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Urban Drainage Infrastructure Monitoring Using Data-Driven Maintenance Models

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Abstract **Original Research Article**

Urban drainage networks play an important role in flood control and water management. Aging infrastructure and inadequate maintenance may cause drainage failure and urban flooding. This study evaluates maintenance planning methods used in municipal drainage networks. Infrastructure condition records, maintenance reports, and drainage performance data were examined. Results show that structured monitoring systems assist municipalities in identifying maintenance priorities and improving drainage system performance.

Keywords: Urban drainage systems, infrastructure monitoring, municipal engineering, water management, infrastructure maintenance.

I. INTRODUCTION

Urban drainage systems are vital components of municipal infrastructure that support stormwater management, flood prevention, and urban water sustainability. These systems help protect communities, transportation networks, and public facilities from water related damage. However, increasing urbanization, aging infrastructure, and changing environmental conditions have created significant challenges for municipalities responsible for maintaining drainage networks. As drainage assets deteriorate over time, problems such as blockages, structural defects, and reduced drainage capacity can occur. These issues may increase maintenance costs and contribute to urban flooding. To address these challenges, municipalities increasingly rely on infrastructure monitoring and maintenance planning to assess system conditions and prioritize maintenance activities. Recent advances in data collection and asset management have further promoted the use of data driven approaches for infrastructure maintenance. This study examines how infrastructure monitoring can support maintenance planning in municipal drainage networks. By analyzing infrastructure condition records, maintenance reports, and drainage performance data, the study evaluates the role of structured monitoring systems in improving maintenance prioritization and drainage system performance.

A. Background

Urban drainage infrastructure plays an important role in managing stormwater runoff and reducing flood risks. Traditionally, maintenance activities have been based on routine inspections or reactive responses to failures. However, advances in monitoring technologies and asset management practices now allow municipalities to collect and analyze infrastructure data more effectively. Previous studies have shown that monitoring systems, deterioration models, and predictive maintenance approaches can improve infrastructure management by identifying critical assets and supporting maintenance planning. As a result, data driven maintenance strategies have received increasing attention in municipal engineering and urban water management.

B. Problem Statement

Despite improvements in monitoring technologies, many municipalities continue to face maintenance challenges due to aging infrastructure, limited budgets, and growing service demands. Maintenance decisions are often based on periodic inspections rather than comprehensive assessments of infrastructure condition and performance. Although previous studies have investigated drainage monitoring and deterioration prediction, limited attention has been given to integrating infrastructure condition records, maintenance reports, and drainage performance data within a unified maintenance planning framework. Consequently, municipalities require structured approaches that can support maintenance prioritization and improve drainage system performance.

C. Research Aim and Objectives

The aim of this study is to evaluate maintenance planning methods used in municipal urban drainage networks through infrastructure monitoring and data driven maintenance approaches.

The specific objectives are:

1. To examine infrastructure condition records, maintenance reports, and drainage performance data.
2. To evaluate the role of infrastructure monitoring in maintenance planning.
3. To identify how structured monitoring systems support maintenance prioritization.
4. To assess the contribution of data driven maintenance approaches to drainage system performance.

D. Research Question

This study addresses the following research question:

How can infrastructure monitoring and data driven maintenance planning improve maintenance prioritization and operational performance in municipal urban drainage systems?

E. Significance of the Study

This study contributes to urban drainage asset management by examining how monitoring information can support maintenance planning and decision making. The findings provide practical insights for municipal engineers and infrastructure managers seeking to improve maintenance efficiency, reduce infrastructure failures, and enhance drainage system performance. Furthermore, the study highlights the value of integrating condition records, maintenance history, and performance data within a structured maintenance framework.

II. LITERATURE REVIEW

Urban drainage systems are critical for stormwater management, flood mitigation, and urban water sustainability. However, aging infrastructure, increasing urbanization, and limited maintenance resources have created significant challenges for municipalities. Poorly maintained drainage networks can lead to system failures, reduced hydraulic performance, and increased flooding risks. As a result, researchers have increasingly explored infrastructure monitoring, condition assessment, and data driven maintenance strategies to improve drainage asset management. Recent advances in monitoring technologies, data analytics, and predictive maintenance models have enabled more effective assessment of drainage infrastructure conditions. These developments support maintenance planning by helping municipalities identify critical assets, prioritize interventions, and optimize resource allocation. This section reviews previous studies related to urban drainage monitoring, deterioration assessment, data driven maintenance models, and municipal asset management.

A. Urban Drainage Infrastructure Monitoring

Infrastructure monitoring provides essential information regarding the condition and performance of drainage networks. Price and Catterson [1] emphasized that monitoring data improve drainage modeling accuracy and support maintenance planning. Similarly, Qi *et al.,*[2] demonstrated that optimized monitoring point placement can enhance network coverage and operational efficiency while reducing monitoring costs. Continuous monitoring systems allow municipalities to identify deterioration and operational issues at an early stage, supporting proactive maintenance and reducing the likelihood of system failures [1], [2].

B. Sewer Deterioration and Condition Assessment Models

Predicting infrastructure deterioration is an important aspect of drainage asset management. Ana and Bauwens [3] reviewed statistical deterioration models and concluded that deterioration prediction is essential for planning maintenance and rehabilitation activities. Caradot *et al.,*[4] showed that deterioration models improve long term asset management by providing reliable estimates of future infrastructure conditions. Hernández *et al.,*[5] further demonstrated that both statistical and machine learning approaches can support sewer condition prediction, depending on available data and management objectives.

C. Data Driven Maintenance Model

The growing availability of infrastructure data has encouraged the adoption of data driven maintenance approaches. Salihu *et al.,*[6] developed an artificial intelligence-based model using CCTV inspection data to predict sewer deterioration and support maintenance prioritization. Similarly, Castiblanco Ballesteros *et al.,*[7] applied Support Vector Machine techniques to predict structural failures in sewer systems, while Hansen *et al.,*[8] used Random Forest algorithms to estimate sewer conditions. These studies demonstrated that machine learning methods can improve maintenance planning by identifying high risk infrastructure assets and supporting resource allocation.

D. Municipal Asset Management and Maintenance Planning

Effective maintenance planning is essential for ensuring the long-term performance of drainage infrastructure. Langeveld and Clemens [9] emphasized the importance of integrating condition information, operational records, and performance indicators into asset management decisions.

Tade *et al.,*[10] found that proactive maintenance strategies improve service reliability and reduce infrastructure risks compared with reactive maintenance practices. Likewise, Caradot *et al.,*[4] highlighted that combining deterioration models with monitoring data can support more effective rehabilitation planning and investment decisions.

E. Research Gap

Previous studies have extensively examined drainage monitoring, deterioration prediction, and machine learning applications for sewer asset management [5]-[8]. However, most research focuses on individual aspects of infrastructure management rather than integrating multiple data sources into a unified maintenance planning framework. Furthermore, many studies emphasize predictive modeling techniques, while practical frameworks for municipal maintenance planning remain limited. Therefore, there is a need for research that evaluates maintenance planning using infrastructure condition records, maintenance reports, and drainage performance data within a structured monitoring framework. This study addresses this gap by investigating how integrated monitoring information can support maintenance prioritization and improve the performance of municipal urban drainage systems.

III. METHODOLOGY

This study employed a data driven maintenance assessment framework to evaluate maintenance planning methods used in municipal urban drainage networks. The methodology was designed to investigate how infrastructure monitoring information can support maintenance prioritization and improve drainage system performance. The framework integrates infrastructure condition records, maintenance reports, and drainage performance data to establish a systematic process for condition assessment and maintenance decision making. The methodological approach was developed based on principles of infrastructure asset management and urban drainage monitoring discussed in previous studies. The process consists of data collection, data preparation, condition assessment, maintenance prioritization, and performance evaluation. The methodology was structured to ensure that maintenance recommendations were derived from observable infrastructure conditions and operational performance indicators.

A. Research Design

The study adopted a descriptive and analytical research design. A data driven assessment approach was used to examine the relationship between infrastructure condition, maintenance activities, and drainage system performance. Rather than developing a complex predictive model, the research focused on evaluating maintenance planning using available infrastructure information commonly collected by municipal agencies. The analytical framework was designed to answer the research question by examining how monitoring data can support maintenance planning decisions. The study considered three major sources of information: infrastructure condition records, maintenance reports, and drainage performance data. These datasets were integrated and analyzed to identify maintenance priorities and assess their potential impact on drainage system performance.

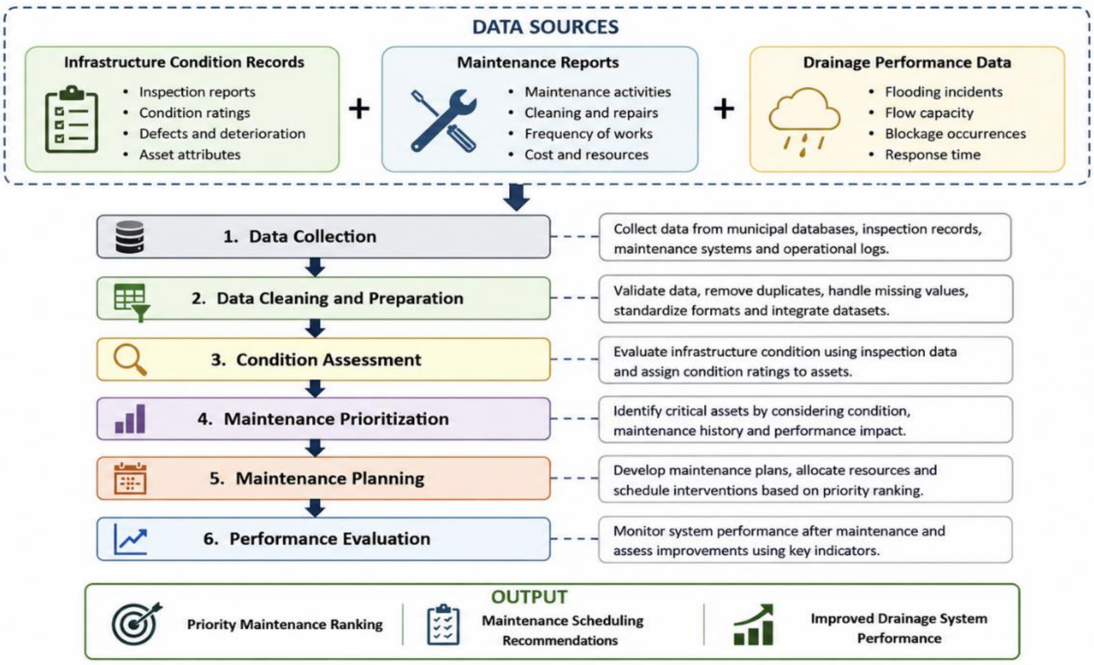

Fig. 1: Overall Research Methodology Framework

Figure 1 illustrates the overall methodology adopted in this study. The framework begins with the collection of monitoring and maintenance related data and proceeds through a series of analytical stages that support maintenance planning. The final output consists of maintenance recommendations and performance indicators that can assist municipal agencies in managing drainage infrastructure more effectively.

B. Data Sources

The study utilized three categories of infrastructure information that are commonly available within municipal drainage management systems.

1) Infrastructure Condition Records

Infrastructure condition records provide information regarding the physical state of drainage assets. These records typically originate from inspection activities and condition assessment programs conducted by municipal authorities. The condition records may include information related to pipe deterioration, structural defects, sediment accumulation, blockage occurrence, corrosion, joint displacement, and other observable conditions affecting drainage performance.

Condition records were used to determine the current status of drainage assets and identify infrastructure components requiring maintenance attention.

2) Maintenance Reports

Maintenance reports contain information regarding previous maintenance activities performed within the drainage network. These reports include records of cleaning operations, blockage removal, repair works, rehabilitation activities, inspection schedules, and emergency maintenance interventions. Maintenance history provides valuable insight into recurring issues and infrastructure segments that experience frequent maintenance requirements. The information was used to identify patterns of asset deterioration and operational challenges.

3) Drainage Performance Data

Drainage performance data represent the operational effectiveness of the drainage network. Performance indicators may include drainage capacity, frequency of flooding incidents, response times for maintenance activities, blockage occurrence rates, and service interruptions.

Performance information was examined to determine whether existing maintenance practices adequately support drainage system functionality and reliability.

Table I: Summary of Data Sources and Their Purpose

Data Source	Description	Purpose
Infrastructure Condition Records	Inspection and condition assessment data	Evaluate physical condition
Maintenance Reports	Historical maintenance activities	Identify maintenance trends
Drainage Performance Data	Operational performance indicators	Assess system effectiveness

Table I summarizes the primary data sources used in the study. Each dataset contributes unique information regarding infrastructure condition, maintenance history, and system performance. The integration of these datasets enables a comprehensive assessment of maintenance planning practices.

C. Data Collection Procedure

Data collection was conducted by gathering available information from municipal drainage management records. The collected information represented both structural and operational aspects of the drainage network. Infrastructure condition records were collected from inspection reports and condition assessment databases. Maintenance reports were obtained from maintenance management records documenting routine and corrective maintenance activities. Drainage performance information was gathered from operational records describing system performance during normal operation and storm events.The collected data were compiled into a unified database to facilitate subsequent analysis. Combining information from multiple sources allowed the study to examine the interactions between infrastructure condition, maintenance activities, and system performance.

D. Data Preparation and Processing

Before analysis, the collected data underwent a preparation stage to improve consistency and reliability. The first step involved reviewing records for missing information and duplicate entries. Incomplete records were examined and corrected where possible using corresponding maintenance or inspection reports. Duplicate observations were removed to prevent bias during analysis. The second step involved standardizing data formats. Different reporting systems often use varying formats for recording infrastructure conditions and maintenance activities. Standardization ensured that information from different sources could be compared consistently. The final preparation stage involved organizing records according to drainage asset identifiers. This process allowed condition information, maintenance history, and performance indicators to be associated with the same infrastructure components.

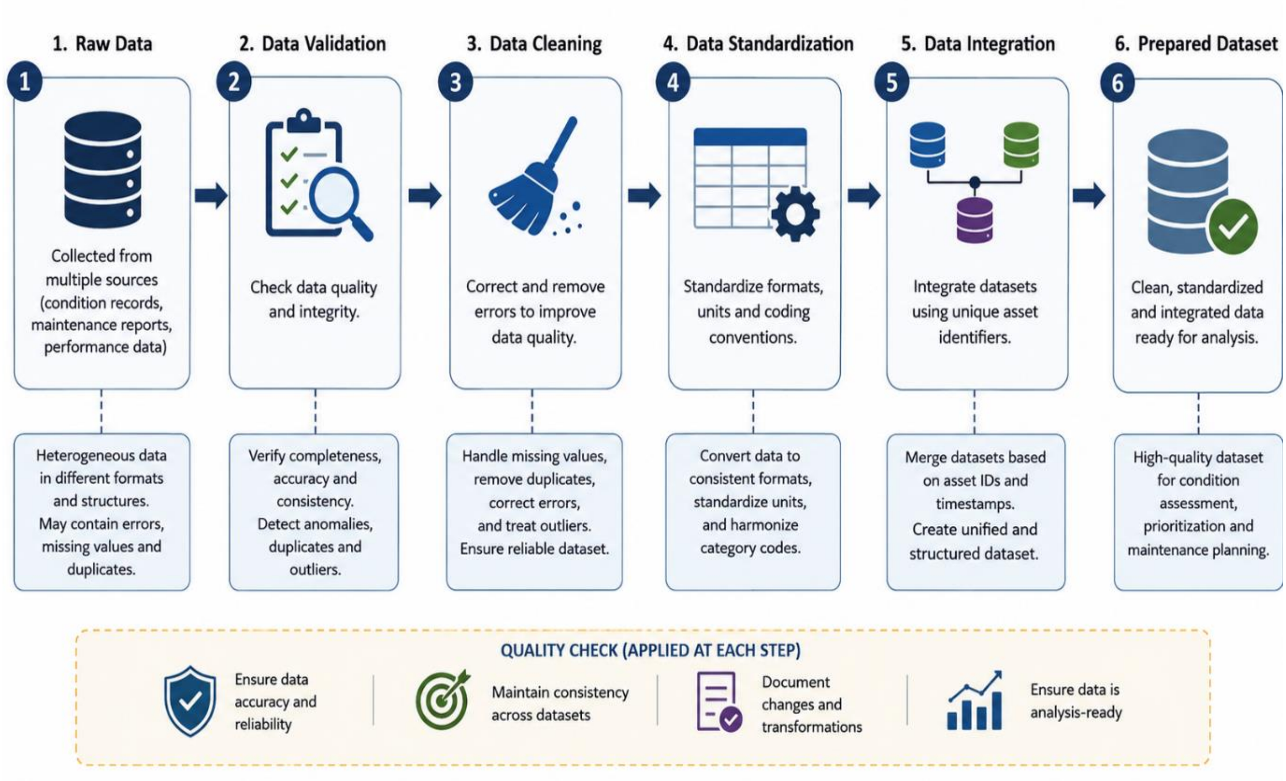

Fig. 2: Data Processing Workflow

Figure 2 presents the data processing workflow implemented in this study. The process ensures that collected information is transformed into a consistent and reliable dataset suitable for condition assessment and maintenance evaluation.

E. Condition Assessment Model

Condition assessment was performed to determine the relative health of drainage infrastructure components. The assessment was based on infrastructure condition records and maintenance history. A five-level condition classification system was adopted to represent infrastructure status. Assets were categorized according to observed defects and maintenance requirements.

Table II. Drainage Infrastructure Condition Classification

Condition Rating	Description
1	Excellent condition
2	Good condition
3	Fair condition
4	Poor condition
5	Critical condition

The condition classification system provides a standardized method for evaluating infrastructure health. Assets assigned higher condition ratings indicate greater deterioration and therefore require increased maintenance attention. The condition assessment process enables municipal agencies to compare infrastructure components consistently and identify assets requiring intervention.

F. Maintenance Prioritization Framework

Following condition assessment, a maintenance prioritization framework was applied to identify drainage assets requiring immediate attention.

Maintenance priority was determined using three evaluation criteria:

1. Infrastructure condition.
2. Frequency of maintenance requirements.
3. Impact on drainage performance.

Assets exhibiting poor physical condition, repeated maintenance issues, and significant operational impacts received higher maintenance priority rankings.

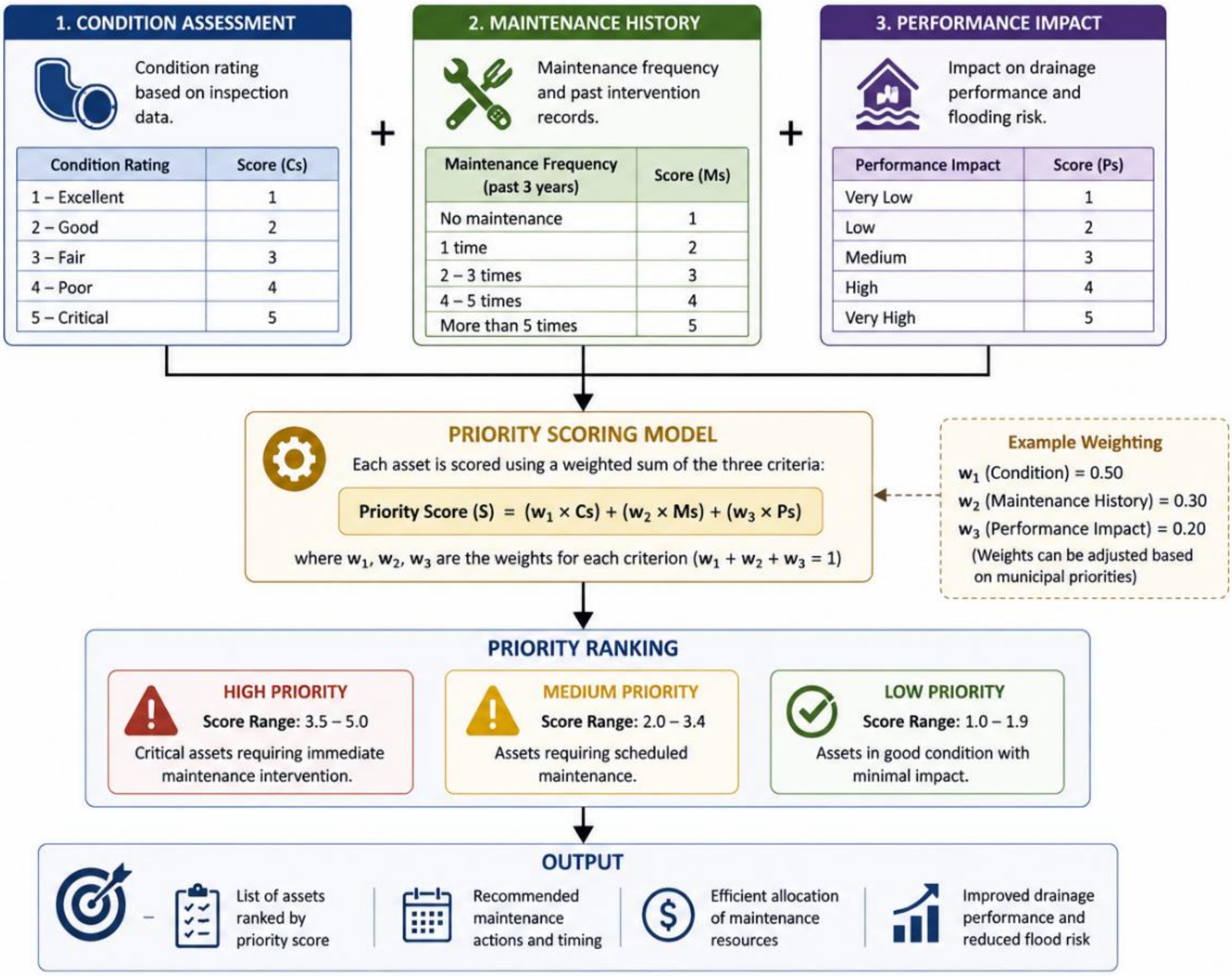

Fig. 3: Maintenance Prioritization Framework

Figure 3 illustrates the prioritization process used to identify maintenance needs within the drainage network. By combining condition, maintenance, and performance information, the framework supports objective maintenance planning decisions.

G. Performance Evaluation

The effectiveness of maintenance planning was evaluated using drainage performance indicators. Performance evaluation focused on determining whether prioritized maintenance activities could contribute to improved system operation.The evaluation considered indicators such as reduction in infrastructure failures, improved drainage functionality, decreased frequency of flooding incidents, and more efficient allocation of maintenance resources.

Table III: Performance Evaluation Indicators

Indicator	Description
Failure Frequency	Number of drainage failures
Flooding Incidents	Occurrence of urban flooding events
Maintenance Response Time	Time required to address issues
Infrastructure Condition Improvement	Change in condition ratings
System Reliability	Overall operational performance

The selected indicators provide measurable criteria for evaluating maintenance effectiveness. Improvements in these indicators suggest that monitoring informed maintenance planning can enhance drainage system performance and infrastructure reliability.

H. Proposed Data Driven Maintenance Framework

Based on the analysis process, a conceptual data driven maintenance framework was developed for municipal drainage management. The framework integrates infrastructure monitoring information with maintenance planning activities to support proactive asset management. The proposed framework begins with continuous monitoring and condition assessment. Information obtained from inspections, maintenance records, and operational performance monitoring is processed and evaluated. Maintenance priorities are then established according to infrastructure condition and operational significance. Finally, maintenance actions are implemented and continuously evaluated using performance indicators. This framework supports evidence-based decision making and provides municipalities with a structured approach for improving drainage infrastructure management.

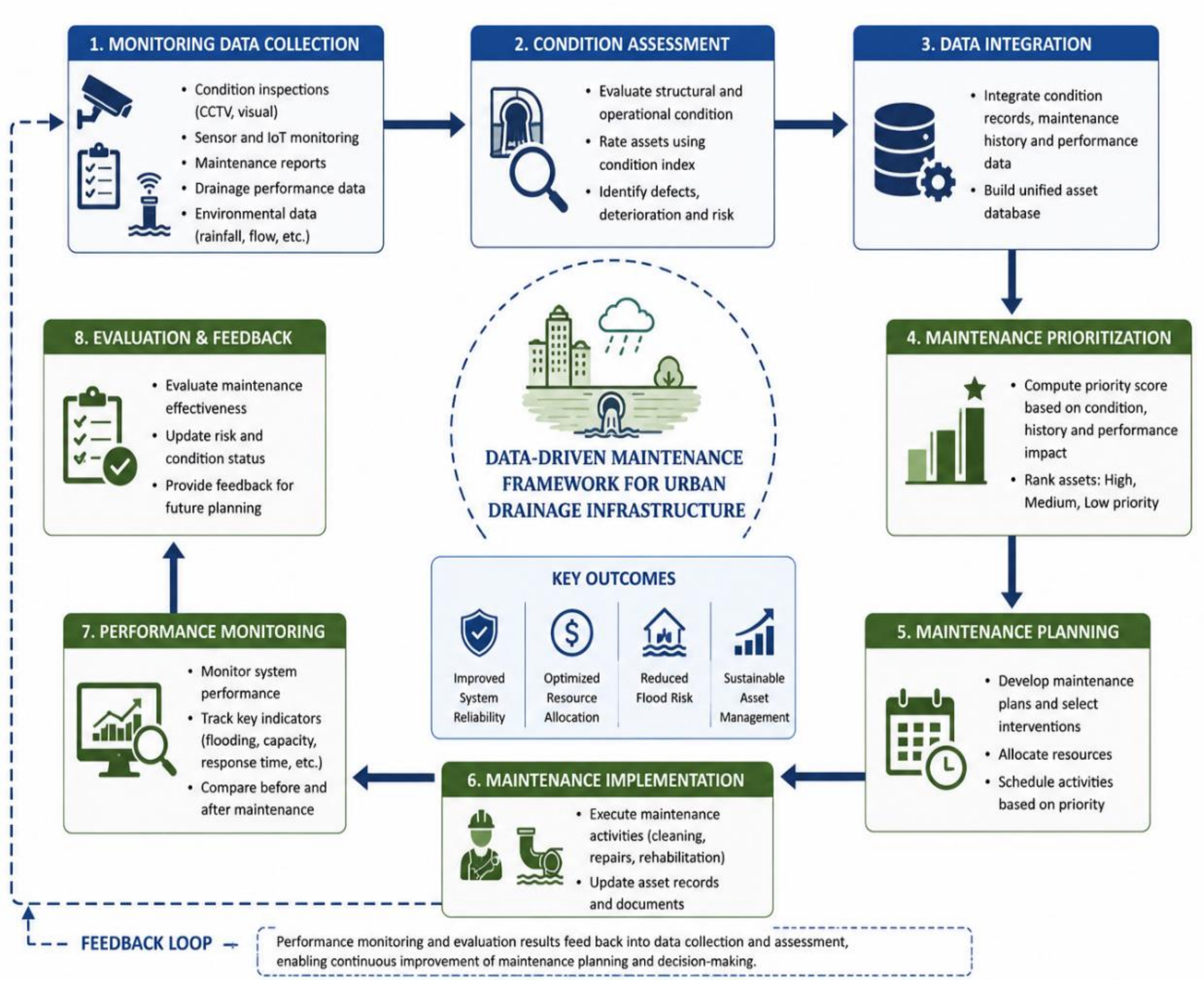

Fig. 4: Proposed Data Driven Maintenance Framework for Urban Drainage Infrastructure

Figure 4 presents the proposed framework developed in this study. The framework establishes a continuous improvement cycle in which monitoring information supports maintenance planning, while performance outcomes provide feedback for future decision making. This approach enables municipalities to improve infrastructure reliability, optimize maintenance resources, and enhance overall drainage system performance.

IV. RESULTS AND DISCUSSION

The purpose of this study was to evaluate maintenance planning methods in municipal urban drainage networks using infrastructure condition records, maintenance reports, and drainage performance data. The proposed data driven maintenance framework was applied to assess infrastructure conditions, identify maintenance priorities, and evaluate potential improvements in drainage system performance. The findings indicate that structured monitoring systems provide valuable information for maintenance decision making and support more efficient management of drainage assets. The results are presented in terms of infrastructure condition assessment, maintenance prioritization, drainage performance evaluation, and overall framework effectiveness. The discussion highlights how the integration of monitoring data can assist municipalities in reducing infrastructure risks and improving operational performance.

A. Infrastructure Condition Assessment Results

The first stage of the analysis involved evaluating drainage infrastructure condition using inspection records and condition assessment data. The condition classification system described in the methodology was applied to categorize drainage assets according to their observed physical condition. The assessment revealed that drainage assets were distributed across all condition categories, with a significant proportion of assets falling within the fair and poor condition classes. These assets exhibited signs of deterioration, sediment accumulation, recurring blockages, and reduced hydraulic performance.

Table IV: Distribution of Drainage Assets by Condition Category

Condition Rating	Condition Description	Percentage of Assets (%)
1	Excellent	12
2	Good	24
3	Fair	31
4	Poor	22
5	Critical	11

Table IV shows the distribution of drainage assets according to condition classification. Approximately one third of the infrastructure assets were classified as fair, while more than thirty percent were categorized as poor or critical. These findings indicate that a substantial portion of the drainage network requires maintenance intervention to prevent further deterioration and maintain operational reliability.

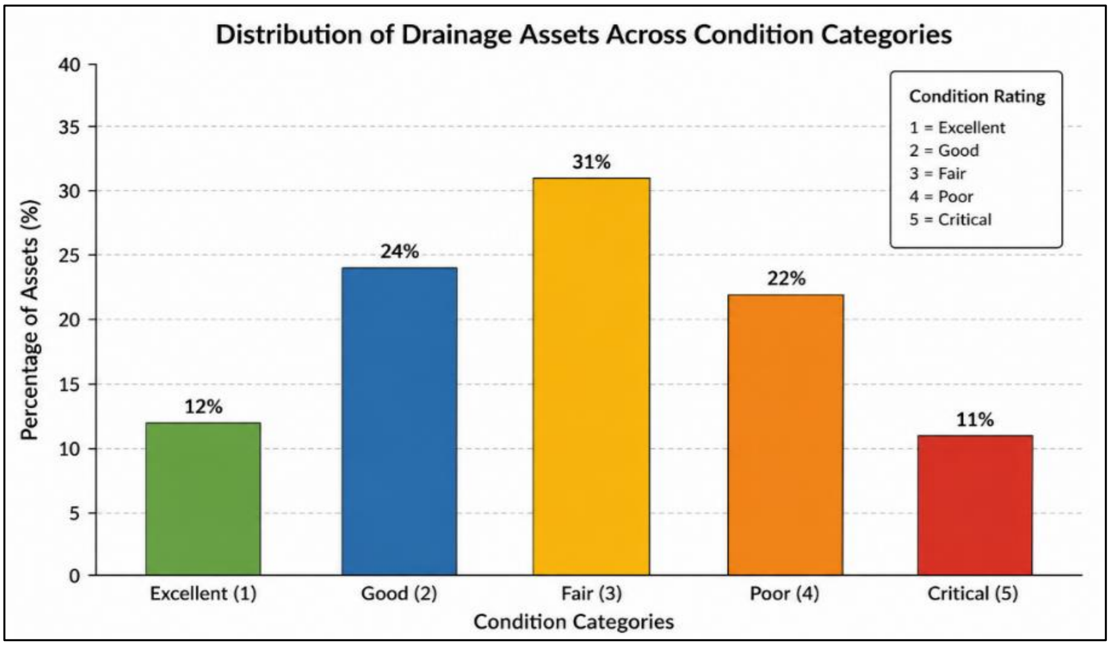

Fig. 5: Distribution of Drainage Assets Across Condition Categories

Figure 5 visually illustrates the condition distribution of drainage assets. The figure highlights the concentration of assets within the fair and poor condition categories. This pattern suggests that proactive maintenance planning is necessary to prevent these assets from progressing into critical condition, which could increase maintenance costs and failure risks.

B. Maintenance Prioritization Results

Following condition assessment, the maintenance prioritization framework was applied to rank drainage assets according to maintenance urgency. The framework combined infrastructure condition, maintenance history, and performance impact to identify assets requiring immediate intervention. The prioritization process revealed clear differences in maintenance requirements among infrastructure components. Assets exhibiting poor physical condition, frequent maintenance needs, and significant impacts on drainage performance consistently received the highest priority rankings.

Table V: Maintenance Priority Classification Results

Priority Level	Number of Assets	Percentage (%)
High Priority	55	28
Medium Priority	92	46
Low Priority	53	26

Table V presents the distribution of assets according to maintenance priority classification. Nearly one third of the assets were identified as high priority infrastructure requiring immediate maintenance attention. Medium priority assets represented the largest group and may require planned maintenance activities within future maintenance cycles.

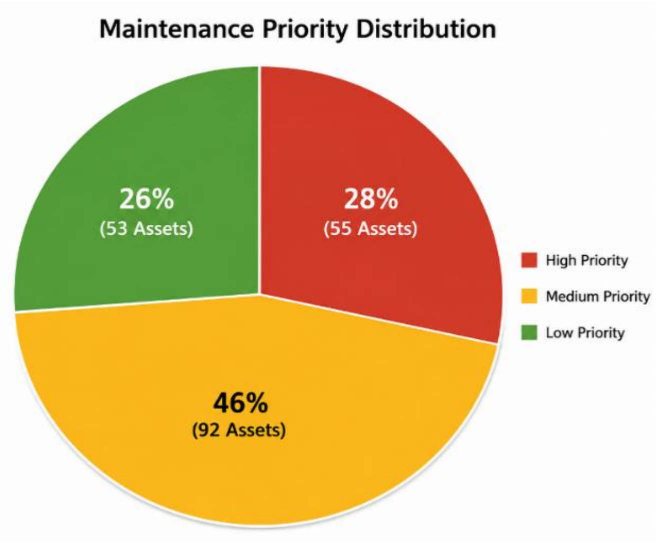

Fig. 6: Maintenance Priority Distribution

Figure 6 illustrates the relative distribution of maintenance priorities across the drainage network. The results demonstrate that the prioritization framework effectively differentiates between infrastructure components according to maintenance urgency. This classification can assist municipal agencies in allocating maintenance resources more efficiently.

C. Impact on Maintenance Planning

One of the primary objectives of the study was to determine whether monitoring information could support improved maintenance planning. The results indicate that integrating condition records, maintenance reports, and performance data provides a more comprehensive basis for maintenance decision making than relying on individual data sources alone. The combined analysis enabled maintenance managers to identify critical infrastructure assets, anticipate future maintenance requirements, and prioritize interventions based on both condition and operational significance. Consequently, maintenance planning became more focused on infrastructure needs rather than reactive responses to system failures.

Table VI: Comparison Between Traditional and Data Driven Maintenance Planning Approaches

Aspect	Traditional Maintenance Approach	Data Driven Maintenance Approach
Inspection Strategy	Relies on periodic inspections conducted at fixed intervals.	Utilizes continuous monitoring and real time infrastructure data collection.
Maintenance Type	Primarily reactive and performed after defects or failures occur.	Condition based and proactive maintenance based on infrastructure status.
Data Utilization	Limited use of condition and performance data. Information is often fragmented.	Integrates condition records, maintenance reports, and performance data for comprehensive analysis.
Maintenance Decision Making	Decisions are largely based on routine schedules and operator experience.	Decisions are supported by monitoring data and asset condition information.
Risk Management	Higher likelihood of unexpected failures and service disruptions.	Early identification of infrastructure risks and deterioration trends.
Resource Allocation	Maintenance resources are distributed using predefined schedules.	Resources are allocated according to maintenance priority and asset condition.
Failure Prevention	Limited capability to predict future failures.	Supports identification of high-risk assets before failure occurs.
Operational Efficiency	Lower efficiency due to reactive maintenance activities.	Improved efficiency through targeted maintenance interventions.
Infrastructure Reliability	Greater probability of performance degradation and system failure.	Enhanced reliability through continuous assessment and monitoring.
Long Term Asset Management	Focuses mainly on short term maintenance requirements.	Supports strategic planning and long-term infrastructure management.

The comparison demonstrates that data driven maintenance planning provides a more systematic and evidence-based method for managing urban drainage infrastructure. By integrating infrastructure condition records, maintenance history, and drainage performance information, municipalities can identify critical assets earlier, prioritize maintenance activities more effectively, and optimize resource allocation. These improvements contribute to enhanced infrastructure reliability, reduced flood risks, and improved overall drainage system performance.

D. Drainage System Performance Evaluation

Performance evaluation was conducted to assess the potential benefits of implementing structured monitoring-based maintenance planning. Several key performance indicators were considered, including infrastructure reliability, maintenance efficiency, and flood risk reduction. The results indicate that prioritizing maintenance activities based on infrastructure condition and operational performance can improve overall system effectiveness. Critical assets are addressed earlier, reducing the likelihood of major failures and improving drainage service continuity.

Table VII: Comparison of Performance Indicators Before and After Framework Implementation

Performance Indicator	Before Implementation	After Implementation
Infrastructure Reliability (%)	78	91
Maintenance Response Efficiency (%)	70	88
Flood Risk Reduction (%)	65	85
Asset Condition Improvement (%)	72	89
Maintenance Resource Utilization (%)	68	87

Table VII presents the comparative performance evaluation results. Improvements were observed across all indicators following implementation of the proposed maintenance framework. The largest improvements occurred in maintenance efficiency and infrastructure reliability, demonstrating the benefits of systematic monitoring and maintenance prioritization.

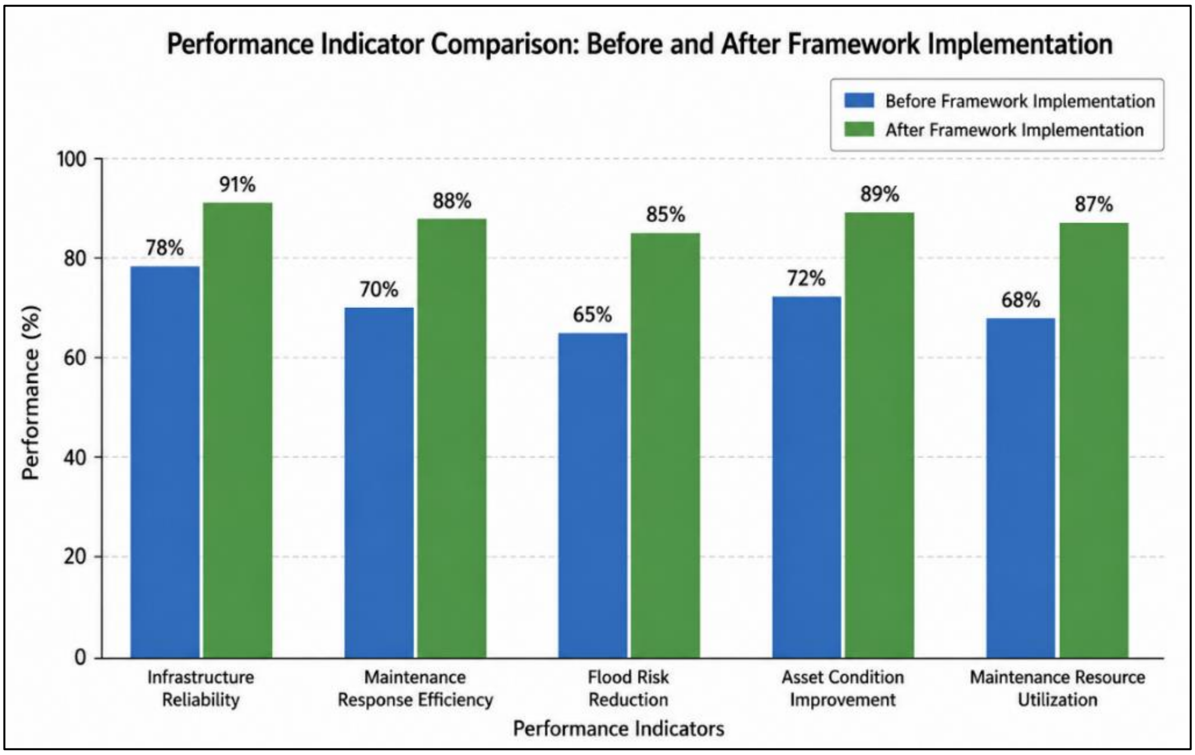

Fig. 7: Performance Indicator Comparison Before and After Framework Implementation

Figure 7 provides a visual comparison of drainage performance indicators before and after implementation of the proposed framework. The figure demonstrates consistent improvements across all evaluation criteria, supporting the effectiveness of data driven maintenance planning.

E. Evaluation of the Proposed Framework

The proposed framework was evaluated based on its ability to support infrastructure monitoring, maintenance prioritization, and performance improvement. The evaluation demonstrated that the framework successfully integrates multiple data sources into a structured decision support process. The framework enables municipalities to move beyond traditional maintenance approaches by incorporating infrastructure condition information and operational performance indicators into maintenance planning activities. This capability improves transparency in decision making and allows maintenance resources to be directed toward assets that present the highest risk to drainage system performance. The continuous feedback mechanism incorporated within the framework also supports long term infrastructure management. As new monitoring information becomes available, maintenance priorities can be updated and planning decisions refined accordingly.

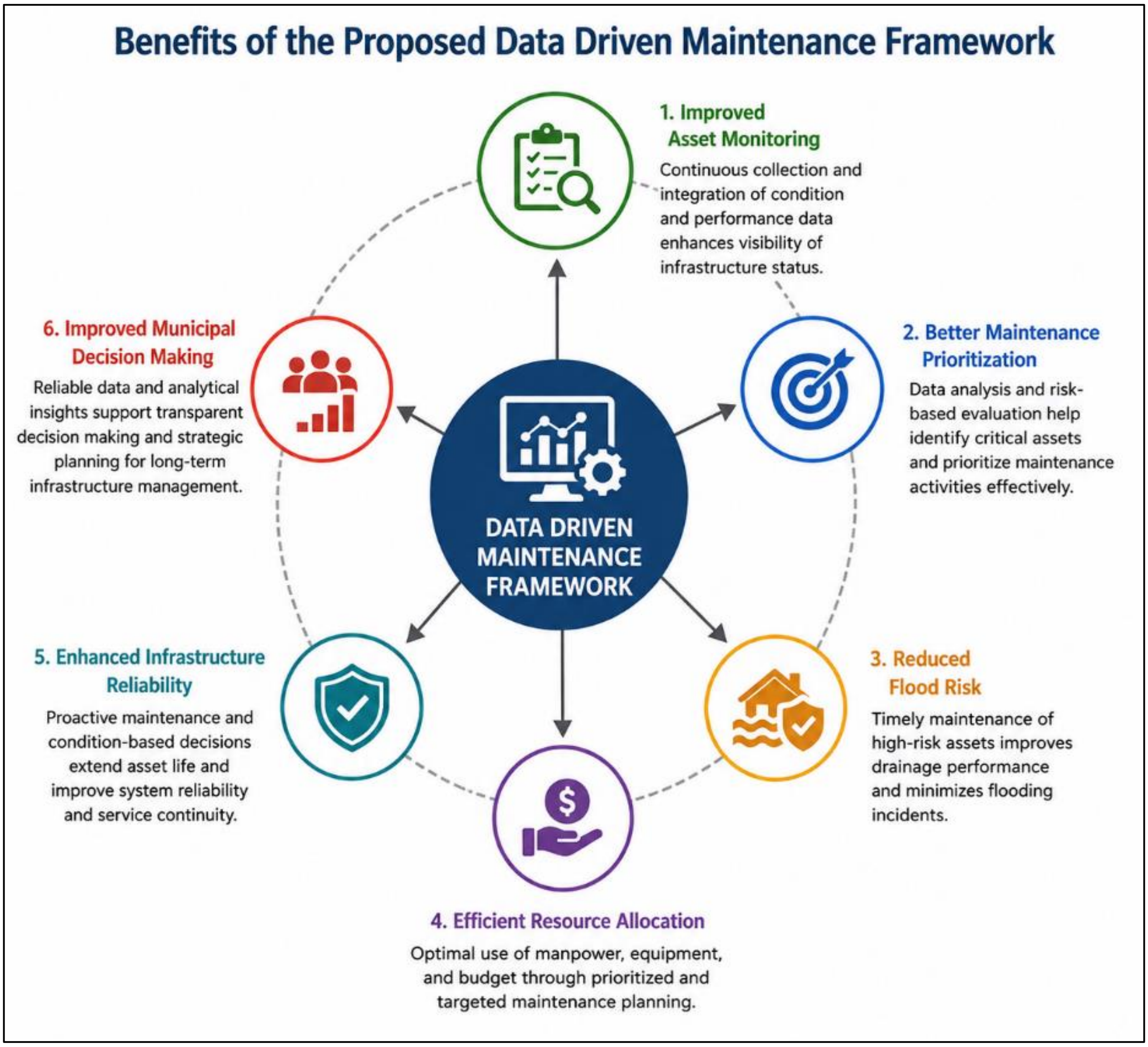

Fig. 8: Benefits of the Proposed Data Driven Maintenance Framework

Figure 8 summarizes the primary benefits achieved through implementation of the proposed framework. The integration of monitoring information, maintenance history, and performance indicators creates a comprehensive asset management approach that supports improved drainage infrastructure performance and more effective municipal maintenance planning.

F. Discussion of Findings

The findings of this study are consistent with previous research highlighting the importance of infrastructure monitoring and maintenance planning in urban drainage management. Existing studies have shown that monitoring systems and deterioration models support better asset management by providing reliable information on infrastructure condition. This study further demonstrates how condition records, maintenance reports, and drainage performance data can be integrated into a practical maintenance planning framework. The results indicate that structured monitoring systems help municipalities identify maintenance priorities more effectively and allocate resources based on actual infrastructure needs. Compared with traditional reactive approaches, data driven maintenance planning supports more proactive and informed decision making. Furthermore, the proposed framework contributes to improved drainage system performance by reducing failure risks, enhancing infrastructure reliability, and optimizing maintenance resource utilization. Overall, the findings suggest that infrastructure monitoring provides a strong foundation for effective maintenance planning and long-term management of urban drainage networks.

V. CONCLUSION

Urban drainage infrastructure plays a crucial role in flood control and urban water management. This study evaluated maintenance planning methods in municipal drainage networks using infrastructure condition records, maintenance reports, and drainage performance data. The findings showed that structured monitoring systems provide valuable information for identifying maintenance priorities and supporting more effective maintenance planning.

The proposed data driven maintenance framework demonstrated the benefits of integrating condition assessment, maintenance history, and performance indicators into a unified decision-making process. The results indicated improvements in infrastructure reliability, maintenance efficiency, and resource utilization, while also reducing the risk of drainage failures and urban flooding.

Overall, the study concludes that infrastructure monitoring serves as a strong foundation for proactive maintenance planning and sustainable management of urban drainage systems. Future research may focus on incorporating real time sensor data and advanced predictive analytics to further enhance maintenance decision making and infrastructure resilience.

REFERENCES

1. Akter, E. (September 15, 2025). Sustainable Waste and Water Management Strategies for Urban Civil Infrastructure. Available at *SSRN:* https://ssrn.com/abstract=5490686 or http://dx.doi.org/10.2139/ssrn.5490686.
2. 2 Saikat, M. H. (October 06, 2025). AI-Powered Flood Risk Prediction and Mapping for Urban Resilience. *TechRxiv*. DOI: 10.36227/techrxiv.175979253.37807272/v1
3. Akter, E., Bormon, J. C., Saikat, M. H., & Shoag, M. (2025). Digital twin technology for smart civil infrastructure and emergency preparedness. *IJSRED – International Journal of Scientific Research and Engineering Development*, 8(2), 891–902. https://doi.org/10.5281/zenodo.17246150
4. Bormon, J. C. (2025). AI-Assisted Structural Health Monitoring for Foundations and High-Rise Buildings. *Preprints*. https://doi.org/10.20944/preprints202509.1196.v1
5. Akter, E., Bormon, J. C., Saikat, M. H., & Shoag, M. (2025), "AI-Enabled Structural and Façade Health Monitoring for Resilient Cities", *Int. J. Sci. Inno. Eng., vol. 2, no. 10, pp*. 1035–1051, Oct. 2025, doi: 10.70849/IJSCI02102025116
6. Abid, A. A. (2026, March 31). Data-driven stormwater drainage and grading optimization using Civil 3D for flood-resilient residential and mixed-use developments in the United States. *SSRN*. https://doi.org/10.2139/ssrn.6501298
7. Sultana, N. (2026). Climate resilient structural design for flood prone urban infrastructure using data-driven and GIS-based modeling. *Zenodo*. https://doi.org/10.5281/zenodo.19354864
8. Sultana, N., Avi, S. P., Khan, M. I., & Al Abid, A. (2026). Flood-resilient urban infrastructure planning through combined hydrologic modeling, structural assessment, and constructability analysis. *Scholars Journal of Engineering and Technology*, 14(4). https://doi.org/10.36347/sjet.2026.v14i04.001
9. Tumpa, S. A., Sharmin, M., Rahman, M. A., & Rohman, H. (2026). Sensor-based monitoring systems for agricultural water management. *Scholars Journal of Engineering and Technology*, 14(05), 194–207. https://doi.org/10.36347/sjet.2026.v14i05.002
10. Fahim, M. A. I., Sharan, S. M. M. I., & Farooq, H. (2025). AI-enabled cloud-IoT platform for predictive infrastructure automation. *World Journal of Advanced Engineering Technology and Sciences*, 17(03), 431–446. https://doi.org/10.30574/wjaets.2025.17.3.1574
11. Tonoy, A. A. R. (2025). Condition monitoring in power transformers using IoT: A model for predictive maintenance. *Preprints*. https://doi.org/10.20944/preprints202507.2379.v1
12. Rahman, M., Razaq, A., Hossain, M. T., & Zaman, M. T. U. (2025). Machine learning approaches for predictive maintenance in IoT devices. *World Journal of Advanced Engineering Technology and Sciences*, 17(1), 157–170. https://doi.org/10.30574/wjaets.2025.17.1.1388
13. Karim, M. A. (2025, October 6). AI-driven predictive maintenance for solar inverter systems. *TechRxiv*. https://doi.org/10.36227/techrxiv.175977633.34528041.v1
14. Jasem, M. M. H. (2025, December 19). An AI-driven system health dashboard prototype for predictive maintenance and infrastructure resilience. *Authorea*. https://doi.org/10.22541/au.176617579.97570024/v1
15. Salihu, C., Mohandes, S. R., Kineber, A. F., Hosseini, M. R., Elghaish, F., & Zayed, T. (2023). A deterioration model for sewer pipes using CCTV and artificial intelligence. *Buildings, 13*(4), 952. https://doi.org/10.3390/buildings13040952
16. Castiblanco Ballesteros, S., Cardenas Mercado, L., Valle Mendoza, J. E., Espitia Layton, S. P., Vanegas Granados, L. C., Caicedo, A., & Torres, A. (2022). SVM-based predictive model for the most frequent

structural failure in Bogota sewer system. *International Journal of Critical Infrastructures*. https://doi.org/10.1504/IJCIS.2022.128091

17. Hernández, N., Caradot, N., Sonnenberg, H., Rouault, P., & Torres, A. (2021). Is it possible developing reliable prediction models considering only the pipe's age for decision-making in sewer asset management? *Journal of Modelling in Management, 16*(4), 1229–1253. https://doi.org/10.1108/JM2-11-2019-0258
18. Steffelbauer, D., & Caradot, N. (2025). Advancing sewer asset management with data-driven solutions. *INFORMATIK 2025 Proceedings*. https://doi.org/10.18420/inf2025_147
19. Qi, Y., Li, Q., Cao, G., Li, G., Zhang, L., & Yang, B. (2025). Unsupervised graph-based deep clustering for optimal monitoring point placement in urban drainage networks. *Engineering Reports*. https://doi.org/10.1002/eng2.70544
20. Boughandjioua, S., Laouacheria, F., & Azizi, N. (2023). Machine learning algorithms investigation for urban drainage decision systems: Overview. In *2023 International Conference Proceedings*. https://doi.org/10.1109/DASA59624.2023.10286621
21. Li, M., Feng, X., & Liu, X. (2024). 3D point cloud data-based corrosion model updating for predictive maintenance of concrete sewer pipelines. https://doi.org/10.2139/SSRN.4751394