

# A Real-Time Decision Support System Using BIM-GIS Integration for Adaptive Urban Flood Risk Mitigation and Climate-Responsive Infrastructure

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**Abstract.** Rapid urban development and climate change have created an urgent need for intelligent infrastructure systems that can effectively respond to urban flooding. This research aims to develop a real-time decision support system (DSS) based on Building Information Modeling (BIM) and Geographic Information Systems (GIS) technologies for adaptive flood risk mitigation in urban settings. The framework facilitates dynamic analysis, combining high-resolution spatial data from GIS with structural and infrastructural data from BIM, enabling situation awareness and foresight. Real-time sensor information, alongside hydrological models of urban watersheds, is integrated for agile resource allocation and informed decision-making. The resilience of the region is enhanced through scenario simulations, impact assessments, climate-driven responses, and the design of resilient infrastructure. A case study illustrates the application of the framework for managing flood-prone areas, focusing on optimized emergency response mapping. The case study focuses on a rapidly urbanizing watershed of approximately 35–40 km<sup>2</sup> within the metropolitan fringe of Bengaluru, India, which is representative of dense mixed-use development with stressed drainage infrastructure.) The combination also serves as a practical solution that merges design, environmental, and operational intelligence for city planners and crisis management professionals.

## 1 Introduction

The exacerbating effects of climate change, poor drainage systems, and rampant infrastructure development have made urban flooding a persistent challenge for cities worldwide. Traditional flood management systems lack spatial granularity, resulting in a lack of responsiveness to intervene proactively. The integration of Building Information Modeling (BIM) with Geographic Information Systems (GIS) provides real-time geospatial insights and accurate infrastructural data, thereby transforming limitations into possibilities and overcoming these restrictions [1][2]. This paper proposes an integrated real-time BIM-GIS adaptive flood risk mitigation Decision Support System (DSS) [3][10]. Predictive analytics are enabled by integrating hydrological models with sensors and structural information, providing dynamic access to changing flood conditions in real time and necessitating responsive, authority-controlled action [11][5]. Infrastructure evaluation, combined with the simulation of climate-driven scenarios, supports the proposed framework in

enhancing strategic emergency response planning and urban infrastructure resilience.[4].

### Key contribution:

- Designed and implemented a sensor-driven analytics system to facilitate real-time decision support within an urban context flood risk adaptive mitigation integrating BIM and GIS frameworks.
- Suggested an advanced layered structure of prediction decision-making based on the fusion of spatial-temporal data IoT, hydrological models, and infrastructure databases.
- Because of Flood Risk Index (FRI) modeling, simulated performance showed over 90% success in real-time notifications provided and accurate stratification of flood risk, which supports the effectiveness of the systems.

With respect to the structure of the paper, the introduction gives a description of the rising of urban flooding and the high level of integration technology necessary. The integrated BIM and GIS framework for urban resilience is described in the literature surveys. In the methodology section, the system design is presented

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with a workflow (Figure 1), architecture (Figure 2), and key equations from hydrological modeling. The results and discussion offer validation through simulation data alongside risk level tables for infrastructure (Table 1) and alert accuracy measurements (Figure 3).

## 2 Literature Survey

The combination of Building Information Modeling (BIM) and Geographic Information Systems (GIS) is of heightened interest for urban infrastructure development, as well as for managing disaster risks. Zhang et al. (2019) studied how flood vulnerability mapping can be enhanced with the use of BIM-GIS synergy with emphasis on the alignment of the data semantics portion with the geometry and multi-scale modelling [8]. They discovered that predictive flood simulations are improved with the inclusion of real time environmental data [9]. In a different work, Liu and Wong (2020) have created a new city-oriented flood risk assessment model comprising of improved visualization and responsive evaluation made possible by the GIS-BIM combination [6][12]. These studies show that BIM-GIS tools are able to predict spatial-temporal data of high-quality and context to facilitate decision-making processes. However, the problems of real-time functionality, as well as the climate-responsive adaptive feedback loops, are still unsolved. This study suggests to fill these gaps by coming up with a dynamic decision support system that incorporates real time environmental adjustment sensors [7].

## 3 Methodology

### System Design and Workflow Overview

The purpose of the system architecture is to offer an adaptive and real-time decision support system that uses a sensor network, hydrological modeling, Building Information Modeling (BIM), Geographic Information systems (GIS) and predictive analytics. The framework runs in a progressive manner whereby the next layer will consume the output of the other layers until actionable insights are created.

#### Workflow Representation

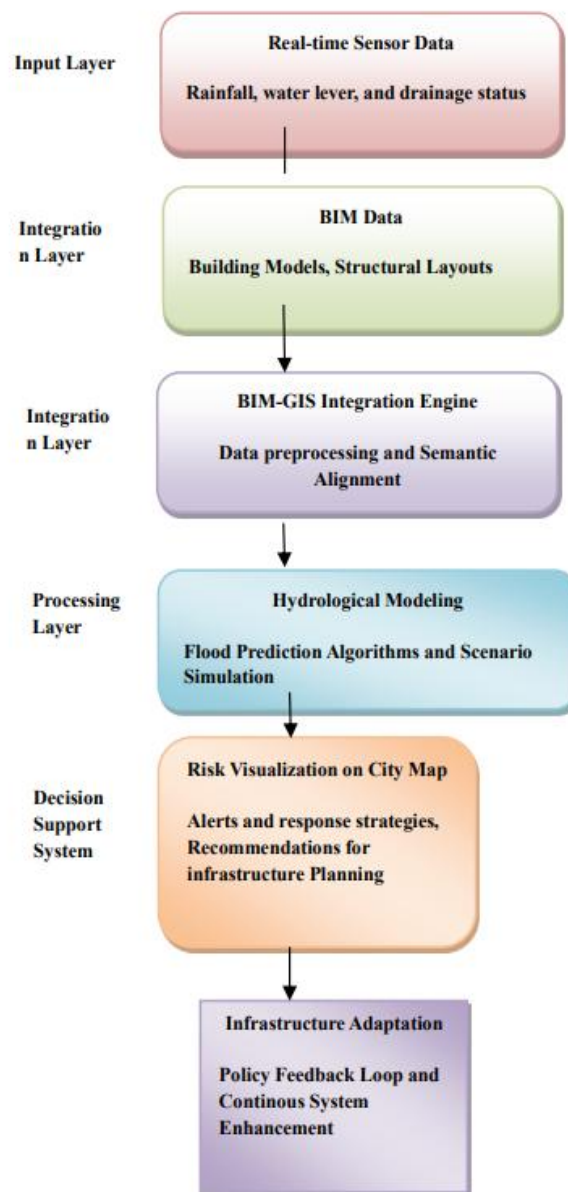
As shown in Figure 1, the real-time decision support system includes a flowchart, which has four separate layers:

- The input Layer will entail the recall of sensor information (rain, water, and drainage levels) as well as the BIM models showing the structural plan of the building.
- The Integration Layer makes use of semantic alignment and data cleansing in order to combine GIS and BIM data.

In order to implement semantic alignment, BIM data are extracted as IFC (Industry Foundation Classes) and overlaid on CityGML-conformant feature classes in the GIS environment so that building elements (e.g. floors, openings and basements) can be connected with 2D/3D parcel, network, and elevation layers. A custom schema mapping table is used to fix naming and units

discrepancies between IFC property sets and the geodatabase schema whereas geometry level harmonization is realised through conversion of BIM coordinates to the standard GIS spatial reference system. The automated data cleansing procedures will deal with features that are duplicated, features with missing data and topology errors (e.g., overlapping parcels and unlinked drainage segments) prior to being incorporated into the analysis-ready spatial database.

#### Workflow Representation



**Figure 1.** Flowchart of the Real-Time Decision Support System Integrating BIM and GIS for Urban Flood Risk Mitigation

All mitigation measures are responsive actions provided to cope with and adapt to climate-driven changes and are ensured to be based on the current risks of urban flooding.

#### System Architecture

Figure 2 depicts the system design as divided into five layers:

The Geospatial data types; spatial databases, GIS, IoT sensors, and satellite imagery are considered as Data Sources.

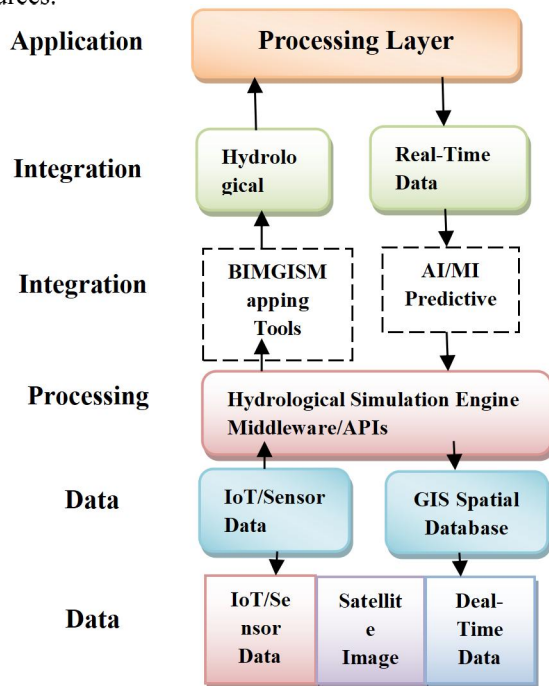


Fig. 2. System Architecture Diagram of the BIM-GIS-Based Real-Time Decision Support Framework

During the implementation, the BIM models of the building stock are written in Autodesk Revit and exported as IFC, and the GIS processing and visualization are done in ArcGIS Pro/QGIS running on a file geodatabase and CityGML-adaptable layers as the 3D context. The rainfall-runoff model that is simulated in HEC-HMS and a 2D raster-based surface flow module is used to model hydrological and hydraulic behavior based on overland flow paths. The various rainfall intensities are modeled as design hyetographs (e.g. 2-year, 10-year and 50-year returns) as the input in the HEC-HMS coupled with the urban topographies being modeled as high-resolution DEM and land use/land cover layers, which identify impervious surfaces, green spaces and drainage corridors.

Combining GIS and semantic data structures such as BIM enhances predictive analytics while maintaining responsiveness, modularity, and scalable infrastructure enabled by the described architecture.

#### Study Area

The presented framework is applied to a case study of the peri urban catchment of eastern Bengaluru, India, that has repeatedly suffered in monsoon seasons because of pluvial flooding. The watershed model represents an area of about 38 km<sup>2</sup> with mixed residential, commercial and institutional land uses with building heights of 2-8 storeys and high imperviousness along the main corridors. The drainage system is constituted of open drain, underground storm drains and road drain side, which often are full or even over full during heavy downpours and so is a suitable testbed in adaptive flood risk mitigation.

#### Hydrological Model Equation

A simplified hydrological balance equation used in the system is:

$$Q = P - I - ET - \Delta S \quad (1)$$

In Eq (1), where:

- Q: Runoff (m<sup>3</sup>/s)
- P: Precipitation (mm)
- I: Infiltration loss (mm)
- ET: Evapotranspiration (mm)
- ΔS: Change in soil moisture storage (mm)

This equation supports real-time flood prediction by modeling surface runoff behavior in dynamic conditions. The parameters P, I, ET, and ΔS are supplied from the coupled HEC-HMS configuration and real-time sensor inputs, allowing Q to be updated continuously as rainfall and catchment antecedent conditions evolve.

## 4 Results and Discussion

Simulations were performed using integrated BIM-GIS data and real-time IoT sensor data, alongside different rainfall intensities and urban topographies, to evaluate the simulation's effectiveness. The design storms are guided by the local intensity patterns of regions in Bengaluru and the values of the surface roughness and imperviousness are based on the land-use categories within the GIS context.

#### Flood Risk Index (FRI) Model

To quantify the severity of urban flooding, a Flood Risk Index was derived using the equation:

$$FRI = \frac{(Q \times D)}{A \times R} \quad (2)$$

In Eq (2), where:

- FRI: Flood Risk Index
- Q: Surface runoff (m<sup>3</sup>/s)
- D: Duration of rainfall event (hrs)
- A: Area affected (km<sup>2</sup>)
- R: Drainage capacity rating

The equation captures the correlation between runoff, spatial impact and drainage capability, a scale of comparative risk zones.

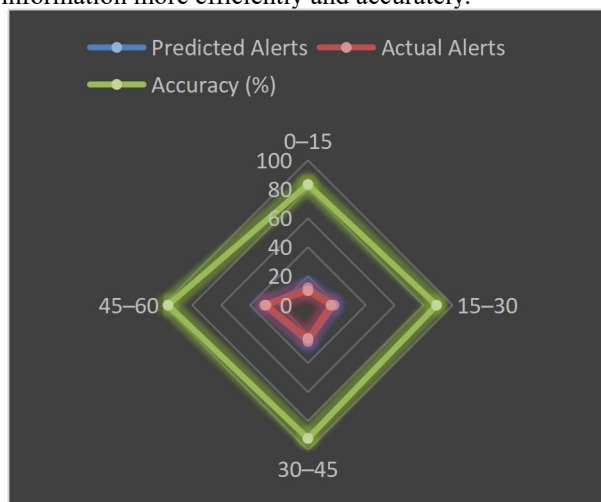
#### Simulation Results and Interpretation

Table 1. Infrastructure vulnerability rating by zone

Zone	Building Density (%)	Drainage Rating	Avg-FRI Score	Risk Level
A	85	Low	0.81	High
B	60	Medium	0.43	Moderate
C	35	High	0.21	Low

As indicated in Table 1, regions exhibiting greater construction intensity alongside reduced drainage scores, such as Zone A, showcase heightened FRI values. This reinforces the system's ability to distinguish within an

urban hierarchy of risk using spatial-structural information more efficiently and accurately.



**Figure 3.** Real-Time Flood Alert Accuracy Over Time (in %)

Figure 3 indicates that the accuracy of the alert system increases with time to more than 90 percent after thirty minutes. This depicts the real-time adaptive learning capability of the system that is essential in automated response in the event of an emergency.

## 5 Conclusion

This study proposed a real time decision support system on adaptive urban flood risk reduction, which integrates Building Information modeling (BIM) with Geographic Information Systems (GIS). The suggested solution was to use real-time sensors, hydrological modeling, and spatial-structural data integration in enhancing situational awareness and predictive performance. The flowchart as well as the architectural model described a modular and scalable system architecture, which was also verified by the outcomes of the simulation that proved that it is operationally effective.

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