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Research paper

TOWARDS A SMART CITY: A SMART DAM INITIATIVE IN NIŠ

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Abstract

A smart city represents an urban environment in which the application of digital technologies enables the improvement of the efficiency of city services such as energy, water management, waste disposal, and public safety. Its primary goals are to promote economic growth and innovation, improve the quality of life for residents, and create a more liveable, sustainable, and inclusive urban space. By establishing a connected and data-driven environment, cities can attract businesses and generate new opportunities. This paper presents a strategic initiative formed during the hackathon activity under the WATERLINE project and aimed at transforming the city of Niš into a smart city, focusing on revitalizing the Nišava River as a central element of urban development. The river training works from 1988 were constructed in both the minor and major riverbed of the Nišava River in the city zone, satisfying the architectural and urban planning requirements at that time. However, the minor riverbed has suffered from a lack of regular maintenance, resulting in significant challenges. In particular, the section of the river between the "Stone" Bridge and the "Mladost" Bridge is challenging due to non-functional thresholds, specifically three inflatable dams that have deteriorated due to insufficient maintenance and the effects of climate change. This decline has undermined the essential cityscape and urban planning objectives, making the Nišava riverbank less attractive for residential, recreational, sporting, tourism, cultural, and entertainment activities. The paper advocates for adopting new sustainable development concepts and intelligent digital solutions, proposing an integrated approach to enhance the community's overall well-being through incremental improvements. A key component of this initiative is establishing a smart dam project, which could be implemented through a public-private partnership (PPP) model. Additionally, this paper conducted a detailed SWOT analysis to assess the feasibility of the smart dam project.

Key words: *smart city, digital solution, river engineering, sustainable development, public-private partnership, SWOT analysis*

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1. INTRODUCTION

In the final decades of the 20th century, two significant trends emerged that dramatically reshaped urban landscapes: rapid urbanization and the widespread adoption of intelligent digital solutions. Technological developments pushed cities worldwide to seek efficient ways to manage new urban challenges.

Smart cities all share the characteristic of acting on their services and activities to make them more efficient. The ways they achieve this are very diverse, but they often have in common the use of digital technology resources (or ICTs, information and communication technologies) [1].

Figure 1 illustrates the technologies for creating smart cities. Data is a fundamental resource for any smart city, powering intelligent solutions. A smart city is considered 'data-driven,' meaning its operations and decisions revolve around data [2]. Rather than relying on gut instinct or outdated practices, smart cities leverage real-time data analytics to support evidence-based decision-making, ensuring urban interventions are precise, efficient, and responsive to citizens' needs.

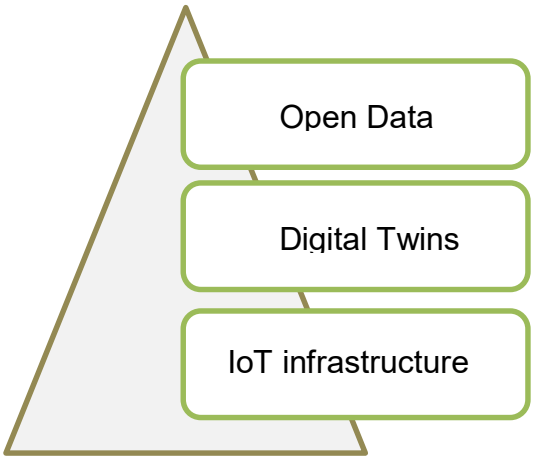

Figure 1. Technologies for creating smart cities

Smart cities initiatives generate transformative scientific value by merging IoT-enabled urban sensing, cyber-physical digital twins, AI-driven governance, distributed edge-cloud systems, and blockchain-secured collaboration into an integrated urban intelligence framework [3].

This paper presents a draft initiative to restore one of the three inflatable dams on the Nišava River in Niš and highlights how ICT solutions can improve the city's overall image and quality of life. Implementing it through Public-Private Partnerships (PPPs) can enhance urban resilience, optimize costs, and improve efficiency.

The study evaluates internal capabilities (Strengths and Weaknesses) and external factors (Opportunities and Threats) to determine the initiative’s strategic positioning and implementation challenges through SWOT analysis.

2. STUDY AREA

2.1 The City of Niš

Niš serves as a compelling case study in urban development, offering valuable insights into the dynamics of post-industrial transition, the integration of smart city initiatives, and regional economic resilience within Southeast Europe.

Scientifically analyzing its transformation reveals several key patterns: the city has successfully cultivated a knowledge-based economy through strategic clustering in the ICT sector [4], demonstrating an annual growth rate of approximately 15% [5], while simultaneously navigating the challenges of shifting from traditional manufacturing to high-value electronics production. According to [6], demographic trends present both challenges and opportunities, with negative net migration (-0.8% annually) among skilled youth contrasting with the IT sector's growing capacity for talent retention.

Over the past two decades, Niš has increasingly positioned itself as a regional innovation hub in Southeastern Europe, leveraging its university ecosystem, availability of skilled labor, and improving digital infrastructure. The presence of the Science and Technology Park, alongside initiatives supporting startup incubation, has further embedded innovation into the urban fabric. Nevertheless, the city continues to wrestle with infrastructural legacies from its industrial past, especially regarding environmental sustainability, energy efficiency, and water resource management. These issues have brought attention to the need for integrated, smart infrastructure solutions that combine digital technology with green urban planning principles. The "Smart Dam" initiative thus emerges as a natural extension of Niš's broader smart city agenda. By incorporating real-time monitoring systems, predictive analytics for flood prevention, and citizen-centric data platforms, the project serves as a pilot for integrating resilient water management into urban development strategies. Such efforts are aligned with EU smart specialization policies and reinforce the city’s ambition to become a model of sustainable urban transformation in the Western Balkans.

The city's ongoing transformation generates valuable data for researchers examining the complex relationship between legacy infrastructure, digital modernization, and spatial equity in developing urban contexts. In this sense, Niš stands not only as a case of economic transition but as a testing ground for adaptive governance, digital experimentation, and the democratization of urban innovation.

2.2 The Nišava River

The completed works in the minor and major riverbeds of the Nišava River within the urban zone meet architectural and urban planning requirements. The riverbed platforms include promenades and amphitheatres for sports and cultural-recreational activities. According to the Institute Jaroslav Černi [7], along the Nišava River from the railway bridge near the old "Vulkan" to the "Fortress" bridge, the left bank quay wall was constructed in the period 1957-1958. The bilateral river engineering structures of the Nišava River through the City (begun in 1987) cover the reach from the "Stone Bridge"to the bridge in "Proleterska" Street.

The minor riverbed is generally well-maintained and regularly cleaned. However, a problem persists on the section between the "Stone Bridge" and the "Mladost" Bridge, where three defunct inflatable dams (due to poor maintenance) have compromised the original

architectural and urban planning objective: creating a wider water surface in the minor riverbed to enhance aesthetic and microclimatic effects, making the Nišava riverbanks more attractive for leisure, sports, tourism, and cultural activities (Figure 2).

Figure 2. Urban zone of the Nišava River between the Fortress Bridge and the "Mladost" Bridge

Figure 3. The Nišava River Cross Profile at the Section between the Fortress Bridge and the “Mladost” Bridge near the kayak club “Gusar”

During low-water periods, when the riverside promenade is most appealing, the shallow water level and low flow velocity, combined with poor water quality, promote algae growth, often covering the entire minor riverbed (Figure 3).

The condition and maintenance of the river engineering structures along the Nišava in the city area are satisfactory. While the structures are generally well-maintained, the non-functional inflatable dams and the proliferation of algae during low-flow periods diminish the intended urban aesthetic and recreational benefits. Revitalizing these elements could enhance Nišava's role as a central public space in Niš. For instance, Figure 4 presents an illustrative example of an inflatable dam installation in Svrljig, in Serbia. It is evident that such a structure improves not only the aesthetic appeal of the river and its banks but also serves as a starting point for urban development. By improving the visual and functional quality of the waterway, the installation exemplifies how infrastructure can act as a foundational component for further urban revitalization efforts.

Figure 4. Before and after inflatable dam installation in the City of Svrljig

3. THE SMART SYSTEM

Over the past two decades, advancements in applying ICT in the water sector have increasingly transformed water resource management. These innovations will enhance real-time monitoring, predictive analytics, and adaptive governance of river systems, addressing critical challenges in efficiency, equity, and sustainability [8].

Industry 4.0 comes with high demands for system interconnectivity and high system autonomy. In order to provide high system autonomy, dependence on human factors should be minimized. Nowadays, with the fast development of artificial intelligence (AI) techniques, especially Machine Learning (ML) and Deep Learning (DL), it is possible to design intelligent control systems with viable applications in water level management [9-11]. The greatest advantage ML and DL models provide is noticing and learning patterns invisible to the human eye that exist in the data. Here, we propose a Smart IoT solution to solve the problem of water level management in the Nišava River. Figure 5 represents the position of the sensors for real-time monitoring according to the position of the inflatable dam.

The Smart IoT water level management system scheme is proposed in Figure 6. A Rubber Dam Controller unit (3) would control the rubber dam (2), which would receive information from several sensors (1) such as water level, water flow, and water quality sensors. The controller would also get information from a DL model, previously trained on the data from the Republic Hydrometeorological Service of Serbia. The DL model would be used to predict potential hazardous events such as droughts or floods based on the precipitation data and signals from the previously mentioned sensors. That way, the controller could react in advance and inflate or deflate the rubber dam. If such an event is predicted, the DL model could send a signal to the data center to alert the citizens of a potential problem.

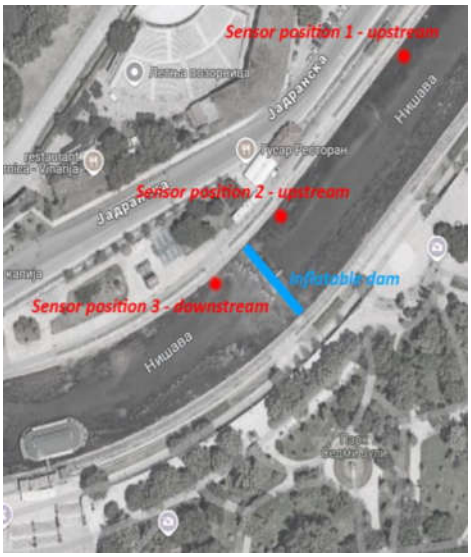

Figure 5. The Nišava River sector with sensor network deployment relative to the inflatable rubber dam

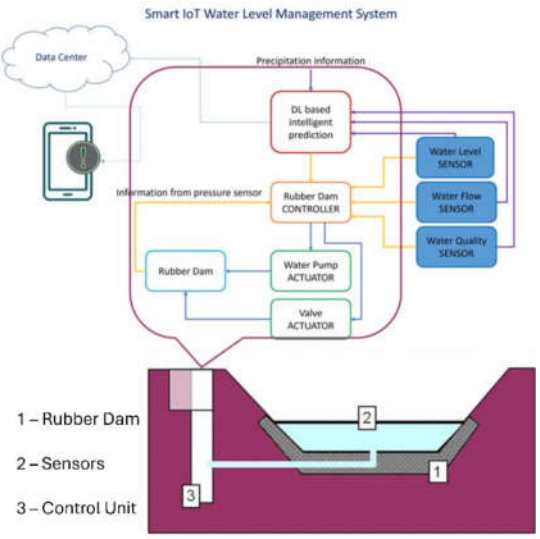

Figure 6.(on the right) Smart IoT Water Level Management System

4. INFLATABLE DAM

An inflatable dam is a modern hydraulic structure made of flexible, rubberized material, typically consisting of multi-layer fabric like nylon that is rubberized on one or both sides. Designed as an elliptical, inflatable, and deflatable structure, it is anchored to a concrete base and can be filled with water, air, or both using pumps, blowers, or valves. The inflatable dams are very similar in their structure. In this case, the water-filled inflatable dam is selected.

These dams are highly adaptable, allowing for adjustable heights to manage varying water levels, making them ideal for flood control, irrigation, water supply, and small-scale hydropower generation. Their installation is simple, requiring minimal labor and foundation work, and they perform well in low-resistance soils. Additionally, inflatable dams are cost-effective, with lower construction and maintenance costs, and their flexibility makes them resistant to earthquakes. However, they are vulnerable to damage from debris, extreme cold, and intentional harm, requiring careful design considerations such as deflectors to manage overflow. Despite these challenges, their ability to be deflated when not in use and their minimal environmental disruption make them a practical solution for modern water management needs [12].

The installation's cross profile of the Nišava River section is presented in Figure 7.

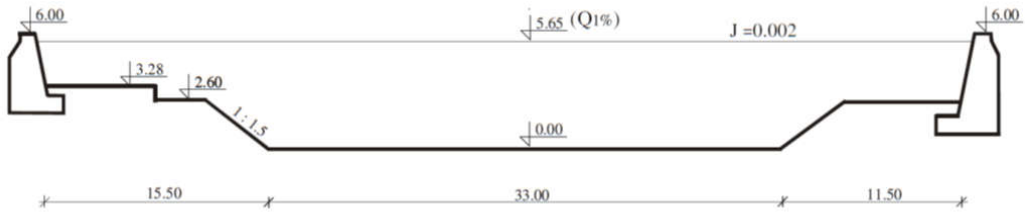

Figure 7. Cross Profile at the Nišava River section [13]

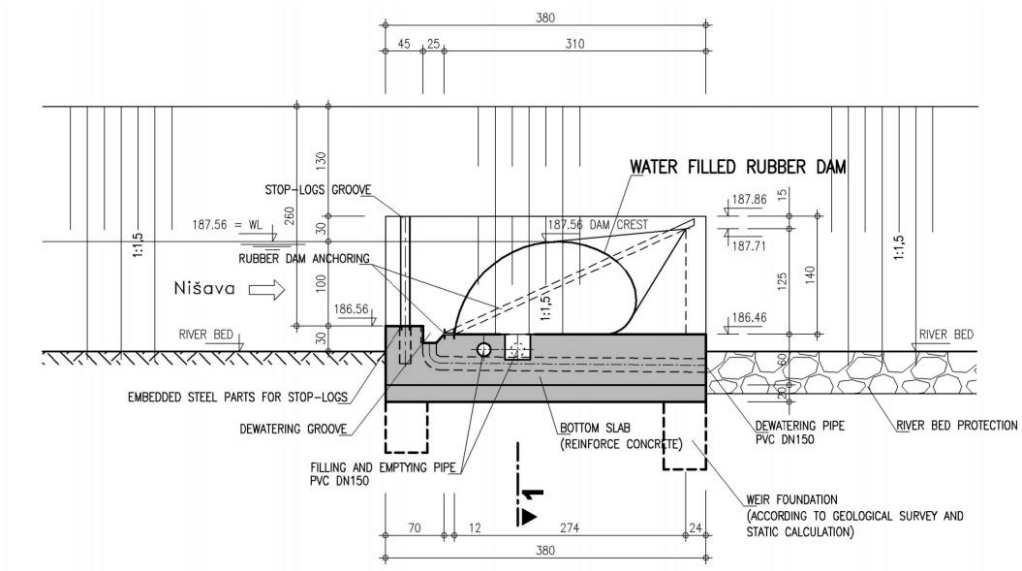

Figure 8. Inflatable Dam Construction Cross Profile

Figure 8 illustrates a proprietary solution of water-filled rubber dam co-developed with Korekt Company in Serbia, a technical partner of Trelleborg Slovenija. In recent years, this company has significantly enhanced its offering by introducing comprehensive turnkey solutions for rubber dam projects. This integrated approach is a fully operational system comprising of: rubber dam anchoring system, piping and control infrastructure, and electronic monitoring and control systems.

Considering the technological and functional benefits of the inflatable dam, its implementation in the urban core of Niš brings to light not only engineering challenges but also governance, financing, and community engagement issues. In such an urban and socially sensitive environment, traditional infrastructure delivery models may fall short in addressing the broader goals of sustainability, inclusivity, and public trust. Therefore, exploring public-private partnerships (PPPs), particularly the emerging “people-first PPP” (4P) approach, offers a promising avenue for balancing financial viability with social value. The next section evaluates the feasibility of applying a PPP model to this project in Niš, focusing on aligning local needs, private sector capabilities, and institutional readiness. A SWOT analysis is also presented to assess the strategic implications and potential risks associated with adopting such a model in the Serbian context.

5. PUBLIC-PRIVATE PARTNERSHIP AND SWOT ANALYSIS

The successful implementation of public-private partnership (PPP) projects is closely linked to improvements in infrastructure service quality, timely delivery, and broader economic growth. By mobilizing private sector investment and fostering efficiency, PPPs can generate significant macroeconomic benefits, including increased public sector capacity to invest in social services. However, achieving these outcomes requires strong institutional frameworks, transparent governance, and sound regulatory policies. When properly implemented, PPPs not only enhance local and regional development but also contribute to long-term national economic advancement by attracting long-term capital to strategic infrastructure sectors [14]. In this specific project, alongside the ordinary PPP project, which would include a public and a private partner, a 4P could be implemented and also include the "people" component, as the 4P accounts for public-private people partnership. This can be done through incorporating local non-governmental organisations, groups of citizens, or, for example, a local kayaking club that also has an interest in a smart working dam and improved conditions in the Nišava river in the center of the city. The public partner would be the City Council of Niš, and a private partner could be the producer of smart dams or some other entity that could find their interest in realising this project.

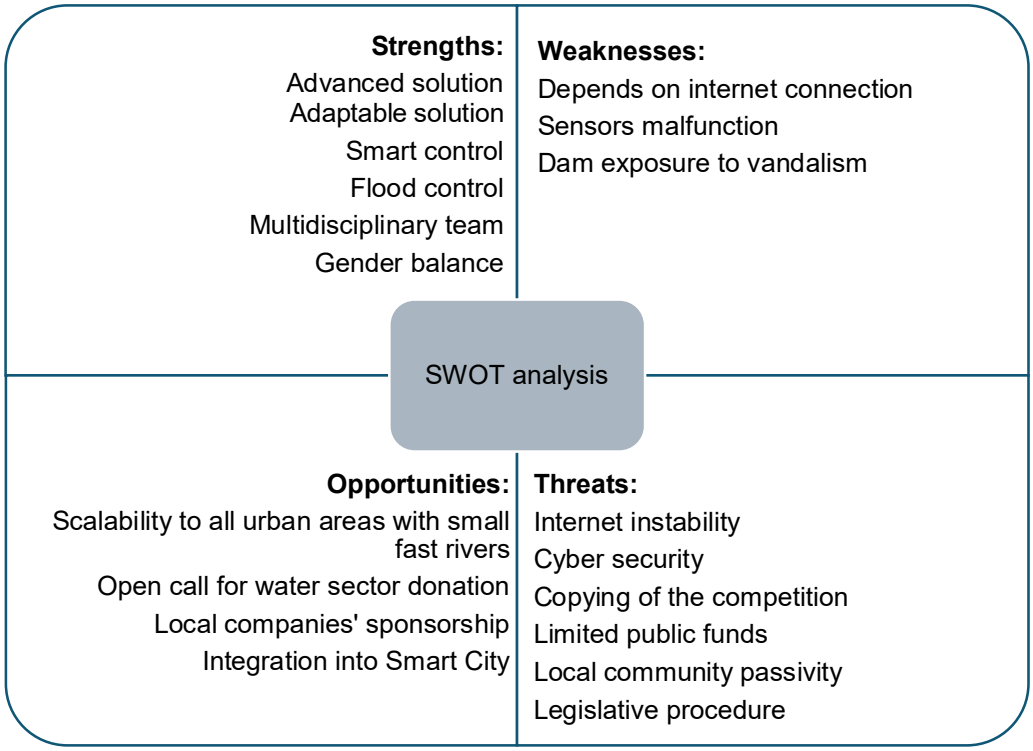

Figure 9. SWOT diagram of the Smart Dam initiative

This paper undertakes a detailed SWOT analysis to systematically assess the feasibility, strategic positioning, and potential challenges of the smart dam project. The SWOT framework examines strengths, weaknesses, opportunities, and threats and offers a structured methodology for evaluating internal and external factors that could influence project outcomes (Figure 9). Specific attention is given to local environmental conditions,

urban planning needs, technological infrastructure, and socio-economic benefits for the Niš community. Furthermore, the analysis considers the smart dam's capacity to foster community engagement, promote digital innovation in water resource management, and contribute to Niš's long-term sustainable urban development objectives [15]. Some strengths also refer to the team (authors of this manuscript) proposing the solution, as this paper was made after the authors took part in an entrepreneurship initiative during the hackathon activity under the WATERLINE project. The solution presented by the team aimed at transforming the city of Niš into a smart city, focusing on revitalizing the Nišava River as a central element of urban development and proposing ways to finance it. This should explain the multidisciplinarity of the team (architect, water engineer, automation engineer, computer engineer, and economist) as one of the strengths listed above. Another item that may need clarification is gender balance, as the team consists of three women and two men. The main trait of a multidisciplinary team is that it is able to analyse the problem from various angles and propose innovative and out-of-the-box solutions, while the gender balance, among other benefits, may serve well when applying for some grants or funds, both locally and internationally. In Table 1, some additional aspects from SWOT analysis are described.

Table 1. SWOT analysis categories and items of the Smart Dam Initiative

Categories	Items
Strengths	Enhanced flood control and water management capabilities; Promotion of digital innovation through real-time monitoring and smart infrastructure; Potential for public-private partnership (PPP) financing; Reducing public fiscal burden; Improved urban resilience and climate adaptation capacity; Opportunity for integration with urban revitalization projects (e.g., recreational spaces along the riverbanks)
Weaknesses	High initial capital investment costs; Potential technological maintenance complexity and long-term system sustainability issues; Dependence on effective governance and regulatory frameworks for PPP success; Limited existing experience with large-scale smart water infrastructure in Serbia; Possible resistance from stakeholders unfamiliar with smart technologies
Opportunities	Strengthening regional leadership in smart environmental infrastructure; Attracting EU funding and support through alignment with Green Deal and digitalization priorities; Fostering community engagement through educational and participatory initiatives; Development of new eco-tourism and recreational activities along revitalized riverfront areas; Potential replication model for other mid-sized cities in the Western Balkans
Threats	Economic fluctuations and fiscal pressures affecting investment capacity; Delays in administrative approvals and regulatory bottlenecks; Cybersecurity risks associated with smart infrastructure technologies; Environmental concerns if the project disrupts natural river ecosystems without careful planning; Public distrust if community involvement and transparency are not adequately ensured

The proposed inflatable smart dam in Niš exemplifies a strategically significant infrastructure initiative that aligns with local needs and broader sustainable development goals. As demonstrated in the SWOT analysis, the project presents a range of strengths, from enhanced flood resilience and digital water management to potential integration with recreational urban revitalization. Moreover, it offers a valuable opportunity to mobilize blended financing through public-private partnerships, thereby reducing fiscal pressure on local governments while ensuring timely and efficient project delivery. Critically, including a "people-first" public-private-people partnership (4P) model adds a unique social dimension to the project. By engaging local community stakeholders such as NGOs, sports clubs, and environmental groups, the initiative can foster public trust, increase community ownership, and ensure that the infrastructure serves not only technical but also social and environmental functions. Such participatory governance mechanisms have been increasingly recognized as essential for the long-term sustainability and public legitimacy of infrastructure projects [16]. Nonetheless, the project's viability depends on several preconditions: securing institutional support at the city level, ensuring technical competence and maintenance capacity, and mitigating risks related to digital infrastructure and environmental integrity. In addition, as this would be one of the first large-scale smart water infrastructure projects in Serbia, careful planning, transparent communication, and capacity building among public officials and citizens will be vital.

If these challenges are addressed through a robust implementation framework and community-centred planning, the inflatable dam in Niš could serve as a benchmark for similar mid-sized cities across the Western Balkans. It would not only demonstrate how to leverage smart technology for environmental resilience but also how to effectively operationalize inclusive PPP frameworks for holistic urban development. Such projects, when well-executed, have the potential to transform micro-level innovation into macro-level impact, thus stimulating economic activity, enhancing public services, and promoting regional competitiveness in line with EU integration and green transition objectives.

6. CONCLUSION

The development of smart cities represents a comprehensive strategy to address modern urbanization challenges through the strategic integration of cutting-edge technologies and collaborative governance models. By leveraging AI, IoT networks, and big data analytics, these initiatives enable evidence-based urban management that enhances infrastructure efficiency and improves the quality of life for residents. Within this framework, the presented Smart Dam initiative emerges as an innovative solution to critical water management challenges, combining technological sophistication with practical adaptability. This approach demonstrates how smart technologies can be effectively applied to solve pressing urban issues while maintaining cost-effectiveness and environmental sustainability.

The Smart Dam initiative embodies the principles of smart urban development through its intelligent water level management system, which offers real-time monitoring and adaptive control capabilities. This system provides cities with a powerful tool to address two major contemporary challenges: climate-induced flooding and water scarcity. The project's success stems from its versatile implementation team, whose multidisciplinary expertise ensures seamless integration with existing urban infrastructure while maintaining operational reliability. What makes this solution particularly valuable is its combination of technical

performance and economic viability, featuring significantly lower implementation costs compared to traditional alternatives and minimal environmental disruption during both deployment and operation.

The proposed inflatable smart dam project in the City of Niš represents an innovative and sustainable infrastructure initiative with strong potential to address local environmental and urban challenges. The project aligns economic efficiency with social inclusion and environmental responsibility by integrating the principles of public-private partnerships (PPP) and expanding toward people-first public-private partnerships (4P). The SWOT analysis underscores that the strengths and opportunities significantly outweigh the weaknesses and threats, especially when backed by strategic planning, transparent governance, and community engagement. The involvement of local citizens and organizations enhances the project's legitimacy and long-term success, transforming a traditional infrastructure investment into a collaborative model for urban resilience and digital innovation. As such, the smart dam project in Niš can serve as a scalable example for other cities in Serbia and the Western Balkans seeking to modernize water infrastructure through inclusive and sustainable partnership models.

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