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Application of BIM+GIS Integration Technology in the Construction of Urban Intelligent Water Informatization

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Abstract: - Urban intelligent water informatization is the process of managing and operating urban water systems with the use of contemporary information and communication technology in order to increase productivity, security, and sustainability. Establishing the appropriate infrastructure is the initial stage in building an intelligent water system so that management can choose wisely how to manage and operate the water system. Building information modeling (BIM) is a digital depiction of a building's or infrastructure's structural and functional details. In most metropolitan regions, a fast development phase is predicted to cause several water issues, including water resource shortages, floods, poor drainage, and water resource contamination. As a result, a practical approach is required for urban intelligent water information technology with the help of artificial intelligence techniques. Intelligent water systems may be built using Building Information Modeling (BIM) software to increase the system's effectiveness, stability, and durability. By offering a potent tool for storing and analyzing geographical data connected to the water distribution system, a geographic information system (GIS) can play a crucial role in the development of urban intelligent water informatization using ArcGIS mapping Software. The Internet of Things (IoT) system is used to implement intelligent water informatization, hardware implementation using ESP32, and software development using MQTT Broker and Node-Red. As a result, we recommended utilizing BIM+GIS integration technology for building urban intelligent water informatization. The suggested system is evaluated using management efficiency, urban flood control, innovative Construction, intensive management, and computation cost. In this research, the main objective is to identify where there are water leaks broken pipes and early warning system and monitoring system for flash flood disasters in urban areas. The result findings show that the integration of BIM and GIS provides a comprehensive platform for managing complex water informatization infrastructure projects and maximizes efficiency and sustainability.

Keywords: Water informatization, urban water, building information modeling (BIM), geographic information system (GIS), innovative Construction, artificial intelligence

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I.Introduction

The term "Building Information Modelling" (BIM) refers to the process of digitally modeling a building and all of its related data, including geometry, spatial connections, geographic information, and other pertinent architectural information.BIM is an approach to creating a digital representation of a structure that requires the participation of many parties. Better coordination and communication may be maintained throughout the project's lifetime with the use of this model, which can be used to mimic the building process, evaluate design possibilities, and assess performance. Additionally, BIM may help with building management and maintenance by increasing the precision of cost estimates and schedules. Based on the BIM model technology and coding tools, this research looks at the way BIM 3D models may be used for design collaboration and water management.Water management systems are only one example of how BIM may be used to enhance the processes leading up to and including their implementation [1].The water management system's response to changes in water pressure, flow rate, and temperature may be simulated using BIM. Engineers and designers may use this information to fine-tune the water management system's layout for maximum efficacy and dependability.Improved project management may be achieved via the use of BIM to facilitate improved communication and coordination between stakeholders and monitor development throughout the project.Facility managers and maintenance teams may benefit from BIM since it provides a digital model of the building that can be used to predict and prepare for maintenance problems and upgrades [2].Water management may benefit greatly from the use of geographic information systems (GIS).The water table, river flow, and groundwater quality are only some of the water resource changes that may be monitored using GIS. Useful decisions, including those involving water conservation measures or resource distribution, may be made with the use of the information provided. GIS are computer programs designed to help people acquire, organize, analyze, and present geographic information. It integrates technology, software, and data to collect, organize, and examine any data with a geographical component. Applications for GIS span from urban planning and natural resource management to emergency response and corporate intelligence, and the

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technology may be used to generate maps, analyze spatial patterns and connections, and build decision support systems. The capacity to combine geographical data with other data sources is fundamental to GIS [3].Data about locations may be stored, analyzed, and displayed with the use of GIS.Roads, buildings, and utilities are only some of the urban infrastructures that benefit from GIS usage in planning and management. It may also be used to assess how a project will affect the local community and environment.Forests, marshes, and other waterways may all be better managed with the use of GIS. It may also be used to measure the effects of climate change and monitor the spread of contaminants.Hurricanes, earthquakes, and wildfires are only a few of the natural calamities for which GIS is employed in both prevention and response. It may be used to mark potential evacuation routes and emergency facilities in high-risk locations.Due to its versatility, GIS technology is now routinely used by decision-makers in a variety of fields.Planners, designers, and builders may all benefit from GIS since it facilitates better group decision-making [4].Students of the Construction Science, Technology, and Management domain and the geospatial industry have been exploring the potential uses and essential information level implications of combining geospatial information technology with modelling of building information for the past decade. It has made the Construction of smart cities and online siblings possible by allowing the building of large-scale simulated city models.Research at the app level focuses mostly on looking at how BIM+GIS technologies may be used together to address real-world challenges such as flood-damage evaluation, noise from traffic evaluation, management of supply chains, offshore station disassembling, and managing building risks [5].There are several ways in which the fields of BIM+GIS might work together to improve the planning, building, and management of artificial structures.Integration technology between BIM and GIS may be used throughout a construction project to boost productivity, accuracy, and sustainability.BIM and GIS may work together to help urban planners generate 3D models of cities and their infrastructure, such as buildings, roads, bridges, and utility networks. It allows them to assess how proposed Construction may affect the local ecosystem.The combination of BIMplusGIS technologies is an emerging and rapidly growing trend in construction management. In contrast to BIM's narrower emphasis on the built environment, GIS collects and analyses a far broader variety of low-density geographical geographic information.Information about water systems may be obtained efficiently via the use of BIM+GIS technology in water management [6].The term urban intelligent water informatization is used to describe the process of enhancing the administration and operation of urban water systems through the use of cutting-edge information technology such as sensors, data analysis, and automation. The purpose is to reduce expenses and improve water quality while increasing the efficiency, sustainability, and resilience of urban water systems.To offer people of urban areas dependable, sustainable, and reasonably priced water services, urban intelligent water informatization aims to build a smart water infrastructure that can respond to changing environmental circumstances. This method may also aid in the prevention of climate change-related disasters in urban areas by way of real-time monitoring and early warning systems.The goal of urban intelligent water informatization is to make urban water systems more sustainable, efficient, and resilient by using cutting-edge technology in water management [7].Leaks in urban water supply networks may be fixed before they create significant interruptions due to the use of sensors by intelligent water management systems.Using the information on weather patterns and soil moisture, urban intelligent water management systems may optimize irrigation schedules, lowering water use and maximizing plant health.Encouraging water conservation with real-time data on water use and incentives for lower consumption with the help of urban intelligent water management systems and other non-potable purposes is made easier by urban intelligent water management systems, which relieves pressure on water supplies and increases water sustainability [8].Maintenance and repairs to the water system may be optimized by employing integrated BIM+GIS technology.When BIM and GIS are combined, water management as a whole may be enhanced. Water managers may get a deeper understanding of the patterns of water use and pinpoint problem areas with the use of real-time data from sensors and other monitoring equipment [9].In quickly developing metropolitan regions, where both the demand for and supply of fresh water are rising, urban intelligent water informatization offers a viable solution to addressing the issues of managing water resources.The environmental effect of an assignment may be assessed by employing BIM+GIS integration. It has several potential applications, including the mapping of ecologically significant places and the design of environmentally friendly infrastructure.Integrating BIM with GIS helps speed up and lower the overall cost of water management operations [10].In this paper, we proposed (BIM+GIS) techniques for the Construction of urban intelligent water informatization.

- **Building Information Modeling (BIM)**

Building Information Modeling (BIM) is the computerized representation of a structure or network. and it is employed to communicate and inform project choices at every stage of the project's lifespan. Using BIM, a comprehensive 3D model of the building is created, complete with its physical geometry and information about its attributes. It incorporates a variety of data kinds, such as energy performance, scheduling, substances, and costs. Stakeholder engagement is facilitated by BIM, which enables real-time sharing and updating of project information (See Figure 1).

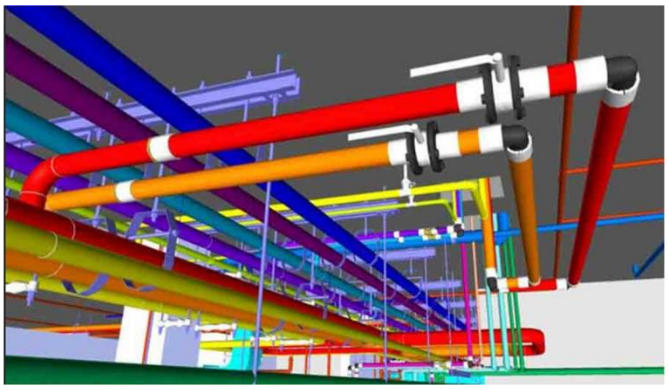

Figure 1: BIM Software Modeling (Source: https://doi.org/10.1016/j.proeng.2013.04.097)

It enhances efficiency and managerial skills across the building lifespan, from original design to facility administration. Through the easy sharing and use of the digital model and related data by other software programs and disciplines, BIM promotes interconnection in Figure 2. Because of its many advantages, including increased productivity, better decision-making, fewer mistakes, and greater cooperation, building information modeling (BIM) has become a common practice in the architectural, engineering, and construction (AEC) sector.

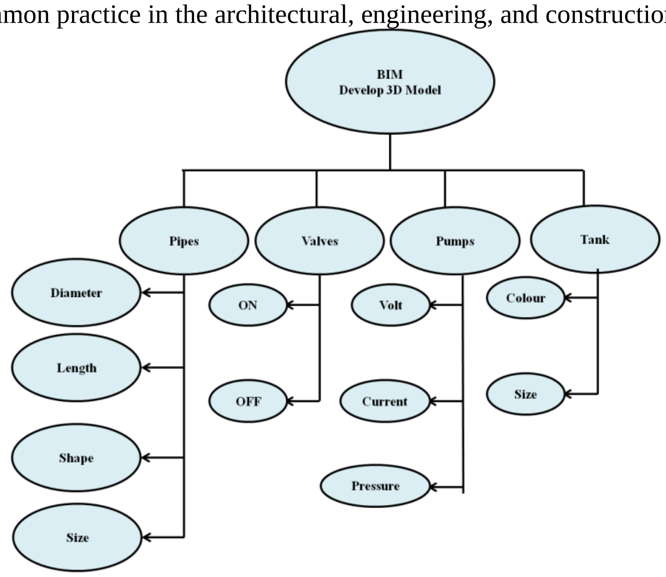

Figure 2: BIM 3D Design Model

➢ GIS

GIS is an essential tool for managing, analyzing, and visualizing the geographical elements of a project (See Figure 3). It does this by combining spatial data with several layers of information. It facilitates the administration of spatial data, planning and selection of sites, mapping and visualization, data analysis, infrastructure management, asset management, environmental impact assessment, and stakeholder cooperation. Terrain, land use, and environmental considerations are just a few of the geographical data relevant to building projects that GIS helps manage and organize.

Figure 3: GIS Software Model (Source: https://doi.org/10.1007/s00799-005-0117-0)

It facilitates the creation of precise and comprehensive maps of construction sites, utility networks, and infrastructural layouts, which helps with decision-making during the planning stage. As a tool to support data-driven decision-making, GIS also helps with data analysis by spotting patterns, trends, and possible problems pertaining to the building site. By recording changes over time and managing pertinent data, it also helps with asset management, monitoring, and maintenance of infrastructure. GIS is an effective tool for maximizing resource utilization, minimizing impact, and enhancing project efficiency since it makes communication and coordination among project teams easier.

II. Application Of Bim And GIS

The study [11] compared and contrasted machine learning and survival estimation techniques, the two most used statistical approaches to modeling pipe breaks. The leaks are a significant problem for cities' drinking water supplies because they cause disruptions in service, financial losses, and an increased risk of water pollution. The article [12] seeks to bridge that gap by analyzing and contrasting “Algeria, Egypt, Libya, Morocco, and Tunisia” in terms of their sensitivity to the social effects of climate change. Exposure to climate change, water resources, sensitivity, and adaptation capability are the main areas of attention in the vulnerability assessment. Due mainly to the country's extreme vulnerability, Algeria is among those most at risk from climate change. The existing dire water situation in North Africa is expected to worsen as a result of climate change and rapid population expansion. The article [13] provided a thorough analysis of the literature on the topic of building data modeling and system integration to identify growing uses and contexts and structural similarities in the approach to handling this problem.

Combining real-time information from IoT systems with BIM provides a robust paradigm for applications to boost building and maintenance efficiency. Connecting high-fidelity BIM models to continuous streams of data from the rapidly expanding IoT information collected could prove useful in many different scenarios. Within the context of the smart city movement, the goal of the study [14] is to investigate how innovative the interdisciplinary connection between reconstructions 5, organizations 3, Building Information Modelling and feasible architecture is currently, as well as how it is expected to develop in the future. The initial effort is to examine this cross-disciplinary study issue using both macro-quantitative and micro-qualitative methodologies. Additionally, the whole-construction life cycle is looked at as a tool for locating study gaps and patterns, suggesting future research with support for a more advanced form of BIM, such as city data modeling, and ultimate integration of Industry 5 and Construction 5 or perhaps Industry metaverse with Construction Metaverse. The article [15] summarized and analyzed the most notable significant initiatives toward more intelligent management of urban infrastructures, with a particular emphasis on transportation networks. Management and maintenance of road networks need massive amounts of information regarding past and present repair practices. GIS seems like an excellent fit to help us manage this data because of the geographic context it delivers. The research suggests rehabilitating current cadres to utilize BIM and GIS technology in the transition to a smart city idea, with the ultimate aim of bettering people's quality of life and making their everyday lives simpler. In the work [16], intelligent city information systems might benefit from collecting, mapping, cleaning, and integrating urban data in the form of a UBD. The objective is to fill in the gaps between the data we have about cities and the data we need to execute an energy simulation of an entire town. For urban energy modeling, which is crucial for addressing the issue of energy efficiency in the context of green city planning, a wealth of specific data is needed to run comprehensive dynamic simulations of a significant amount of structures. The study [17] investigated semantic enrichment by contrasting BIM with computer-aided design over ten years. An important step towards multidisciplinary applications in fields like as construction management, geoinformatics, and urban planning is the inclusion of extra semantics, such as geometric in nature, non-geometric, and topographical data, to already existing BIMs. It's about to cross across and become different from these two approaches. The study [18] suggested a new approach to life cycle management for underground plumbing. Integrating heterogeneous data from BIM and GIS allows for the development of a BIM in a GIS environment. The article also shows a case study conducted in China to demonstrate the practicality of the proposed methodology and framework. For regular upkeep of subterranean infrastructures, an instance study demonstrates that the suggested method performs comparably to trenchless detection and continuous monitoring in real time.

III.Proposed Methodology

The advancement of intelligent water has grown to be a crucial component in the development of building smart cities as a result of the markets and society's sustained growth. The “*Building Information Modeling and Geographic Information System (BIM+GIS)*” for developing urban intelligent water informatization and then Combining the same sensor to the BIM+GIS to form an IOT System with the help of Message Queuing Telemetry Transport (MQTT) Broker web server and Node-Red software to identify and detect the damage pipelines, water leakage, and flood control and drainage in urban area are effectively presented in this section as shown in Figure 4.

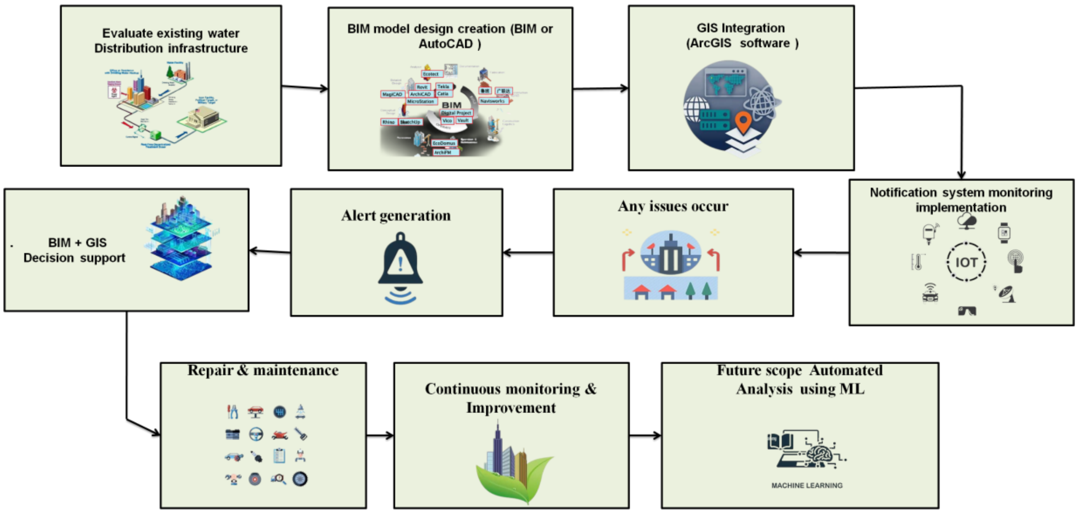

Figure 4: Work Flow Model

A. BIM+GIS for developing an urban intelligent water informatization

➢ Implementation

Building Information Modeling (BIM) and Geographic Information Systems (GIS) can be utilized in tandem with some sensors to implement the informatization system. The water supply system permits the integration of data and sensors for things like temperature, humidity, water flow pressure, and water flow speed. This allows for the real-time monitoring of building and construction-related data as it can gather information from sensors or IOT devices. To develop the IOT device, the sensors are connected to the ESP32 with the help of bme280; the GIS and BIM are not directly related to the ESP32; the GIS and BIM are integrated with the Building Automation Systems (BAS). In smart buildings, BME280 sensor data can be integrated into BAS as shown in Figure 5.

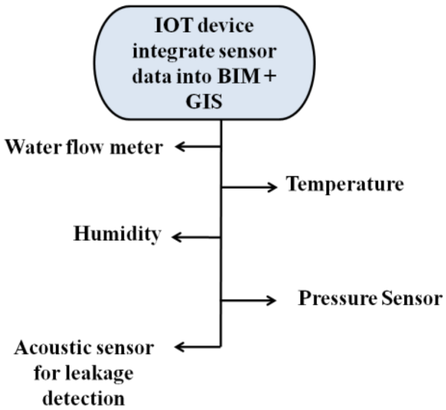

Figure 5: BIM+GIS+Sensor Model

This integration allows for real-time monitoring and control of environmental conditions, helping to create a more energy-efficient and comfortable indoor environment. Building models, geographic characteristics, and other relevant data are connected to databases using APIs or MQTT Broker using the acquired data. Node-red is utilized to process linked data, with each node fulfilling a specific vital function. Building structures and their geological surroundings can be better understood by using Node-red's ability to interact with GIS systems for geospatial analysis. It is also capable of being set up to react to changes or events produced by GIS and BIM software. Nonetheless, consideration must be given to project needs, security, and data integrity. The IOT Informatization System will notify the urban areas' water system control room of any problems with the water distribution system.

➢ Node-Red

IBM created a flow-based programming tool called Node-red flow, which is used to describe the behavior of a node and provides a presentation of the behavior of a computer or application. Runtime builds org. JS. Node-red flow is made up of specific code units called nodes that are connected and through which data is sent. This open-source tool works with a range of computer architectures, including on-premises and cloud environments like Microsoft Azure, Amazon, and IBM Cloud. It is appropriate for event-driven applications. Some pre-built nodes are available in the Node-Red Editor; however, you may add or install new nodes to increase their functionality. These nodes may be moved from the plate to the workpiece, but in order to establish a flow, they need to be connected.

➢ **MQTT Broker**

Low-power devices, like the ESP32, are utilized by the popular Internet of Things message protocol MQTT (Message Queuing Telemetry Transport). These chips provide Bluetooth connectivity and are made for a variety of uses, including Internet of Things applications. Built on top of the Publish/Subscribe paradigm for wireless sensor networks, MQTT is a lightweight message protocol that offers dependable connections between devices. The broker maintains devices linked to the cloud and enables clients to share information in both directions. Through a broker, clients who have subscribed to a subject can send and receive messages. BIM and GIS may be integrated with it to create civil water supply systems. It enables real-time data streaming and integration with BIM by facilitating effective communication and data transmission between various components. MQTT enables real-time updates on system changes by connecting sensors and actuators in a water delivery system. As a result, the accuracy and utility of the BIM model will increase, and real-time data from the water supply network may be integrated into it. BIM and GIS systems can react immediately because MQTT supports event triggers and alerts. Decentralized communication is made possible by publishing/subscribing to the methodology of operation. MQTT can be used with a wide range of devices and systems since it is flexible and adaptable. However, for efficient communication between various system components, security measures, including encryption, authentication, and access control procedures, are required.

IV.Result And Discussion

In this project, an early warning system and monitoring system for flash flood disasters. The water supply system in urban areas, BIM, GIS, and sensor data offer real-time monitoring, early anomaly identification, enhanced asset management, and efficient resource allocation. The sensors provide real-time information on the condition of the system by measuring temperature, humidity, pressure, and flow meter data. GIS geographical analysis enhances system performance, whereas BIM produces a comprehensive virtual model. When BIM, GIS, and sensor data are merged, resource allocation becomes more efficient, fulfilling demand while using less energy. This integration provides effective asset management, condition-based maintenance, fault detection, data analysis, historical trending, user-friendly dashboards, remote monitoring and control, compliance and reporting, scalability and flexibility, and real-time tracking, as well as dynamic BIM representation and spatial visualization in GIS. Real-time data on the water distribution system is made available by BIM and GIS, allowing for thorough monitoring and analysis. Increased system dependability, cost savings, and condition-based maintenance plans are made possible by the integrated data from sensors, BIM, and GIS. Node-RED is capable of analyzing sensor data and sending out notifications when anomalies or malfunctions occur (figure 6).

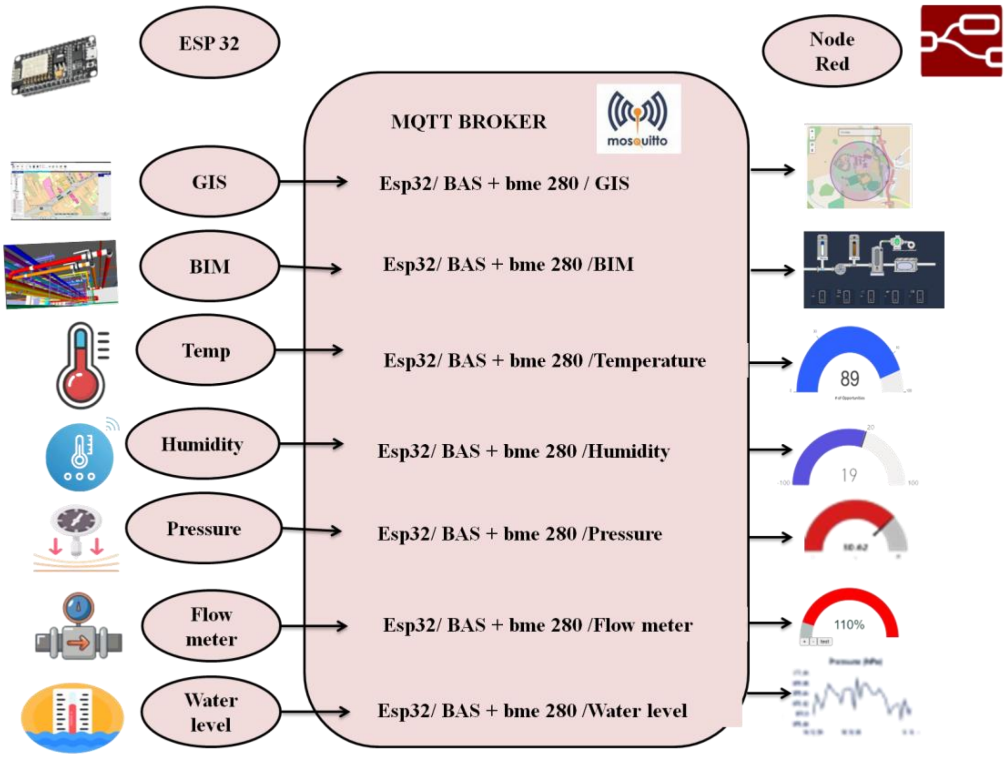

Figure 6: Results

Energy efficiency can be optimized for the integration of sensor data with BIM and GIS, which offers a comprehensive picture of energy use. Supporting well-informed judgments and optimizing overall performance, historical sensor data may be archived and scrutinized to detect patterns and patterns of behavior.

i. Management Efficiency

The capacity of smart water management systems to maximize the efficient use of water resources in urban environments is meant by "management efficiency" in urban smart water informatization. Making choices in real-time based on collected data on water usage, quality, and availability using cutting-edge technological means. The purpose of management efficiency in urban smart water informatization is to make better use of water resources and to cut down on water wastage and conservation efforts. In metropolitan settings, the above may aid in promoting sustainable water management techniques and ensuring equitable water distribution. Figure 7 indicates the management efficiency of the proposed techniques. Table 1 demonstrates the result of management efficiency. In the proposed method the management efficiency is higher compared to the existing approach.

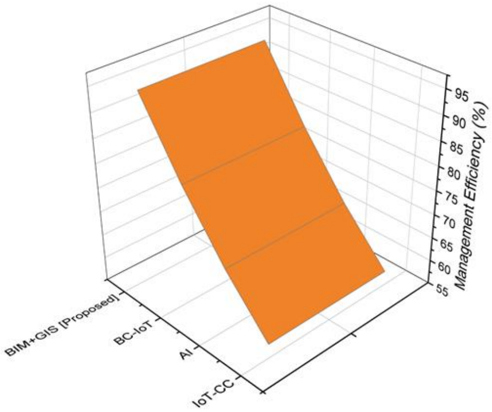

Figure 7: Management efficiency of the proposed and existing techniques

Table 1: Results of management efficiency

	Management Efficiency (%)
IoT-CC	58
AI	68
BC-IoT	80
BIM+GIS [Proposed]	94

ii. Urban flood control

The term "urban flood control" is used to describe the methods and systems put in place to lessen the severity of flooding in populated regions. Drainage systems, floodwalls, levees, and dams are all examples of infrastructure, but there are also non-structural measures that may be taken, such as land-use planning, zoning rules, and public education initiatives. While more people move into flood-prone regions as cities expand, flood protection measures take on more significance. More frequent and intense floods as a result of climate change are increasing the need for efficient urban flood management in many regions of the globe. Figure 8 indicates the urban flood control of the proposed techniques. Table 2 demonstrates the result of urban flood control. In the proposed method the urban flood control is greater compared to the existing approach.

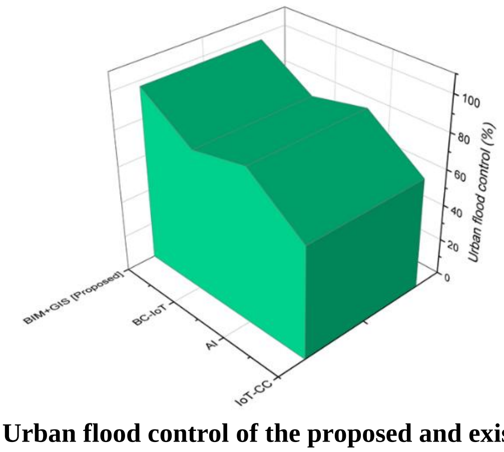

Figure 8: Urban flood control of the proposed and existing techniques

Table 2: Results of Urban flood control

	Urban flood control (%)
IoT-CC	62
AI	85
BC-IoT	78
BIM+GIS [Proposed]	97

iii. Smart construction

Smart construction in urban intelligent water informatization is the use of cutting-edge tools and techniques for the building and upkeep of urban water systems. It has the potential to save expenditures, cut down on waste, and increase the reliability and longevity of water systems. They improve asset management methods, provide accurate and up-to-date information on asset status, and make proactive maintenance and repairs easier for water infrastructure. Water infrastructure development and management may be made more efficient with the use of smart construction, an integral part of urban intelligent water informatization. Figure 9 indicates the smart construction of the proposed techniques. Table 3 demonstrates the result of smart construction. In the proposed method the smart construction is stronger and quality compare to the existing approach.

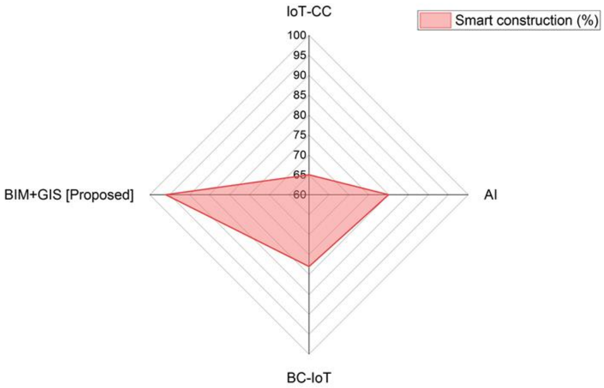

Figure 9: Smart construction of the proposed and existing techniques

Table 3: Results of Smart Construction

	Smart construction (%)
IoT-CC	65
AI	80
BC-IoT	78
BIM+GIS [Proposed]	96

iv. Intensive management

The term "intelligent water informatization" is used to describe the use of cutting-edge tools and systems to the problem of water management in metropolitan settings. It entails the use of numerous sensors, meters, and communication networks to gather and analyze vast volumes of data relating to water supply, distribution, consumption, and wastewater treatment. Smart water systems, such as real-time monitoring and control of water quality, pressure, and flow, as well as the use of predictive models to anticipate and avoid water-related issues, are being implemented as part of intensive management. Increasing the efficiency and sustainability of urban water systems, decreasing water waste and losses, guaranteeing water safety and security, and bettering urban inhabitants' quality of life are all goals of urban intelligent water informatization's intensive management. Figure 10 indicates the intensive management of the proposed techniques. Table 4 demonstrates the result of intensive management. In the proposed method, the intensive management is more effective compared to the existing approach.

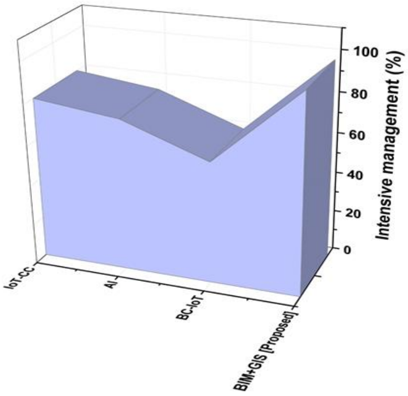

Figure 10: Intensive management of the proposed and existing techniques

Table 4: Results of Intensive management

	Intensive management (%)
IoT-CC	80
AI	75
BC-IoT	60
BIM+GIS [Proposed]	98

v. Computation cost

The computation cost of a specific assignment or method is the sum of its resource costs, including but not limited to the amount of time, memory, energy, and computing power needed to complete the work. The number of times a computer or other computational device performs an operation or executes an instruction is a common metric. The computational cost of completing a job increases in proportion to the number of operations or instructions it requires. When developing algorithms, optimizing software, or choosing hardware and computing resources, it is crucial to keep computational costs into account. Since it requires real-time processing of enormous volumes of data and difficult computing jobs, the computation cost for the development of urban intelligent water informatization might be substantial. Improved water management, conservation, and sustainability are just some of how such a system might pay for itself over time, even if the initial computational cost is high. Figure 11 indicates the computation cost of the proposed techniques. Table 5 demonstrates the result of the computation cost. In the proposed method the computation cost is the lowest compared to the existing approach.

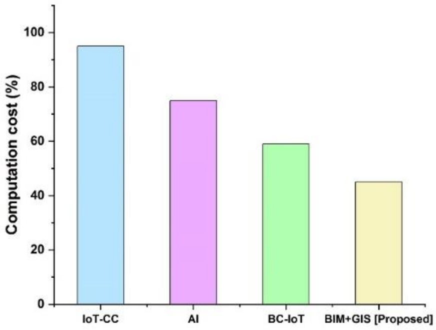

Figure 11: Computation cost of the proposed and existing techniques

Table 5: Results of Computation cost

	Computation cost (%)
IoT-CC	95
AI	75
BC-IoT	59
BIM+GIS [Proposed]	45

Discussion

The author has presided over or participated in a number of studies and projects on innovative water technologies, the recent ones include: GIS-based command platform for urban flood control and drainage and scheduling decisions in Hefei City; GIS-based real-time monitoring and management system for water resources in Anhui Province's Yishan Irrigation District; construction project for flash flood disaster monitoring and early warning system in Maanshan City's Bowang District; comprehensive automation and intelligent operation and management system for wastewater treatment plants in Huangshan City's Huizhou District automation and intelligent operation and management dispatching system; 27 pumping stations such as Xing Hua Yu and Fang Qiao in Hefei City, comprehensive automation system and WEB publishing platform project; Huangshan City secondary water supply intelligent management platform project based on GIS; Huangshan City Huizhou District urban and rural innovative water supply platform based on GIS; rural drinking water safety information platform based on GIS+BIM.

V. Conclusion

Urban intelligent water informatization is crucial to maintaining both the environment's and the community's health and well-being while ensuring the sustainable use of water resources. It makes it possible to utilize water resources more effectively, cutting down on waste and preserving water for future generations. It is feasible to monitor and regulate water consumption more effectively by fusing contemporary information technology with water management systems. This ensures that water is allocated where it is most needed and helps to decrease water losses. Using software to integrate BIM and GIS is crucial to building an intelligent groundwater data repository for cities. These two disciplines are often utilized in the architecture, engineering, and construction (AEC) profession. Together, they may be an effective management tool for urban water resources. Hence, BIM+GIS integration technology is presented to develop an urban intelligent water information system. Management efficiency, urban flood control, clever Construction, intensive management, and computation cost are some of the evaluation criteria for the suggested method. The findings demonstrate that the proposed approach lowers costs, increases water quality and resilience, and boosts water management systems' efficiency and efficacy. The suggested system's performance can be improved in the future by the addition of optimization methods. It enhances the procedures used to make decisions about system performance, upgrades, and maintenance. Proactive water system management will be encouraged by advanced data analysis, predictive modeling, and machine learning, which will reveal trends and potential issues in the future.

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