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Research paper

TOWARDS A SMART CITY: A FRAMEWORK FOR SMART FLOOD MANAGEMENT IN SARAJEVO

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Abstract

Rapid urban development and increasing hydro-meteorological variability are creating new challenges for flood risk management in urban areas. In this context, the concept of a smart city offers opportunities to improve the understanding, prediction, prevention, and management of flood events through the integration of environmental monitoring, digital technologies, data, modelling, and decision-support systems. However, becoming a "smart city" in terms of flood management requires more than the introduction of individual technological solutions. This paper explores what Sarajevo would need to develop an effective smart flood management system. The analysis considers the key components required for such a system, including reliable and spatially distributed meteorological and hydrological monitoring, real-time data acquisition and transmission, integration of heterogeneous data sources, high-resolution geospatial databases, hydraulic and hydrological modelling, flood forecasting and early warning, and decision-support tools for emergency response. Particular attention is given to the integration of existing monitoring and information systems and to the interoperability of data generated by different institutions and infrastructure systems. The paper further considers the importance of defining clear institutional responsibilities, data-sharing mechanisms, communication channels, and procedures for translating technical information into timely decisions. Rather than proposing a single technological solution, the paper identifies the essential components and their interconnections that should form the basis for Sarajevo's transition towards smart flood risk management. The proposed framework can serve as a basis for assessing the current level of preparedness and identifying priorities for future investments in monitoring, modelling, digital infrastructure, institutional capacity, data exchange, and warning communication.

Key words: *Smart city, Sarajevo, Flood Management, Smart Flood Management Framework*

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1. INTRODUCTION

Urban flooding is a growing challenge for cities, where urbanization and climate change can amplify impacts on concentrated populations, infrastructure and economic activities. Urban areas may be affected by interacting flood mechanisms, including fluvial flooding caused by river overflow, pluvial flooding resulting from intense rainfall and inadequate drainage capacity, and rapidly developing flash floods associated with intense rainfall and rapid runoff [1].

Sarajevo, the capital of Bosnia and Herzegovina (BiH), is located within a basin surrounded by mountainous terrain of the Dinaric system. Its wider urban area extends beyond four city municipalities, and is characterized by spatial variability in topography, land use and urban development. These conditions, combined with the local precipitation regime, dense urbanization and river network, contribute to its susceptibility to flooding [2, 3].

The main watercourses relevant to flood hazard in the Sarajevo urban area include the Miljacka, Željeznica, Dobrinja and Bosna rivers. Previous studies have documented riverine flood hazard and risk in the wider Sarajevo area, and demonstrated the importance of hydrological and hydraulic modelling for flood assessment [4, 5]. Densely urbanized and low-lying areas are also susceptible to surface runoff accumulation when urban drainage capacity is exceeded. Flood risk in Sarajevo therefore results from both fluvial and pluvial processes, highlighting the need for an integrated approach combining river flows, urban drainage, monitoring and spatial planning.

Smart-city technologies offer opportunities to integrate flood risk management with monitoring, data management, urban planning and decision-support systems. Smart flood management should therefore be understood not as the application of individual technologies, but as an integrated approach combining monitoring, data, modelling, infrastructure and decision-making [6, 7]. This is particularly relevant for cities exposed to multiple and interacting water-related hazards [7].

Against this background, this study addresses the following research question: What information, technological and institutional components are required to develop a smart flood management system for Sarajevo?

2. MATERIAL AND METHODS

This study used a structured desk-based assessment to examine what Sarajevo needs to develop a smart flood management approach. The assessment brought together scientific literature, publicly available institutional information and data, technical reports, existing flood hazard and risk assessments, monitoring and forecasting systems, and available data on management platforms relevant to Sarajevo.

For the purposes of this study, Sarajevo is considered as an urban flood-management area rather than a single administrative unit. The spatial scope therefore refers to the Sarajevo urban area affected by the main watercourses, urban drainage processes and flood-related infrastructure considered in the study. This functional definition is used because flood monitoring, forecasting, water management, urban

drainage and emergency response involve institutions operating at different administrative and spatial levels.

The review covered several types of sources. First, it included scientific studies on urban flood risk, smart-city solutions, hydrological and hydraulic modelling, early warning systems, and flood-risk management. Second, the study examined publicly available information and data from key institutions. Third, available flood hazard and flood risk maps, modelling studies, and technical reports were reviewed. Finally, the assessment considered the existing hydrometeorological monitoring network, forecasting and warning systems, and data-sharing arrangements.

2. SMART FLOOD MANAGEMENT CONCEPT

The technological foundation of smart urban water management includes the integration of monitoring systems, digital data, GIS, remote sensing (RS), Internet of Things (IoT), modelling and other digital technologies. Their combined use can improve real-time information availability and support more efficient decision-making in urban water management [8, 9]. Examples from European cities demonstrate that the value of these technologies lies in their integration into a coherent management system capable of transforming continuously collected data into actionable information [10]. This principle is directly applicable to flood management, where the integration of monitoring, data processing, modelling, forecasting and decision support is essential for moving from conventional to smart flood risk management. Early warning systems (EWS) are already widely established as an important component of conventional flood management [11].

Table 1 shows the key elements of a smart flood management system addressing pluvial floods caused by intense rainfall, fluvial floods resulting from river overflow, and flash floods.

Table 1. Key elements of smart flood management system

Element	Description
Monitoring	Sensors placed around rivers, drainage systems, and urban areas continuously collecting real-time water level and rainfall data.
Data Integration	A central hub where diverse data streams—from weather stations, river gauges, and IoT devices—are combined for comprehensive analysis
GIS/RS	Maps overlaying flood risk zones, rainfall advancement – spatial patterns, and topography to visually represent vulnerable areas
IoT	Networked smart devices such as weather sensors, water flow meters, and alert systems interconnected for seamless communication
Hydrologic/hydra-ulic modelling	Simulations illustrating flood dynamics and water movement through urban and river environments for better understanding flood behavior
Forecasting and EWS	Predictive models projecting flood events combined with automated alerts to inform authorities and citizens
Decision Support	A control center interface where data-driven insights are used to guide flood response, emergency actions, and urban planning for enhanced resilience
Public communication and preparedness	Communication channels and digital tools for disseminating warnings, preparedness information and guidance to citizens.

3. CURRENT SITUATION AND REQUIREMENTS FOR SMART FLOOD MANAGEMENT IN SARAJEVO

3.1. Existing monitoring

Hydrological and meteorological monitoring in the Sarajevo urban area is primarily provided through the observation network operated by the Federal Hydrometeorological Institute of BiH (FHMZ). The spatial distribution of the relevant stations is shown in Figure 1.

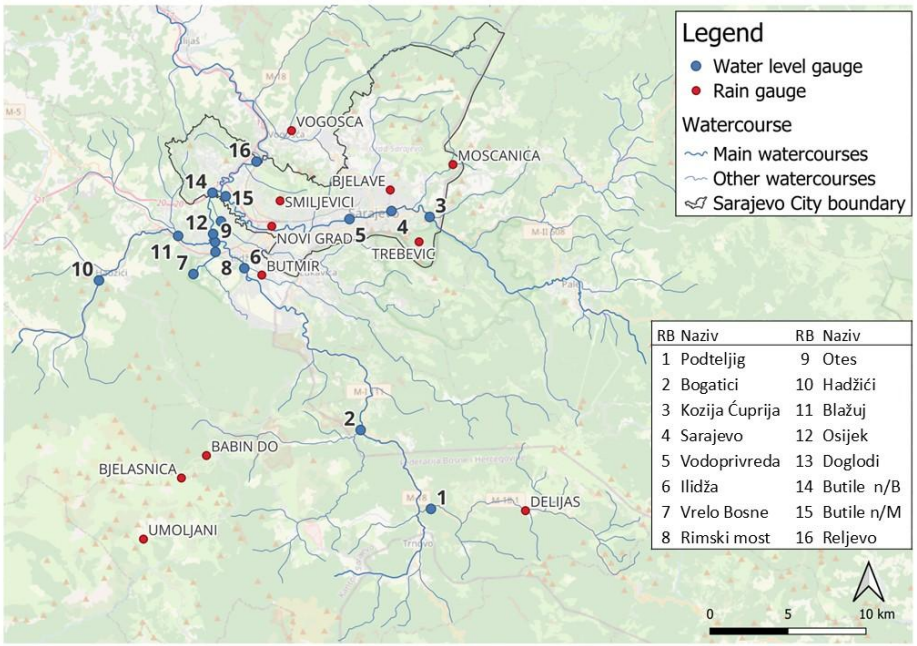


Figure 1. Locations of hydrological (water level gauge) and precipitation (rain gauge) monitoring stations in the Sarajevo urban area. Data source: FHMZ and AVP Sava; map prepared by the Authors.

For pluvial flood management, information relevant to monitoring is primarily associated with the urban stormwater drainage system and its main hydraulic components, including collectors, pumping stations and outfalls. However, unlike the hydrometeorological monitoring network used for river flooding, a dedicated and publicly documented monitoring system specifically designed for real-time observation of intense rainfall, surface-water accumulation and drainage-system performance has not been identified for the Sarajevo urban area. This limits the availability of spatially distributed real-time information required for pluvial flood forecasting and early warning.

3.2. Available data

A range of data relevant to flood risk management is available for the Sarajevo urban area from existing monitoring networks, information systems and previous studies. Precipitation observations, river water levels and discharge data are provided

through the FHMZ monitoring network. Hydrological observations from FHMZ stations are exchanged through the International Sava River Basin Commission (ISRBC) and are available in near real time through the Sava HIS information system [12], while selected real-time observations are also published by FHMZ [13].

Ground-based observations can be complemented by satellite-based precipitation products. For example, the NASA GPM IMERG product provides near-real-time precipitation estimates at a spatial resolution of 0.1° × 0.1° and a temporal resolution of 30 minutes [14]. Although its spatial resolution is relatively coarse for detailed urban flood analysis, it can provide useful supplementary information on the spatial and temporal distribution of precipitation, particularly where ground observations are limited.

In addition to monitoring data, previous flood hazard and risk assessment studies have produced important spatial datasets for the Sarajevo area, including flood hazard and flood risk maps. These maps are publicly available through the Agency for the Sava River Basin District (AVP Sava) [15] and provide an important existing information base for flood risk assessment and the development of future smart flood management applications.

3.3. Institutions

Flood management in Sarajevo involves institutions operating at different administrative and spatial levels, from local utility companies and civil protection to cantonal, federal and river-basin institutions. Their main roles and the information systems relevant to flood management are summarized in Table 2.

Table 2. Key institutions and systems relevant to smart flood management in Sarajevo

Component	Key institutions/systems
Information & data	Federal Hydrometeorological Institute of BiH (FHMZ); Agency for the Sava River Basin District (AVP Sava); the International Sava River Basin Commission (ISRBC) /Sava HIS; Public Utility Company “Water Supply and Sewerage” Sarajevo (KJKP ViK Sarajevo)
Monitoring, modelling & forecasting	FHMZ; Sava FFWS; AVP Sava
Urban drainage information	KJKP ViK Sarajevo
Flood risk assessment & mapping	AVP Sava; FHMZ; relevant technical/research institutions (University of Sarajevo, Hydraulic Engineering Institute (HEIS), Institute for Water Management Sarajevo — IWM Sarajevo, etc.)
Data exchange	FHMZ - AVP Sava - ISRBC/Sava HIS
Flood warning & emergency response	FHMZ; Federal Administration of Civil Protection (FUCZ); Cantonal/local Civil Protection
Water-management policy & coordination	Federal Ministry of Agriculture, Water Management and Forestry (FMAWM); AVP Sava
Operational flood protection	AVP Sava; civil protection authorities; local authorities; relevant water-management/utility organisations

3.4. Modelling

Existing flood hazard maps for the Sarajevo area indicate that both hydrological and hydraulic modelling has already been applied to support flood hazard assessment [15]. These modelling activities provide an important basis for simulating flood flows and inundation under different hydrological scenarios and have resulted in spatially distributed information on flood hazard that can be used for further risk assessment and decision-making. In addition to modelling undertaken for official flood hazard mapping, research-oriented hydrological and hydraulic modelling has also been applied in the Sarajevo area. For example, Binesh et al. [5] used a coupled hydrological–hydraulic modelling approach to simulate river-flood scenarios and assess their implications for urban areas and critical infrastructure. Hadžić et al. [4] likewise demonstrated the application of flood hazard and risk mapping for the Zujevina River within the wider Sarajevo area. Together, these examples indicate that relevant modelling experience and datasets already exist, but they remain fragmented across different applications and are not yet integrated within a common operational smart flood management framework.

3.5. Forecasting and Early Warning System

Following the severe floods of 2014, AVP Sava initiated the development of a real-time flood forecasting system for the Sava River basin in the Federation of BiH. By mid-2021, operational systems integrating real-time hydrometeorological observations, meteorological forecasts and hydrological–hydraulic models covered the major sub-basins, including the Bosna River basin relevant to Sarajevo [16, 17].

At the regional level, additional forecasting and early warning capacity is provided through the Sava Flood Forecasting and Warning System (Sava FFWS), based on the Delft-FEWS platform and involving FHMZ and AVP Sava [18]. An effective EWS integrates risk knowledge, hazard detection and forecasting, warning communication and response preparedness [19]. For Sarajevo, these elements should be linked with local response arrangements, particularly for rapidly developing pluvial and flash-flood events.

3.6. Data sharing and interoperability

Data sharing and interoperability are already established at the river-basin level through cooperation among FHMZ, AVP Sava, and the ISRBC. The Sava HIS [12] provides a common framework for the exchange and harmonisation of hydrological data, while the Sava FFWS integrates data, models and forecasts from national institutions through the Delft-FEWS platform. However, the existing interoperability framework is primarily organised at the national and basin levels, while direct operational links with institutions responsible for urban drainage and local flood management in Sarajevo are less clearly established. This indicates a need to strengthen the integration of basin-scale information with local urban data and decision-making, particularly regarding drainage-system information and rapidly developing urban flood events.

3.7. Identified gaps

A fundamental requirement for the development of a smart flood management system is the availability of reliable and sufficiently detailed hydrological and spatial data. In BiH, however, the development and application of flood hazard and risk assessment methodologies are constrained by the availability, spatial distribution and quality of hydrological data and supporting hydro-meteorological information. Recent analyses of the state of hydrological data in BiH have highlighted the need to improve the data sources used for flood hazard mapping and related risk-management activities [20]. This issue is particularly relevant for Sarajevo, where effective flood management requires not only the availability of hydrological observations, spatial datasets, rainfall information and hydraulic modelling, but also their integration into a consistent and continuously updated information framework.

4. PROPOSED FRAMEWORK FOR SMART FLOOD MANAGEMENT IN SARAJEVO

Based on the analysis of the existing monitoring, data, modelling, forecasting and institutional capacities, a framework for smart flood management in Sarajevo is proposed. The framework is structured around three complementary aspects: (i) information and data, (ii) technology, and (iii) institutional arrangements. The proposed approach builds on existing national and basin-level capacities and connects them with local urban flood management, particularly for pluvial and flash-flood events. The proposed framework, including existing capacities and further requirements, is summarized in Figure 2.

The proposed framework is primarily intended to support real-time monitoring and forecasting, together with emergency preparedness and response. The information generated through the system can also be used for longer-term flood risk prevention and spatial and urban planning. In this way, planning is seen as a secondary use of the system outputs, for example in identifying flood-prone areas, assessing exposure, and supporting future urban development decisions.

Information and data. The first component comprises the establishment of an integrated information base for flood risk management. This should combine observed precipitation, river water levels and discharges from the FHMZ monitoring network with spatial information on the urban drainage system, including stormwater collectors, critical hydraulic structures, outfalls and areas susceptible to surface-water accumulation. Existing flood hazard and risk maps, modelling results, historical flood records and exposure data should be incorporated into the same spatial framework. Real-time data should be complemented by high-resolution rainfall estimates from radar, satellite and other sources, particularly where rain gauges cannot adequately represent intense convective rainfall. The resulting information base should be continuously updated and made accessible to the institutions responsible for assessment, forecasting and emergency response.

Technological components. The second component should transform heterogeneous observations and spatial information into timely flood intelligence. The existing FHMZ monitoring network, the forecasting platform operated by AVP Sava and the Sava FFWS provide an important foundation for flood forecasting and should be complemented by an urban-scale monitoring system focused on intense rainfall, surface-water accumulation and the performance of the stormwater drainage network. A GIS-based data platform should integrate real-time observations, historical records, terrain and land-use data, drainage infrastructure and flood hazard information. Hydrological and hydraulic models should be linked to this platform to support both fluvial and urban pluvial flood forecasting, while high-resolution rainfall nowcasting should improve the prediction of rapidly developing events. The technological framework should also include automated data exchange, alert generation, visualization and decision-support functions, allowing relevant information to be transformed into operational warnings and response actions.

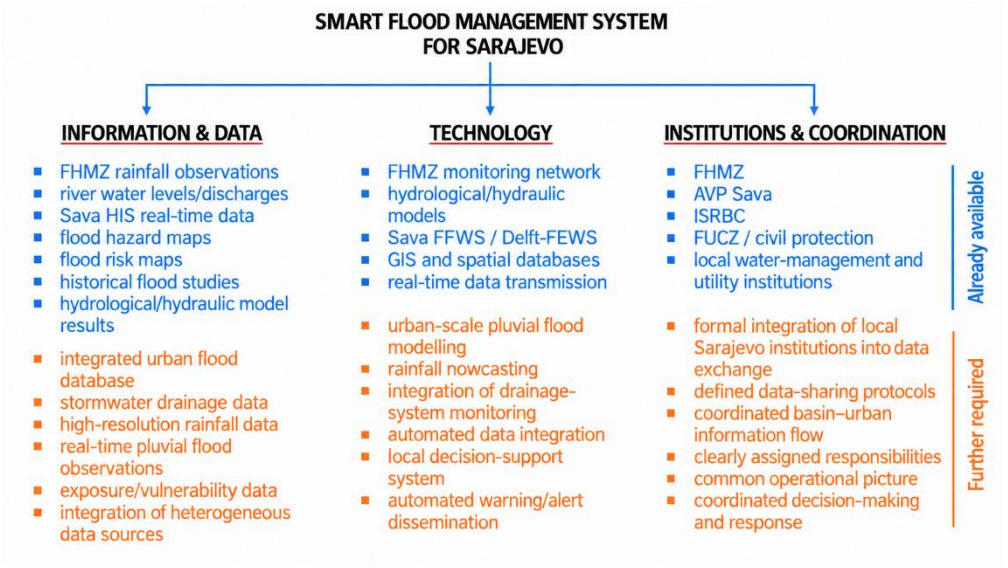


Figure 2. Proposed framework for a smart flood management system in Sarajevo. Source: Authors.

Institutional arrangements. The third component concerns the institutional organization required to ensure that data and technologies are effectively used for decision-making. The existing roles of FHMZ, AVP Sava and ISRBC in monitoring, data exchange, flood forecasting and basin-level management should be connected with the institutions responsible for urban drainage, local water management, spatial planning and civil protection in Sarajevo. Systematic data exchange between basin-level systems and local institutions should include urban drainage and local flood-impact information, with clear responsibilities for data provision, modelling, forecasting, warning dissemination, public communication and emergency response. A coordinated institutional framework would therefore enable information generated at different administrative and spatial scales to be transformed into a common operational picture and shared basis for decision-making.

The three components are interdependent and should not be developed as separate systems. Information provides the evidence, technology transforms information into actionable intelligence, and institutional arrangements ensure that this intelligence reaches the right decision-makers and results in coordinated action. The proposed framework therefore represents a transition from existing but partly fragmented monitoring and flood-management activities towards an integrated smart flood management system for Sarajevo, capable of addressing both riverine flooding and rapidly developing urban pluvial and flash-flood events.

5. CONCLUSION

This study briefly reviewed the existing information and data sources, monitoring infrastructure, hydrological and hydraulic modelling, flood forecasting and early warning capacities, and institutional arrangements relevant to flood risk management in Sarajevo. All these aspects were reviewed with the aim of identifying the key gaps that currently separate Sarajevo from a smart flood management system. Particular attention was given to the availability and integration of data, existing technological solutions, and the links between basin-level and local urban flood management. Based on this assessment, the following conclusions are drawn:

1. Sarajevo already has significant flood-management capacities, including hydrometeorological monitoring, flood hazard and risk maps, hydrological and hydraulic models, and basin-level flood forecasting through AVP Sava forecasting systems and the Sava FFWS.
2. Despite remaining gaps in data availability and quality, the main systemic challenge is their integration, particularly the connection of basin-scale systems with local urban information on rainfall, drainage infrastructure and pluvial flooding.
3. A smart flood management system requires three interconnected components: integrated information and data, interoperable technologies for monitoring, modelling, forecasting and information exchange, and coordinated institutional arrangements.
4. For Sarajevo, priority should be given to linking existing capacities with local urban flood management, with particular attention to high-resolution rainfall monitoring, pluvial and flash-flood forecasting, data sharing, and coordinated decision-making.

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