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To cite this article: Wan Nor Fa'aizah Wan Abdul Basir *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1274** 012002

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IOP Conf. Series: Earth and Environmental Science 1274 (2023) 012002 doi:10.1088/1755-1315/1274/1/012002

Adaptation 4D and 5D BIM for BIM/GIS data integration in construction project management

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Abstract. Construction project management contains a sequence of activities such as planning, completing, scheduling and cost estimation. Building Information Modelling (BIM) is one of the technologies that can be used to manage the complexity of construction documentation. BIM provides a digital visualization of building structures in three dimensional (3D) and store all the geometric and semantic data likes construction element, material properties, construction details, and schedules but lacking feature like geospatial analyses. Geographic Information System (GIS) can apply in construction project to overcome the limitation because GIS can offer advantages in route design, cost estimation, site layout, material layout design and construction planning. Therefore, integration BIM/GIS is recommended to produce an operational of construction project management. This paper presents the advantages of BIM-based in term of scheduling (4D BIM) and cost estimation (5D BIM) in the scope of project management to control the time efficiency and cost saving during the construction process. 4D and 5D BIM data were examine during data integration between BIM and GIS by using Feature Manipulation Engine to bring the gap in construction project management. 4D BIM data develop using Naviswork while 5D BIM developed using Autodesk Revit. GIS data management was used to maintain and update the construction database to assist the project planning.

1. Introduction

Integration Building Information System (BIM) and Geographic Information System (GIS) for construction project management has obtained significant awareness in recent years. This integration permits for seamless exchange and utilization of data interchange involving BIM and GIS platforms, providing various benefits for construction projects. There are several key benefits involving BIM/GIS data integration on construction project management such as improved data consistency, enhanced planning and design, efficient project management, increased collaboration, and sustainable and resilient construction.

Integrating BIM and GIS results in improved data consistency throughout the entire project lifecycle. This integration allows for the linking of information from diverse sources and formats, all rooted in a shared foundation of locational data [1]. Besides improvement on data consistency, integration BIM and GIS facilitates construction and infrastructure plan companies to integrate geospatial elements into their BIM designs. This allows for better planning and placement of newly built objects within their surrounding environment [2].

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The integration of BIM and GIS also offers efficient project management capabilities that grant a comprehensive view of the project's entirety. Through this integrated approach, stakeholders are empowered with the ability to visualize and analyse spatial data, leading to well-informed decision-making. This synergy between BIM and GIS enhances the overall project management process, fostering better coordination and strategic planning.

In addition to the efficient project management benefits that integration can provide, it also has the potential to enhance collaboration among various project stakeholders such as architects, engineers, contractors, and owners. This integration facilitates the smooth sharing and exchange of data in a manner that is both streamlined and efficient. By bridging the gap between these crucial disciplines, the integration of BIM and GIS fosters a collaborative approach that improves communication, coordination, and decision-making across the entire project lifecycle.

Lastly, it's important to highlight the substantial impact that arises from integrating BIM and GIS, particularly in the context of sustainable development and resilient construction practices. This combination empowers professionals in the industry to tap into the possibilities offered by location intelligence and design data, propelling progress within the sector. While the integration of BIM and GIS for managing construction projects brings forth numerous benefits, it's essential to underscore the need for a precisely designed system to ensure flawless data interoperability between these two platforms [3].

Currently, there are many researchers and industry professionals enthusiastically discovering novel approaches and strategies for achieving efficient BIM/GIS data integration in construction projects [4]. In construction project management, the amalgamation of BIM and GIS combines the strengths of spatial data and design information, resulting in enhanced project planning, collaboration, and decision-making across the entire project life cycle.

2. Example of current approach in integration BIM and GIS

Nowadays, aims for integration BIM and GIS is to leverage the strengths of both BIM and GIS to improve project management, collaboration, and decision-making throughout the lifecycle of a built environment. For example, in urban planning and infrastructure management, integration BIM and BIM is applied to plan the construction of a new transportation hub (e.g., a train station) along with related infrastructures such as roads, utilities, and green spaces.

GIS would be used to collect and analyze spatial data, such as topography, land use, zoning regulations, existing infrastructure, and environmental factors. This data helps in understanding the context of the project area. BIM software is used to create a detailed 3D model of the transportation hub and the associated infrastructure. The BIM model includes architectural, structural, mechanical, and electrical components. This level of detail helps in accurate design visualization and coordination.

The GIS data and the BIM model are integrated through data exchange formats or platforms that allow interoperability between the two systems. This integration ensures that the spatial data from GIS is incorporated into the BIM model and vice versa. With the integrated BIM-GIS model, urban planners, architects, engineers, and other stakeholders can perform various analyses. For instance, spatial analysis becomes instrumental in determining the optimal location for the transportation hub, factoring in accessibility, environmental impact, and existing infrastructure. Clash detection plays a pivotal role in identifying conflicts between the proposed infrastructure and pre-existing utilities or structures. Simulation allows for the execution of scenarios to evaluate pedestrian flow, traffic impact, and energy consumption. Additionally, the integration of BIM and GIS data facilitates accurate cost estimation for construction, maintenance, and operation.

Throughout the project lifecycle, the integrated BIM-GIS model remains valuable. During construction, the model can aid in progress tracking and coordination among different teams. After completion, the model serves as a comprehensive reference for maintenance and facility management.

IOP Conf. Series: Earth and Environmental Science 1274 (2023) 012002 doi:10.1088/1755-1315/1274/1/012002

3. 4D and 5D BIM in Geographic Information System for construction project management

BIM can define as a procedure that concerns the creation and managing a digital interpretation of physical and functional descriptions of locations. BIM model are virtualizations of a project from concept to completion and on through its entire life cycle.

BIM is a digital model and collaborative process that encompasses, each adding specific information and value to the model. BIM dimensions are typically referred to 3D, 4D, 5D, 6D and 7D BIM; each dimension indicates the progressive inclusion of additional data and functionality. Table 1 below is the BIM dimensions refers to:

Table 1. Description of BIM Dimension.

BIM Dimension	Description of BIM Dimension
3D BIM	3D BIM forms the foundation of the BIM process. It encompasses generating a digital model that accurately depicts the physical and functional elements of a building or infrastructure project in three dimensions, such as length, width, and height. The 3D BIM model consists of intelligent objects or components that have properties and relationships, enabling stakeholders to gain a visual understanding and conduct analysis of the building elements in a virtual environment.
4D BIM	4D BIM introduces the element of time into the 3D BIM model. It incorporates the construction sequencing and scheduling information, allowing stakeholders to visualize the project's progression over time. With 4D BIM, the model becomes a time-based simulation, providing insights into the construction sequence, potential clashes, and project planning.
5D BIM	5D BIM introduces the dimension of cost to the 3D and 4D BIM model. It integrates cost data with the 3D model and construction schedule, enabling stakeholders to visualize and manage the project's cost throughout its lifecycle. With 5D BIM, the model becomes a dynamic cost estimation and management tool.
6D BIM	6D BIM adds the dimension of sustainability and environmental data to the 3D, 4D, and 5D BIM model. It involves the incorporation of information related to energy performance, life-cycle analysis, and other sustainable aspects of the building. 6D BIM assists in making informed decisions regarding the project's environmental impact and sustainability goals.
7D BIM	7D BIM extends BIM model to include data associated to facility management and operations. It integrates information on maintenance schedules, asset management, and other operational data to support the facility's lifecycle after construction is complete. 7D BIM aids in optimizing building performance, maintenance, and facility operations.

Although there are several of BIM dimension, it's essential to note that not all projects will utilize or require all dimensions of BIM. The level of BIM implementation depends on the project's complexity, requirements, and the extent of collaboration among stakeholders. However, as projects become more sophisticated and stakeholders demand greater efficiency and cost-effectiveness, higher dimensions of BIM may become more common in the construction and facility management industries.

This paper study on part of 4D and 5D BIM in GIS for construction project management. Feature Manipulation Engine (FME) was used as a medium to integrated BIM data into GIS platform.

3.1. 4D BIM

Numerous successful implementations of integrating 4D BIM and GIS within the construction industry have been observed. Liu et al. [5] conducted a comprehensive examination of the benefits and opportunities arising from this integration during project construction. The study explored various technical options and real-world use cases of this combined approach. The results demonstrated a higher level of integration, addressing challenges related to interoperability and showcasing the incorporation of the fourth dimension by linking project schedule data to create 4D GeoBIM. This integration proved highly valuable in facilitating critical aspects of major commercial infrastructure projects. The study focused on several specific use cases, including 4D noise mitigation and monitoring, 4D risk mapping, and enhancing construction safety. Figure 1 illustrates the outcomes derived from the use cases of 4D mapping, while figure 2 presents the risk modelling results.

Figure 1. Noise – buildings labelled by % completion.

Figure 2. Risk modelling.

Deng et al. [6] present a 4D BIM-GIS framework designed for construction supply chain management (CSCM). Through case studies, the authors highlight the benefits of integrating these technologies to streamline CSCM processes. The proposed integration is employed to address three key tasks in CSCM: (1) supplier selection, (2) consolidation centre allocation, and (3) determining the number of material deliveries, utilizing data from 4D BIM and GIS. The 4D BIM-GIS framework is demonstrated and validated through the case studies. The study findings suggest that the number of deliveries and supplier assignments should consider factors like material unit price and transportation distance. To enhance decision-making for the placement of consolidation centres in densely populated areas, the authors devise mathematical solutions based on transportation distances. The outcomes of this research serve as a valuable decision support tool for more efficient CSCM in future projects. Figure 3 showcases the road network results, illustrating the project site and supplier locations. The road network data is utilized to estimate the delivery costs effectively.

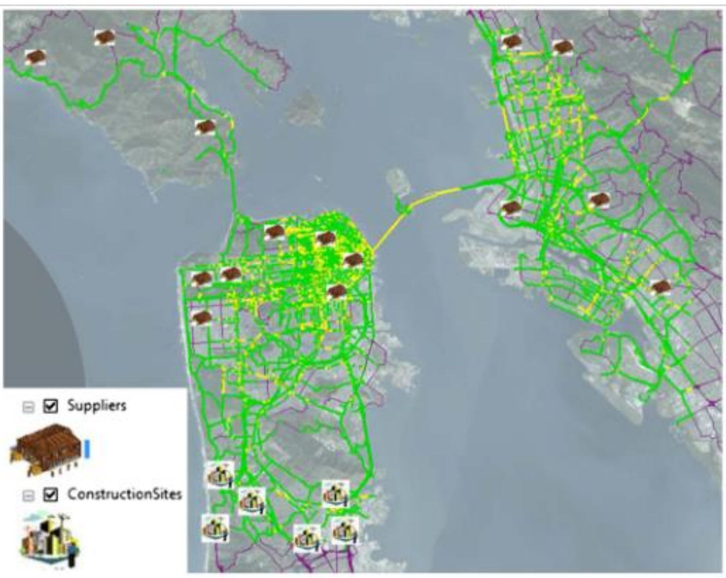

Figure 3. Location of construction site and supplier.

Antoh [7] conducts an analysis of the benefits offered by adopting integrated 4D BIM-GIS for construction supply chain management. The study comprehensively assesses the reasons driving the integration of BIM and GIS in supply chain management. Key drivers identified in the research include increased efficiency and productivity, time savings, and enhanced communication and information sharing. The study aims to evaluate the value propositions of integrating 4D BIM-GIS for supply chain management., there are some perceived value-in-uses to optimize adjustments involving lead-time, transportation cost, and logistics/material quality such as improved relationship among participating entities, reasonable appropriate material quality delivery & contractor selection, enhanced communication and information sharing, time saving, optimal allocation of consolidation centres, enhanced safety and health, enhanced efficiency and productivity, cost savings, enhanced sustainability, and stimulate innovations.

Deng and Cheng [8] create a cohesive framework that integrates 4D BIM and GIS to effectively coordinate construction supply chain activities. The framework aims to improve coordination and efficiency in the supply chain through the integration of these two technologies. The results from this integrated framework, it proves that the choice of contractors must not simply consider factor as unit price or delivery distance. Furthermore, the study incorporates Monte-Carlo Simulation to address the impact of the number of material deliveries on the total invoice cost within the supply chain.

Basir et al. [9] reviews the integration of GIS and BIM techniques in construction project management. It explores the potential techniques to overcome the drawbacks of using these two technologies in construction applications.

Vilventhan et al. [10] explore the 4D BIM as intelligent resolution for the managing of numerous utility data for a replacement plan in municipal surroundings. The finding from this study is the BIM model's development allowed the position of existing sub-surface utilities via 3D visualization and allowed clash detection. These 4D model of BIM can be used to tracking the real development of the repositioning works and can helped to take the crucial action to minimize future delays.

3.2. 5D BIM

Integration 5D BIM and GIS for the construction industry is an emerging trend that offers several benefits, including improved collaboration, better visualization, enhanced data management, and increased efficiency for construction processes.

Song et al. [11] explores the trends and opportunities arising from BIM-GIS integration in the Architecture, Engineering, and Construction (AEC) industry. While the paper discusses the broader concept of BIM-GIS integration, it sheds light on current applications and the evolutionary development of this integration. The study reveals that the successful application of BIM-GIS integration in the AEC industry requires a systematic understanding of integration technologies and the adoption of sophisticated mathematical modelling approaches, such as spatio-temporal statistical modelling in GIS and 4D/nD BIM simulation and management. Viewed from a spatio-temporal statistical perspective, the three fundamental assumptions of BIM-GIS integration facilitate more comprehensive applications throughout the AEC project life cycle. The solutions based on BIM-GIS integration significantly support management methods and coordination mechanisms, encompassing progress management and time efficiency, quality management, improvement of health, safety, and environment (HSE) performance, cost reduction and control, and information management with seamless coordination among various segments. These management approaches and coordination mechanisms rely on the intelligence and insights derived from data, information, and their analytical outcomes, characterized as spatial and temporal diverse, real-time, interactive, dynamic, accurate, and practical.

Harrison and Thurnell [12] establish the identified advantages of obstacles to 5D BIM realisation inside a specific, large multi-national accessing quantity surveying attempt in New Zealand. The results informed and provided understanding into a detailed matters neighbouring the application of 5D BIM, to allow the next process, the change of explanations for affecting the obstacles to acquire the advantages of 5D BIM within that training. The qualitative study was used to explore the encounters of BIM application for the circumstance of an adviser quantity surveying preparation needs encounter of experiences and opinions on concerns associated to the issue. From the study, the benefits of 5D BIM can be separated into several ideas such as improved visualization, effective extraction data for early phase assessing, effective extraction data for detailed assessing, effective extraction data for generating Schedules of Quantities (SoQs), instant recognition of design modifications, increased accurateness, interaction, and access to knowledge in the design, enhanced coordination and clash detection, and ultimately, commercial advantages through optimized resource utilization and project efficiency.

The integration of BIM encompasses a spectrum of advantages that significantly enhance diverse dimensions of project development and management. BIM facilitates improved visualization by offering enhanced visual representations of projects, thereby granting stakeholders a clearer grasp of design intent and project scope. It efficiently extracts data for both early-phase and detailed assessments, aiding in informed decision-making and project evaluation during initial stages and ongoing progress. BIM streamlines the data extraction process for generating precise Schedules of Quantities (SoQs), essential for project costing and resource planning. Real-time capabilities enable swift identification and visualization of design modifications, expediting design iteration and collaboration. Additionally, BIM fosters heightened accuracy, interaction, and knowledge sharing among project stakeholders during the design process. Its integrated approach enhances coordination among project components, facilitating early detection of clashes or conflicts, ultimately minimizing potential disruptions during construction. These comprehensive advantages translate into commercial benefits through improved planning, increased efficiency, and reduced errors, thereby minimizing rework, optimizing resource allocation, and elevating overall project outcomes.

Moses et al. [13] investigates, and assessment of the major challenges faced in the implementation of 5D BIM from the perspective of UK contractors. The study primarily focuses on a critical question concerning the effective utilization of 5D BIM in construction projects led by contractors. The findings reveal that achieving successful 5D BIM costing requires a significant cultural shift, including embracing automation and digitization of cost-related tasks, enhancing construction training, and fostering stronger collaborative relationships between stakeholders involved in costing throughout the design, development, maintenance, and operation phases. The study emphasizes that the adoption of 5D BIM requires the integration of built structures within the framework to enable contractors and the supply chain to fully harness the potential of BIM for successful costing in various project phases. To address the challenges, the identified issues are categorized into three main sections: operational issues, strategic issues, and technological issues. These sections serve as essential references for project teams working on contractor-led projects, guiding them in overcoming obstacles and streamlining the implementation of 5D BIM effectively.

The instances showcased above illustrate the successful integration of 5D BIM and GIS in diverse facets of the construction industry, encompassing decision-making, supply chain management, and project management. This integration of technologies yields advantages such as enhanced collaboration, improved visualization, efficient data management, and increased construction process efficiency. Nevertheless, despite these achievements, practical case studies remain limited, indicating the necessity for further research to fully explore the potential of 5D BIM-GIS integration in the construction domain.

4. Case Study

A 4-story building project has been utilized to show the suggested of 4D and 5D BIM for integration BIM/GIS in construction project management. The BIM model for this study was developed using Autodesk Revit which contains the geometry and semantic data of the building. Figure 4 show the methodology that has been applied for this study while figure 5 show the BIM model (3D BIM) in Autodesk Revit software.

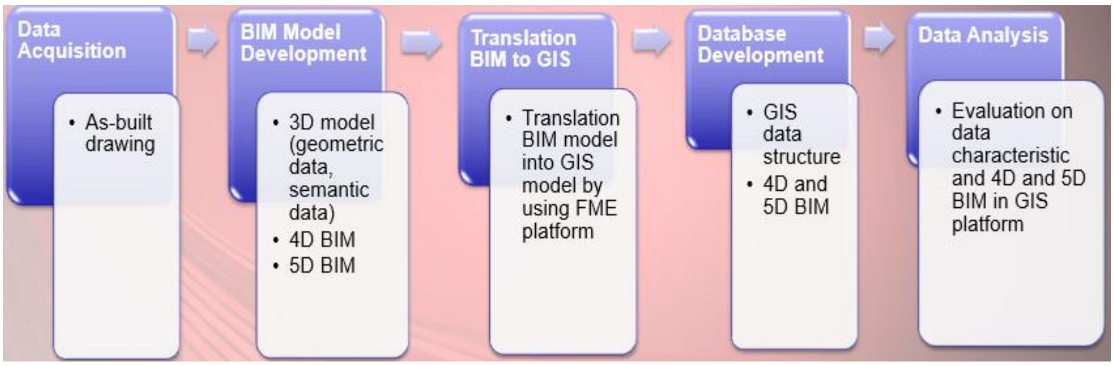

Figure 4. Flow of the methodology for the study.

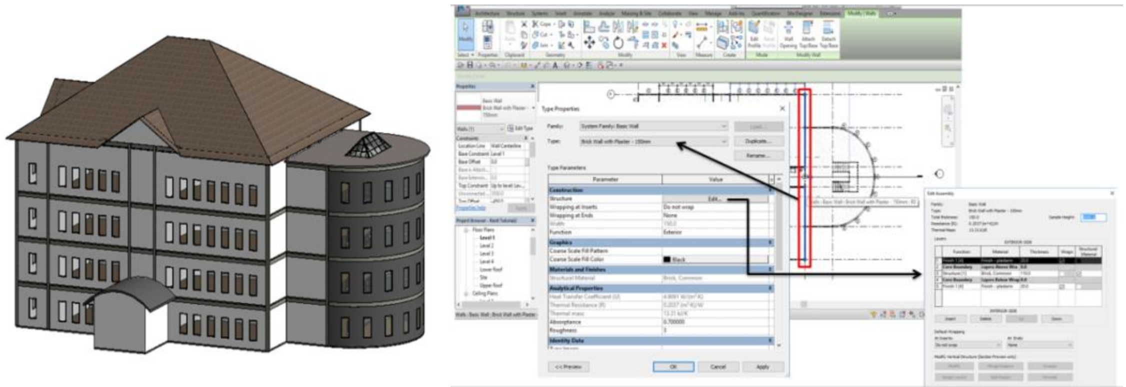

Figure 5. BIM model (3D BIM) in Autodesk Revit software.

For the development of 4D BIM model, Autodesk Navisworks was used to develop the 4D BIM data based on the 3D BIM in Autodesk Revit. All requirement data of the scheduling construction project throughout the construction model was included. Figure 6 display the results of the 4D BIM data in Autodesk Navisworks.

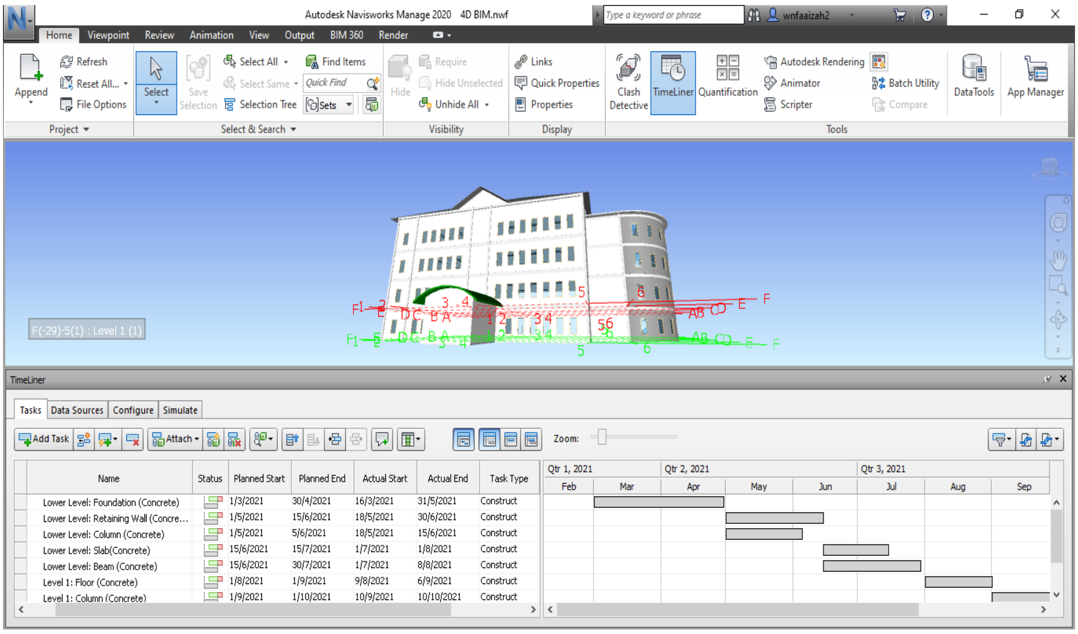

Figure 6. 4D BIM model in Naviswork.

In this study, 5D BIM model developed in Autodesk Revit. Each entity in the 3D BIM model was updated with their costing data. Figure 7 show the costing data in Autodesk Revit for each entity.

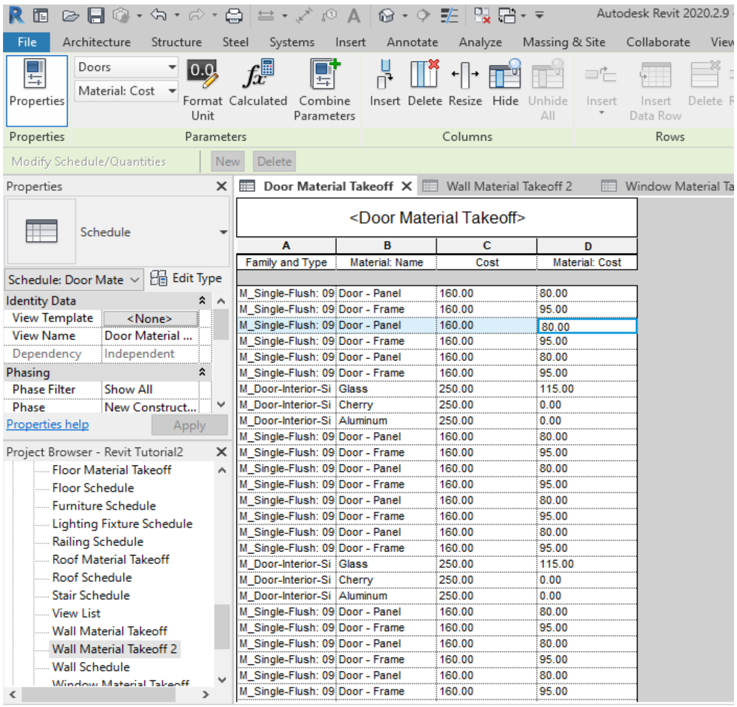

Figure 7. Costing data in 5D BIM model.

The Feature Manipulation Engine (FME) was used to integrate the BIM model into GIS platform. This integration includes the geometry and semantic data of the building model which contain all the information needed for construction project. Figure 8 show the BIM model in FME platform before the translation process while figure 9 display the workflow of translation process from BIM to GIS. In FME workflow, all information from BIM model was examined and clarify their format and data in orders to carry all BIM data into GIS platform without missing data and mismatch problems.

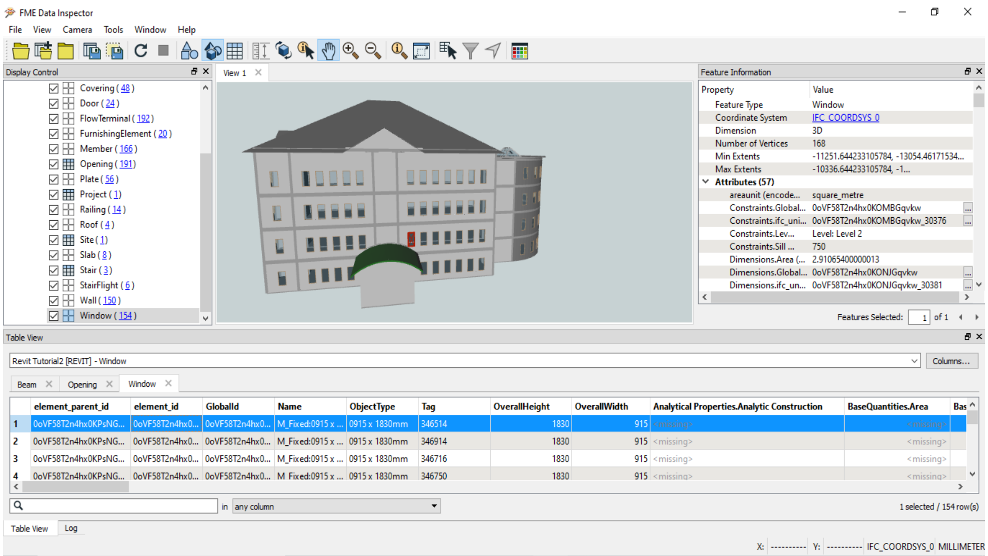

Figure 8. BIM model in FME platform

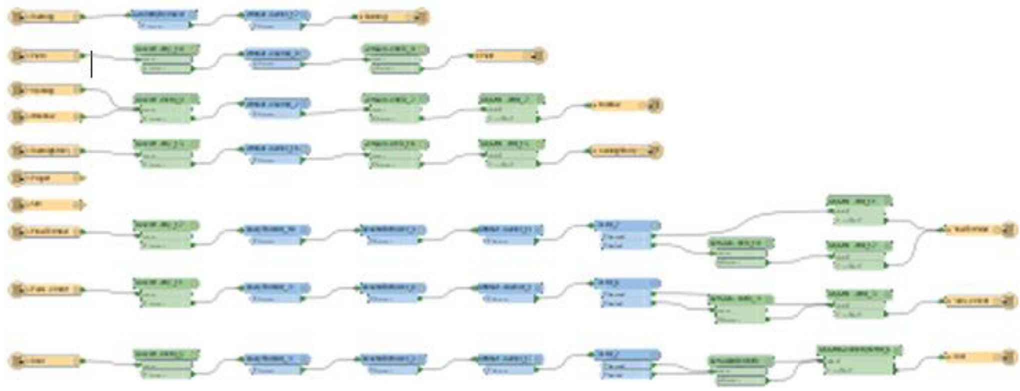

Figure 9. Workflow of translation using FME platform.

After the translation process, the ArcGIS software was used to display and manipulate the BIM model. In ArcGIS, it shows that all geometry and semantic data including the scheduling and costing data was included. From the results, it shows that there is some drawback in displaying the 4D BIM data which is the data that carry forward become as a table not in the time frame. Because of this problem, the data need to link back to the Naviswork software to view their construction process using 3D environment. Figure below show the translation results in ArcGIS software (Figure 10: 3D BIM, Figure 11: 4D BIM and Figure 12: 5D BIM).

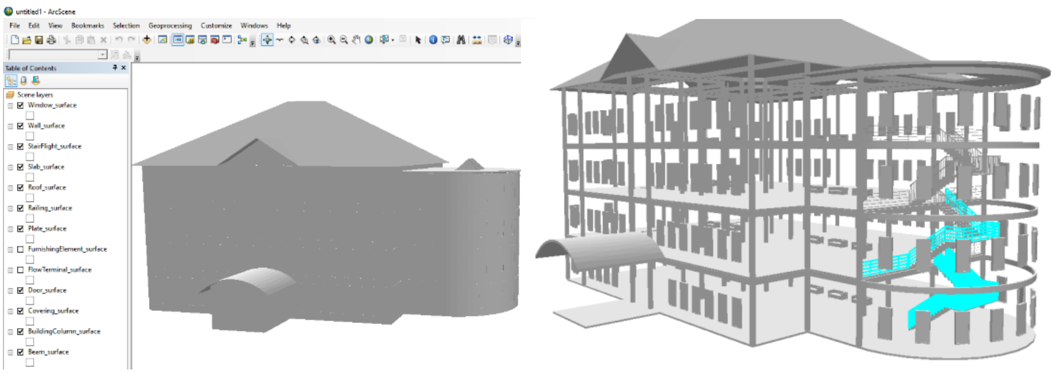

Figure 10. 3D BIM model.

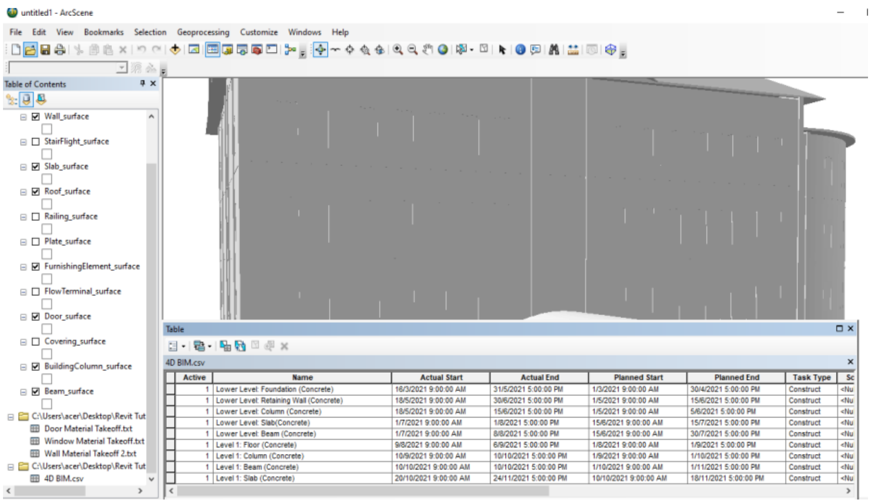

Figure 11. 4D BIM model.

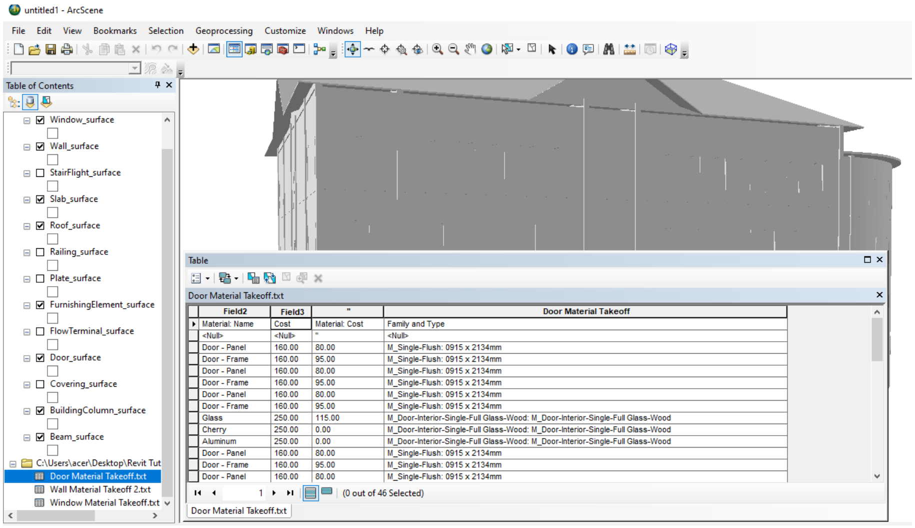

Figure 12. 5D BIM model.

5. Conclusion

This paper aims to highlight the advantages of integration 4D and 5D BIM into GIS platform. Through this study, the benefits of integrating 4D and 5D BIM in construction industry has shown to improve construction planning by managing the life cycle of construction project. From this study, we can conclude that 4D and 5D BIM inter-related to each other as without it the construction schedule becomes longer and the costing of the project higher. All the constructions' stakeholders need to utilize the use of 4D and 5D BIM data to increase the efficiency of the construction process and will be able to save the construction time and project costing.

For future work, some experiments need to be conducted to overcome the displaying issue of 4D BIM model in GIS platform so that the 3D model of 4D BIM can also be carried forward during the integration process.

However, integrating BIM and GIS presents challenges that require careful consideration. One of the primary challenges is ensuring interoperability between the two systems. Both BIM and GIS platforms use different data formats, standards, and methodologies, making seamless data exchange and synchronization complex. Ensuring data consistency and accuracy throughout the project lifecycle can be a challenge due to updates and changes made in different phases.

Looking ahead, the integration of BIM and GIS is expected to continue evolving. Advanced technologies such as cloud computing, real-time data streaming, and AI-driven analytics will likely play a crucial role in enhancing data exchange and collaboration. The development of standardized protocols and open data formats will contribute to smoother interoperability. Additionally, as projects become more complex and global, the integration of BIM and GIS will play an increasingly critical role in achieving sustainable, efficient, and resilient construction practices.

In conclusion, the integration of BIM and GIS in construction projects offers transformative benefits. It enhances project visualization, planning, coordination, and decision-making. Although challenges in interoperability, advancements in technology and standards are prepared to drive the seamless integration of BIM and GIS, shaping the future of construction with greater efficiency and effectiveness.

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