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DIGITALISING URBAN DRAINAGE SYSTEMS: BARRIERS AND IMPLICATIONS FOR VIETNAM

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ABSTRACT

Urban flooding is an increasing challenge for cities due to rapid urbanisation, climate change, and the growing complexity of urban infrastructure systems. Digital technologies such as Internet of Things monitoring networks, Artificial Intelligence (AI), digital twins, and geographic information systems have been proposed to enhance the monitoring and management of Urban Drainage Systems (UDS). However, large-scale implementation of digitalised drainage infrastructure remains constrained by multiple socio-technical barriers. This study conducts a structured literature review to identify key barriers to the digitalisation of urban drainage systems and to examine their implications for digital infrastructure governance in Vietnam. Using the Scopus database, a multi-stage screening process identified 71 peer-reviewed publications addressing digital technologies in drainage infrastructure. The studies were analysed using thematic synthesis to identify recurring implementation challenges and develop a structured framework of barriers to UDS digitalisation. The analysis reveals four major barrier categories. Data-related barriers include incomplete infrastructure records, legacy datasets, fragmented data management, and unreliable sensor data. Technological barriers involve integration with legacy infrastructure, high computational requirements, limited model scalability, and low interpretability of AI systems. Institutional barriers relate to shortages of interdisciplinary expertise, fragmented governance structures, and risk-averse organisational cultures, while financial barriers include high capital investment, ongoing operational costs, and uncertain economic returns. The findings highlight several implications for Vietnam, including strengthening infrastructure data governance, adopting phased technology deployment strategies, improving coordination among urban infrastructure agencies, and developing sustainable financing mechanisms for digital infrastructure investment.

Keywords: *Digital Infrastructure Barriers; Digitalisation; Smart Water Management; Urban Drainage Systems; Urban Flood Resilience.*

1. INTRODUCTION

Urban flooding has become an increasingly critical challenge for cities worldwide due to rapid urbanisation, climate change, and the growing complexity of urban infrastructure systems. Intensifying rainfall events and expanding impervious surfaces have placed substantial pressure on conventional UDS, many of which were designed under historical climatic assumptions. As a result, cities are experiencing more frequent pluvial flooding

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and infrastructure overload, highlighting the need for more adaptive drainage management strategies (Pirone et al., 2026; Rasool et al., 2025).

Traditionally, drainage management has relied on hydraulic modelling, periodic inspections, and reactive maintenance. While these approaches remain essential for infrastructure operation, their effectiveness is increasingly constrained by limited monitoring coverage, delayed data availability, and fragmented infrastructure information systems (Okwori et al., 2024). These limitations reduce the ability of urban authorities to anticipate flooding risks and coordinate infrastructure planning across complex urban systems.

Recent advances in digital technologies offer new opportunities to enhance the monitoring and management of drainage infrastructure. The integration of these technologies supports a transition from reactive maintenance toward more proactive and data-driven drainage management (Rousso & Gong, 2026). In this study, digitalisation refers to the progressive integration of digital technologies, data infrastructures, and analytical capabilities into the planning, operation, and management of urban drainage systems. This process may range from basic digital asset management and monitoring to more advanced applications such as predictive analytics and digital twins (Rousso & Gong, 2026). Accordingly, barriers are defined as technical, organisational, institutional, or financial constraints that hinder the adoption, integration, or scaling of digital technologies within urban drainage management.

Despite recent technological developments, the implementation of digitalised drainage systems remains uneven across cities due to barriers related to fragmented datasets, technological integration, institutional coordination, and financial capacity (Cabral et al., 2019; Okwori et al., 2024; Rousso et al., 2024). These challenges are particularly relevant in rapidly urbanising countries such as Vietnam. Although drainage infrastructure in cities such as Hanoi and Ho Chi Minh City has been upgraded in recent decades, many networks still rely on incomplete infrastructure records, limited monitoring systems, and fragmented data management practices (Doan et al., 2023; Nguyen et al., 2022). Recent studies have begun to explore the application of digital technologies for drainage modelling and infrastructure management in Vietnam (Mai et al., 2025).

However, existing research largely focuses on the technical performance of individual technologies rather than the broader socio-technical barriers affecting large-scale digital transformation of UDS. Consequently, there remains limited synthesis of the organisational, technological, and financial constraints shaping the digitalisation of drainage infrastructure (Pirone et al., 2026; Rousso & Gong, 2026). To address this gap, this study provides a structured literature review of the barriers to the digitalisation of urban drainage systems and examines their implications for urban infrastructure management in Vietnam.

Specifically, the study addresses the following research questions: (i) What are the main barriers to the digitalisation of UDS identified in the existing literature? (ii) What implications do these barriers have for the development of digital drainage management strategies in Vietnam? By synthesising current research on digital technologies and infrastructure governance, this study makes three contributions. First, it provides one of the first integrated reviews focused specifically on the digitalisation of urban drainage systems rather than individual technologies or broader smart water initiatives. Second, it develops a synthesis framework that consolidates fragmented evidence into four interconnected categories of barriers affecting digital transformation. Third, it translates international evidence into context-specific implications for Vietnam, thereby linking global digitalisation challenges with the needs of rapidly urbanising cities.

2. RESEARCH METHODOLOGY

This study adopts a structured literature review to identify and synthesise research on the digitalisation of UDS and the associated technological and organisational challenges. Literature reviews are widely used to consolidate fragmented knowledge in rapidly evolving interdisciplinary domains such as smart infrastructure and digital water management (Pirone et al., 2026; Rousso & Gong, 2026). The review process comprised three stages: literature identification, screening of relevant publications, and thematic synthesis.

2.1 LITERATURE SEARCH AND DATA COLLECTION

The primary data source was the Scopus database, one of the largest indexing platforms for peer-reviewed research in engineering and environmental infrastructure. A structured keyword query was used to identify studies addressing both urban drainage systems and digital technologies. The search expression included terms related to drainage infrastructure and digitalisation technologies such as BIM, digital twins, remote sensing, and reality capture.

(urban OR city OR cities OR metropolitan OR municipal) AND (("drainage system*" OR "drainage network*" OR "stormwater system*" OR "stormwater drainage" OR "sewer system" OR "sewer network*" OR "wastewater network*" OR "drainage infrastructure") AND (BIM OR "Building Information Modelling" OR "Building Information Modeling" OR digital* OR "digital twin" OR "digital twins" OR "reality capture" OR "point cloud" OR "laser scanning" OR LiDAR OR photogrammetry OR UAV OR "remote sensing"))

The initial search returned 741 publications. After restricting the dataset to English-language research papers and removing unrelated subject areas, the dataset was reduced to 372 studies. Title and abstract screening were then conducted to identify studies specifically addressing digital technologies in UDS. After verifying full-text availability, the final dataset consisted of 71 peer-reviewed publications from different international contexts, which formed the basis for the thematic synthesis of barriers.

2.2 IDENTIFICATION OF STUDIES RELATED TO VIETNAM

To provide contextual insights for policy implications, a supplementary search was conducted to identify studies addressing urban drainage systems in Vietnam using the following query:

(urban OR city OR cities OR metropolitan OR municipal) AND (("drainage system*" OR "drainage network*" OR "stormwater system*" OR "stormwater drainage" OR "sewer system" OR "sewer network*" OR "wastewater network*" OR "drainage infrastructure") AND Vietnam)

The search initially identified 73 publications. After excluding conference reviews and screening titles and abstracts, the dataset was restricted to studies published from 2020 onwards. Following full-text screening, 22 publications were retained (including one study overlapping with the international dataset). These studies were used solely to provide contextual insights for the discussion of implications in Vietnam and were not included in the primary thematic synthesis, which was based on the 71 international publications identified in Section 2.1.

2.3 LITERATURE SYNTHESIS AND ANALYTICAL APPROACH

The selected publications were analysed using thematic synthesis, a method commonly applied in structured literature reviews to identify recurring patterns across heterogeneous studies (Pirone et al., 2026; Rousso & Gong, 2026). An inductive coding approach was adopted to allow barrier categories to emerge from the literature rather than being predefined. Similar coding procedures have been widely adopted in thematic synthesis studies to improve transparency and consistency in qualitative evidence synthesis (Thomas & Harden, 2008).

The coding process involved three stages. First, statements describing implementation challenges were extracted from each publication and assigned descriptive codes. For example, findings related to missing historical flood records, incomplete monitoring datasets, and outdated infrastructure documentation were initially coded as data availability limitations. These codes were subsequently grouped into the broader theme of data management challenges and ultimately classified under the category of data-related barriers. Similarly, findings describing fragmented agency responsibilities and coordination difficulties were initially coded as governance fragmentation. These codes were subsequently grouped into broader institutional coordination challenges and ultimately classified under institutional and human capacity barriers. Second, similar codes were iteratively compared and grouped into higher-order themes through constant comparison across the reviewed studies. Third, the resulting themes were repeatedly reviewed and refined to ensure conceptual consistency and minimise overlaps between categories. To enhance methodological rigour, the coding process involved multiple rounds of review and re-coding, and categories were retained only when they consistently represented similar implementation challenges across multiple publications. This iterative process continued until no additional categories emerged from the literature.

The final synthesis identified four major categories of barriers: data-related barriers, technological and modelling barriers, institutional and human capacity barriers, and financial barriers. These categories form the analytical framework used to examine the challenges of digitalising urban drainage systems.

3. DIGITALISATION TECHNOLOGIES IN UDS

Recent advances in digital technologies are transforming the monitoring and management of UDS. Conventional drainage management has traditionally relied on hydraulic modelling and periodic inspections; however, these approaches often struggle to address the increasing complexity of urban hydrological processes driven by urbanisation and climate change. Consequently, digital technologies have emerged as key enablers for improving monitoring accuracy, predictive capabilities, and operational efficiency in drainage management (Pirone et al., 2026; Rousso & Gong, 2026). The literature indicates that the digitalisation of UDS typically involves the integration of several complementary technologies that support real-time monitoring, data-driven analysis, and infrastructure simulation. Four major technological domains are commonly highlighted i.e. (i) IoT-based monitoring systems, (ii) artificial intelligence for flood prediction, (iii) digital twin platforms, and (iv) GIS-based infrastructure mapping.

3.1 IoT-Based Monitoring Systems

IoT-based monitoring systems enable continuous observation of drainage network conditions through sensors deployed in pipes, manholes, and pumping stations. These sensors monitor variables such as water level, flow velocity, and rainfall intensity, transmitting real-time data to monitoring platforms. Such systems improve situational awareness and enable utilities to detect anomalies and respond more rapidly to flooding risks (Pedersen et al., 2022; Wei et al., 2026). Although widely adopted, IoT monitoring systems face operational challenges, including sensor degradation, signal interference, and maintenance requirements in harsh sewer environments (Cabral et al., 2019). Nevertheless, real-time monitoring remains a foundational component of digitalised drainage systems.

3.2 AI and Data-Driven Flood Prediction

Artificial intelligence and machine learning techniques are increasingly applied to improve flood prediction and hydrological modelling in urban drainage systems. By analysing datasets generated from monitoring systems and rainfall observations, machine learning models can identify patterns and support short-term flood prediction and anomaly detection in drainage networks (Agonafir et al., 2022). Recent studies have explored deep learning architectures, including convolutional and recurrent neural networks, for analysing large spatiotemporal datasets associated with urban flooding (Gao et al., 2024). While these models show promising predictive performance, their reliability depends strongly on data availability and monitoring coverage.

3.3 Digital Twin Platforms

Digital twin technology has gained increasing attention as a platform for integrating monitoring data, simulation models, and decision-support tools. A digital twin represents a dynamic virtual model of infrastructure that continuously updates its state using real-time monitoring data (Kim & Bartos, 2024). In drainage management, digital twins allow operators to simulate hydraulic behaviour, evaluate infrastructure performance, and support predictive maintenance and operational decision-making (Fan et al., 2025). However, implementing such systems requires substantial investment in digital infrastructure and organisational capacity.

3.4 GIS and Digital Infrastructure Mapping

GIS provide the spatial framework for managing drainage infrastructure data. GIS-based platforms enable utilities to map drainage networks, manage asset inventories, and analyse flood vulnerability using spatial datasets such as topography and land use (Martin et al., 2020). Recent research also highlights the integration of GIS with BIM and digital twin platforms to create more comprehensive digital representations of urban infrastructure systems (Smith et al., 2023; Yang et al., 2021).

Table 1 summarises the main digital technologies identified in the literature together with their key functions and applications in urban drainage management.

Table 1: Major digital technologies applied in urban drainage systems

Technology	Main functions	Typical applications in drainage systems	Key references
IoT sensors and monitoring networks	Real-time data acquisition and infrastructure monitoring	Monitoring water levels, flow rates, rainfall intensity, and sewer network performance	(Pedersen et al., 2022); (Wei et al., 2026)
Artificial intelligence models	Data-driven prediction and anomaly detection	Flood prediction, pattern recognition, and anomaly detection in drainage networks	(Agonafir et al., 2022); (Gao et al., 2024)
Digital twin platforms	Dynamic simulation and system optimisation	Simulation of drainage network behaviour, predictive maintenance, and operational decision support	(Kim & Bartos, 2024); (Fan et al., 2025)
GIS infrastructure databases	Spatial infrastructure mapping and asset management	Mapping drainage networks, flood vulnerability analysis, and infrastructure asset management	(Martin et al., 2020); (Smith et al., 2023)

Table 1 illustrates that the digitalisation of UDS relies on the integration of monitoring, analytical, simulation, and spatial information technologies. These technologies provide the technical foundation for more proactive and data-driven drainage management. The following section examines the key barriers that constrain their large-scale implementation.

4. BARRIERS TO THE DIGITALISATION OF UDS

Despite growing interest in digital technologies for urban drainage management, the implementation of digitalised UDS remains constrained by several systemic barriers. Based on the synthesis of the 71 peer-reviewed publications analysed in this study, the literature indicates that these challenges can be broadly grouped into four categories: data-related barriers, technological and modelling barriers, institutional and human capacity barriers, and financial and economic barriers. These barriers are closely interconnected and collectively influence the pace and effectiveness of digital transformation. Although certain barriers are more strongly associated with specific technologies (e.g., sensor reliability for IoT systems or interoperability challenges for digital twins), the reviewed literature indicates that many barriers, particularly those related to data governance, institutional capacity, and financing, recur across multiple digital technologies. For this reason, the barriers were classified according to their underlying characteristics rather than individual technology types.

4.1 DATA-RELATED BARRIERS

Data-related barriers represent one of the most frequently reported challenges in the literature. Digital technologies such as AI-based flood prediction, digital twins, and predictive maintenance systems depend on reliable datasets describing infrastructure assets and hydrological conditions. However, many studies highlight that drainage infrastructure data are often incomplete, fragmented, or outdated. In many cities, historical flood records and infrastructure documentation remain limited, which restricts the development and calibration of predictive models (Ahmad et al., 2025; Anik et al., 2025). Legacy data formats remain a major constraint. Infrastructure information is frequently stored in paper archives or static CAD drawings, which limits integration with digital monitoring platforms and modelling systems (Sivakumar et al., 2025). Another widely reported issue is data fragmentation across organisational units. Infrastructure datasets are often maintained by separate agencies using incompatible database structures and asset identification systems, which complicates data integration and interoperability between digital platforms (Li et al., 2022; Okwori et al., 2024). In addition, sensor-based monitoring systems may generate noisy or incomplete datasets due to harsh underground operating environments. These data quality issues can reduce the reliability of digital models and decision-support systems (Kim et al., 2025; Wei et al., 2026). These findings highlight the importance of improving data availability, standardisation, and governance.

4.2 TECHNOLOGICAL AND MODELLING BARRIERS

The literature identifies several technological and modelling challenges associated with implementing digital solutions in drainage infrastructure systems. One major challenge concerns the integration of new digital technologies with legacy drainage infrastructure. Urban sewer networks often consist of heterogeneous components developed over long periods, which complicates the integration of modern monitoring systems and digital platforms (Okwori et al., 2024). Hardware reliability represents a significant constraint. Sensors deployed in underground sewer environments are exposed to moisture, corrosion, sediment accumulation, and limited maintenance accessibility, which can reduce system reliability and increase maintenance requirements (Rousso & Gong, 2026). Another challenge relates to the computational requirements of advanced modelling systems. High-resolution hydrodynamic simulations and digital twin platforms often require substantial computational resources that may exceed the technical capacity of many municipal utilities (Fan et al., 2025; Yang et al., 2021). The literature highlights limitations associated with AI-based modelling approaches. While machine learning algorithms can improve predictive performance, many models function as “black box” systems, which reduces interpretability and may limit trust among infrastructure operators (Sharifi et al., 2024). In addition, many digital modelling frameworks remain highly site-specific and require extensive recalibration when applied to different urban contexts, limiting their scalability (Wei et al., 2026).

4.3 INSTITUTIONAL AND HUMAN CAPACITY BARRIERS

Digitalisation of UDS requires significant organisational adaptation within infrastructure management institutions. One commonly cited barrier is the shortage of interdisciplinary expertise required to develop and operate digital infrastructure systems. Implementing technologies such as digital twins or AI-based monitoring requires combined knowledge in hydrology, data science, and information technology, which remains limited in many water utilities (Bertrand-Krajewski et al., 2025; Martin et al., 2020). Organisational culture can influence technology adoption. Several studies report that water utilities often exhibit risk-averse management cultures, where decision-makers prioritise established operational practices over innovative digital approaches (Rousso et al., 2024). Institutional fragmentation further complicates digital transformation. Responsibilities for drainage infrastructure are frequently distributed across multiple government agencies, which can limit coordination in data management, infrastructure planning, and digitalisation strategies (Mai et al., 2025). In addition, the absence of clear governance frameworks for digital infrastructure management such as guidelines for data sharing and asset identification, can hinder the development of coherent digitalisation strategies.

4.4 FINANCIAL AND ECONOMIC BARRIERS

Financial constraints represent another major obstacle to the digitalisation of UDS. Implementing digital infrastructure requires substantial investment in monitoring systems, communication networks, and modelling platforms. One commonly cited challenge concerns the high initial capital expenditure associated with deploying sensor networks and digital infrastructure platforms (Cabral et al., 2019). Digital systems generate ongoing operational expenditures related to system maintenance, data management, and hardware replacement (Kim et al., 2025). Another challenge involves the difficulty of quantifying the economic benefits of digitalisation initiatives. Although digital technologies can improve monitoring and flood management capabilities, their financial returns are often difficult to measure in conventional cost–benefit frameworks (Rousso et al., 2024).

Finally, many digital infrastructure initiatives rely on short-term research funding or pilot programmes, which may limit the long-term sustainability of implemented technologies. Table 2 summarises the main barriers identified in the literature together with representative examples discussed in previous studies.

Table 2: Key barriers to the digitalisation of urban drainage systems identified in the literature

Category & specific barrier	Description of barrier	Representative references
Data-related barriers		
Lack of reliable infrastructure data	Many drainage networks lack accurate digital records, as-built drawings, or long-term monitoring data required for hydraulic model calibration and digital twin development	(Ahmad et al., 2025); (Anik et al., 2025)
Legacy and non-digital datasets	Infrastructure information often remains stored in paper archives or static CAD drawings, limiting integration with modern digital platforms	(Sivakumar et al., 2025)
Fragmented data management	Infrastructure data are frequently distributed across multiple agencies and databases using incompatible data structures and asset identification systems	(Li et al., 2022); (Okwori et al., 2024)
Lack of data standardisation	Absence of standardised metadata frameworks and asset identification systems reduces interoperability between digital platforms such as GIS, hydraulic models, and digital twins	(Li et al., 2022); (Okwori et al., 2024)
Sensor data reliability issues	IoT sensors deployed in sewer environments often produce noisy, incomplete, or inconsistent datasets due to harsh environmental conditions	(Kim et al., 2025); (Wei et al., 2026)
Technological and modelling barriers		
Integration with legacy infrastructure	Existing drainage systems consist of heterogeneous infrastructure built over long periods, making integration with modern digital technologies technically complex	(Okwori et al., 2024)

Category & specific barrier	Description of barrier	Representative references
Hardware reliability and maintenance	Sensors and monitoring equipment in sewer environments are exposed to corrosion, debris, and high humidity, increasing maintenance requirements	(Rousso & Gong, 2026)
High computational requirements	Advanced hydrodynamic models and digital twin simulations require high-performance computing resources that may exceed the technical capacity of many utilities	(Yang et al., 2021); (Fan et al., 2025)
Limited interpretability of AI models	Many machine learning models operate as "black-box" systems, which reduces trust among infrastructure operators and decision-makers	(Sharifi et al., 2024)
Limited scalability of digital models	Digital modelling frameworks often require extensive recalibration when applied to different urban environments	(Wei et al., 2026)
Institutional and human capacity barriers		
Lack of interdisciplinary expertise	Digital drainage systems require combined expertise in hydrology, data science, and software engineering, which is often scarce in municipal utilities	(Martin et al., 2020); (Bertrand-Krajewski et al., 2025)
Conservative organisational culture	Water utilities often exhibit risk-averse management cultures that discourage the adoption of innovative digital technologies	(Rousso et al., 2024)
Fragmented institutional governance	Drainage management responsibilities are often distributed across multiple government agencies, limiting coordinated digitalisation efforts	(Mai et al., 2025)
Absence of digital governance frameworks	Many cities lack clear policies or guidelines for data sharing, digital asset management, and digital infrastructure governance	(Asghari et al., 2023)
Financial and economic barriers		
High initial capital investment (CAPEX)	Deployment of monitoring infrastructure, sensor networks, and digital platforms requires substantial upfront investments	(Cabral et al., 2019)
Long-term operational costs (OPEX)	Maintenance of sensors, communication networks, and data platforms generates ongoing operational costs	(Kim et al., 2025)
Uncertain economic benefits	Difficulty in quantifying economic returns of digital drainage systems can discourage investment decisions	(Rousso et al., 2024)
Dependence on short-term project funding	Many digital infrastructure initiatives rely on research grants or pilot projects that lack long-term financial sustainability	(Cabral et al., 2019)

Table 2 demonstrates that barriers to UDS digitalisation extend beyond technology and encompass data, institutional, and financial dimensions. These findings provide the basis for the implications discussed in the following section. Although the identified barriers may influence different stages and levels of digitalisation to varying degrees, the reviewed literature consistently highlights them as recurrent constraints affecting the broader digital transformation of urban drainage systems.

The reviewed studies further suggest that these barriers are highly interdependent rather than isolated. Data-related limitations, such as fragmented infrastructure records and poor data quality, directly constrain the effectiveness of AI models, digital twins, and other advanced technologies. At the same time, institutional fragmentation and limited interdisciplinary expertise often hinder data sharing, technology integration, and long-term digital governance. Financial constraints further influence the ability of utilities to invest in monitoring infrastructure, maintain digital platforms, and develop organisational capabilities. Consequently, barriers to UDS digitalisation should be viewed as a socio-technical system of interacting constraints rather than as independent challenges.

5. IMPLICATIONS FOR VIETNAM

The synthesis identifies four key implications for the digital transformation of urban drainage systems in Vietnam i.e. (i) data governance, (ii) technology adoption pathways, (iii) institutional coordination, and (iv) financing strategies.

5.1 STRENGTHENING DATA GOVERNANCE FOR DIGITAL DRAINAGE INFRASTRUCTURE

Reliable and interoperable data represent a fundamental requirement for digital drainage systems. However, drainage management in Vietnam still relies heavily on fragmented datasets and non-standardised documentation, often stored in paper records or static CAD drawings. International studies emphasise that standardised infrastructure datasets and monitoring data are essential for hydraulic modelling, predictive flood management, and digital platform integration (Pedersen et al., 2022; Smith et al., 2023). Similar challenges related to fragmented databases and inconsistent asset records have been widely reported in municipal water utilities (Okwori et al., 2024). Evidence from Vietnamese studies confirms that limited monitoring data and incomplete infrastructure records often constrain drainage modelling efforts in cities such as Hanoi and Ho Chi Minh City (Doan et al., 2023; Nguyen et al., 2025). In addition, rainfall and hydrological datasets remain insufficient in many cities, reducing the reliability of flood prediction models (Minh et al., 2022). An important implication for Vietnam is therefore the development of national or municipal data governance frameworks that support standardised asset identification, shared geospatial databases, and interoperable data platforms. International experience shows that GIS-based infrastructure databases can significantly enhance drainage planning and monitoring capabilities (Martin et al., 2020).

5.2 PATHWAYS FOR TECHNOLOGY ADOPTION IN VIETNAMESE CITIES

Digital technologies such as IoT monitoring systems, AI-based flood prediction, and digital twin platforms offer significant opportunities for improving drainage management (Fan et al., 2025; Sharifi et al., 2024). However, their implementation in Vietnam must account for the physical and operational constraints of existing infrastructure systems. Many drainage networks in Vietnamese cities consist of legacy infrastructure that was not designed for current rainfall intensities and urban densities. As a result, large-scale deployment of advanced digital technologies may face significant technical and operational constraints. International studies highlight that successful digitalisation often occurs through incremental technological integration rather than large-scale system replacement (Rousso et al., 2024). Initial steps may include sensor-based monitoring and GIS asset databases, followed by the gradual integration of predictive modelling and digital twin technologies. Existing modelling studies in Vietnamese cities already demonstrate the potential of digital tools to improve flood management and drainage system planning (Doan et al., 2023; Nguyen et al., 2022). These findings suggest that a phased technology adoption strategy would be the most feasible pathway for digital drainage transformation.

5.3 INSTITUTIONAL COORDINATION AND GOVERNANCE REFORM

Digital drainage management requires institutional coordination across multiple agencies responsible for urban infrastructure. International studies highlight that fragmented governance structures often hinder digital infrastructure integration (Asghari et al., 2023). In Vietnam, responsibilities for drainage management are distributed across municipal departments, utilities, and environmental agencies, which can limit coordination in infrastructure planning and data management. Studies on urban flood management in Vietnamese cities emphasise the importance of cross-sector collaboration between planning authorities, water utilities, and environmental agencies (Downes et al., 2024; Nguyen et al., 2025). Developing integrated governance frameworks and cross-agency data-sharing mechanisms will therefore be essential for supporting the implementation of digital drainage systems.

5.4 FINANCING STRATEGIES FOR DIGITAL DRAINAGE TRANSFORMATION

Financial constraints represent another major challenge for digital drainage transformation. Deploying monitoring infrastructure, modelling platforms, and digital data systems requires significant investment, while operational expenditures for system maintenance and upgrades can further increase long-term costs. International studies show that digital water management systems often involve substantial capital investment, particularly for cities with limited financial resources (Cabral et al., 2019). In Vietnam, infrastructure investment gaps and rapid urbanisation continue to intensify urban flooding risks (Nguyen et al., 2025). As a result, incremental financing strategies may provide a more feasible pathway for digitalisation. Pilot projects in high-risk flood zones, combined with public–private partnerships or international development funding, could help demonstrate the benefits of digital drainage technologies before scaling them across larger urban areas (Nguyen & Huynh, 2024).

6. CONCLUSIONS

This study examined the digitalisation of UDS through a structured synthesis of international literature together with contextual insights from Vietnamese studies. The review highlights the increasing role of digital technologies including IoT monitoring networks, artificial intelligence, digital twins, and GIS-based infrastructure databases in enabling more proactive and data-driven drainage management. The analysis identifies four major categories of barriers to UDS digitalisation i.e. (i) data-related constraints, (ii) technological and modelling challenges, (iii) institutional and human capacity limitations, and (iv) financial barriers. These challenges are closely interconnected, as fragmented data infrastructures, limited institutional coordination, and high investment requirements collectively constrain the large-scale implementation of digital drainage solutions. For rapidly urbanising countries such as Vietnam, the findings highlight several key implications. Improving data governance and establishing interoperable infrastructure databases are essential foundations for digitalisation. Technological adoption should follow a gradual pathway, beginning with sensor-based monitoring and GIS-based asset management before progressing toward advanced tools such as predictive analytics and digital twins. In addition, effective implementation requires stronger institutional coordination and sustainable financing mechanisms for digital infrastructure development.

Beyond synthesising existing knowledge, the study contributes by consolidating fragmented evidence into a coherent barrier framework and by contextualising international lessons for Vietnam. The findings highlight that successful digitalisation of UDS depends not only on technological innovation but also on improvements in data governance, institutional coordination, and long-term investment strategies. Future research should further explore economic evaluation frameworks for digital drainage investments and empirical case studies of digital monitoring and digital twin implementation in rapidly urbanising cities. Such research will be critical for supporting evidence-based digital transformation of urban water infrastructure in rapidly urbanising regions.

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