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An Overview of Integrating GIS and BIM for Smarter Infrastructure Development

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Abstract
Integrating Geographic Information Systems (GIS) with Building Information Modeling (BIM) has become a potent strategy for handling the complexity of contemporary facility management, infrastructure development and urban planning. GIS is superior at geographical analysis and large-scale environmental context however, BIM is largely focused on precise building design and lifecycle management. The amalgamation of these two technologies facilitates stakeholders in thoroughly comprehending project elements at both the micro and macro levels. On the other hand, GIS offers extensive spatial datasets encompassing geographical, environmental, and topographical information. By integrating BIM and GIS users can analyze the building's interaction with their surrounding environments, optimize site selection, enhance project planning and ensure better sustainability outcomes. BIM offers precise 3D models enhanced with metadata for building components, facilitating accuracy in construction and maintenance. Improved decision-making, expedited workflows and more cross-disciplinary cooperation are just a few advantages of this synergy. Applications include facility management, smart city planning, urban infrastructure development and disaster management. However, there are still issues with technology integration, standards alignment and data interoperability. However, the combination of BIM and GIS has enormous potential to influence future infrastructure projects and cities provided that data transmission formats and software capabilities continue to progress.
Keywords: *Urban Planning, Lifecycle Management, 3D Models, Urban infrastructure, Data Interoperability.*

1. Introduction
The building industry is the main engine of the country's economic expansion. Its sustainable development influences both the creation of a human-friendly ecosystem and the sustainable growth of the economy. Combining the capabilities of BIM and GIS technology would create a single tool for controlling an object's whole life cycle in various settings and geographical areas. The integration of these two systems can not only significantly speed up the management decision-making process but also provide an opportunity for a more comprehensive and in-depth analysis during the pre-investment stage of the building project development [1]. One of the main trends in developed and developing countries alike is the growing urbanization. By 2050, almost 68% of the world's population is predicted to reside in cities. One of the concepts that has evolved the most in the last 20 years is smart cities. The concept of smart cities has been developed and defined by numerous organizations and research groups. On the other hand, the majority of these criteria and actions focus on the city's operating stage. This study provides a thorough framework for integrating Geographic Information Systems (GIS) and Building Information Modeling (BIM) to plan and forecast the utility infrastructure needs of expanding and developing communities. The intention is to highlight "smartness" during the planning stage [2]. Around 60 percent of all raw

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material extraction worldwide is accounted for by the building sector, which also uses the most raw materials overall. Reusing and recycling construction materials that have reached the end of their useful lives can help reduce consumption Sadly, the building stock is not well-documented. Based on Building Information Modeling (BIM) and Geographic Information System (GIS), this study suggests a bottom-up approach for predicting material amounts. This methodology is tested on an actual building. A BIM model, pre-existing planning data, on-site studies, and laser scanning are used to establish the material intensity. The results of the research demonstrate how material intensities are calculated and how the applied approach may be used to predict construction supplies [10]. Through integration, the advantages of geographic information systems (GIS) and building information modeling (BIM) are integrated. Building Information Modeling (BIM) is used to digitally depict the physical and functional aspects of buildings to manage project schedules, cost, safety and contracts as well as to facilitate information exchange and communication among stakeholders at every step of an engineering project [14].

1.1.Supply Chain Management

Over the past ten years, many academics have emphasized the advantages of the supply chain management philosophy to the construction industry, especially in light of the need to reduce the enormous waste produced by ineffective material management and control and boost construction performance. Competent materials management is also unanimously recognized as being essential in the industry community at large. Although the importance of understanding the supply chain's entirety has been the subject of several studies, supply chain management usually refers to the management of the actual physical distribution of commodities from raw materials through contractor supply chain operations to the final product [6].

1.2.Sustainability and Smart Cities

As the concept of a "Smart City" has gained traction, people's focus has gradually moved to modern city management and planning. The planning, research, design, construction and operation phases of a building project are all incredibly dynamic processes. Various technologies will inevitably combine and integrate. Combining geographic information systems (GIS) and building information modeling (BIM) technology is a new and rapidly expanding trend in construction management. GIS focuses on low-density spatial geographic information data of a larger range, whereas BIM concentrates on high-density geographical component data of the building environment itself of a narrower range. The integration of GIS and BIM technology can yield more comprehensive and detailed data information about the integrated human environmental activity space. As a result, most cities find that GIS-BIM integration technology is effective in meeting the demands of various building life cycle phases, which makes it more palatable for use in engineering practice. Promoting the integration of GIS and BIM technology in the building engineering field will result in further advancements in the effective exchange of information between individuals and procedures [20]. Among other applications for BIM that can expand the use of GIS is the development of internal networks for emergency response, the analysis of the effects of floods on a room and the measurement of the influence of noise on a structure. GIS is more capable of handling environmental data than BIM, such as temperature, light and topography. Utilizing this data is necessary for sustainable building techniques [7].

1.3.Maximizing Value Through Interoperability

The advent of digital technology has revolutionized the construction sector, leading to improved project management concerning cost, schedule, and performance. Geographical data facilitates the management of location-related information on the surface of the Earth, which makes it indispensable for the development and management of infrastructure. Specialized tools have been developed over time, one such tool is the geographic information system (GIS), which is well-known for its capacity to do complex spatial queries and analyses. In GIS, discrete objects are represented using raster and vector formats, whereas continuous-field conceptualization is used to store and manipulate these things in the future within an existing context. In addition to analyzing how airport infrastructure interacts with the surrounding environment, this study looks at the benefits and possibilities of integrating airport infrastructure into the BIM system. Airports are the main topic of discussion when it comes to BIM-GIS interoperability. Beginning with the addition of an obstacle-free Zone (OFZ) surface to the BIM system, this study provides a detailed analysis of how the use of this technology might support airport infrastructure management. Through the provision of the territorial context, the GIS system aids in achieving the goal [11].

1.4.Leveraging Technology for Intelligent Design and Planning

The use of BIM in conjunction with GIS is growing in popularity. However most research still concentrates on transferring BIM data into GIS applications and vice versa. Leveraging the best components of GIS technology in BIM as well as the best characteristics of both BIM and GIS technologies is necessary for effective BIM & GIS integration [15].

1.5.Transforming Urban Planning through Spatial Intelligence

The integration of Building Information Models (BIM) in environments such as Geographic Information Systems (GIS) is one of the most investigated study challenges in the field of urban spatial information at the time. One of the many challenges that must be overcome to fully implement this kind of integration and one that is highly relevant to the GIS community is geo-referencing data from the BIM domain. This second method, which originated in the field of computer-aided design (CAD), often uses local coordinate systems, providing models with erroneous or no global position information. This paper describes an automatic system for converting a BIM model's local coordinates to its actual geographic coordinates in the real world. It is based on well-established computer vision techniques. To obtain the transformation matrix that will align the BIM's geometry with the map's, our method starts with a geo-referenced 2D polygon of the building (either a footprint or a vertical projection), and then directly applies a rigid motion transformation to a corresponding 2D projection generated by the BIM model [16].

1.6.Application of BIM-GIS Integration

Every piece of utility infrastructure data utilized in the planning, design, building and operation phases is included in the created BIM GIS model. The following are some examples of how BIM is used in GIS integration:

- **Visualization:** Each component's geometric 3D depiction, which includes geometric and semantic information, is offered via the BIM vs. GIS platform. Planning and carrying out the project are made easier by the visualization. The GIS environment allows for the depiction of geographic landscapes, terrain details, neighboring facilities and subsurface and ground infrastructure.
- **Facility Management:** Regular schedules or utility failures necessitate the need for operations and maintenance activities. To help the operation and maintenance crew identify the position, types and material of the utilities, the BIM-GIS integrated model offers readily available information about them. Accessible utility information lowers waiting times and overrun expenses while increasing system efficacy.
- **Clash Detection:** During the operation stages, renovation and repair work are frequent. Traditionally, 2D CAD drawings or no information at all about the utility is accessible. The precise utility information that could lead to a conflict between the utilities is very hard to derive from 2D drawings. Many BIM tools (Navisworks, Civil 3D) and GIS tools (ArcGIS) in this BIM-GIS integrated platform allow for collision identification between the 3D utility

model. The information provided by the 3D model aids in subsequent activities.

1.7.Benefits of Integration of BIM and GIS

- Enhance the comprehension of extremely specific geospatial context, and maximize the benefits of current investments in BIM & GIS software.
- Facilitate cooperative processes that make data reuse easier for all persons involved.
- To expedite project completion and enhance the upkeep and operations of finished assets, make a more intelligent selection.
- Assist engineering GIS and architectural teams in collaborating more successfully to centralize data, eliminate silos and link workflows.
- Facilitate the creation of more intelligent, cost-effective infrastructure and structures by engineers and architects.
- Enhance communication with important stakeholders by gathering and evaluating data from the field.

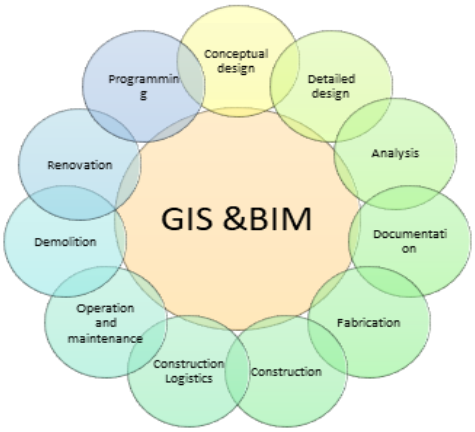

Figure 1 Benefits of GIS & BIM Integration

- Connect existing systems of record to create a federated source of truth that helps minimize costly errors and delays regarding critical design decisions.
- Adopting 3D BIM processes and GIS technologies will largely benefit the environment and remediation industries.
- It will open the door for more inclusive stakeholder engagement, better design quality and data-driven decision-making. Figure 1 shows the benefits of GIS and BIM integration.

2. Research Methodology

The planned research aims to illustrate a newly developed data integration approach that will support the continued operation of the two distinct settings. In this study, topography and land boundary data are imported using a GIS system, while data on road components are saved using an IFC system based on BIM. To create semantic interoperability between BIM & GIS operations and retrieve and integrate the two distinct types of data formats, this research uses the idea of the semantic web in RDF format [5]. In the subject of cultural heritage, a novel method known as "scan to BIM" is applied to produce 3D GIS models that have the potential to combine different information and thus, facilitate an interdisciplinary approach. The recommended method was used in a case study of a rock church in the well-known pottery district of Grottaglie, Italy. An integrated survey utilizing terrestrial laser scanning technology and close-range photogrammetry was required to be finished before a 3D GIS model of the structure under study could be created [9]. A mixed-methods approach was utilized to look at collaboration issues and identify requirements. More than 500 people in the construction business with backgrounds in rail, BIM and GIS were asked via email or social media to participate in the initial data collection, which involved an online questionnaire survey. The purpose of the questionnaire was to ascertain the current state of BIM and GIS in railway design, with a focus on their potential to promote collaboration throughout the process. Following the questionnaire, which probed more into the issues identified by the respondents and gathered suggestions for potential remedies, fifteen in-depth interviews were held [17]. To evaluate the BIM and GIS integration, the SWOT method was used. As stated in the Introduction, most articles on the topic tend to concentrate on one aspect of the acronym SWOT, or a particular application area. An

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instrument for analyzing internal and external challenges is the SWOT analysis, which stands for strengths, weaknesses, opportunities and threats. It is examined in two different periods the present and the future. The analysis of a process or service is another use for this technology. It is frequently employed to assess a business's strategic positioning within the industry and ascertain its approach. This is true concerning BIM-GIS integration. This allows for the identification of the benefits, drawbacks, opportunities and dangers related to the subject of investigation [18]. The integration methodology's output is explained in Figure 2.

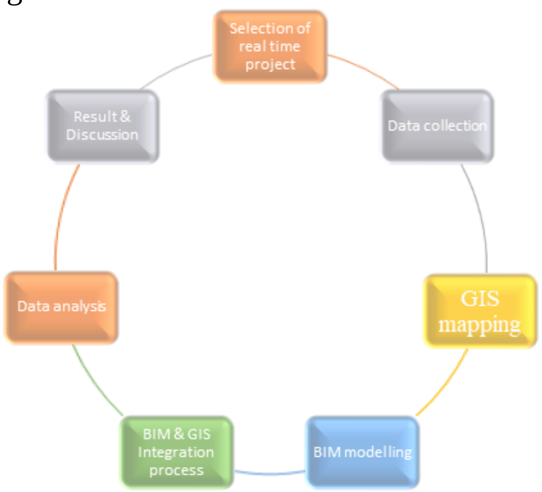

Figure 2 Methodology

3. Literature Review

Building Information Modeling (BIM) and Geographic Information Systems (GIS) are becoming more and more integrated in digital built Asset Management (AM). This integration has the potential to enhance AM operations and offer benefits in process control and quality AM service delivery, in addition to underlying data management benefits over the asset's entire life cycle. Research has been done on the use of GeoBIM/AM on infrastructure assets, such as buildings, where significant cost savings are possible. While BIM information might be adequate for building AM, infrastructure AM requires a combination of BIM and GIS [3]. The integration of BIM (Building Information Modeling) with GIS (Geographical Information System) for indoor geovisual analytics is presented in this study. First, the advantages of the two different technology types GIS and BIM are examined about interior environments. While BIM offers advantages for indoor 3D modeling and dynamic simulation, GIS has well-developed spatial analysis capabilities, such as network analysis. The important components of merging GIS and BIM are initially examined in this work. There is a discussion of various data formats and standards, including Industry Foundation Classes (IFC) and Geographic Markup Language (GML). Semantic and geometric information is used to analyze their benefits and drawbacks in terms of data transition between GIS and BIM. Then an ideal method for exchanging data across GIS and BIM datasets is suggested. Following that a plan is described that uses BIM for 3D indoor modeling, GIS for spatial analysis and BIM once more for dynamic simulation and presentation of the analysis results. This study showcases the integration of GIS and BIM for indoor geo-visual analytics by focusing on an optimized interior emergency evacuation scenario, which is representative of current advancements [4]. A new technique called scan to BIM is used in the field of cultural heritage to create 3D GIS models that may link various datasets and as a result support an interdisciplinary approach. The suggested approach was used in a case study of a rock church in Grottaglie, Italy a well-known ceramics district. To create a 3D GIS model of the structure under study, an integrated survey using close-range photogrammetry and terrestrial laser scanning technology had to be completed first[9]. The construction industry is the greatest user of raw materials, accounting for 60% of global raw material extraction. Building materials that have reached the end of their useful lives can be reused and recycled to minimize consumption unfortunately, the building stock is not well-documented. This study proposes a bottom-up method for estimating material amounts that is based on Geographic Information System (GIS) and Building Information Modeling (BIM). A real-world building is used to test this methodology.

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The material intensity is determined using laser scanning, on-site investigations, pre-existing planning data and a BIM model. The paper's findings illustrate the process for determining material intensities and show how the applied approach may be utilized to forecast construction stocks[10]. The integration of Building Information Models (BIM) in environments such as Geographic Information Systems (GIS) is currently one of the most frequently explored research challenges in the field of urban spatial information. One of the numerous challenges that must be overcome to successfully implement this type of connection is georeferencing data from the BIM domain, which is crucial for the GIS community. This second method, which originated in the field of computer-aided design (CAD), usually uses local coordinate systems, providing models with little to no insight into their actual global location. The automatic framework presented in this study makes it possible to translate the local coordinates of a BIM model into the actual geographic coordinates of the model in the real world [16]. Disasters have a gravely detrimental effect on towns worldwide in the twenty-first century. Disaster management agencies and the general public must improve urban disaster management in light of the substantial casualties and property damage caused by catastrophes. Urban disaster management can be greatly enhanced by the efficient technique of BIM (Building Information Modeling) and GIS (Geographic Information System) integration. The implementation of BIM-GIS integration in urban disaster management is rare, despite its significance. This greatly impedes the development of urban catastrophe management's quality and efficiency [19].

4. Findings and Interpretation

Digital-built asset management (AM) is increasingly integrating Geographic Information Systems (GIS) and Building Information Modeling (BIM). In addition to providing benefits for process control and quality AM service delivery, this integration may improve AM operations and provide underlying data management advantages for the asset's whole life cycle. The application of GeoBIM/AM to infrastructure assets like buildings where considerable cost savings are feasible, has been studied. For building AM, BIM data may be sufficient, but for infrastructure AM, BIM and GIS are needed [3]. The integration of building information modeling with geographic information systems offers several advantages in the domains of design, engineering and construction. This integration enables a more comprehensive and efficient approach to project design, construction and management. Despite these challenges, the AEC industry is witnessing an increase in BIM and GIS integration. The benefits of integration become increasingly apparent as standards and technology advance. To overcome the challenges, it is imperative to address data incompatibility issues, make the appropriate investments in hardware and software and promote industry-wide standards. In the future, integrating BIM and GIS will require streamlined processes, cloud-based platforms, artificial intelligence to automate tasks and the extraction of meaningful data from the aggregated information.

Conclusion

Integrating BIM with GIS aims to enable AEC firms, project owners, operators and government organizations to focus on infrastructure, but also on the where and why of it. Its goal is to build a more robust and sustainable infrastructure for the future, manage our planet's resources responsibly and foster an environment that supports the expansion of our cities and population. Finally, using BIM and GIS can mean improved workflows. Designers can use it to make well-informed judgments. The application of BIM and GIS in environmental protection, urban planning and building is truly revolutionary. This insightful blend aids project teams in making wise choices, boosting output and achieving sustainability. The use of GIS technology and BIM processes will be very advantageous to the environmental and remediation sectors. The current infrastructure development process may change in the future due to the integration of BIM and GIS. The efficiency of design, construction and maintenance activities will be improved by the application of developments in data collecting, processing and display. A key component of the project's success is implementing this integration, which maintains a healthy industrial sector environment and community. The building's and its components overall safety is guaranteed by this collaboration. A comprehensive project picture provided by GIS integration makes resource allocation and decision-making more efficient. It can be used by project teams to improve decision-making, boost output and be more sustainable. The application of BIM techniques and GIS technology will be highly advantageous for the construction sector.

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