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A REVIEW PAPER TO STUDY THE FLOOD RESISTANT SMART CITY

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ABSTRACT

Urban flooding is one of the major problems faced by cities because of heavy rainfall, rapid urbanization, concrete surfaces, poor drainage systems, climate change, and reduction of natural water-storage areas. During heavy rainfall, water cannot easily enter the ground because roads, buildings and other surfaces are mostly impermeable. As a result, water collects on roads and in low-lying areas and causes damage to buildings, transportation, infrastructure and daily life.

A Flood Resistant Smart City is a concept that combines civil engineering solutions, green infrastructure and smart technologies to reduce the effects of urban flooding. The proposed system includes permeable roads, rainwater harvesting, green roofs, rain gardens, detention ponds, smart drainage, water-level sensors, rainfall sensors, GIS mapping, artificial intelligence (AI), Internet of Things (IoT), and an early-warning system.

Keywords: Flood resistant smart city, Urban flooding, Smart drainage, IoT, AI, GIS, Permeable road, Green infrastructure, Sponge city, Rainwater harvesting, Early warning system

I. INTRODUCTION

Urban flooding is a major problem caused by rapid urbanization, heavy rainfall, climate change, and poor drainage. A Flood Resistant Smart City combines sustainable infrastructure with modern technologies such as IoT sensors, GIS, AI, smart drainage, rainwater harvesting, permeable roads, and nature-based solutions to reduce flood risks. This review paper studies these methods, their benefits, limitations, and research gaps for developing safer, sustainable, and climate-resilient cities.

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Figure 1: Flood resistant smart city

II. OBJECTIVES

1. To study the main causes of flooding in urban areas.
2. To understand the effects of floods on people, buildings and roads.
3. To study modern technologies used for flood prevention and control.
4. To understand the importance of proper drainage systems and rainwater harvesting.
5. To find ways to reduce flood damage and make cities safer for the future.

III. LITERATURE REVIEW

3.1 Jiacheng Zhu (2026): In this paper author studied urban flood management under climate change and rapid urbanization. The study highlighted the importance of combining smart technologies like AI and IoT with nature-based solutions such as green roofs, permeable pavements, and sponge cities. This integrated approach can improve flood prediction, early warning, and urban resilience. However, challenges such as cost, maintenance, and governance remain.

3.2 Md Enamul Huq (2026): In this paper author reviewed 96 studies on Low Impact Development (LID) techniques for urban flood management. The study found that methods such as permeable pavements, green roofs, rain gardens and bioretention systems help reduce stormwater runoff and flooding. The authors also highlighted challenges related to cost, maintenance and implementation. They concluded that integrating LID techniques with conventional drainage systems can improve urban flood resilience and support sustainable development.

3.3 Shahrzad Hamidiaala (2026): In this paper author studied how real time control can improve nature-based solutions for urban stormwater management. The study showed that using sensors, weather forecasts and automated systems in green and blue-green roofs can help store rainwater and reduce peak runoff. However, challenges such as limited research,

maintenance and sensor reliability still need to be addressed. The authors concluded that combining smart control systems with nature-based solutions can make urban drainage more efficient and improve flood resilience.

3.4 Mohd Furkhan (2026): In this paper author discusses the role of permeable roads and pavement in urban stormwater management and flood reduction. It highlights how these pavements allow rainwater to infiltrate into the ground, reducing surface runoff and waterlogging. The study also discusses their benefits, limitations, maintenance requirements and construction costs. The paper concludes that permeable pavements can be an effective part of sustainable urban drainage systems and help improve urban flood resilience

3.5 Medisetty, S. G. S., & Sadhukhan, S. (2026): The disruptions caused by floods are enormous in urban areas due to urbanisation and climate change over the past two decades. Increased precipitation levels and urban development in India exacerbate the frequency and duration of floods. The present study identified a list of publications and research articles from 2005 to 2025 and further refined them based on the 'United Nations Sustainable Development Goals 6, 11, and 13'. The bibliometric analysis revealed trends in publications from the past two decades and, through keyword frequency mapping, identified three clusters related to resilience, rainfall, and urban areas. The systematic literature review identified relevant studies to analyze flood-related factors, parameters, and methods, to understand functional flood resilience, the flood risk index, and the flood susceptibility index. This study identifies a research gap in urban flood resilience in India in the subject areas of Microclimate management, Institutional Mechanisms, and financial mechanisms, which justify further exploration.

3.6 Shabnam Varzeshi (2026): In this paper author reviewed how smart city technologies can contribute to urban resilience and sustainable urban planning. The study analyzed 115 peer-reviewed studies and examined technologies such as Internet of Things (IoT), Geographic Information Systems (GIS), Artificial Intelligence (AI), digital twins, and big-data platforms. The authors found that IoT and GIS have strong applications in real-time monitoring, risk mapping, early warning systems, and infrastructure management. AI and digital twin technologies also show potential for improving urban decision-making, although many applications are still at the pilot or conceptual stage. The study emphasizes that technology alone cannot create urban resilience; its benefits depend on proper integration with urban planning, governance, institutional capacity, and community participation. The review also found that existing research is concentrated mainly in high-income cities, while cities in the Global South are less represented. Overall, the study highlights the importance of combining smart technologies with planning and governance to develop more resilient urban areas.

3.7 Pirone, D., Padulano, R., & Del Giudice, G (2026): This paper aims to demonstrate that the suitable spatial resolution depends on the objective of the model application and the area of application. Thus, existing approaches to achieving satisfactory urban flood modelling are reviewed according to the available data and desired objectives. Then, the advantages and

limitations of data-rich environments and the benefits of the simplifications are explored. This study identified two main objectives that are the most concerned with ongoing urban flood modelling: flood risk mapping for preliminary assessment and flood risk mapping for flood hazard mapping. For each of them, this study investigates how previous authors approached data collection tasks and which resolution they considered sufficiently high to retain their objectives achieved.

3.8 Lorette Gollois (2026): In this paper author studied how Nature-based Solutions (NbS) can be selected for effective flood management. The study reviewed 92 research papers and 132 case studies. The authors developed a framework to assess NbS based on environmental, social, economic, and disaster-risk factors. They suggested a three-step approach to select suitable solutions according to land conditions, potential risks, and community needs. The study concluded that considering multiple factors can help in choosing suitable and sustainable flood management solutions for urban areas**.**

3.9 Zhewei Liu (2025): In this paper author reviewed the application of Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) techniques in flood risk management. The study analyzed more than 300 research papers and examined the use of AI according to different flood types, AI models, spatial scales, input data, and practical applications. The authors found that AI-based methods can support flood prediction, flood susceptibility mapping, early warning systems, damage assessment, and emergency decision-making. Compared with some traditional approaches, AI can process large and complex datasets and provide faster predictions, which can be useful for real-time flood management. However, the study also identified important challenges, including limited and biased datasets, differences in data quality, difficulties in applying models to new locations, and the lack of explainability of some AI models. The authors suggested that future research should focus on improving data quality, developing explainable AI models, and integrating AI with existing flood-management methods. Overall, the study shows that AI has significant potential to support more adaptive and data-driven flood risk management.

3.10 Md Shike Bin Mazid Anik (2025): In this paper author reviewed the development of urban flood prediction methods, focusing on traditional models and modern AI-based techniques. The study found that machine learning and deep learning can provide faster flood predictions using rainfall, sensor and GIS data. Hybrid models combining physical and AIbased approaches can also improve prediction accuracy and efficiency. However, data limitations and difficulties in integrating these models into urban planning remain major challenges. The authors highlighted the importance of combining AI, GIS, IoT and real-time monitoring to improve urban flood management and resilience.

3.11 Z. Li , Z. Zhou, H. Wang (2025): In this paper author reviewed the use of artificial intelligence and machine learning for urban flood prediction. The study found that AI-based models can provide faster flood predictions and support real-time forecasting and earlywarning systems. However, challenges such as limited data, model accuracy and reliability still remain.

The authors suggested combining AI with traditional flood models to improve flood prediction and urban flood management.

3.12 Sibuyisele S. Pakati (2025): In this paper author reviewed various methods for urban flood modelling and risk assessment. The study highlighted the importance of combining hydraulic models, GIS, remote sensing and machine learning to improve flood prediction and risk mapping. It also showed that accurate results depend on reliable data and proper model validation. The authors emphasized the need for better climate data and improved flood assessment in poorly planned urban areas.

3.13 Pham Ngoc Thinh (2025): In this paper author reviewed the role of early warning systems in improving urban flood resilience. The study found that IoT sensors, remote sensing and AI can help predict floods and provide timely warnings. However, challenges such as data integration, poor coordination and limited access to information remain. The author concluded that combining modern technology with community participation and effective communication can improve flood preparedness and management.

3.14 Hijrah Saputra (2025): In this paper author reviewed the use of IoT technologies for improving urban disaster management and infrastructure resilience. The study found that sensors, drones and AI can help monitor hazards, detect risks and provide early warnings. However, challenges such as limited advanced technology and a lack of research in developing regions remain. The authors concluded that integrating IoT with urban planning and community participation can improve disaster preparedness and urban resilience.

3.15 Mohammed Hlal (2025): In this paper author reviewed the use of Digital Twin technology for urban flood management. The study found that combining Digital Twins with IoT sensors, remote sensing and AI can improve flood prediction, early warnings and emergency response. However, challenges such as high costs, data integration and system complexity remain. The authors suggested developing affordable and scalable Digital Twin systems to improve urban flood resilience.

3.16 Johannes Bhanye (2025): In this paper author reviewed the role of Artificial Intelligence in urban flood management, including flood prediction, risk mapping, early warning and emergency response. The study found that AI can process large amounts of data and support faster decision-making. However, challenges such as poor data quality, limited infrastructure and lack of transparency remain. The author emphasized the need for locally adaptable AI systems, community participation and effective planning to improve urban flood resilience.

3.17 Muhammad Asif (2025): In this paper author reviewed and compared machine learning techniques for short-term flood forecasting using 94 research papers. The study found that models such as ANN, LSTM, Random Forest, and hybrid models can help predict floods and improve early warning systems. The authors highlighted that combining different machine

learning techniques can improve prediction accuracy, although performance generally decreases as forecasting time increases.

3.18 Ali Zoghi (2025): In this paper author reviewed nature-based solutions for flood management in Canadian cities. The study examined methods such as green roofs, permeable pavements, rain gardens, and rainwater harvesting. The authors found that these methods can help reduce stormwater runoff and improve urban flood resilience. However, they highlighted challenges such as limited long-term data, lack of local design guidelines, and difficulties in implementing these solutions. The study recommended combining green infrastructure with traditional drainage systems for better flood management.

3.19 Liaqat Ali, Shirley Gato-Trinidad &MonzurImteaz (2025): In this paper authors examine the use of green infrastructure for urban flood management. The study showed that green infrastructure can reduce stormwater runoff and peak flow while providing environmental benefits. It also discussed different modelling approaches used to evaluate green infrastructure under changing climate conditions. The authors highlighted the need for better modelling methods and proper site-specific design.

More long-term field studies and reliable modelling are needed to evaluate green infrastructure under different rainfall and climate conditions.

3.20 Tainah Frota Carvalho & Newton Célio Becker de Moura (2025): In this paper author reviewed blue infrastructure as a nature-based approach for urban drainage and flood resilience. The study discussed how water bodies and natural drainage features can support stormwater management while providing environmental and social benefits. It highlighted the potential of treating nature as part of urban drainage infrastructure. Portal de Revistas da USP

More practical studies are needed to determine how blue infrastructure can be effectively integrated into existing urban drainage networks.

3.21 André Ricardo Cansian, Diego A. Guzmán, Altair Rosa, and Juliana de Toledo Machado (2025): In this paper author reviewed methods used to design, size and monitor nature-based solutions for urban drainage. It found increasing use of hydrological models, AI, remote sensing and IoT-based monitoring. These technologies can help improve the design and performance monitoring of sustainable drainage systems.

Standardized methods for sizing, monitoring and validating nature-based drainage systems are still limited.

3.22 Jiankun Xie (2025): In this paper author review examined ways to improve the resilience of urban drainage systems under climate change and rapid urbanization. It discussed drainage-network optimization, detention basins, flow-control devices, real-time control and deep-learning applications. The study suggested that combining traditional drainage with smart control can make urban stormwater systems more adaptive.

Future research should improve the integration of real-time control, deep learning and hybrid green-grey infrastructure.

3.23 Revolutionizing Urban Water Resilience (2025): In this paper author review examined recent developments in Sustainable Urban Drainage Systems. It reviewed their performance, cost-effectiveness, policy issues and large-scale implementation. The study showed that SuDS can reduce flood risk and improve water quality while supporting climate-resilient urban development

More research is needed on the long-term performance, cost and large-scale implementation of SuDS under changing climate conditions.

3.24 Esraz-Ul-Zannat (2025): In this paper author review examined why nature-based solutions are not yet widely implemented in cities. The authors identified barriers related to knowledge, technology, governance, institutions, physical conditions and social factors. The study suggested that better planning and coordination are required to increase the use of nature-based solutions for flood resilience. Wiley Interdisciplinary Reviews

More research is needed on practical strategies that can overcome institutional, financial and social barriers to large-scale implementation.

3.25 KamaleddinAghaloo (2024): In this paper author reviewed 582 studies on Nature-based Solutions (NbS) for improving urban flood resilience and climate adaptation. The study highlighted strategies such as green roofs, sustainable urban drainage systems, green infrastructure, and sponge cities for managing stormwater and reducing flood risks. The authors found that the effectiveness of these solutions depends on local conditions. They concluded that NbS should be integrated into urban planning, with proper monitoring and community participation, to achieve sustainable flood management.

3.26 Jiayi Song (2024): In this paper author reviewed various techniques for real-time urban flood monitoring based on 834 publications. The study examined sensors, IoT, cameras, remote sensing, and social media for flood detection. The authors highlighted that combining these technologies can improve flood monitoring accuracy, provide timely warnings, and support better urban flood management.

3.27 Vahid Bakhtiari (2024): In this paper author reviewed the use of digital visualisation technologies in urban flood risk management. The study examined technologies such as virtual reality, augmented reality, mixed reality, and digital twins. The authors found that these technologies help stakeholders understand flood risks, improve communication, and support flood preparedness and response. The study also identified a need for greater involvement of policymakers, researchers, and insurancue providers in flood management .

3.28 Esraz-Ul-Zannat et al (2024): In this paper author reviewed nature-based solutions such as green roofs, wetlands and rain gardens for reducing urban flood risk. The study found that

these solutions can work alone or with traditional drainage systems and provide environmental benefits. However, more real-world studies are needed for different urban conditions.

3.29 Adekunle Olorunlowo David et al (2024): In this paper authors reviewed the use of artificial intelligence for flood susceptibility assessment and flood management. The review covered machine learning, image processing, data analysis and remote sensing approaches. AI can help identify flood-prone areas and support faster flood-management decisions.

Future research should improve the quality of flood datasets and develop AI models that can be reliably applied to different locations.

3.30 Mina khodadad (2023): In this paper author reviewed the role of green infrastructure in improving urban flood resilience. The study examined different methods, including green roofs, urban parks, and sustainable drainage systems. The authors found that green infrastructure can reduce stormwater runoff and flood risks. The study also highlighted research gaps and the need for better planning and integration of green infrastructure in urban areas.

3.31 V. Bakhtiar (2023): In this paper author reviewed the use of advanced digital visualisation technologies for urban flood risk management. It examined technologies such as GIS, 3D modelling, and digital twins for flood mapping, monitoring, and risk assessment. The authors highlighted that these technologies can improve flood prediction, support better planning, and help authorities make informed decisions for effective urban flood management.

3.32 Wei Zhu (2022): In this paper author reviewed the use of remote sensing technology in urban flood management by analysing 347 research papers. The study highlighted its importance in flood mapping, risk assessment, and damage evaluation. Satellite imagery, DEM, and land-use data were widely used for flood analysis. The authors also identified research gaps, including limited studies in developing countries, lack of standardised data, and the need to integrate remote sensing with machine learning for better flood management.

3.33 Ioannis M. Kourtis and Vassilios A. Tsihrintzis (2021): In this paper author reviewed the adaptation of urban drainage systems to climate change. It highlighted how increasing rainfall and extreme weather can put pressure on existing drainage networks. The authors discussed different strategies to improve drainage capacity and reduce urban flooding. The study emphasized the need for climateadaptive drainage systems to improve urban flood relisence.

3.34 Nawnit Kumar (2021): In this paper author reviewed urban flood management practices in India and China, focusing on China's Sponge City Program. The study examined major flood events and existing flood-control methods from 2014 to 2020. It highlighted the importance of sustainable drainage systems, rainwater harvesting and better urban planning. The authors suggested improving government coordination, funding and public participation to reduce

urban flooding. The study also emphasized the need to adopt suitable flood management strategies according to local conditions.

3.35 H. P. Pour (2020): In this paper author reviewed the use of Low Impact Development (LID) techniques for urban flood management. The study highlighted methods such as green roofs, rain gardens, and permeable pavements to reduce stormwater runoff and flooding. The authors found that LID techniques can reduce flood risks and support conventional drainage systems. However, their effectiveness depends on rainfall, soil conditions, and local urban environments. The study also emphasized the need for further research to improve LID performance during extreme rainfall.

3.36 Yinghong Qin (2020): In this paper author reviewed various techniques for urban flood management, including green roofs, permeable pavements, rain gardens, and underground storage systems. The study found that these methods help reduce stormwater runoff and peak flow during small and moderate rainfall events. However, their effectiveness decreases during heavy rainfall. The authors highlighted the need for improved drainage systems, controllable water storage, and long-term performance evaluation to manage urban flooding effectively.

3.37 Zongmin Li (2018): In this paper author reviewed research on Sponge City concepts and sustainable urban water management. The study analysed 962 research papers and identified key topics such as urban flooding, stormwater management, permeable pavements, and climate change. The authors highlighted the importance of combining engineering solutions with information technology and proper urban planning. The study also emphasised the need for integrated approaches, better management frameworks, and more case studies from different regions to improve Sponge City implementation.

3.38 Musa Akther (2018): In this paper author reviewed the use of green roofs for urban stormwater management under different climatic conditions. The study found that green roofs help reduce stormwater runoff, but their performance depends on rainfall, vegetation, roof slope, and growing-media properties. The authors highlighted the need for climate-specific designs and further research in tropical and dry regions to improve the effectiveness of green roofs in urban flood management.mprove urban flood resilience.nsurance providers in flood management.

IV. CONCLUSION

From this review paper, we can conclude that developing a flood-resistant smart city is very important to protect people and buildings from floods. Floods can damage roads, houses and other infrastructure and create many problems in daily life.

By using modern technology like smart sensors, IoT, early warning systems and proper drainage systems, we can detect flood risks and reduce their harmful effects. Proper city planning, rainwater harvesting and green spaces can also help in controlling floods.

Overall, a flood-resistant smart city helps to keep people safe, reduce damage and protect the environment. With proper planning and the use of modern technology, we can make our cities safer and better for the future.

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