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Maximizing the Project Efficiency Through Comprehensive BIM Coordination and GIS Integration

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Abstract
Building Information Modeling (BIM) and Geographic Information Systems (GIS) integration is changing how construction projects are managed, making them more efficient by reducing mistakes and delays. This combination is crucial for better project coordination and integration in the Architecture, Engineering, and Construction (AEC) industry. Using BIM tools to create detailed 3D models gives projects a solid digital base. These models are filled with important information, from shapes and materials to timelines and costs, ensuring they meet project goals. GIS makes project management even better by allowing real-time tracking and the ability to see complex data in 3D. This helps make better decisions and uses new technologies like drones to take high-quality aerial photos. These photos help create detailed maps and accurate site checks, improving project tracking and management. This paper shows how BIM and GIS are making a big difference in construction, with examples from projects in Canada. It looks at how tools like ArcGIS monitor project progress and how cloud platforms help organize models and find potential issues. The goal is to show how these technologies make project work smoother, more effective, and data-driven, changing how the construction industry manages projects.

Keywords: **BIM; Integration; Coordination; ArcGIS; Point clouds; GIS data**

1. INTRODUCTION

Achieving precise coordination and integration has been a long-standing goal of civil and building engineering. Construction projects are complex, involving various disciplines that must work together efficiently. The industry has embraced technological advancements, particularly Building Information Modeling (BIM), Geographic Information System (GIS) tools, and other innovative solutions to address this challenge. Integrating BIM's 3D modeling capabilities with GIS tools has marked the beginning of a new phase in project management efficiency. Industry-wide, project managers are faced with the critical task of determining the precise amount and timing of resource deployment on construction sites. In an economic context where skilled labor is costly, the construction industry must innovate its decision-making methods regarding the optimal number of resources to be mobilized on site. Also, monitoring project progress to control the budget and schedule is a task that can take several hours of work per week for a site team. This task is required on all major construction projects. By automating progress tracking as much as possible, site resources can devote more time to performing value-added tasks, whether related to OHS or the quality of their respective project. The challenge of optimizing project coordination, clash detection, real-time tracking, resource management, and efficiency to minimize errors and deliver higher-quality construction projects is highly relevant to the broader construction industry. This challenge occurs on all construction sites, and adopting a solution to these recurring issues can generate considerable economic growth for Canada.

This transformation involves creating accurate 3D models using BIM tools like AutoCAD, Autodesk Civil 3D, and Autodesk Revit. These models replace traditional 2D drawings and significantly improve project planning. BIM integration enhances coordination and conflict detection, while GIS tools add spatial analysis capabilities for precise progress tracking, activity monitoring, and quantity assessment. Innovations like drones and cloud-based collaboration platforms streamline communication and data sharing among project teams. Despite these advantages, challenges persist, particularly in integrating various software tools. Industry must adapt, embrace, and adopt innovations as technology evolves.

The main objective of this paper is to demonstrate the application of GIS tools for project progress tracking, activity monitoring, quantity assessment, and construction cloud platforms for 3D model coordination and conflict detection. Moreover, the importance of BIM coordination and integration will be detailed by presenting real-world examples from Canadian construction projects.

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2. APPLICATION OF GIS IN BIM PROJECT PROGRESS MONITORING

In recent years, a challenging and necessary improvement related to BIM and 3D capabilities has been integrating GIS data and interoperability with BIM data. Nowadays, the relationship between 3D BIM data can be kept within GIS frameworks and tools, keeping the rich information from BIM data while making the most of GIS tools available. The collaboration between Esri and Autodesk facilitates exchanging and retaining information from BIM to GIS and vice versa [11]. Customized GIS tools allow users to inspect, interpret, and interact with their data to facilitate the understanding of projects' content and environments by providing accurate geospatial content. Having the GIS and BIM data coexisting in the same platform or cloud is essential for the stakeholders as it makes it easier for them to manage that data. GIS and BIM have been used in symphony for multiple usages such as flood inundation simulation [2], life cycle impact of urban systems [3], supply chain or schedule management, bridge management [4], and underground utility management [5]. High-precision drones using real-time kinematic (RTK) positioning with high-resolution cameras are utilized to survey project sites in most of our civil projects. Georeferenced high-definition orthophotos can be developed from those surveys to visualize project progression. Those orthophotos are then added to GIS scenes, which can be populated with other BIM data sources. That process allows us to easily share that rich visual information with the clients without them needing to go on-site. RGB points clouds are also generated from the drone surveys to help visualize the actual up-to-date 3D progress context and visual comparison between BIM models and as-built progress (as shown in Figure 1). Point clouds acquired from drone surveys are also frequently employed for calculating, managing, and tracking stockpile volumes across sites. This practice significantly enhances effective planning, assessment, and materials monitoring capacity, leading to substantial cost savings.

Additionally, there is a growing reliance on open-data GIS information, including government-provided lidar point clouds and derivatives such as Digital Elevation Models (DEM) and Digital Terrain Models (DTM). Lidar technology offers numerous applications beneficial to the field, encompassing hydrology mapping, object classification, and the automated creation of features (for instance, extracting 3D buildings from lidar data, illustrated in Figure 2) and geological, topographical, and land-surface mapping. These capabilities extend to the automated categorization of objects and land uses alongside spatial analyses, such as developing flood risk maps (demonstrated in Figure 3).

Fig 1: A Combination of drone point cloud data and 3D BIM models in the ArcGIS portal

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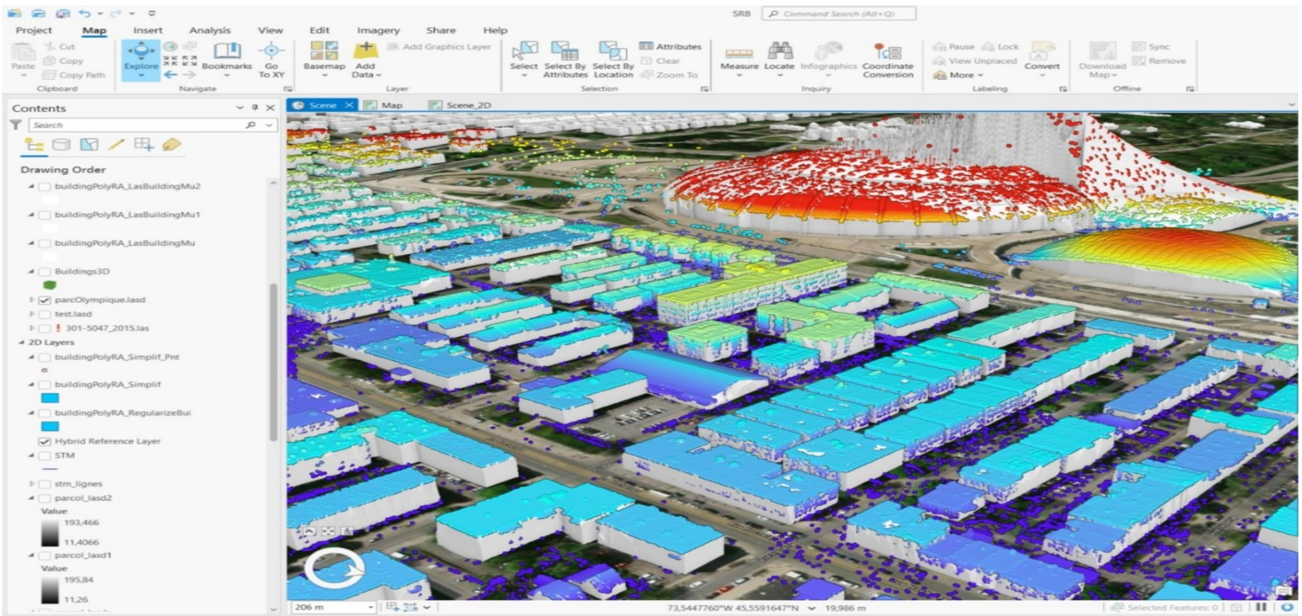

Fig 2: The 3D model automatically generated from Lidar data in the ArcGIS portal

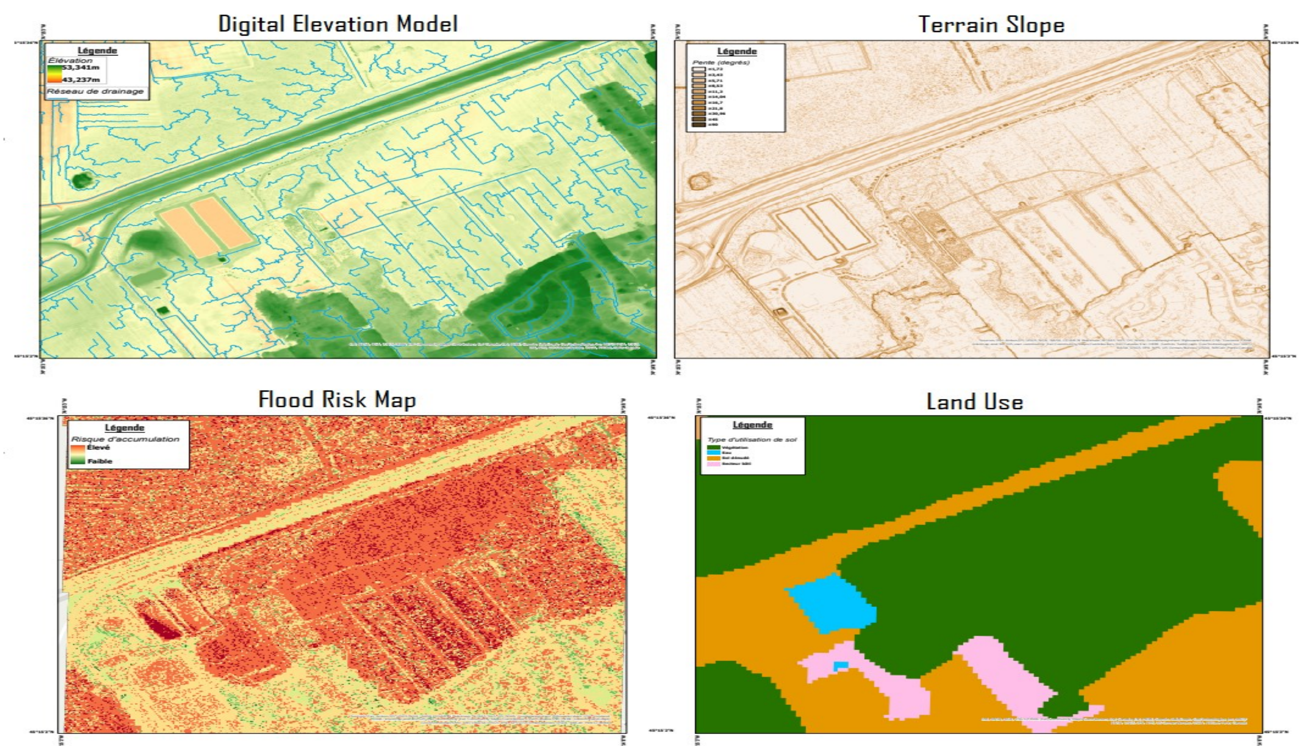

Fig 3: DEM, terrain slope, and the land used to generate flooding risk map in the ArcGIS portal

2.1. The proposed activity tracking visualization dashboard for a case study application

Georeferenced ArcGIS features seamlessly integrate with Autodesk records, streamlining the process of accessing, visualizing, and querying project documentation from various sources. Moreover, ArcGIS scenes and dashboards facilitate improved communication and collaboration through a secure online platform, which can be customized to meet the specific needs of different stakeholders. A Personalized dashboard designed to visually represent project advancement and allow real-time tracking for project participants was created to help enhance progress monitoring. In addition to project status, the proposed dashboard can display additional information relevant to the project's activities. The primary benefit of creating the customized GIS dashboard, developed and presented in this study, is its ability to perform real-time statistical analyses, summarizing critical successes and challenges a project faces. As shown in Figure 4, it enables project managers to access a comprehensive view of all project activities on a unified map, eliminating the necessity for dedicated desktop software. Alongside real-time BIM and GIS data, there is also the functionality to integrate dashboards with tabular information, providing valuable insights into the project's progression. Elevating these insights earlier in the project's journey will empower stakeholders to anticipate potential problems, optimize the project's progression, and minimize expensive delays.

2.2. The proposed quantity tracking visualization dashboard for a case study application

Survey123, a cloud-based extension of ArcGIS, can be utilized as an input tool for management and workers in the survey and inspection processes. The project manager or supervisor can also use the proposed dashboard to control the condition and progress of the building elements. The system links various statistics, which automatically update upon selection. Moreover, it can effortlessly integrate live data sources, such as survey responses and instant updates, into geometrical configurations, ensuring the most up-to-date information is readily available. In addition, the platform provides the flexibility to integrate multiple maps into a comprehensive view, enhancing the user's ability to gain valuable insights from a wealth of data sources.

Utilizing the object-oriented and spatial functionalities of BIM and GIS technologies, the digital construction twin has introduced a novel and efficient approach to improving project coordination, enabling real-time monitoring, optimizing resource allocation, increasing efficiency and accuracy, streamlining workflows, minimizing errors, and achieving higher quality in construction projects. This digital twin represents a revolutionary development in slip formwork construction, establishing new standards for precision and efficiency in the industry.

Fig 4: A Custom data visualization ArcGIS dashboard developed for project progress and activity tracking

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3. IOT SENSORS

Integrating BIM and Internet of Things (IoT) technologies introduces a transformative change in construction methodologies. BIM, known for its precise geometric representations and rich metadata information, integrates seamlessly with IoT, facilitating real-time data integration and significantly improving construction operations and management. For instance, IoT can collect extensive data and information about facilities in real-time. Combined with BIM models, they can be applied to a broad range of applications, such as the monitoring management of buildings in smart cities [6, 7, 8, 9, 10]. This combination of BIM's detailed design models and IoT's instant updates and sharing takes construction monitoring to a new level, covering many aspects.

IoT sensors collect information about location, size, and the environment, arranging it in sequences over time. Accessing BIM and IoT data involves various methods, including APIs and open standards. As this combination develops, it reveals clear patterns, problems, and chances that influence the future of how construction projects are done and managed. The benefits brought by the integration of IoT sensors and BIM can be applied to various aspects of construction projects as follows:

3.1. Quality control and construction progress monitoring

Construction performance and progress monitoring can benefit from IoT devices and BIM. Firstly, reality data, including actual project status, construction activity, physical context, and other real-time project information, could be captured with sensors. When combined with models and BIM tools, this data can be used to monitor the construction process and update the construction activity planning list. Furthermore, sensors have been employed to identify progress data for quality control. In the most recent projects leveraging IoT capabilities, GPS and thermal sensors are utilized to gather position data, including roll, pitch, rotation, elevation, and temperature, to construct concrete silos compo for the construction of concrete silo components. This is a precise comparison against BIM models to ensure a proper match with design models.

The models and sensor data are integrated into ArcGIS software to create a live digital twin of the construction project where elevation data and concrete progress are tracked live to the centimeter. For instance, when the actual concrete elevation reaches three meters of an opening or an embedded steel plate, the person on-site gets an automatic notification with a detailed report. Moreover, the data collected from IoT sensors gives insights into workers' productivity during concrete pouring, enabling project managers to optimize team productivity. While some benefits are qualitative and not easily measurable, the aim is to assess the technology's impact on overall productivity by comparing data with historical benchmarks.

3.2.Energy management

IoT device integration also improved energy management for construction teams, allowing them to monitor construction components' temperature and energy performance in real-time. For example, a smart site heater control initiative using United Rental Wedge keeps precise control over the heaters on project sites. This technology guarantees a direct return on investment by utilizing a variety of sensors and probes for accurate remote control and monitoring of heating equipment. The outcome includes 15-20% fuel savings, decreased in-person maintenance, and improved concrete pouring and cooling consistency.

4. APPLICATION OF BIM IN THE COORDINATION PROCESS

One of the most common and highly valued applications of BIM in the construction industry involves design coordination and conflict resolution. However, observations during design coordination meetings reveal a tendency among teams to use 3D models created from plans often to help the team plan and visualize the big picture, even when BIM issues and clash tools are readily available. They cannot utilize BIM tools without the assistance of a dedicated BIM Coordinator. The design coordination process enables project stakeholders to detect problems and conflicts within building systems before they arise at the construction site. This typically involves architectural, structural, mechanical, electrical, and plumbing (MEP) designs and requires a comprehensive understanding of building systems.

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Clash detection is one of several essential quality checks designers perform before finalizing and sharing their BIM models for downstream delivery processes. These clashes, characterized as errors or omissions, are typically resolved through interdisciplinary discussions involving designers, modelers, and constructors. The origins of project clashes can be attributed to factors such as design uncertainty, wherein a designer uses a placeholder for a component, anticipating resolution at a later stage; non-compliance with design rules, leading to clashes between components from different design disciplines; acceptance of model inaccuracies due to tight deadlines, to be rectified at a later phase; and design errors, which may include dimension or location discrepancies resulting in clashes.

BIM-based design coordination improves schedule performance, cost control, and productivity and reduces deficiencies on site. Implementing BIM can reduce costs and cut time by up to 50% [1]. For most construction projects, clash detection using platforms such as the Autodesk Construction Cloud (ACC) is vital in improving accuracy and minimizing errors. Identifying clashes in the virtual model allows the resolution of design conflicts in the preconstruction phase, as shown in Figure 5; working with the designers to address potential issues helps mitigate the need for expensive on-site revisions. As shown in Figure 6, real-time visibility into construction activities through BIM models facilitates effective project management and decision-making.

Fig 5: Issues and conflict detection in the ACC platform

Fig 6: The 3-D Models Coordination in ACC

5. CONCLUSIONS

By leveraging recent object-oriented technologies and spatial capabilities (BIM and GIS), the digital construction twin provided a new and efficient way to optimize project coordination, real-time tracking, resource management, efficiency and accuracy, streamlined processes to minimize errors, and deliver higher-quality construction projects. It helps organizations improve processes, reduce risks, optimize operations, automate decision-making, and enhance stakeholder engagement.

The significant level of automation achieved through integrating BIM, GIS, and IoT technologies enables the transmission of crucial information to the construction team. This level of automation is unparalleled on typical construction sites and lays the foundation for utilizing automation and artificial intelligence in the construction sector. The combination of BIM and GIS holds the potential to deliver more intelligent outcomes for communities and enhance project efficiency for AEC service providers. Achieving this goal extends beyond collaboration among software vendors. Local government and asset management organizations must define BIM information specifications incorporating attributes in the early design phase for later use in operational and management workflows. Implementing advanced technologies like BIM and GIS in construction creates employment opportunities for skilled professionals and significantly improves project efficiency and productivity. By reducing construction timelines and minimizing rework, these technologies enhance cost efficiency while ensuring the delivery of high-quality infrastructure.

Additionally, using advanced technologies encourages innovation, leading to better ways of doing things and developing more efficient construction methods. This positive impact extends beyond single projects, benefiting the construction industry and laying the foundation for long-term growth and progress. As a result, the construction sector remains dynamic, adaptable, and ready to face future challenges and opportunities.

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