

Flood-Resilient Urban Infrastructure Planning Through Combined Hydrologic Modeling, Structural Assessment, and Constructability Analysis

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Abstract

Original Research Article

Urban flooding has been recognized as a major issue for cities, which is being exacerbated by the consequences of rapid urbanization, expansion of impervious areas, and the increase in rainfall intensity, which is being influenced by climate variability. In the conventional approach to flood management studies, either hydrologic modeling or infrastructure assessment is typically conducted, which does not necessarily provide an effective approach to urban infrastructure planning under flood conditions. In this study, a framework for flood resilient urban infrastructure planning is proposed, which integrates hydrologic flood modeling, infrastructure assessment, and constructability assessment based on a multi-criteria decision approach. Hydrologic modeling is conducted to assess the rainfall-runoff behavior and to identify flood-prone areas based on flood depth and inundation maps. On the other hand, structural assessment focuses on the assessment of the reliability of structural elements such as bridges, embankments, culverts, and drainage channels subjected to hydraulic loading. The constructability assessment focuses on the assessment of the feasibility of the proposed mitigation measures based on the complexity of the construction, spatial constraints, and construction costs. The integrated decision analysis compares the flood mitigation measures based on integrated performance measures. The results show that the expansion of the drainage network and the hydraulic structures are viable for flood risk mitigation with favorable construction conditions in dense urban areas. The proposed method provides a framework for supporting the development of resilient urban infrastructures in flood-prone regions.

Keywords: Flood Resilience, Urban Infrastructure Planning, Hydrologic Modeling, Infrastructure Vulnerability Assessment, Constructability Analysis, Urban Flood Mitigation, Multi-Criteria Decision Analysis, Urban Drainage Systems.

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I. INTRODUCTION

Urban flooding presents a growing challenge for cities worldwide. Expansion of urban areas, increased surface impermeability, and shifts in precipitation patterns contribute to higher flood risk in many metropolitan regions. Urban growth often outpaces the development of drainage infrastructure and flood management systems. Heavy rainfall events therefore generate large volumes of runoff that exceed the capacity of existing drainage networks. These conditions lead to water accumulation on roads, disruption of transportation systems, and damage to critical infrastructure. Climate variability has also increased the occurrence of intense rainfall events, which further raises the exposure of urban infrastructure to flood hazards. Recent research has focused on improving flood prediction through hydrologic and hydrodynamic modeling. Coupled hydrologic-hydrodynamic models

simulate rainfall-runoff processes together with urban drainage flow under different storm scenarios. These models produce detailed information on flood depth, inundation extent, and flow velocity within urban catchments [3-6]. Such modeling approaches support flood hazard mapping and identification of locations where drainage systems reach capacity limits during heavy rainfall. In addition, integration of watershed-scale hydrologic modeling with digital infrastructure representations such as Building Information Modeling allows simulation of interactions between natural watershed processes and urban infrastructure systems [1].

Structural resilience assessment has also received attention in recent studies. Hydraulic modeling tools combined with spatial analysis techniques have been used to evaluate the vulnerability of infrastructure

exposed to flood conditions. Geographic Information Systems together with analytical decision models allow evaluation of infrastructure performance based on resistance to hydraulic loading, redundancy within infrastructure networks, and potential cascading impacts on connected systems [2]. Infrastructure resilience indices have also been applied to assess transportation networks under disaster scenarios. These approaches provide quantitative indicators that support planning decisions related to infrastructure investment and disaster risk reduction [4].

Research on urban flood mitigation has also examined the role of green infrastructure and nature-based solutions. Measures such as permeable surfaces, vegetated drainage channels, and distributed stormwater retention systems can reduce runoff volumes and improve infiltration capacity within urban areas. These systems can lower peak discharge levels and contribute to more sustainable drainage strategies [5]. Multiscale analysis methods have also been used to examine interactions between distributed green infrastructure systems and urban drainage networks under varying rainfall conditions [8]. In addition, spatial decision frameworks have been proposed to support flood management planning through integration of hazard mapping, land-use characteristics, and infrastructure planning alternatives [7]. Although these studies contribute valuable insight into flood risk analysis and infrastructure resilience, many investigations address hydrologic simulation, structural evaluation, or infrastructure planning as separate tasks. Hydrologic modeling produces detailed flood hazard information, yet it often lacks direct evaluation of infrastructure structural performance. Structural resilience studies focus on infrastructure capacity but frequently exclude hydrologic simulation outputs from planning analysis. Constructability considerations, which involve practical implementation constraints such as construction complexity and spatial limitations, also receive limited attention in many flood resilience investigations. The absence of an integrated analytical framework complicates infrastructure planning in flood-prone urban environments. Flood mitigation strategies that appear effective in hydraulic simulations may face structural limitations or implementation challenges during construction. Urban flood resilience therefore requires an approach that combines flood hazard modeling, infrastructure structural assessment, and implementation feasibility evaluation within a unified planning framework.

This study aims to develop an integrated framework for flood-resilient urban infrastructure planning that combines hydrologic modeling, structural infrastructure assessment, and constructability analysis within a unified decision structure. The research evaluates flood hazards through hydrologic simulation and examines the structural performance of infrastructure systems exposed to these conditions. The

study also investigates the feasibility of different mitigation strategies through constructability evaluation that considers construction complexity, spatial constraints, and implementation requirements. Results from these analyses are combined through a multi-criteria decision framework that compares alternative infrastructure planning strategies. The objective is to identify infrastructure interventions that reduce flood risk while maintaining structural reliability and practical feasibility within urban environments.

II. RELATED WORK

Integrated Hydrologic and Urban Modeling Approaches

Urban flood studies increasingly combine hydrologic and hydraulic models with detailed urban infrastructure information to improve flood prediction and planning. Integrated modeling frameworks simulate rainfall runoff processes together with drainage system behavior and spatial infrastructure characteristics. Several studies show that linking watershed-scale hydrologic models with Geographic Information Systems (GIS) improves representation of urban surface conditions, drainage networks, and topographic variation. Such integration supports identification of flood-prone zones and infrastructure exposure across complex urban environments [2-6]. Recent research also connects hydrologic simulation with digital infrastructure models. Watershed modeling linked with Building Information Modeling (BIM) allows representation of natural watershed processes together with detailed structural elements within cities. These systems support analysis of flood propagation across urban infrastructure networks and allow planners to examine potential impacts on transportation corridors and drainage facilities [1]. Integrated hydrologic hydraulic modeling has also improved simulation accuracy for urban flood scenarios that involve different rainfall intensities and drainage configurations [6]. Although these approaches improve flood hazard analysis, many studies focus primarily on flood extent prediction and hydraulic behavior. Less attention has been given to linking flood simulation outputs with structural infrastructure performance and implementation feasibility within infrastructure planning systems.

Structural Assessment and Resilience Modeling of Urban Infrastructure

Structural resilience assessment evaluates how infrastructure systems perform during flood events. Research in this area focuses on the ability of buildings, transportation networks, and drainage structures to resist hydraulic loading and maintain operational functionality. Several studies integrate hydraulic simulation with spatial analysis tools to evaluate infrastructure vulnerability. Hydraulic modeling platforms such as HEC-RAS combined with GIS datasets allow identification of buildings and infrastructure components located within flood-prone areas. These analyses often

include multi-criteria evaluation methods that measure resilience across multiple indicators such as structural resistance, redundancy, and potential cascading failures [2]. Decision-support techniques including Analytical Hierarchy Process (AHP), LISREL modeling, and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) have been used to evaluate infrastructure resilience under flood conditions. These approaches consider structural performance indicators and system interactions within urban infrastructure networks. Results from such analyses support prioritization of infrastructure improvements and identification of vulnerable components within critical systems [2]. Many studies concentrate on buildings or isolated infrastructure elements. Integrated analysis of transportation systems, drainage infrastructure, and structural reliability within a single planning framework remains limited.

Constructability Analysis and Cost-Effective Flood Mitigation

Flood mitigation planning requires solutions that remain technically effective and practically implementable within urban environments. Constructability analysis examines implementation feasibility with respect to construction complexity, spatial constraints, and economic requirements. Recent research examines infrastructure resilience through scenario-based analysis of transportation networks exposed to disaster events. Infrastructure resilience indices evaluate system performance across multiple phases of disaster response, including avoidance, endurance, recovery, and adaptability. Such approaches allow assessment of investment priorities for road infrastructure systems exposed to flood hazards [4]. Green infrastructure has also received attention as a flood mitigation strategy. Measures such as permeable pavements, vegetated drainage systems, and rain gardens reduce runoff volume and improve infiltration capacity within urban catchments. Studies show that these approaches can reduce peak discharge levels while maintaining relatively moderate construction costs and environmental impacts [5-8]. Hydrologic modeling has also been applied to examine the interaction between green infrastructure elements and urban drainage systems. Multiscale analysis methods evaluate how distributed mitigation elements influence runoff patterns and drainage network performance across urban areas [6-8]. Despite these developments, constructability analysis often receives limited attention in flood mitigation studies. Many investigations evaluate hydraulic performance without examining construction feasibility in dense urban environments where infrastructure modification may involve logistical and spatial constraints.

Collaborative Spatial Decision-Making for Urban Flood Governance

Flood resilience planning also incorporates spatial decision frameworks that combine technical analysis with planning and governance considerations. Geographic Information Systems integrated with multi-criteria decision analysis provide tools for evaluating infrastructure planning alternatives based on environmental, spatial, and economic indicators. Recent studies propose collaborative spatial decision-making systems that incorporate stakeholder participation within flood management planning. These frameworks combine flood hazard maps with spatial datasets such as land use, terrain slope, and geological characteristics. Multi-criteria analysis supports comparison of planning alternatives and identification of suitable infrastructure locations for runoff management systems [7]. Participatory planning approaches contribute to transparent infrastructure planning and improve coordination among engineers, planners, and policymakers. Spatial decision systems also assist in balancing technical flood risk analysis with broader urban development priorities.

III. METHODOLOGY

Overall Research Framework

Urban flood resilience requires coordinated evaluation of hydrologic processes, infrastructure performance, and construction feasibility. This study presents an integrated analytical framework that combines hydrologic modeling, structural infrastructure assessment, and constructability analysis within a unified planning system. The objective is to identify infrastructure interventions that reduce flood exposure while maintaining structural reliability and practical feasibility during implementation. The research framework follows a sequential analytical structure. Hydrologic and hydraulic simulations first quantify rainfall runoff processes and urban flood propagation under extreme precipitation scenarios. Structural evaluation then examines the capacity of infrastructure components such as bridges, road embankments, culverts, and drainage networks to withstand hydraulic loads generated during flood events. Constructability analysis examines implementation feasibility in relation to construction complexity, site accessibility, and economic considerations. Results from these components are integrated through a multi-criteria evaluation model that identifies infrastructure planning strategies with the highest overall performance. This structure addresses a limitation in many flood risk studies, where hazard modeling and infrastructure planning remain separate tasks. The proposed method links flood simulation results with infrastructure performance evaluation and construction feasibility assessment. The outcome provides practical guidance for infrastructure planning rather than only hazard prediction.

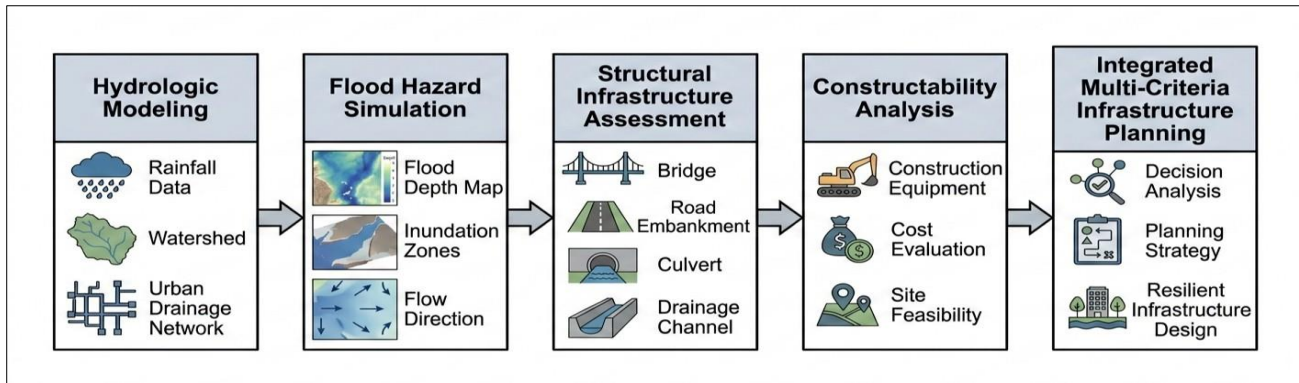


Figure 1: Conceptual Research Framework for Flood-Resilient Infrastructure Planning

The framework also allows evaluation of multiple infrastructure design alternatives under different hydrologic scenarios. Drainage expansion, embankment reinforcement, or flood protection barriers can therefore be compared through a consistent analytical process.

Hydrologic and Flood Modeling

The first stage quantifies flood hazards through rainfall-runoff and hydraulic simulations. Historical precipitation records and design storm data represent rainfall events with different return periods. Required inputs include rainfall intensity, catchment characteristics, land-use distribution, and drainage network capacity.

Peak runoff entering the drainage system is estimated using the rational rainfall-runoff relationship:

$$Q = C \times I \times A$$

where

Q = peak runoff discharge (m^3/s)

C = runoff coefficient representing surface impermeability

I = rainfall intensity (mm/hr)

A = drainage area (km^2)

The equation provides a first estimate of discharge generated within urban catchments. Impervious surfaces typically produce higher runoff coefficients, which increases flood potential in densely developed zones.

Hydraulic routing of flow through drainage channels follows Manning's equation:

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Where

V = flow velocity (m/s)

n = Manning roughness coefficient

R = hydraulic radius (m)

S = slope of the hydraulic grade line

Velocity and discharge outputs support simulation of flood propagation across the urban drainage network. Spatial flood characteristics such as

inundation depth, flow velocity, and flood duration are then generated through two dimensional flood modeling. Flood depth maps for several storm intensities reveal locations where infrastructure faces high hydraulic stress. These hazard indicators form the input dataset for infrastructure vulnerability analysis.

Structural Infrastructure Assessment

The second stage evaluates structural performance of infrastructure exposed to simulated flood conditions. The analysis focuses on components that influence urban mobility and drainage capacity, including bridges, culverts, road embankments, and stormwater channels. Flood loading on infrastructure structures depends on water depth and hydraulic forces. Hydrostatic pressure acting on structural surfaces follows:

$$P = \gamma h$$

Where

P = hydrostatic pressure (kN/m^2)

γ = unit weight of water

h = floodwater depth

This pressure contributes to lateral loading on retaining structures and bridge supports. Hydraulic forces also affect road embankments and drainage structures.

Infrastructure reliability is evaluated through a structural reliability index:

$$RI = \frac{R - S}{\sigma}$$

Where

RI = reliability index

R = structural resistance capacity

S = applied flood load

σ = uncertainty associated with loading and resistance

The index indicates the safety margin between structural resistance and hydraulic loading. Larger values correspond to greater reliability. Infrastructure elements with reliability values below a predefined threshold are classified as vulnerable to flood damage. Combining flood hazard outputs with structural reliability results produces an infrastructure vulnerability map. The map

identifies segments that require reinforcement, redesign, or protective measures.

Constructability Analysis

Structural feasibility alone does not determine infrastructure suitability. Urban projects often face restrictions related to construction access, available space, and project cost. Constructability evaluation therefore forms a key component of the methodology. Each infrastructure intervention receives a constructability score derived from several criteria:

- construction complexity
- equipment accessibility
- construction duration
- availability of materials
- estimated project cost

Urban locations with dense development frequently impose restrictions on construction operations. Road closures, limited staging space, and underground utility conflicts can affect project implementation. The constructability assessment considers these factors in order to compare potential interventions under realistic site conditions. Scores for each criterion are normalized to allow comparison across different infrastructure solutions. This procedure produces a composite constructability value for each proposed mitigation measure.

Integrated Decision Framework

The final stage combines results from hydrologic analysis, structural reliability evaluation, and constructability assessment into a unified decision model. The objective is to determine which infrastructure interventions perform best across multiple evaluation criteria.

A weighted multi-criteria scoring model is used for this purpose:

$$DS = \sum_{i=1}^n w_i X_i$$

Where

DS = overall decision score
 w_i = weight assigned to criterion i
 X_i = normalized value of criterion i

The criteria included in the evaluation reflect flood hazard indicators, infrastructure reliability measures, and constructability parameters. Table 1 summarizes the variables incorporated in the analysis.

Table 1: Multi-Criteria Parameters for Integrated Flood-Resilient Infrastructure Evaluation

Parameter	Description	Data Source	Evaluation Method
Flood Depth	Maximum simulated water level during storm events	Hydrologic model outputs	Hazard intensity analysis
Flow Velocity	Speed of floodwater movement across the drainage system	Hydraulic simulation	Hydraulic flow analysis
Drainage Capacity	Maximum discharge handled by the drainage network	Infrastructure design data	Capacity assessment
Infrastructure Reliability	Structural ability to resist flood loading	Structural design parameters	Reliability index calculation
Construction Feasibility	Practical difficulty associated with construction	Engineering evaluation	Constructability scoring
Economic Feasibility	Relative project cost compared with benefits	Cost estimates	Cost-benefit comparison

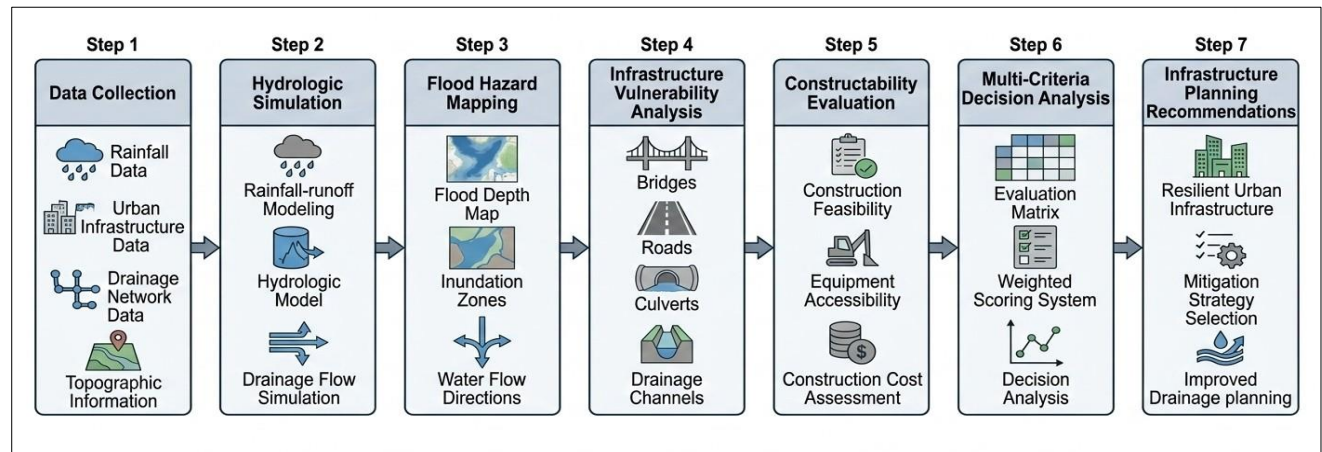


Figure 2: Methodological Workflow for Integrated Flood-Resilient Infrastructure Planning

IV. DISCUSSION AND RESULTS

Hydrologic Flood Modeling Results

Hydrologic simulations produced spatial flood distributions for high-intensity rainfall scenarios. The results show considerable variation in flood depth across the urban catchment. Areas with dense impervious surfaces and limited drainage capacity experienced rapid surface runoff accumulation. These conditions resulted in localized inundation that directly affects transportation corridors and drainage infrastructure. Flood depth mapping indicates that several low-elevation zones experience significant water accumulation during peak rainfall periods. In these locations, water levels exceed operational limits for urban roads. Flood depths greater than 0.5 m appear along multiple road segments, which restricts vehicle movement and interrupts emergency

access routes. These conditions also increase hydrostatic loading on nearby structural components. Spatial patterns of inundation indicate that drainage bottlenecks influence flood propagation across the network. Sections where culverts restrict flow show higher upstream flood depths than surrounding areas. During intense rainfall, discharge volume surpasses the conveyance capacity of these structures. Water accumulation therefore develops upstream and spreads across adjacent roads and open surfaces. Several intersections where drainage channels converge show particularly high flood depths. Runoff from multiple sub-catchments concentrates at these points. When rainfall intensity increases, these junctions receive discharge from several upstream locations at the same time. The drainage system cannot discharge this combined flow quickly enough, which leads to temporary storage and surface flooding.

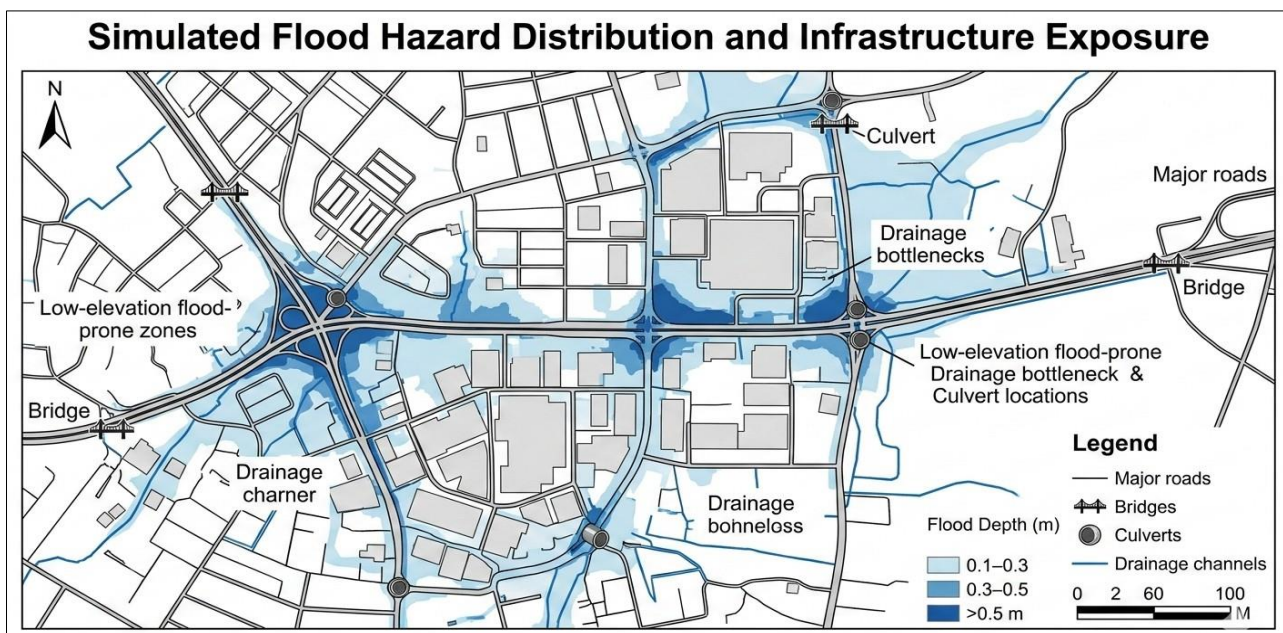


Figure 3: Simulated Flood Hazard Distribution and Infrastructure Exposure

Flood hazard maps identify corridors where infrastructure exposure remains highest. Transportation routes located in depressions or near drainage convergence zones show repeated inundation during simulated storm events. These results indicate that targeted mitigation in selected locations produces larger reductions in system-wide flood risk than uniform interventions across the entire urban area.

Infrastructure Structural Performance Assessment

Structural performance assessment examined infrastructure components exposed to simulated flood conditions. Bridges, culverts, road embankments, and drainage channels were evaluated to determine their capacity under hydraulic loading. Bridge structures located in higher sections of the transport network show strong performance during simulated flood events. Clearance between bridge decks and water levels reduces hydraulic pressure on structural components. Water flow passes beneath these structures with limited direct

loading. As a result, bridges maintain higher structural reliability compared with other infrastructure elements. Culverts located within low-lying drainage corridors display lower reliability levels. Restricted cross-sectional capacity limits discharge flow. When water levels exceed inlet height, pressurized flow conditions occur. This condition increases hydraulic forces on culvert walls and causes upstream water accumulation. Reliability assessment identifies several culverts that operate close to their structural limits during peak flood scenarios. Road embankments situated near flood accumulation zones show signs of structural vulnerability. Continuous exposure to floodwater increases lateral pressure on embankment slopes and reduces soil stability. Prolonged water retention also weakens pavement foundations and increases long-term deterioration risk. Drainage channels present mixed structural performance across the study network. Channels with larger cross-sections maintain sufficient discharge capacity during moderate rainfall events.

Smaller channels, however, exceed capacity limits during high-intensity storms. Overflow from these channels spreads across adjacent roads and increases infrastructure exposure. Structural reliability results therefore indicate that drainage components represent the most vulnerable infrastructure category within the system. Enlargement of culverts and channels appears necessary in locations where hydraulic restrictions generate repeated upstream flooding.

Constructability Evaluation of Flood Mitigation Strategies

Several mitigation strategies were evaluated with respect to construction feasibility. The analysis considered drainage network expansion, culvert enlargement, road reconstruction with higher surface levels, and installation of flood barriers. Drainage network expansion presents relatively high feasibility. Construction activities occur within existing drainage corridors, which limits the need for extensive structural modifications. Standard excavation and channel widening techniques can complete most tasks. These projects also allow staged construction, which reduces disruption to nearby urban activities. Culvert enlargement projects show moderate feasibility. Replacement of undersized culverts improves hydraulic conveyance and reduces upstream flood accumulation. Construction requires temporary excavation and traffic diversion, yet the overall process remains technically manageable. Road reconstruction with increased surface height offers strong flood protection potential. However, these projects face several implementation challenges. Reconstruction requires large volumes of fill material and modification of surrounding drainage systems. Underground utilities often require relocation before construction begins. These requirements extend construction duration and increase project complexity. Flood barrier installation shows variable feasibility depending on site conditions. Open corridors along rivers

or drainage channels allow relatively straightforward construction. Dense urban zones present spatial constraints that complicate barrier installation. Limited construction space and the presence of nearby buildings increase logistical difficulty. Constructability evaluation therefore reveals practical limitations associated with certain mitigation options. Infrastructure planning must consider both hydraulic performance and implementation feasibility when selecting mitigation strategies.

Integrated Decision Analysis for Flood-Resilient Planning

Results from hydrologic modeling, structural reliability assessment, and constructability evaluation were combined through a multi-criteria decision framework. Each mitigation strategy received a composite resilience score that reflects performance across these three dimensions.

The Integrated Resilience Index is defined as:

$$IRI = w_h H + w_s S + w_c C$$

Where

IRI = Integrated Resilience Index

H = normalized flood reduction effectiveness derived from hydrologic simulation

S = structural reliability improvement score

C = constructability feasibility score

w_h, w_s, w_c = weighting factors assigned to each evaluation criterion

h s c

This index aggregates hydrologic, structural, and implementation performance into a single metric for comparative analysis.

Table 2: Comparative Evaluation of Flood Mitigation Strategies

Strategy	Flood Reduction Effectiveness	Structural Reliability Score	Constructability Feasibility	Integrated Resilience Score
Drainage Network Expansion	High	Moderate	High	0.83
Culvert Enlargement	Moderate	High	Moderate	0.77
Road Reconstruction (Raised Surface)	High	High	Low	0.71
Flood Barrier Installation	Moderate	Moderate	Moderate	0.69

Drainage network expansion achieved the highest resilience score in the integrated evaluation. The strategy reduces flood depth in critical locations while maintaining high construction feasibility. Culvert enlargement also improves hydraulic conveyance and structural reliability, though its feasibility remains slightly lower due to excavation requirements. Road reconstruction with increased elevation provides strong

structural protection but introduces implementation challenges. Construction complexity and required modifications to surrounding infrastructure reduce its overall ranking in the integrated evaluation. Flood barrier installation demonstrates moderate performance across all criteria. This strategy offers localized flood protection but does not address upstream drainage capacity limitations.

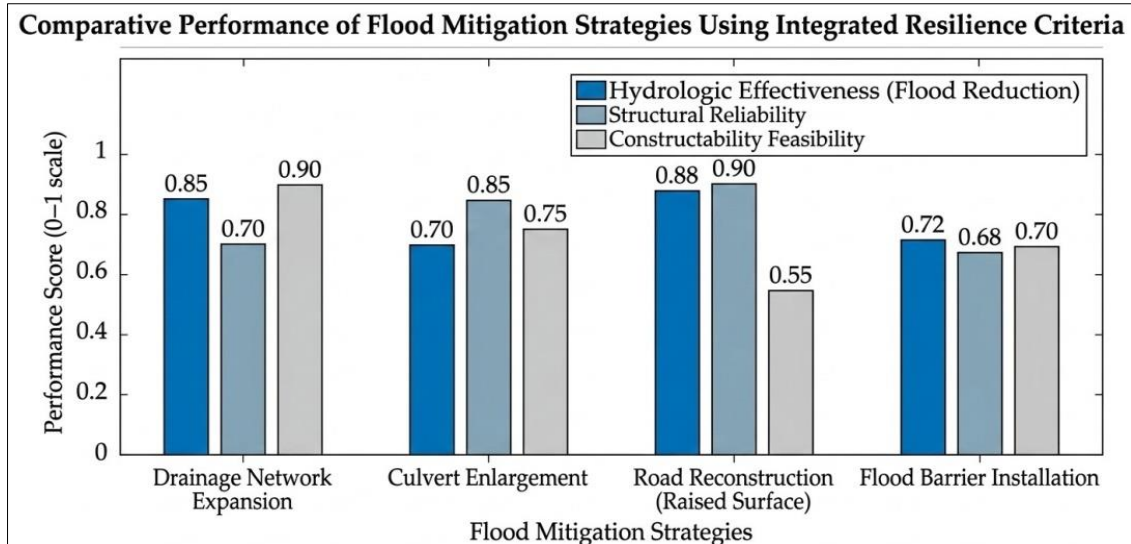


Figure 4: Comparative Performance of Flood Mitigation Strategies Using Integrated Resilience Criteria

The integrated evaluation indicates that infrastructure planning decisions must consider multiple system dimensions. Hydrologic analysis alone identifies flood-prone areas but does not determine which interventions remain structurally reliable and practically feasible. Structural evaluation highlights infrastructure weaknesses yet does not account for implementation constraints. A combined framework allows identification of infrastructure strategies that reduce flood exposure while maintaining structural safety and realistic construction requirements. This approach provides planners with a structured method for selecting infrastructure investments that improve overall urban flood resilience.

Limitations of the Study

The results presented in this study are subject to several limitations. Hydrologic simulations rely on rainfall records and drainage network parameters that may contain uncertainties due to limited monitoring resolution or incomplete infrastructure documentation. Flood modeling also assumes simplified surface characteristics, which may not capture all interactions within complex urban drainage systems. Structural reliability assessment uses representative resistance parameters rather than detailed structural design models for each infrastructure component. Constructability evaluation includes engineering judgment and generalized cost estimates that may vary across project locations. In addition, the analysis represents a generalized urban infrastructure scenario rather than a detailed application to a specific city. Future research may incorporate higher-resolution hydrologic data, detailed structural information, and site-specific construction constraints to improve analytical accuracy.

V. CONCLUSION

Urban flooding, as a threat to urban infrastructure, still persists in various cities due to increasing rainfall intensities, urban sprawl, and limited

drainage capabilities. Within this context, this study developed an integrated framework for flood-resilient urban infrastructure planning, which incorporated hydrologic flood modeling, structural infrastructure evaluation, and constructability evaluation as a multi-criteria decision tool. Hydrologic simulation was utilized to identify flood-prone areas and infrastructure segments that are exposed to deep flood inundation depths due to extreme rainfall events. Structural evaluation was conducted to assess the reliability of bridges, road embankments, culverts, and drainage channels under various hydraulic loading conditions. Constructability evaluation was also conducted to assess the feasibility of various mitigation strategies, including infrastructure complexity, spatial limitations, and requirements. The results of the integrated decision analysis tool revealed that drainage infrastructure improvements and hydraulic structure upgrades are effective solutions for reducing urban flood risk, including their practicality of implementation.

Future research can apply the proposed framework to specific cities using detailed topographic data, drainage system information, and infrastructure design records. Case-based studies would allow a more accurate evaluation of local flood behavior and infrastructure performance. Climate change scenarios may also be included to examine how changing rainfall patterns could affect long-term flood risk. Additional data from monitoring systems and remote sensing technologies could improve flood simulations and infrastructure assessments. More detailed numerical models and higher-resolution datasets would further improve the reliability of flood prediction and infrastructure evaluation. These efforts can support better planning decisions and contribute to safer and more resilient urban infrastructure systems in flood-prone areas.

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