Use of BIM in Development of Smart Cities: A Review

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Abstract. A smart city is a community that uses information and communication technologies (ICT) to enhance the standard of community services and the health of people. The smart city concept takes into account the better engagement of its citizens for sustainable resource utilization, social and better relational capital while assuring its quality and performance. Building Information Modeling (BIM) is a computer-aided modern parametric solution to revolutionize the decision-making process in the construction of energy-efficient buildings and smart cities. BIM enables design, development, operate and manage the construction endeavors cost-effectively while sharing and exchanging information to all the stakeholders involved. The practical implementation of BIM results in the mitigation of risks in the initial phases of the projects. This paper explores the components of a smart city concept using BIM and its various variants in the development of a smart city. The geographic information system (GIS) environment can aid in providing a suitable data management system in transportation design with minimum accidents, earthquake mitigation, and preventing fire hazards to build a smart city. The review highlights the various tools such as GIS, Building Energy Model (BEM) could be an innovative concept to make a smart city. The given review will help policymakers to adopt BIM on their way to build a sustainable, reliable, energy-efficient smart city construction.

1. Introduction
There are ever-increasing environmental concerns over the growing urban population of the world. The apprehensive growth in the community will demand repair of the existing infrastructure as well as the addition of new infrastructure. The change in the global climate, environment, sea-level rise, etc. would warrant a unique perspective on the sustainable use of the city resources [1]. The perception of a smart city is to tackle the challenges posed by the ever-growing modern cities. It is an amalgamation of physical, ICT, and traditional systems. It delivers a sustainable, convenient, and participative milieu to the inhabitants of the urban. A smart city is a community that practices ICT to enhance the standard of community services and the health of people. The smart city concept takes into account the better engagement of its citizens for sustainable resource utilization, social and better relational capital while
assuring its quality and performance. The term 'smart' refers to the intelligent system comprising of ICT and cyber-physical system (CPS).

BIM is a rapidly popularizing technology that can represent information-rich 3D models of the building projects to assist all the stakeholders in planning, design, construct, operate, and manage the facility in time and cost-efficient ways. It requires effective implementation of BIM during the life cycle of infrastructure projects to realize the much-coveted benefits like the single central data source to support decision making at all the stages of the project and to mitigate the risks and conflicts at the very early stages of the process [2]. Though BIM was designed for the building sector applications, it is finding its acceptance and utility into all civil infrastructure. The BIM-enabled buildings in the smart city are always integrated technologically with IoT devices and other infrastructure like smart transportation, municipal utilities, smart grid, etc. The development of the city aspires for new heights and leads to a promising future. The smart buildings have the target for energy efficiency, comfort, sustainability, and convenience by integrating intelligence, industry, material, and construction practices [3].

2. Building Information Modeling

The BIM cannot be defined unilaterally, but the term should rather encompass various vital characteristics associated with it. BIM offers a platform to share information, knowledge, and communications among all the stakeholders. BIM is a representation of computers to simulate the building or civil infrastructure as an object. It is a great visualization tool. BIM is a computer-aided modern parametric solution to revolutionize the decision-making process in the edifice of energy-efficient structures and smart cities. BIM enables design, development, operate and manage the construction endeavors cost-effectively while sharing and exchanging information to all the stakeholders involved. The practical implementation of BIM results in the mitigation of risks in the initial phases of the projects. The collaboration among various actors in the project consists of the sharing of information through interaction, communication, exchange, and coordination. BIM provides a concerted environment transversely multiple disciplines among all the backers in the construction project, thereby raising trust issues. It gives rise to the bewilderment as to the roles as well as the responsibilities of various stakeholders [4]. The idea of creating, distributing, and centrally storing all the information needed throughout the execution of the project is a departure from what has been achieved in the conventional way of implementing the construction processes. Data models with rich attributes may include information like size metrics, weight, material types, cost parameters, etc. A high interconnection and compatibility are required between the different applications used by project stakeholders to effectively combine construction activities, to use the data bi-directionally, and to coordinate the entire project digitally. BIM is getting popular because of some very apparent benefits like improved quality and accuracy, time and cost efficiency, more rigorous design and analysis processes, better coordination, energy efficiency, and predictable lifecycle performance [5].

3. Smart City – The Concept, Components, and Usage of BIM

A city can be smart only with the active participation of its citizens in all the involved services [6]. The concept of a smart city involves a well-connected chain of interdependent systems [7]. There is an improvement in the infrastructure, health, equity, and well-being for the convenience of the citizens. The metropolis is developed in a smart, sustainable way with interaction and communication among the city resource services and the various private initiatives through the use of technology and real-time analysis of the contextual information involved. The smart city's resources are managed by the integration of ICT along with internet services. The concept of the smart city is realized by implementing innovative technologies at the initial, i.e., the design and planning stages of the building assets [8]. The smart city business model guides the development of future urban conglomerates. It involves the smart, sustainable, and efficient use and management of the city resources. [9]. A myriad of applications and technologies exist today. The necessity for understanding modern tools such as scanners, light detection
and ranging, etc. in smart cities is the need of the hour [10]. Figure 1 summarises the various components that go into making a city smart. The details involved in smart city and BIM are explained here.

![Smart city components diagram](image)

**Figure 1.** Smart city components.

### 3.1 Smart infrastructure
Infrastructure is a general term that refers to the physical system of a society. Core infrastructure may include transportation systems, food, communication networks, sewage, water, health, waste and sanitation, electric systems, and buildings.

### 3.2 Spatial computing
It is an umbrella concept that encompasses ideas, solutions, technology to use and examine the information with geographic evidence, helping reform the city infrastructure. Spatial computing has many promising opportunities for the smart cities of the future. Risks such as global warming, widening inequality, fertility rates, etc. and options such as automated driving, decentralized energy generation, etc. are best addressed by GIS. The ICT needs to use big data of the spatial computing that includes the spatial nature of all city infrastructure, transportation system, energy, building, food, health, and utility systems. Spatial computing is of utmost importance in achieving the goals of smart city viz. comfort, safety, health, equity, and sustainability [1].

### 3.3 Smart highways, traffic, and transportation system
Route optimization is done using GPS navigation and digital maps. The model of the driver behavior at the smart road signs installations is simulated, and their effect on the traffic pattern is generated [11]. An urban traffic information model can be utilized through the assistance of BIM and GIS. The 3D model of the transportation system can simulate the drainage system, the speed limit for the smooth flow of traffic, and congestion on the road, all at the design stage. Smart signals can alert the road users of the impending dangers or traffic jams ahead. Asset data management enhances safety and can use virtual reality. Robotics can be used for digging trenches [12]. The advancement in the field of IoT has enhanced the demand for planning for smart and intelligent infrastructure in modern cities [3].

### 3.4 Building energy modeling (BEM)
The construction sector is the largest consumer of energy. All-out efforts are required to reduce energy consumption, get a green certification, and use code compliance. The multipurpose, versatile BEM simulation is a way to simulate the energy consumption of a building and improve energy efficiency [13]. Numerous features of the structure, such as construction materials, the performance of architectural aspects, HVAC, local weather patterns, and water heating data, are analyzed. BEM is a crucial subset of BIM that combines design, construction, operation, building maintenance, and refurbishment with energy analysis [14]. Nonetheless, the automated exchange of data between BIMs and the power
simulator is indeed an "ambiguous goal" [15]. More efficient design alternatives for energy efficiency can be analyzed in the design stages itself by applying the central, collaborated, interconnected and consistent information of the BIM model [16].

3.5 **BIG data**

It is the volume, variety, and velocity of the data throughout the life cycle of a building in a smart city that demands the adoption of big data technology in BIM applications. The data growing exponentially in all types of formats coming from BIM, IoT devices, Artificial Intelligence (AI), mobile, social media, videos, and others has to stream at an unprecedented speed. Real-time interaction with RFID tags, sensors, other IoT devices is an essential component of the smart city paradigm [17]. Big Data can alleviate the bias that can creep due to small data. BIM aims to identify latent information or actionable information as required in the decision-making process by analyzing big data [18]. The main characteristics of big data are depicted in Figure 2.

![Figure 2. The characteristics of big data.](image)

3.6 **Integrating BIM models with 3D scenery from UAV**

Unmanned Aerial Vehicles (UAV) are handy data collection tools that have experienced massive progress in the functionality of the machinery. These devices can get high-resolution images from different incidence angles. With the use of photogrammetry, various features such as distances, areas, volume elevations, object sizes, and shapes can be determined within the overlapping regions [19]. Exploring the frequent use of BIM and UAV technologies for collecting as-built data collection and 3D illustrations of the progress of the construction projects consider that few of BIM models fully consider the local conditions occurring as in the infrastructural bodies like bridges, highways, dams, and their surrounding landscape. The study used UAVs in surveying 3D real landscapes, their features both before and during the construction [20]. UAVs can be a more effective, compact, flexible, and sustainable approach to recording cultural heritage buildings as they provide a cost-effective, reliable, and easy imaging method [21]. The incorporation of low-cost UAVs and structure from motion algorithms further enables higher flexibility and also better coverage and documentation [22].

3.7 **Sustainable construction**

Sustainability refers to the process and actions of humankind to use natural resources wisely. The construction industry, one of the vital energy-consuming industries, is placing high stakes in the use of BIM in minimizing consumption and waste to increase industrial productivity [23]. The various issues like rapid urbanization, reduction of the emission rate, meeting the ever-increasing electricity demands, and the shrinking fuel resources gave emergence to the concept of smart, sustainable cities [24]. The report depicted the impact of BIM on building waste, the environmental sustainability measure for building projects. The infrastructure and building constructions have a long-lasting effect on the environment. Due to environmental concerns, various green building standards, certifications, and international and national rating systems are created. The construction is positioned in a rating system after evaluating its sustainability performance and hence accruing economic and social benefits to the owners also [25].
3.8 IoT-enabled smart city paradigm

IoT is a convergence of multiple technologies that hold the promise of transforming existing metropolises into smart cities, as explained in Figure 3. Embedded sensors and wireless technologies are used to collect, distribute, and exchange data quickly. IoT intelligence and sensor technologies will play a vital role in managing information, transmission, and the sensor-based model network, as IoT is at the core of the smart city technologies [26].

![Mapping of the internet of things](image)

**Figure 3.** Mapping of the internet of things for smart cities.

3.8.1 Radio-frequency identification (RFID)

RFID is one of the main wireless systems where a reader collects and stores digital data encoded in RFID tags over radio waves in a database. It usually consists of four parts, namely an RFID tag or smart label, a reader, an antenna, the software, and a network of computers. RFID has resulted in automation, the associated costs being reduced, and the quality of construction work is increased. BIM works in the tendon with the RFID data for real-time management and monitoring of construction sites. For the convergence of BIM 3D models and the Virtual Reality, no frontiers open. Methods of automatic identification and the automatic capture of data classify objects, collect data information, and feed the computer systems with data directly that typically do not require human intervention. The RFID system has significantly resulted in more accurate and complete BIM models that use positioning tasks such as real-time location and material and resource tracking [27].

3.8.2 BIM and the IoT devices integration

BIM integration and real-time data from IoT devices dramatically improve the operational and construction efficiencies. The connection of real-time data from the IoT sensor networks to the high-fidelity BIM models has resulted in several applications. However, the integration of BIM models and IoT devices is only in its infancy carried out a comprehensive review. The BIM-IoT integration works to explore standard fields of application and design patterns, constraints, and foresee future developments in the field of a task [28].

3.9 Smart waste management system

The growing global consumption of non-renewable resources, reducing the land available for disposal of waste material, scarcity in the supply of primary raw materials are the main reasons that waste management is an environmental concern for the smart society today [29]. BIM can help achieve improvement in ecological and smart waste management [30]. The IoT, among other elements of smart city, is impacting positively on the city transport, energy distribution, water, and waste management [31]. By urban regeneration and urban developments such as smart energy, water distribution, waste management, smart grids, various smart city initiatives address different city challenges [32].

3.10 Cognitive buildings

The concept of automated buildings had surfaced in the late 20th century. Then the smart buildings were there with a network of sensors enabled by IoT. But the optimization of the data was still lacking, giving the need for cognitive buildings. Making buildings more intelligent can result in a reduction in energy
requirements, reduced disruption, enhanced space utilization, improvement in safety and security, convenience, comfort, and adaption to the needs of each occupant. Cognitive buildings are a reality today and are helping the facility managers in asset management, interaction with staff, ensuring the comfort of the occupants while increasing the utilization of the building asset. Some prototype smart product projects have all been established on a different scale. Google Nest or Qivivo are smart sensors; Dublin Lab introduces IBM’s idea of intelligent buildings; Conicity, in London, is a real example of a future smart city [33].

3.11 BIM-GIS integration
The integration of the GIS-BIM is the latest area of data mining for collecting information for decision support systems, as shown in Figure 4. In very recent times, the integration of BIM and GIS into the construction industry is moving from the research arena to the sound stage. BIM provides rich geometric and semantic information about the built assets; the GIS is a broad field of geo-visualization and geospatial modeling review applications and discusses future trends for the integration of BIM-GIS in the AEC sector. Their results show that systematic theories are needed to use the BIM-GIS integration, which includes spatiotemporal statistical modeling in GIS, and simulation and management of 4D/D BIM. However, the incorporation of BIM-GIS is stifled due to the various data formats and modeling methods used in these respective domains [34-35].

![Figure 4. GIS-BIM integration.](image)

3.12 Urban deep excavation projects
The surrounding environment of the deep excavations gets more and more complex with the depth of the excavation. The information is sought for the management of risks and making decisions as far as possible. The BIM-GIS are being used widely in the visualization of construction progress [36].

3.13 Cadastre of the future
BIM’s multidisciplinary and interoperability approach, the mining of related big data, gives rise to the new concept of Cadastre of the future, the digitization of the built heritage, that is dynamic as well as updated [37]. The smart cities are mapped in detail and are used by stakeholders for collaboration and exchange of data of any civil infrastructure or building. As the mapping is done in 3D, it is complemented by BIM by 3D Cadastre to provide legal status to the objects, land, and space [38].

3.14 Geospatial technology
The integration of GIS and BIM data, also known as Geo-BIM, is widely expected to confront the multidisciplinary challenges of the built environment [39, 47]. City management requires the leverage of the smart city to meet the challenges put by the growing urbanization. One element of ICT, the core of the smart city, is sustainable transport and intelligent transport system. Geospatial can be of help in monitoring and coordinating the traffic [40]. During the design and preconstruction phases, the planning process will derive significant benefits from the integration of BIM and geospatial analyses [41]. Hence, in this era of smart cities, when aspirations for a better tomorrow run high, this integration of BIM and Geospatial technologies can no longer be ignored [42].
3.15 Sustainable design analysis
The sustainable design has the primary purpose of maximizing environmental versus cost benefits. The decisions in this regard are taken at the early stages of the design considering different factors such as the selection of building materials, energy consumption and efficiency, carbon footprint, water consumption, waste and indoor air quality [43].

3.16 Smart citizen sensing
The study of feelings is called the review of the views, sentiments, evaluations, attitudes, social behavior, personal choices about products, services, politics, problems, events, etc. It is historically mined from worldwide websites, blogs, social media, news, reviews, etc. believes that sentiment analysis is a crucial factor in all smart city domains growth. The authors have developed a novel citizen sensing method that leverages the ability to analyze visual feelings [6].

3.17 Microclimates in the smart city
The open spaces are examined as an essential part of smart cities [44]. Our work tries to study how landscape architecture projects can communicate with the microclimate and natural airflow, e.g., tree planting techniques, greenery on roofs, etc. The expected results would help to design sustainable strategies for the environment and improve resilience to climate change.

3.18 Visualization
The evaluation of the buildings is much supported by the interactive visualization of 3D building models [45]. BIM facility management needs tools that are user friendly for improved data, visualization, and decision making [46]. Therefore, even for big data BIMs, the visualization software can provide adequate rendering services to realize smooth and immersive experiences [47].

3.19 Disaster risk reduction
There is a need to increase the resilience of the construction industry to the disasters and their consequences [48]. Resilience is the capability and ability of the objects to go back to its stable state after a disruption [49]. A country can mitigate the impact of recurring and intense weather occurrences by designing civil infrastructure and buildings that are more resilient and by integrating the information data from their modeling into the disaster response planning systems [50]. The vision of smart cities is connected directly with BIM and construction information modeling (CIM). CIM models and IoT device data, such as BIM models for buildings, can be simulated to help cities track water, energy, infrastructure, traffic, natural disaster effects, etc. [51]. CIM models and IoT device data, such as BIM models for buildings, can be simulated to help cities track water, energy, infrastructure, traffic, natural disaster effects, etc. [51].

4. Concluding Remarks
The city infrastructure, as well as the resources, need to be utilized efficiently, sustainably, and innovatively to assuage the socio-economic needs of the citizens. So, the paper presented components of a smart city notion employing BIM. The geographic information system environment can aid in providing a suitable data management system in transportation design with minimum accidents, earthquake mitigation, and preventing fire hazards to build a smart city. The BIM and GIS environment can aid in providing a suitable data management system in transportation design with minimum accidents, earthquake mitigation, and preventing fire hazards to build a smart city. The review highlights that various tools such as GIS, BEM could be an innovative concept to make a smart city. The resilience of the smart city as to disasters is crucial towards sustainability.

City management demands the smart city’s leverage to meet the challenges posed by growing urbanization. Sustainable transport and an intelligent transport system are one element of ICT and the core of the smart city. Spatial computing is of paramount importance for achieving smart city goals viz: comfort, safety, health, equity, and sustainable development. BIM facility management needs user-
friendly tools for enhanced data, visualization, and decision making. Furthermore, the incorporation of low-cost UAVs and structure from movement algorithms allows for greater flexibility and more coverage and documentation. The BIM-GIS is commonly used in creating progress visualization. Information is sought for risk management and decision making to the fullest extent possible. BIM can help achieve environmental and smart waste management changes. The construction industry needs to be more resilient to disasters and their effects. Resilience is the ability and capability of the object to return to their stable post disruption state. The need of the hour is to understand modern tools such as scanners, light detection, and range, etc. in smart cities. The review presented will help policymakers adopt BIM on their way to building a sustainable, reliable, energy-efficient smart city building.

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