Implementation of urban plans

Interviewees state that Belgrade's recent urban development plans have been poorly implemented. For instance, many of the buildings constructed within the city did not satisfy legal requirements, such as terrain adequations and the use of appropriate materials. One interviewee noted that one of the leading causes of these rushed constructions is excess housing demand created by immigrants and refugees following the Balkan wars of the 1990s. Additionally, the other interviewee states that many of these buildings are constructed without the proper construction and use permits. These illegal constructions are generally more vulnerable to natural hazards.

The region with the highest concentration of these illegal buildings is the area on the northern bank of the Danube, which is heavily exposed to riverine flood risk. Thus, it is identifiable as an area that requires more robust measures to reduce the flood risk and inhabitants' vulnerabilities.

"There was less control of the urban development in previous years, but this situation must change. Adequate urban planning is necessary to ensure everyone's safety."

Interviewees highlight the importance of implementing adequate urban plans that comprehensively factor the structural aspects of the city, including the distribution and nature of social classes, infrastructure type, natural spaces, and risks. Interviewees agree that adequate plans raise efficiency, reduce risks, and enhance resilience. A clear example noted by one interviewee is the case of Novi Beograd; the interviewee notes that before this area of the city was constructed, the Government invested significant resources into building a solid foundation for the future municipality by adapting the terrain and constructing the Sava embankment. Therefore, while Novi Beograd is highly exposed to riverine flooding, the same interviewee claims that this investment has significantly reduced the area's vulnerability to flooding. Interviewees emphasise that greater investment in protection measures is urgently needed in other areas of Belgrade, such as the Old City and the neighbourhoods on the Danube's northern bank.

"New infrastructure is definitively needed in Belgrade; however, we should be smart to understand different city aspects, as social and economical divisions, and, of course, the risks."

Despite the critical situation with these areas, one interviewee is more worried for the northern neighbourhoods, which lack tailored plans to directly tackle their riverine flood risks besides their current embankments. Interviewees are concerned about the state of the embankments on the Danube and the Sava. They highlight that this protective measure does not span the entire length of both rivers within Belgrade and thus leaves some areas exposed to higher risks of flooding. They also note that the current embankments are not designed to cope with the raised water levels and precipitation projections caused by climate change. As a result, this measure should not be expected to contain the risk of severe floods affecting the city in the future.

The interviewees emphasise that their primary concern for the implementation of protective measures relates to the availability of funds. They agree that although there are resources allocated for urban planning and DRM, present funding levels are insufficient. One interviewee claims that most of the local resources are earmarked for social and economic development and do not consider other areas of concern like hazard protection and climate change adaptation. Hence, this budgetary gap creates a need for significant international investment and foreign assistance, which, as agreed by the interviewees, is not easy for Serbia to obtain.

"The implementation depends on the availability of funds; however, as you might know, the city is struggling budgetary resources to satisfy all its needs."

4.2.6. Belgrade's DRM efforts in response to urban risks

The city's DRM systems have been gradually improving in recent years; however, there is still significant scope for improvement. The interviewees note that some additional systems for flood protection (e.g. drainage) are old, insufficient in some parts of the city, and are often non-existent, especially in the Old City. In light of this, local governments are currently designing new protection measures in parallel with urban development projects, in order to satisfy the growing population's needs whilst also ensuring their safety. For instance, the local public company, Belgrade Waters, is working on the implementation of retention basins to alleviate the flood risk in certain areas resulting in more available space for housing.

> *"There are a lot of opportunities for improvement. However, this is being done in parallel with the urban development, since the city is developing rapidly."*

The interviewees note that the city's improved DRM system considers not only the use of artificial infrastructure but also non-structural measures and nature-based solutions (NBSs). They highlight that Belgrade's Government is looking to preserve, as much as possible, remaining urban forests and green areas. This decision was taken following extensive research which highlighted the importance of green areas to reduce natural hazard risks and mitigate the effects of climate change.

The interviewees state that the Government hopes to increase the city's air quality, decrease the UHI effect, augment water absorption capacity, and reduce landslide and flooding risks through NBSs. Additionally, one interviewee claims that the government is planning to increase the relative size of green areas. For example, there are current projects to plant local flora (in particular, trees) along the riverbank. In this way, the city links climate change adaptation with disaster risk reduction (DRR)—a relationship that should be strengthened in light of the interviewees' comments.

> *"During recent years, the situation has improved. The Government is now controlling the construction in these forests and preventing its urbanisation."*

4.2.7. Urbanisation pockets and investment in physical infrastructure

Belgrade is indeed a heavily constructed city with most of its essential structures located in the Old City (the traditional city centre) and Novi Beograd. These areas form the city's cores, on both sides of the Sava river, as noted in Figure 7. On the eastern side of the river is the Old City where Belgrade was first established. Besides housing and commercial buildings, this area contains buildings used by local and national government departments, including the Ministries of Trade, Finance, Culture and information, Education and science, Foreign affairs, most of the city's embassies, consular representations, and even the presidential offices. Additionally, the city centre is home to many national museums and historical sites, such as the Nikola Tesla Museum and the Kalemegdan Fortress and Park, which are considered two of the country's most important cultural assets.

Novi Beograd is located on the west side of the Sava river. It is a planned municipality, which nowadays serves as the central business district in Serbia, and is identified by locals as the most important in the Balkan region. It boasts a modern infrastructure, making it attractive for businesses, which has thus prompted further development in the area.

The Sava river provides a natural division between the old and the new Belgrade. Within the city's zones, the river bed has been altered in order to provide protection against riverine flooding and to diminish risk exposure. Figure 10 displays four photos taken during a visit to the city. They exhibit the state of the Sava in the central region of Belgrade. Note that the riverbank is paved along one side of the riverbed. The photos show structures located alongside the riverbank and across the water. There is insufficient space to include all photos taken, but they exemplify the state of the Sava inside the territory of Belgrade.

Figure 10. Photos from the Sava river, which flows through the centre of Belgrade.

As a final remark, the total value of investment into construction projects increased by 35% during the period between 2018 and 2019 in Belgrade, becoming one of Europe's construction boom cities (Bjelotomic, 2020). By the end of 2019, there were around 55,000 active construction sites in the city, which is four times more than in 2015 (Bjelotomic, 2020). This is expected to continue, given the rate of predicted urban population growth in the near future.

An increasing number of people are moving to Belgrade, such that it is critical to ensure that buildings and infrastructure are capable of counteracting present risks as well as those that will accompany the future effects of climate change.

4.3. The role of climate change on urban flooding

Document analysis and interviews confirm that natural hazard risks in the Western Balkan region is raised due to climate change apart from the effects of human activity (UNISDR & World Bank, 2008). Climate change is playing a critical role within Belgrade's risk levels to different natural hazards. For instance, over the 60 years from 1949 to 2009, a small increment in mean annual precipitation was documented (City of Belgrade, 2015; Ministry of Environment and Spatial Planning, 2010). Although a slight rise does not necessarily suggest substantial consequences for the risk faced, the absence of a balanced distribution between the different seasons does imply higher risks.

During this period, it was observed that precipitation levels decreased during winter and spring, but increased in summer and autumn, indicating heavier and longer rain periods for the latter seasons (City of Belgrade, 2015; Ministry of Environment and Spatial Planning, 2010). The same data shows that the aggregate number of heavy rainfall days rose across the country (Ministry of Environment and Spatial Planning, 2010). Note that the model in the 2015 City of Belgrade's vulnerability assessment indicates no notable changes in the mean annual number of heavy-rainfall days. However, it reflects a moderate increase in rain intensity from 10 to 40% by the year 2050, translating into heavier rainfall with a higher possibility of catastrophic consequences via flooding.

Both interviewees and literature reveal that the climate is changing more rapidly now than at any previous point in documented history, resulting in an increased frequency of extreme weather events—including more intense droughts in some seasons and raised levels of precipitation in others (Djalante, Holley, & Thomalla, 2011; Huang, 2019; IPCC, 2012; UNISDR, 2015; World Economic Forum, 2019). The interviewees state that most of the projects designed to tackle natural hazards and enhance the system's resilience do not consider expected changes in the climate over the long term.

> *"There are certain investment projects under development, but many of them do not take into account the projected climate change conditions for Serbia."*

Notwithstanding, both interviewees acknowledge that this tendency has been declining over recent years, as local and national governments are enacting new regulations to enhance local capacity to perform risk assessments and increase preparedness. These include the strategy for DRM, and methodologies for disaster risk assessment, with are both aligned with the

Sendai Framework[3]. Additionally, other entities, such as the UNDP, are trying to strengthen linkages between policies for DRM and climate change adaptation in order to ensure more comprehensive plans in the short term.

> *"I am afraid that there is still a lot to be done in order to convince decisionmakers and public entities that they must use climate research to ensure a sustainable future."*

[3] *The Sendai Framework for Disaster Risk Reduction 2015-2030* recommends specific actions to member states aiming to substantially reduce disaster risk and associated losses (UNISDR, 2015).

5. Discussion

This section provides the analysis of the results obtained from the literature study, description of the situation of Belgrade, and interviews undertaken. The discussion of results presented in the previous section is divided in the two secondary research questions stated in the introduction, and into the following.

5.1. The uneven nature of Belgrade's urban development

The urban development process in Belgrade has been mixed. Interviewees state that infrastructure development plans have been poorly implemented in recent years, and that this situation, in conjunction with other factors, including rapid population growth, and internal and international migration, has caused city areas to develop in an unregulated manner. These areas end up with buildings and infrastructure which do not meet minimum safety standards. This is particularly observable in neighbourhoods located along the northern bank of the Danube, which possesses a high number of illegal constructions.

However, not all urban planning has been mismanaged. For instance, the case of Novi Beograd, a planned municipality which is one of the newest in Belgrade, is notable. Interviewees state that before building in this area, the Government invested significant resources into reducing its high exposure to flooding by adapting the terrain and building the East Sava Embankment.

As noted in the results, various activities related to DRM and climate change adaptation have been integrated into the country's urban plans. Not only the Government of Belgrade but also the national—Serbian—and other local governments have enacted new regulations to strengthen local capacities for DRR and preparedness.

An example of this improvement can be seen in the most recent MPB for 2021 (Figure 8 and 9). The MPB was developed to satisfy the needs of the increasing population and to manage the various hazards affecting different city areas as much as possible, according to risk maps, such as that of Figure 7. For instance, large areas are dedicated to housing and the commercial facilities are spread around the city in less exposed areas, whereas the most at-risk areas are marked for agriculture or as forest and other green land.

Figure 7, which shows the spatial distribution of natural hazards, identifies flood-prone areas within the city, largely in agreement with those identified in the MBP 2021 urban development limitations (Figure 9). Therefore, it can be claimed that the MPB is based upon risk assessments, therefore increasing the area's level of resilience by maximising the reactive part of the recognition function as identified by Becker (2014) and Huong and Pathirana (2013).

The MBP land use plan (Figure 8) notes that most of these flood-prone areas are allocated as green areas, forest land, agriculture and other green spaces, especially along the banks of the southern part of the Sava river and along the northern bank of the Danube. The importance of this aspect is highlighted by the literature study, in placing green areas in zones prone to flooding using them as buffer zones (Konrad, 2003).

Using green infrastructure and spaces as strategically planned networks of nature-friendly areas (e.g. parks, green corridors and forests) help to deliver, protect and enhance various ecosystem services (such as water filtration and air quality) and to improve environmental conditions, personal safety and quality of life (City of Belgrade, 2015; European Commission, 2019). This measure is crucial because the restoration of riparian vegetation and the incorporation of native vegetation in high-risk areas of the city is highly effective in terms of water absorption and reducing runoff speeds (Ilieva, et al., 2018). These greening activities reduce risks related to the impervious material coverage and UHI negative effects, which are direct outcomes of urban development. However, other negative effects of urban development also require attention, including the alteration of the water cycle, waste production and increased vulnerability resulting from inadequate plans and constructions.

The Government of Belgrade is currently designing other types of protection measures in parallel with current urban development projects in order to tackle some of urban development's other negative effects. These measures aim to satisfy the population's needs whilst also ensuring their safety. An example of this is Belgrade Water—a local public company—which is currently working on the implementation of retention basins that alleviate the flood risk in certain areas.

Retention basins are excavations that are used to temporarily store excess water, later discharge it at a controlled rate, and thus reduce the peak flow downstream (APFM, 2006; City of Belgrade, 2015; TUHH, 2019). This measure is crucial for Belgrade to control runoff after heavy rainfall, as the intensity of runoff is expected to increase due to climate change (City of Belgrade, 2015). The results demonstrate that these measures should be considered by the Government of Belgrade, with an emphasis placed on the Danube's upstream section, in order to reduce the flood-risk of the northern Danube neighbourhoods.

The older areas of Belgrade, such as the Old City, were not constructed in accordance with comprehensive urban plans since they were built centuries ago. Interviewees note that the Old City has an aging drainage network that is incapable of handling high-volume runoff. Other neighbourhoods, including Dedinje, Kaluđerica and Banovo Brdo, also lack adequate rain drainage systems (City of Belgrade, 2015). Water drainage systems minimise the impact of flooding by directing runoff and excess water towards primary streams and rivers (APFM, 2006; Melbourne Water, 2017). Therefore, it is necessary that the Government of Belgrade designs, builds and maintains the canals and rainwater collectors, and reinforces stream protection regulation to reduce the flood risk (City of Belgrade, 2015). Urgent measures should be taken in the areas previously identified.

One of the largest barriers to a better integration of protection measures within the city's urban development plans lies in funding availability. As stated in the results, the resources allocated for DRM and urban planning are insufficient due to other budgetary priorities, such as social and economic development. However, the results highlight the importance of implementing adequate urban development plans that consider risks and climate change effects, since these plans can raise resource efficiency and economic development. Adequate plans can also enhance resilience, reduce exposure and vulnerability to hazards, and thus reduce risks significantly.

5.2. Urban development and flooding vulnerability in Belgrade

Urban development heavily influences the magnitude and exposure to natural hazards. For the case of Belgrade, the urban development process has increased the city's vulnerability to riverine flooding. Pointing out the primary factor influencing vulnerability in Belgrade is a difficult task since a combination of different factors influences it directly and indirectly. However, this subsection presents some of the factors that increase Belgrade's vulnerability to flooding the most, following the results presented. Most of these factors relate to infrastructural development and density of population which is aggravated by climate fluctuations.

a. Lack of adequate urban planning. As mentioned previously, urban development plans have been poorly implemented in previous years, and although this situation has been getting better, there is still scope for improvement. When analysing together the MPB land use plan (Figure 8) and the MPB urban development limitations (Figure 9) it is possible to agree that not the whole territory identified as flood-prone is dedicated to green buffer zones. Both the city urban cores—the Old City and Novi Beograd—and the neighbourhoods in the northern Danube are highly exposed to riverine flooding due to their low elevation and close distance to the Sava and Danube rivers. These areas are profoundly, and, until a certain point, dangerously constructed, in special both city cores.

Another aspect to note regarding Belgrade situation relates to the construction of new buildings and infrastructure projects. It seems that Belgrade's urban planning should consider more the natural hazards affecting the city. For instance, new constructions are currently being done along the riverbanks, having negative impacts like narrowing the channel, which raises the water level and increases flow resistance (Jha, et al., 2011; Konrad, 2003). The photos provided by Figure 10 show that in central Belgrade, there are buildings along the length of the riverbank. It is also possible to see that, in some cases, buildings partially stand above the water, over pillars and platforms. These types of constructions reduce the river's maximum capacity for transporting water and also create obstacles, reducing the discharge speed (Jha, et al., 2011; Konrad, 2003). This situation raises the risk faced by adjacent areas, such that stricter regulation of river-adjacent construction is needed urgently.

It is critical to strengthen the city's urban planning aiming to minimise risks. Land use plans should consider the hazard-prone areas and incorporate special measures for specific terrains. Neighbourhood-specific urban plans could complement the aims of the MBP, which is based on comprehensive risk assessments and identifies highly exposed areas (City of Belgrade, 2015).

b. Insufficient building codes. On the other side, other areas of the city have inadequate constructions, worsening their vulnerability to natural hazards. For instance, the main problem with the northern neighbourhoods falls into the quality of its housing and infrastructure. The interviews highlight that massive concentration of illegal and inadequate constructions spread throughout this area, and little has been done to enhance its inhabitants living conditions.

Existing building codes could be strengthened and reinforced to ensure appropriate designs and the use of suitable materials, resulting in hazard-resistant constructions (FEMA, 2018). For flood management, these codes could establish the use of flood-resistant materials, the minimum elevation for the lowest floor, under-floor ventilation and drainage, among other aspects (FEMA, 2018). Belgrade's Government should introduce these codes as open and straightforward standards and enforce them in flood-prone areas (City of Belgrade, 2015).

c. Impermeable surface coverage. As stated in the literature review, materials that replace natural permeable soil impede water infiltration, diminish the undergrown water storage and increase the runoff reaching water channels (Booth & Jackson, 1997; Hollis, 1975; Huang, 2019; Jha, et al., 2011; Konrad, 2003; Leopold, 1968; Mukherjee, 2016; Pattison & Lane, 2012). Roads, car parks and buildings, among other structures, do not only degrade water infiltration through their impervious nature but cover the natural land depressions used for water storage. They thereby lessen the land's capacity to absorb, retain and manage excess water (Hollis, 1975; Jha, et al., 2011; Konrad, 2003; Mukherjee, 2016). Additionally, the removal of natural vegetation along riverbanks reduces water retention capacity (Jha, et al., 2011; Konrad, 2003).

Figure 5 shows the relationship between impervious cover and surface runoff. When there is between 75 and 100% impermeable surface coverage, around 55% of the rainwater becomes runoff, flowing towards low-lying areas. It is noteworthy that both city cores are almost entirely covered in pavement, cement and other impervious materials, increasing their vulnerability to flooding after heavy rainfall.

Due to the direct connection between impervious cover and surface runoff shown in Figure 5, it is recommended that permeable surfaces are incorporated into the design of new developments (City of Belgrade, 2015; Konrad, 2003). Artificial impermeable materials should be replaced as much as possible, giving special attention to the low-lying areas in both city cores.

d. Waste production. New construction projects can lead to the release of solid waste, debris or sediment into the river, which can affect its water management capacity (Booth & Jackson, 1997; Huong & Pathirana, 2013; Konrad, 2003; Leopold, 1968). Enforcing waste management regulation is crucial to reducing the flood hazard in exposed areas, especially in the case of Belgrade as being a city with a large number of active construction sites, and much more future projects. Figure 9 present wide and narrow zones of protection along both banks of the Sava river. These zones should be protected, and urban development projects within them should be heavily regulated, to avoid the contamination of the river and prevent further increases in flood risks.

e. Concentration of population, commerce and critical infrastructure. If a riverine flood occurs in any of the city cores, the consequences might have immense economic costs and impacts, since most of the Belgrade's commercial and governmental facilities are located there. A massive flood affecting either of these areas represent enormous consequences not only to Belgrade itself but to all Serbia due to the city's importance nationally.

If flooding occurs in the northern bank of the Danube, thousands of people might be affected, resulting in large amounts of losses, injured and the possible destruction of the people's homes and livelihoods, critically reducing their quality of life and resulting in people needing urgent help. In order to decrease this probability for these areas to be affected, resulting in such consequences, measures should be taken to reduce the city's vulnerability and augment its resilience.

An additional notable area that is identified as being prone to riverine flooding is the south-eastern Sava bank. This area is set to house a large commercial zone and the Belgrade marshalling yard—the largest railway station in the country—is also located here. Large-scale flooding in this area would have catastrophic consequences for the entire country, as well as the areas mentioned previously. Therefore, proactive measures should be taken to reduce the area's vulnerability and reduce the probability of a disaster that would significantly disrupt the country's transport operations.

f. Negative effect of other protective measures. In an attempt to proactively decrease the Sava river's resistance to water flow, parts of the riverbed and the shore were paved in an area of the city centre immediately upstream from the confluence point. The literature review highlights that it is possible to augment the efficiency of the flow by using such structural measures, as well as by straightening or deepening the river (Booth & Jackson, 1997; Konrad, 2003). These changes seek to increase the rate of water discharge downstream; however, it is crucial to balance the localised benefits of these measures against the risk of raising the flood risk downstream (Booth & Jackson, 1997; Konrad, 2003).

Since this proactive protective measure is applied before the Sava merges with the Danube, this could worsen the situation at the confluence point, increasing the risk on the northern side of the Danube. This is an area that is already exposed to riverine flooding, as noted in Figure 7, and, as highlighted in the interviews, it is highly vulnerable to various natural hazards, but flooding in particular. Therefore, it is critical to reduce the exposure of the northern bank of the Danube by applying flood protection measures.

Protective measures which have been pointed out to decrease the Danube's northern bank risks include structural flood protection measures. This measures involves various activities, such as the reconstruction and maintenance of embankments, river dykes, and floodwalls (City of Belgrade, 2015; TUHH, 2019). This measure should focus on both sides of the Sava and Danube rivers, but prioritise the eastern embankment in the area of Novi Beograd and the northern embankment of the Danube (City of Belgrade, 2015).

g. Climate change effects over runoff. The hills in the south of the city impose a hazard on the surrounding areas. Were they to be hit by heavy rainfall or rapid snowmelt, the runoff flowing towards water channels could flood the neighbourhoods at the base of these hills. The elevation map of Belgrade (see Figure 6) shows that the Old City, which is already exposed to riverine flooding, is also exposed to runoff flooding due to the area's positioning.

Climate change is expected to cause an increase in rain intensity of between 10 to 40% by the year 2050, resulting in more torrential rainfalls (City of Belgrade, 2015). Therefore, it is expected that if no proactive measures are taken, this precipitation change will increase the city's exposure to riverine flooding, resulting in the Old City becoming the most at-risk area. This also shows the importance of connecting disaster management actions with climate change trends in order to create comprehensive measures that protect the city and its inhabitants.

h. Most vulnerable sectors to flooding. The City of Belgrade's action plan and vulnerability assessment (2015) identified three sectors as being the most vulnerable to flooding with high-risk: housing, commercial facilities and transportation infrastructure (see Table 1). The receptors' identification derives from their significant presence in both city cores, which are highly exposed to flooding, the inadequacy of the constructions in the northern bank of the Danube. Additionally, the identification considers the possible catastrophic consequences for the entire city if these areas are hit by riverine flooding. These vulnerabilities should be addressed to drastically reduce possible consequences after the impact of riverine flooding.

The results show that the Government of Belgrade is acting proactively by implementing preventive measures to reduce the existing vulnerability to the riverine flood risk. Also, it shows that the Government understands the risks affecting its territory in order to provide a limit to the urban development, ensure its population safety, mitigate the hazards' consequences, and enhance the ecosystems' quality, hence, augmenting the city's resilience and climate change mitigation capacities. This is a critical factor for the city as the interviewees agree that stronger linkages between DRM and climate change adaptation are essential for the future of the city.

6. Conclusion

Urban development could be considered a double-edged sword which creates both positive and negative consequences, where one of the major negative outcomes is environmental change. It is the responsibility of governments to minimise these negative effects. In this regard, urban development in the city of Belgrade has a mixed record. Urban development plans have been mismanaged and poorly implemented. This situation, in conjunction with other factors, such as rapid population growth, migration and rushed development in the post-war period, have caused buildings and infrastructure to be constructed without adherence to adequate safety standards.

However, the city's urban development has been slowly improving over recent years. Building codes have been established and enforced, and activities related to DRM and climate change adaptation have been integrated into the country's urban plans. Nevertheless, there is still scope for improvement.

A combination of different factors resulting from the urban development process has increased Belgrade's vulnerability to riverine flooding. The most significant factors include: (1) a lack of adequate urban planning, since some of the most flood-prone areas host large numbers of houses, commercial buildings and governmental facilities, whilst flood protection systems are incomplete or inefficient; (2) insufficient building codes because inadequate and illegal developments still account for a large proportion of the buildings in Belgrade, especially on the Danube's northern bank, which is a highly exposed area; and (3) impervious surfaces, which increase vulnerability to flooding in any context. Both city cores are covered by impervious materials (e.g. pavement, cement), reducing their water absorption capacity and increasing vulnerability to flooding.

These factors raise vulnerability to flooding, in conjunction with the rapid construction of infrastructure in order to accommodate a rising population, and inadequate flood protection measures worsen the situation in areas which were already facing high flood risks. This combination increases not only vulnerability to flooding but also the exposure of affected areas within Belgrade, in a similar manner to any other city.

Recently, the Government of Belgrade has sought to improve this situation and protect its citizens. The recent urban development plan of the city, the MPB, was developed after considering risk assessments. It aims to satisfy the needs of the increasing population whilst reducing the various hazards affecting the city. This goal is aided by the production of land use maps, which mark areas according to their possible uses and prevent construction in some areas based on their terrain types and exposure to natural hazards.

The Government of Belgrade is starting to act proactively by designing and implementing various artificial infrastructural protection measures (e.g. retention basins) and non-structural protection measures (e.g. DRM laws and hazard-based development plans). These measures aim to tackle the multiple natural hazards threatening the city and reduce associated vulnerability. However, much more could be implemented to further increase the city's resilience because the measures focus on some negative effects while leaving others unattended.

This demonstrates that it is critical to create and implement measures that protect the city by paying special attention to the Old City, Novi Beograd and the neighbourhoods north of the Danube. However, the relationship between urbanisation and flooding in rapidly growing cities needs to be further studied and developed in order to understand possible methods of improving the city's resilience, and to protect its population and future development.

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Appendices

Appendix A – Population data and trends in the Western Balkans

Table 2. *Annual total population (thousands).*

Location	1980	1990	2000	2010	2020*	2030*	2040*	2050*
Albania	2,681	3,281	3,122	2,941	2,942	2,933	2,833	2,664
Bosnia and Herzegovina	4,180	4,463	3,767	3,722	3,498	3,405	3,251	3,058
Montenegro	581	615	614	624	629	625	610	588
North Macedonia	1,924	1,996	2,035	2,071	2,088	2,076	2,016	1,931
Serbia including Kosovo	8,908	9,518	9,488	9,030	8,704	8,355	7,913	7,447

Source: United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization Prospects: The 2018 Revision.
**Projections.*

Table 3. *Annual urban population (thousands).*

Location	1980	1990	2000	2010	2020*	2030*	2040*	2050*
Albania	905	1,195	1,303	1,534	1,827	2,038	2,106	2,083
Bosnia and Herzegovina	1,486	1,752	1,596	1,696	1,715	1,824	1,919	1,976
Montenegro	214	295	359	400	425	443	453	454
North Macedonia	1,029	1,154	1,191	1,182	1,221	1,303	1,370	1,405
Serbia including Kosovo	4,111	4,796	5,006	4,966	4,913	4,953	5,041	5,121

Source: United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization Prospects: The 2018 Revision.
**Projections.*

Table 4. *Annual percentage of population residing in urban areas.*

Location	1980	1990	2000	2010	2020*	2030*	2040*	2050*
Albania	33.8	36.4	41.7	52.2	62.1	69.5	74.3	78.2
Bosnia and Herzegovina	35.5	39.2	42.4	45.6	49.0	53.6	59.0	64.6
Montenegro	36.8	48.0	58.5	64.1	67.5	70.9	74.2	77.3
North Macedonia	53.5	57.8	58.5	57.1	58.5	62.7	68.0	72.8
Serbia including Kosovo	46.1	50.4	52.8	55.0	56.4	59.3	63.7	68.8

Source: United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization Prospects: The 2018 Revision.
**Projections.*

Appendix B – Western Balkans flood risk maps

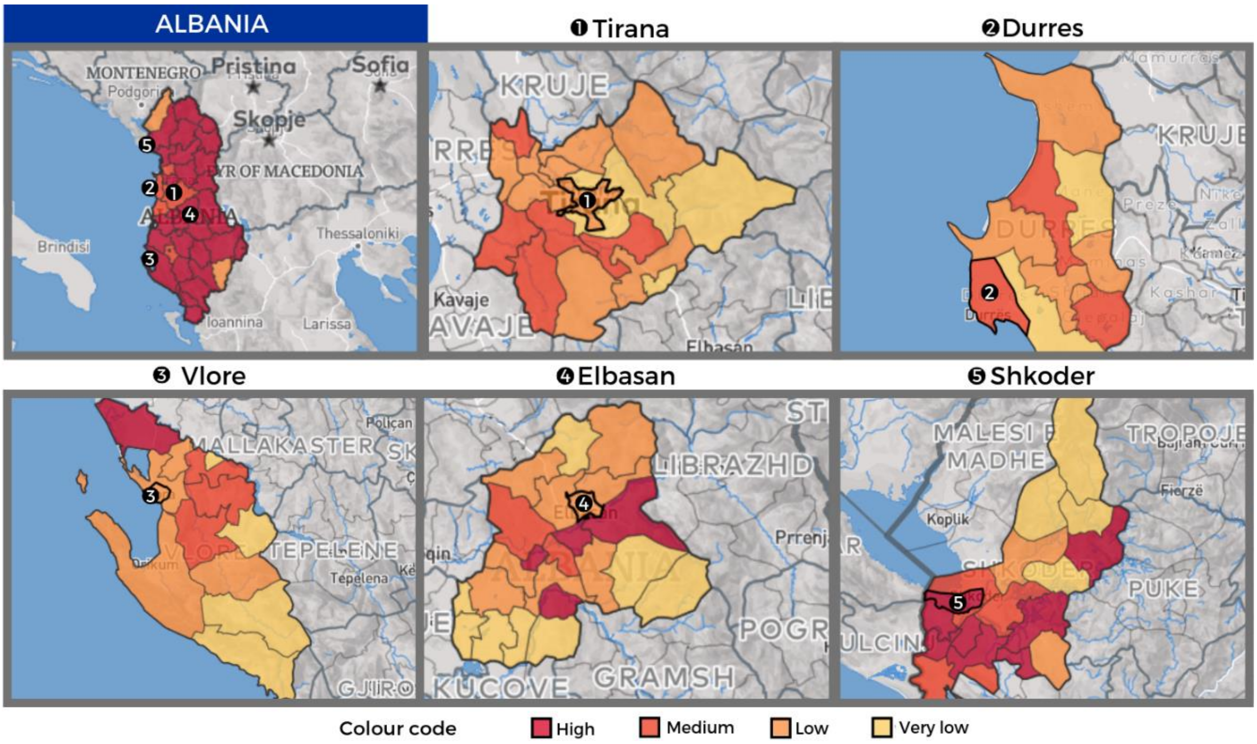

Figure 11. Flood risk map of Albania pointing the five most populated cities.
Note. Adapted from GFDRR (2019).

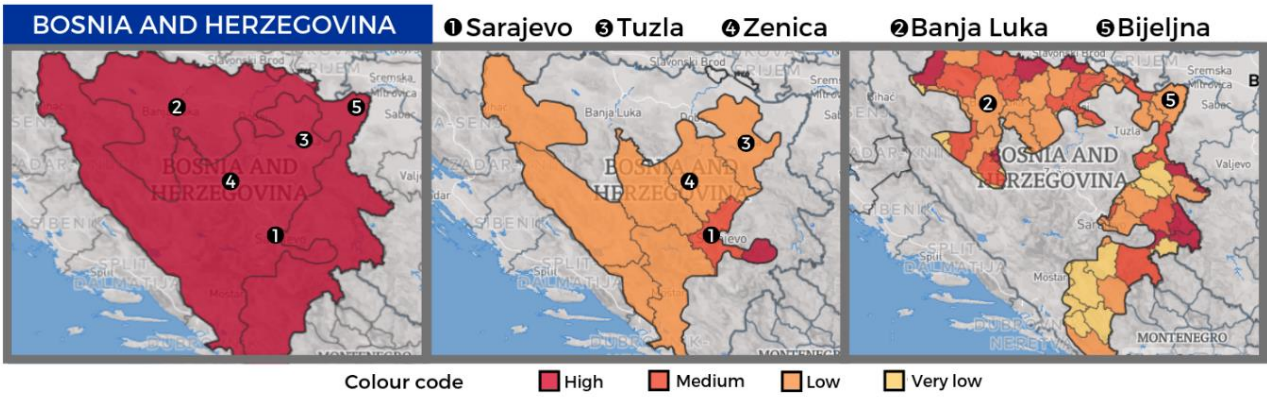

Figure 12. Flood risk map of Bosnia-Herzegovina pointing the five most populated cities.
Note. Adapted from GFDRR (2019).

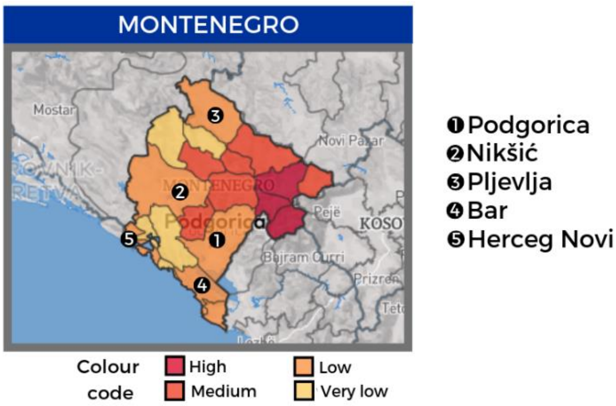

Figure 13. Flood risk map of Montenegro pointing the five most populated cities.
Note. Adapted from GFDRR (2019).

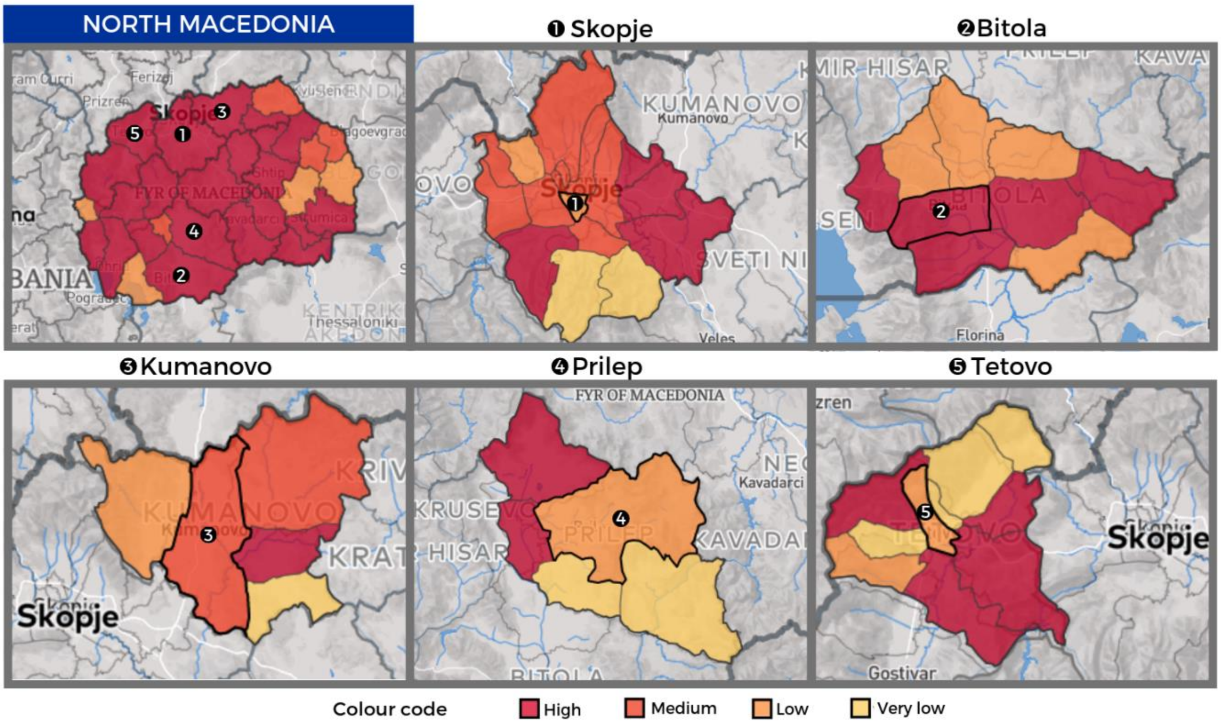

Figure 14. Flood risk map of North Macedonia pointing the five most populated cities
Note. Adapted from GFDRR (2019).

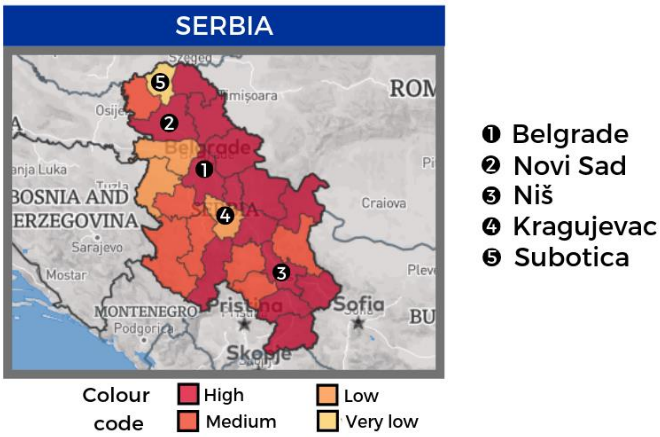

Figure 15. Flood risk map of Serbia pointing the five most populated cities.
Note. Adapted from GFDRR (2019).

Table 5 presents the inhabitants' information inside of what is considered the city's urban area. This information was retrieved from the most recent national census made by each country. There is a column indicating the position of each city pointed in the maps above and the urban flood risk level according to the GFDRR (2019). Noteworthy that the table does not consider the suburban areas, as well as the rural areas surrounding these cities, due to the research paper's goal to tackle urban development only. Additionally, there was not any information available about Kosovo's risk levels in the ThinkHazard! web tool, but the populational information was added to show the country's main cities which need proper development plans to increase their general resilience.

Table 5. *Most populated Western Balkan cities' urban flood risk level.*

Country	City	Population*	Position	Risk level
Albania	Tirana	418,495	1	Low
	Durres	113,249	2	Medium
	Vlore	79,513	3	Low
	Elbasan	78,703	4	Low
	Shkoder	77,075	5	High
Bosnia and Herzegovina	Sarajevo	275,524	1	Medium
	Banja Luka	185,042	2	Low
	Tuzla	110,979	3	Low
	Zenica	110,663	4	Low
	Bijeljina	107,715	5	Low
Montenegro	Podgorica	150,977	1	Low
	Nikšić	56,970	2	Low
	Pljevlja	19,136	3	Low
	Bar	13,503	4	Low
	Herceg Novi	11,059	5	Low
North Macedonia	Skopje	506,926	1	Low
	Bitola	74,550	2	High
	Kumanovo	70,842	3	Medium
	Prilep	66,246	4	Low
	Tetovo	52,915	5	Low
Serbia	Belgrade	1,166,763	1	High
	Novi Sad	277,522	2	High
	Niš	183,164	3	High
	Kragujevac	150,835	4	Low
	Subotica	105,681	5	Very low
Kosovo	Pristina	145,149	1	NA
	Prizren	85,119	2	NA
	Gjilan	54,239	3	NA
	Peć	48,962	4	NA
	Mitrovica	46,230	5	NA

**Source: Recent national census per country (Albania 2011[4]; Bosnia and Herzegovina 2013[5]; Montenegro 2011[6]; North Macedonia 2002[7]; Serbia 2011[8]; Kosovo 2011[9]).*

The information compiled in the Table 5 shows that the most affected country in the Western Balkan region is Serbia, since its three most populated cities—**Belgrade**, **Novi Sad** and **Niš**—are under the **high** level risk category. Additionally, these three cities' population is enormous

[4] (Institue of Statistis (INSTAT), 2011)
[5] (Agency for Statistics of Bosnia and Herzegovina, 2016)
[6] (Statistical Office of Montenegro (MONSTAT), 2011)
[7] (Republic of Macedonia State Statistical Office, 2005)
[8] (Statistical Office of the Republic of Serbia, 2014)
[9] (Population statistics of Eastern Europe & former URSS, 2011)

compared to the other countries in the region. Belgrade is the most distinctive case, since it has the most significant population in the region, doubling Skopje's inhabitants, which is the second biggest city in the region. Moreover, these Serbian cities need to develop adequate plans in order to tackle their exposure to the urban flood hazard, and therefore, to protect their growing population.

Although Serbia is the most urgent country needing to develop mitigation and adaptations measures to enhance its resilience, North Macedonia is not much more advanced. For instance, the second and third largest cities in North Macedonia—**Bitola** and **Kumanovo**—are respectively under **high** and **medium** risk levels. These two cities should be put in the spotlight while developing national disaster management plans since they are prone to have a more catastrophic disaster due to urban floods if nothing is done. The same goes for **Sarajevo**, in Bosnia and Herzegovina. As the largest city in the country and with a **medium** risk level, it is the country's most exposed city. Thus, the national strategies for disaster risk management should have a focus on handling the floods inside the city.

Furthermore, the Albanian cities of **Durres** and **Shkoder**—the second and fifth most populous cities in the country—have **high** and **medium** risk level respectively. The national plans should also consider them in the same ways as mentioned for the other countries in the region. It seems, at least according to the information shown in the tables, that the least affected country by urban settlements in the region is Montenegro. Nevertheless, disaster management plans should be included in the national strategies to tackle any possible consequences. These plans should give special attention to the city of **Podgorica**, since it is the county's largest city and urban centre, almost doubling the size of the second-largest city, and still having a **low** risk level. A similar case is **Pristina** in Kosovo, which without the risk information to consider, the plans should be based on the total population. In this case, Pristina is the biggest city in the country whose population is even bigger than the second largest city in Kosovo.

Appendix C – Interview guide

Different potential interviewees were approached directly by email, introducing the interviewer, and the study's topic, aim and purpose. The ones who gave definite answers were contacted to schedule the final interview. The interviews were conducted using video call software and recorded to transcribe the data afterwards. Information about the ethical principles was given before the interviews were conducted. It was firmly stated that the interviewees have freedom of speech and to keep silence if needed. It was encouraged for the interviewees to give rich, detailed and in-depth answers as long as they are comfortable.

The interviews were intended to be as flexible as possible to accommodate and guide the interviewees' answers. This guide does not include the follow-up questions since they varied per person. The interviews were planned to take around 30 minutes. Five different questions were designed to obtain as much essential information as possible while fitting into the scheduled time.

The thesis aim to answer the following question: *What are the effects of urban development in Belgrade on the riverine flood hazard?* It also aimed to answer the next sub-questions: (1) *What has been the nature of the urban development process in Belgrade?*; (2) *In what way urban development contributes towards vulnerability in terms of urban floods?*

The questions asked are the following:

- What is your general view about the increased urban—infrastructural—development inside Belgrade?
- Are there challenges to implement proper urban development plans in Belgrade? If yes, what implication do they have concerning flooding?
- What are the existing ways for the Belgrade Government to deal with the riverine flood risk?
- Would you consider that the Government's approach to flood management changed with the time, especially after the 2014 floods? If yes, how (for better or worse)?
- What do you think could be done further to decrease the flood risks inside the city?

Table 6 provides information about the interviewees, the organisation they are working for and their job position.

Table 6. Information about the interviewees.

INTERVIEWEES' INFORMATION			
Name	**Position**	**Organisation**	**Date**
Interviewee 1	Climate change adaptation expert	UNDP Serbia	30/03/2020
Interviewee 2	Programme specialist: Recovery, EWS and response	UNDP Regional Office Europe and Central Asia	31/03/2020