Scan to BIM for Building Asset Management

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Abstract: *Building Information Modelling (BIM) is a transformative technology that integrates three-dimensional modelling with asset management, offering enhanced visualization and improved decision-making capabilities throughout the building lifecycle. This study explores the implementation of scan to BIM technology for asset management in the Faculty of Civil Engineering and Built Environment (FKAAB) at Universiti Tun Hussein Onn Malaysia. The methodology involved three key phases: laser scanner data collection, asset database development, and asset validation. A Traverse survey and Trigonometry method were used to collect precise coordinate data, which was processed and integrated into a BIM model using Autodesk Revit and ARCHIBUS software. The resulting asset database significantly improved the accuracy and reliability of asset information, facilitating better management and maintenance. The study showed the benefits of scanning to BIM technology in asset management and suggested future research on automating data integration and exploring Artificial Intelligence (AI) and Machine Learning (ML) applications.*

Keywords: BIM; scan to BIM, asset database and management

1. INTRODUCTION

BIM is an integrated 3-dimensional object-based information management system that enables professionals to design buildings effectively, detect potential clashes, and accurately calculate quantities through model visualization, optimizing the construction process and enhancing project outcomes [1]. It also facilitates asset management by offering a digital representation of a building's lifecycle and streamlining maintenance [2,3].

Integrating 3D laser scanning with BIM has become pivotal in construction and facility management for enhancing asset management. This approach, known as scan to BIM, efficiently generates detailed digital models of structures, significantly improving visualisation, analysis, and management [4]. Its transformative impact on asset management practices offers comprehensive data for better decision-making. Scanning to BIM has demonstrated promising results in improving asset documentation and maintenance, mainly restoring historical buildings where blueprints are often unavailable [5,6].

Furthermore, organisations can derive significant value from implementing scan to BIM technology for developing an asset database. This process is extremely important as it directly contributes to creating accurate models that represent historical buildings as they currently exist. This is particularly crucial when the original geometric documentation of these buildings is either unavailable or incomplete [7]. This approach not only aids in the effective organisation and centralisation of asset information but also enhances overall asset management practices. Additionally, validating assets from the database is crucial for precision, accuracy, and reliability. Organisations can integrate scanning technology with BIM systems for comprehensive validation. This strategic fusion allows a deep dive into the asset data, enabling meticulous verification against actual conditions and specifications. In doing so, the trustworthiness of asset information is significantly elevated, paving the way for organisations to rely on this data with confidence and assurance. This enhanced reliability is critical for making informed decisions affecting short-term operational efficiency and long-term strategic planning.

However, recent advancements in asset management emphasize the importance of incorporating additional environmental and structural data, such as building usage patterns and maintenance history, to enhance the precision and accuracy of asset management models. Building usage patterns provide critical insights into the operational dynamics and lifecycle of assets, influencing wear and tear rates and informing maintenance strategies. Maintenance history, on the other hand, helps in understanding past performance issues and predicting future maintenance needs. Integrating these data types into asset management systems can significantly improve predictive maintenance and asset longevity, leading to more efficient and effective management practices.

The Faculty of Civil Engineering and Built Environment (FKAAB) at Universiti Tun Hussein Onn Malaysia faces significant challenges in managing its extensive assets, which include a 21,066 m² space containing 25 laboratories. Traditional asset management approaches have proven insufficient for such a complex environment, necessitating a more efficient and accurate system. This study aims to address these challenges by integrating scan to BIM technology with additional environmental and structural data to enhance asset management practices at FKAAB. By leveraging laser scanning data, building usage patterns, and maintenance history, this research seeks to develop a comprehensive asset database that improves visualization, coordination, and management practices within the faculty.

This paper details the methodologies and findings of the scan to BIM implementation at FKAAB, including the integration of building usage patterns and maintenance history into the asset management model. It provides an in-depth analysis of the process from data collection to BIM model development, integration with the ARCHIBUS asset management system, and the resulting improvements in asset management practices. The objectives of this study are to generate a reliable asset database through the integration of diverse data sources, validate the accuracy of the asset data, and demonstrate the practical benefits of scan to BIM technology in an academic setting. By doing so, this research contributes to advancing asset management practices and offers a blueprint for managing similar facilities efficiently.

2. LITERATURE REVIEW

This literature review addresses key parameters related to the impact of scan to BIM technology on asset management, with a particular emphasis on the FKAAB building.

2.1 Building Information Modelling (BIM)

BIM has always been interpreted as 3D software modelling that can produce virtual buildings in 3D instead of two dimensions (2D). BIM is more than 3D modelling software; it encompasses processes for managing digital data across a construction project's lifecycle, improving efficiency and communication [8,9]. As 3D modelling, BIM integrates diverse design information for use in planning, sustainability, and maintenance, among other phases [10]. In asset management, BIM can bring significant benefits in various aspects. BIM provides a "single source of truth" for asset data and information, enabling better collaboration among stakeholders and improving decision-making throughout the asset's lifecycle [11].

The use of BIM in asset management brings several significant advantages. It ensures the alignment of asset breakdown structures, work breakdown structures, and cost breakdown structures. This alignment, in combination with BIM, boosts transparency, tracks progress, and facilitates structured outcomes. Moreover, BIM significantly improves the monitoring of asset installation progress once assets are designated to specific rooms or spaces. By integrating BIM with Computerized Maintenance Management Systems (CMMS), organizations can efficiently analyze asset portfolio performance, enabling more effective data analysis and leading to informed decision-making. BIM also increases workforce effectiveness by providing unified asset data, ensuring that all stakeholders have access to accurate and up-to-date information [12]. It is essential to recognize that BIM and asset management complement each other across three critical scenarios: integrating existing assets into BIM, developing new assets within BIM environments, and managing both existing and new assets through BIM [11].

2.2 Building Information Modelling in Malaysia

In Malaysia, BIM was introduced in 2007 by Malaysian Public Works Department (JKR), which established the BIM Standard Manual and Guidelines, signaling a positive trend in its adoption. By 2019, BIM became mandatory for public projects exceeding RM 100 million, contributing to a notable % adoption rate of 55% by 2021 [13]. The government targets an 80% BIM adoption rate by 2025, highlighting its benefits, such as enhanced design visualization and improved cost management in the IBS industry [14,15]. However, challenges such as a lack of BIM tools and experts and intellectual property protection have been identified [16]. Despite the progress, the implementation of BIM in Malaysia is still at a relatively low level [17]. Many construction companies in Malaysia are familiar with the concept of BIM but have not yet implemented it in the management of their construction projects [18]. Barriers to BIM implementation include financial and legal issues, lack of awareness, and organizations' delay in adopting the technology [19].

2.3 Scan to BIM

Scan to BIM is a process that involves digitally capturing a physical space or site using 3D laser scanners and then using the captured data to create and maintain a BIM model. This technology is quickly becoming an integral part of the BIM process, allowing for creating accurate, data-rich, connected, and constructible BIM models from 3D scan data of physical spaces or sites [20]. Scanning to BIM can be divided into several stages, including identifying requirements, scan planning, data capture, and model creation. Before starting the scanning process, it is essential to determine the criteria for the desired model, such as the required building elements and the level of detail. Scan to BIM is used in various industries, including architecture, construction, civil engineering, and facility management. It has applications in reconstruction, restoration, conservation, scanning roads, volume calculations, clash detections, quality controls, and facility management planning [21].

The benefits of scanning to BIM are numerous. It enables more accessible design, simpler coordination between team members, and easier structure maintenance. Additionally, it allows for active project management at every step and facilitates collaboration among engineers, contractors, and architects. The technology also enables the quick production of highly accurate digital measurements and images, making it a valuable tool for various professionals. Scan to BIM is a technology that offers significant advantages in creating, developing, and maintaining BIM models. It has the potential to streamline processes, improve accuracy, and facilitate collaboration across different industries, making it an increasingly essential tool in construction and design [22].

2.4 Environmental and Structural Data in Asset Management

Recent advancements in asset management emphasize the importance of incorporating additional environmental and structural data, such as building usage patterns and maintenance history, to enhance the precision and accuracy of asset management models. Building usage patterns provide critical insights into the operational dynamics and lifecycle of assets, influencing wear and tear rates and informing maintenance strategies. Maintenance history helps in understanding past performance issues and predicting future maintenance needs. Integrating these data types into asset management systems can significantly improve predictive maintenance and asset longevity, leading to more efficient and effective management practices.

Studies have shown that incorporating building usage patterns into asset management models allows for better forecasting of maintenance needs and more accurate scheduling of maintenance activities. For example, areas with high usage frequencies tend to deteriorate faster, requiring more frequent inspections and maintenance. Maintenance history provides valuable information about the performance and reliability of assets over time, enabling the identification of recurring issues and the implementation of preventive measures to avoid future failures [25,26].

By integrating environmental and structural data with BIM, organizations can create more detailed and accurate asset management models. This integration facilitates a deeper understanding of asset conditions, leading to improved decision-making and optimized maintenance strategies. The combination of BIM and comprehensive data analysis enables organizations to move from reactive to proactive maintenance, ultimately extending the lifespan of assets and reducing operational costs [27,28].

2.5 Asset Management

Asset management is a structured approach to governing and maximizing the value a group or entity holds responsibility for, ensuring comprehensive oversight and practical realization of assets. It is a critical organizational culture and decision-making process, particularly in the context of transportation programs [24]. Asset management encompasses various disciplines, including fixed assets, Information Technology assets, and digital assets management. According to a study on building asset management systems, the aim is to review existing building inventory systems and evaluate factors such as ownership structure and asset structure. This research underscores the importance of a structured approach to managing building assets for performance evaluation and overall operational efficiency [25]. In construction, asset management is vital to organizing essential documents and plans for a project, boosting productivity and investment returns. It underlines the importance of effectively managing assets to enhance their value and ensure long-term performance. Building asset management combines management, finance, and engineering principles to oversee a building's physical components throughout its lifecycle, emphasizing the significance of an asset inventory for condition assessment and deterioration forecasting [26].

2.6 Leveraging BIM for Asset Database Creation

A database for building asset management, particularly inventory assets, is critical for organizations to track and manage their assets effectively. When creating an asset management database, it is essential to consider the asset database creation, consideration of inventory assets and implementation. Creating an asset database must clearly define what constitutes an asset for the organization, including all physical and non-physical items that hold value for the business [27]. This includes all physical and non-physical items that hold value for the business. Additionally, maintaining inventory assets requires comprehensive information, including brand, model, serial number, purchase date, warranty details, and location. Regular asset inventory updates and maintenance are essential to ensure accurate and up-to-date data [28]. Therefore, integrating BIM with asset management practice is an excellent idea since BIM enables sustainability and asset management through knowledge management [29]. Integrating BIM with real-world infrastructure data can improve asset management [30]. In conclusion, the integration of environmental and structural data into BIM models significantly enhances the accuracy and reliability of asset management systems. This strategic approach allows for more effective management of assets, leading to improved operational efficiency and long-term sustainability. The ongoing advancements in scan to BIM technology and data integration techniques continue to push the boundaries of asset management, offering new opportunities for innovation and improvement in the field.

3. METHODOLOGY PROCESS

This study employs the scan to BIM method, integrating 3D laser scanning technology with Autodesk Revit software to produce a precise digital image of the building. This image captures fine details critical for informed asset management practices. The procedure involves connecting this data to ARCHIBUS to create a centralized asset database, providing a repository for asset information and historical data. This method systematically examines asset life cycles, retrieving essential insights from the asset database to inform proactive and data-driven asset management procedures. Using scan to BIM technology makes the FKAAB building a prime example for studying and improving building asset management.

3.1 Preliminaries Study

A preliminary study in the context of scanning to BIM for building asset management involves several key activities. First, surveying the FKAAB lab provides fundamental information about their physical characteristics and surroundings. Second, figuring out how to apply scan to BIM in laser scanner data collection requires selecting rooms for laser scanning operations. This involves discussing the feasibility and relevance of each space for effective data capture. Additionally, engaging with Architecture students from FKAAB to learn about the operation and utilization of laser scanning equipment such as Leica BLK 360 and associated software Leica Cyclone REGISTER 360 is essential. This collaborative learning process ensures a comprehensive understanding of the technology and its potential applications in data collection. The outcomes of this preliminary study will likely guide the development of a more structured and detailed research plan for integrating scan to BIM within the academic setting.

3.2 Laser Scanner Data Collection

The methodology involves a Traverse survey and a Trigonometry method to obtain the coordinate placement of the laser scanner device. In the Traverse survey for S2 to S1, the bearing for the datum has been assumed to be 180˚00’00’’. The bearing and distance for each station (S1,S2, and S3) are recorded, and the coordinate was calculated. Meanwhile for line S3 to S4 can’t observe directly. For S4 coordinate, the length from S4 to SX and from SX to S3 measured perpendicular by tape, and trigonometry is applied for coordinate calculation. The illustration can be seen in Figure 1. Proceed to the 3D point cloud data capture using the Leica BLK360 laser scanner (see Figure 2) connected with Leica Cyclone FIELD 360 for monitoring and initial processing. After that in Leica Cyclone REGISTER 360 software for data refinement. The processed data can be exported into alternative file formats like *.rcp and Autodesk Recap Pro for further point cloud manipulation. After converting the point cloud to Autodesk Recap Pro format, it is imported into Autodesk Revit, where image tracing is performed to model building elements.

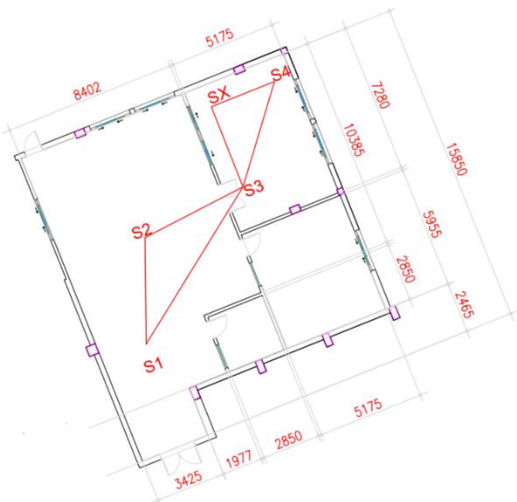


Fig. 1. Illustration for each station

Fig. 2. Leica BLK360 laser scanner setup at Station 1

3.3 Incorporation of Environmental and Structural Data

To enhance the precision and accuracy of the asset management model, this study incorporates additional environmental and structural data, specifically building usage patterns and maintenance history.

3.4 Building Usage Patterns

Building usage patterns were manually collected through occupant surveys and manual observations. These surveys and observations recorded the frequency and duration of usage for different spaces, providing insights into which areas experience the most wear and tear.

3.5 Maintenance History

Maintenance history data were obtained from facility management records, detailing past maintenance activities, repair histories, and performance issues. This data was critical for identifying recurring problems and predicting future maintenance needs.

3.6 Integration with BIM

These environmental and structural data were integrated into the BIM model using ARCHIBUS software. The building usage data were mapped to specific rooms and assets within the BIM model, allowing for detailed analysis of usage patterns. Maintenance history was linked to corresponding assets, providing a comprehensive view of each asset's performance over time. This integration facilitated a more precise and accurate asset management model, capable of predicting maintenance needs and optimizing asset performance.

3.7 Develop an Asset Database

The process of creating an asset database involved several stages. Initially, an asset database in Microsoft Excel was created following ARCHIBUS standard data requirements. The ARCHIBUS Extension for Revit was used to extract data directly from the Revit model and catalog the assets into ARCHIBUS. This involved establishing synchronization connections between Revit levels and ARCHIBUS floor assets. The Revit asset parameters were mapped to the appropriate ARCHIBUS equipment tables, allowing the system to capture and transform the data. Once the assets were in ARCHIBUS, they could be viewed in the Smart Client or Web Central applications. The floor plan was captured to publish the assets in ARCHIBUS Web Central 3D, integrating the assets into the system's functionality.

3.8 Validate Asset from Asset Database

The methodology for validating assets involved ensuring the accuracy and completeness of the data after integrating it into the ARCHIBUS system. For example, if a specific furniture code was searched in ARCHIBUS and the data was found, it was considered validated. This validation process ensured that the asset data was successfully transferred from the BIM model and integrated into the ARCHIBUS asset management system.

4. RESULT AND DISCUSSION

This section presents the results and discussion of the scan to BIM implementation at FKAAB. The process is divided into three main phases: laser scanner data collection, asset database development, and asset validation.

4.1 Data result from traverse survey

The first phase involved the traverse survey results. (Table 1) indicated from assumed bearing S2 to S1 and coordinate S2 as N18000.00 E9000.00. The linear misclosure was calculate and define as second class survey (>1:4000). The coordinates for the other stations can derived from the computation.

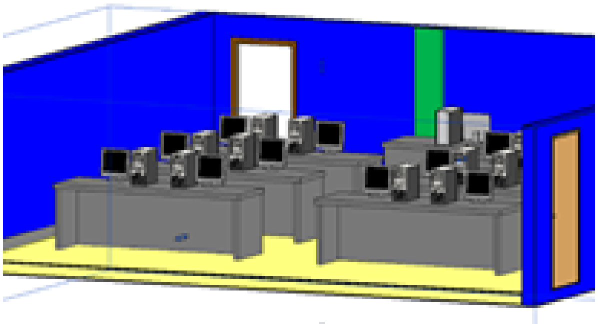
Table 1. Traverse survey result

Station	Distance (m)	Coordinate	
		N/S	E/W
S2		18000.00	9000.00
S1	6.754	18006.75	8999.99
S3	10.412	17997.83	8994.63
S2	5.791	18000.00	9000.00

4.2 Laser Scanner Data Output

Eliminating unnecessary points from the point cloud model is essential for enhancing its overall accuracy and quality. By removing unwanted points, the visual clarity of the model is significantly improved. Unwanted points often introduce noise and clutter, which can obscure the actual features of the scanned object. Therefore, cleaning up point clouds refines the model and streamlines its interpretation, resulting in a cleaner and more visually comprehensible representation. Tracing the point cloud process can be tricky and challenging since it needs to be done carefully according to their dimension. This is necessary to ensure that the tracing accurately reflects the actual features and geometry of the scanned object. Figure 3 shows the BIM model after the tracing process.

(a)



(b)

Fig.3 Tracing result (a) Top view; (b) Cross section

The dimension measured as shown in Figure 4. The comparison outlined in Tables 2 and 3 provides a comprehensive analysis of the variations between the measurements obtained from point cloud data and those taken on-site. Disparities were noted, likely due to potential human errors or the inherent variability of point cloud data, posing challenges in achieving 0.000m - 0.005m measurements in horizontal. Meanwhile for vertical measurement accuracy within 0.003m – 0.094m.

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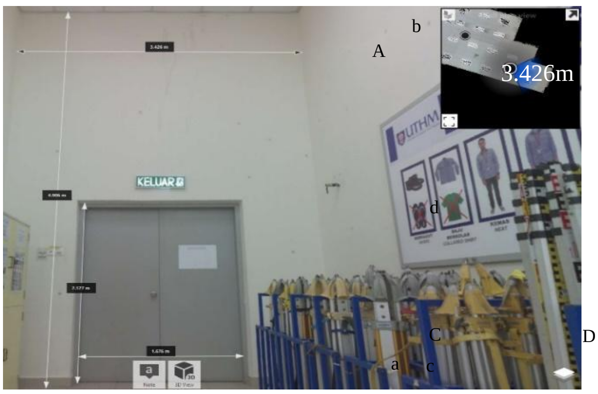


Fig.4 Point cloud measurement in Recap Pro

Table 2. X-axis measurement comparison

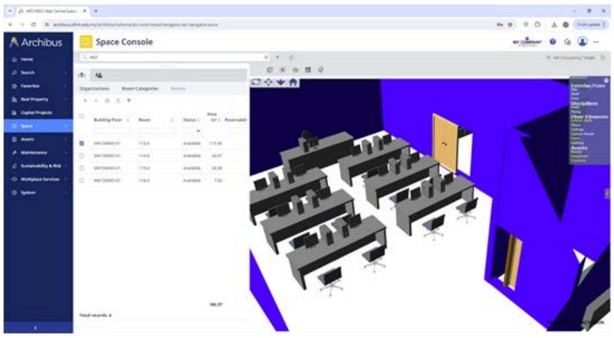
X-axis			
Location	Point Cloud (m)	On-site (m)	Difference (m)
A-B	3.426	3.425	0.001
C-D	1.676	1.679	0.003
E-F	1.885	1.880	0.005
GH	10.385	10.385	0.000
IJ	5.179	5.175	0.004

Table 3. Y-axis measurement comparison

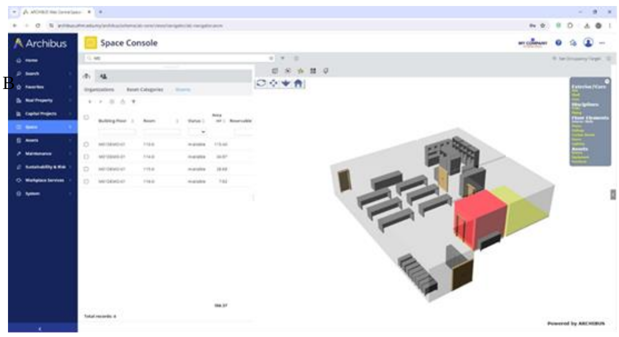
Y-axis			
Location	Point Cloud (m)	On-site (m)	Difference (m)
ab	4.906	5.000	0.094
cd	2.127	2.130	0.003
ef	0.908	0.914	0.006
gh	4.914	5.000	0.086
ij	2.785	2.800	0.015

4.3 Asset Database Output

The second phase focused on developing an asset database. The standard data requirements for seven pieces of furniture and equipment were fulfilled based on the list of capital assets and inventory with observations. Some information was missing while some was provided. Figure 5 presents the results of integrating BIM into ARCHIBUS. The BIM model was used to generate asset data in Revit and publish the BIM model to the asset management system (ARCHIBUS). This process culminated in the development of a comprehensive asset database, allowing facility managers to view and interact with 3D models in Web Central effortlessly.



(a)



(b)

Fig. 5 BIM model to ARCHIBUS (a) View with building elements; (b) View of furniture

4.4 Asset Validation Output

The third phase involved validating the assets. After importing all the data from Excel and Revit into ARCHIBUS, it was necessary to validate the assets to ensure data accuracy and completeness. If a specific furniture code was searched in ARCHIBUS and the data was found, it was considered validated. This process ensured that the asset data was successfully transferred from the BIM model and integrated into the ARCHIBUS asset management system. Figures 6 and 7 depict the validated assets for furniture and equipment, respectively.

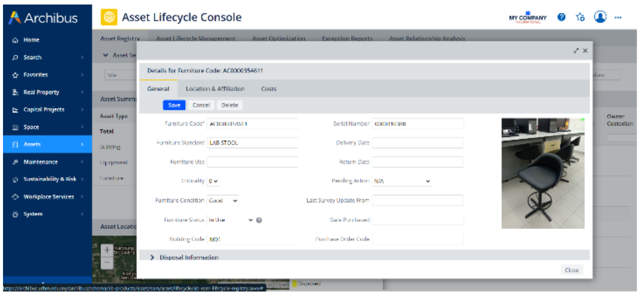


Fig. 6 Asset in ARCHIBUS (Furniture)

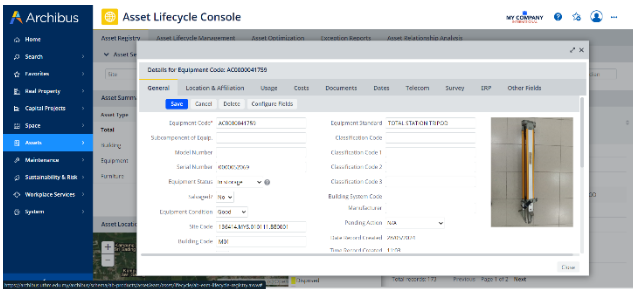


Fig. 7 Asset in ARCHIBUS (Equipment)

4.5 Integration of Environmental and Structural Data

4.5.1 Integration Limitations:

Although the system was set up to facilitate the integration of environmental and structural data, such as building usage patterns and maintenance history, these data were not available for the current study. Therefore, the focus was placed on implementing the integration of scan to BIM technology up to the point of generating 3D BIM models and incorporating them into the ARCHIBUS system.

4.5.2 Building Usage Patterns and Maintenance History: While the plan was to include building usage patterns collected through occupant surveys **and** manual observations, as well as maintenance history data from facility management records, these data could not be obtained. As a result, the study concentrated on the available data and processes to integrate the scan to BIM technology effectively.

4.6 Improvements in Asset Management Practices.

Despite the absence of environmental and structural data, the integration of scan to BIM technology into the ARCHIBUS system showed significant improvements in several key areas:

4.6.1 Precision and Accuracy

The scan to BIM process improved the precision and accuracy of asset condition assessments. This allowed for more accurate representations of the building's current state and better planning of maintenance activities.

4.6.2 Resource Allocation:

The enhanced model facilitated more efficient allocation of maintenance resources by providing a clear and detailed view of the building's assets. This ensured that maintenance activities were better planned and executed.

4.6.3 Predictive Maintenance:

The integration with ARCHIBUS allowed for the potential future implementation of predictive maintenance strategies once additional data is available. This could further reduce downtime and extend asset lifespan.

4.6.4 Informed Decision-Making

The comprehensive view of asset conditions provided by the BIM model supported more informed decision-making. Facility managers could rely on accurate and up-to-date information to plan maintenance activities, allocate resources, and make strategic decisions regarding asset management.

4.7 Case Study: FKAAB Building

The Faculty of Civil Engineering and Built Environment (FKAAB) at Universiti Tun Hussein Onn Malaysia provided a complex environment to test the enhanced asset management model. The building, with its extensive 21,066 m² space containing 25 laboratories, posed significant challenges for traditional asset management approaches. The integration of scan to BIM technology addressed these challenges effectively.

4.7.1 Data Collection

Laser scanning data was collected using the Leica BLK360 laser scanner, and the point cloud data was processed and integrated into Autodesk Revit. Despite the absence of additional data on building usage patterns and maintenance history, the focus remained on the integration of scan to BIM technology up to the point of generating 3D BIM models.

4.7.2 Model Development

The collected data was integrated into the BIM model using ARCHIBUS software. This integration facilitated a detailed analysis of asset conditions and performance, although it was limited to the available data.

4.7.3 Results

The enhanced BIM model significantly improved asset management practices at FKAAB. The model's capabilities allowed for better planning and execution of maintenance activities, even in the absence of comprehensive environmental and structural data. Facility managers were able to make informed decisions based on the accurate and reliable asset data available.

In conclusion, while the integration of environmental and structural data was not achieved due to data unavailability, the implementation of scan to BIM technology up to generating 3D BIM models and integrating them into the ARCHIBUS system significantly enhanced the precision and accuracy of the asset management system. This approach laid the groundwork for future improvements once additional data becomes available, allowing for more effective management of assets and improved operational efficiency.

4.8 Long-term Monitoring Programs

Implementing long-term monitoring programs is essential to validate the model's predictions and track actual changes in asset conditions over time. By continuously collecting data through IoT sensors and manual inspections, the accuracy and reliability of the asset management system can be further improved. This would enable real-time monitoring, predictive maintenance, and timely interventions, ensuring the longevity and optimal performance of the assets.

In conclusion, while the integration of environmental and structural data was not achieved due to data unavailability, the implementation of scan to BIM technology up to generating 3D BIM models and integrating them into the ARCHIBUS system significantly enhanced the precision and accuracy of the asset management system. This approach laid the groundwork for future improvements once additional data becomes available, allowing for more effective management of assets and improved operational efficiency. The inclusion of long-term monitoring programs would further strengthen the model's predictive capabilities and ensure the sustained performance of the assets.

5. CONCLUSION

This study successfully demonstrated the application of scan to BIM technology for asset management in the Faculty of Civil Engineering and Built Environment (FKAAB) at Universiti Tun Hussein Onn Malaysia. By integrating laser scanning data with BIM, a comprehensive and accurate digital representation of the building was developed. This model facilitated the creation of a centralized asset database in ARCHIBUS, significantly enhancing the visualization, coordination, and management of assets. The process included meticulous validation to ensure data accuracy and reliability, which is crucial for informed decision-making in both short-term operations and long-term strategic planning.

The study met its objectives by generating a reliable asset database through the integration of laser scanning data and BIM, validating the accuracy of the asset data, and demonstrating the practical benefits of scan to BIM technology in an academic setting. The results underscored the potential of scan to BIM technology to address common challenges in asset management, such as data inaccuracies and inefficient asset tracking. The study highlighted the importance of eliminating unnecessary points from point cloud data to improve model accuracy and the utility of integrating BIM data with asset management systems for better asset documentation and maintenance.

Despite these advancements, the study faced challenges, including integrating different software versions and capturing concealed elements within the building. These challenges point to the need for further research and development in this field.

5.1 Limitation of the research

The primary limitations of this research include the unavailability of comprehensive environmental and structural data, reliance on manual data collection methods prone to human error, and a focus on a single case study, limiting generalizability. The validation process was restricted to data accuracy within the BIM model and its integration into the ARCHIBUS system, without long-term validation of the model's predictive capabilities. Additionally, the study's reliance on specific technologies and software, which may have interoperability issues with other systems, further constrained the scope and applicability of the findings.

5.2 Future research direction

Future research should focus on automating the data integration process to streamline workflow and reduce potential errors associated with manual data entry. This includes integrating comprehensive environmental and structural data, such as continuous building usage patterns and detailed maintenance history, utilizing IoT sensors and automated methods for more accurate asset management models. Expanding the application of scan to BIM technology to other types of facilities, such as historical buildings or large industrial complexes, could provide further insights into its benefits and limitations. Long-term monitoring and validation of model predictions are crucial, and further studies should explore integrating advanced technologies such as Artificial Intelligence (AI) and Machine Learning (ML) with scan to BIM processes to enhance predictive maintenance and automated anomaly detection. Investigating the economic implications of implementing scan to BIM technology, including cost-benefit analyses and return on investment (ROI) studies, could provide valuable information for stakeholders. Additionally, improving interoperability and standardization of technologies will facilitate seamless data integration, and understanding barriers to adoption and developing user training programs will enhance the effectiveness and acceptance of scan to BIM technology in asset management. Ongoing research and technological advancements are essential to fully realize the potential of scan to BIM technology and address existing challenges.

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