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Terrestrial Laser Scanning for 3D Assets Registry

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Abstract

This study aimed to assess the feasibility of using terrestrial laser scanning (TLS) technology for creating 3D asset registries in facilities management. The research utilized a case study approach to scanning an industrial facility, and the resulting data was processed to create a 3D model of the assets. The study found that TLS technology can produce highly accurate and detailed 3D models of assets, which can aid in asset management and maintenance. However, the technology has some limitations, such as cost and the need for skilled operators. The average accuracy findings reveal a value less than or equal to 2 mm (≤ 0.002 m) for each object, therefore the study suggests that TLS technology can be a valuable tool for asset management and recommends further research in this area.

A. Introduction

The increasing complexity of modern facilities and infrastructure has made asset management a crucial task for facility managers, engineers, and other stakeholders [1], [2]. One of the critical components of effective asset management is the creation of a detailed 3D asset registry, which can provide a comprehensive overview of the physical assets, such as buildings, equipment, and furniture [3]. Terrestrial Laser Scanning (TLS) is a technology that has gained popularity in recent years due to its ability to create accurate and detailed 3D models of indoor environments [4], [5]. This research paper aims to explore the use of TLS for creating 3D asset registries in indoor environments and identify its potential benefits and drawbacks. Specifically, the research question is: How can terrestrial laser scanning create 3D asset registries in indoor environments? The paper will begin with an overview of TLS and 3D asset registries, followed by a discussion of existing research and methodologies. The results of a case study using TLS for 3D asset registry creation will then be presented, followed by a discussion of the potential benefits and drawbacks of using TLS. Finally, the paper will conclude with a summary of findings and suggestions for future research.

Terrestrial Laser Scanning (TLS) is a technology that uses lasers to collect data on the surfaces of objects or environments [6]–[9]. The data collected is a point cloud, which can be used to create a detailed 3D model of the scanned area [10]. The accuracy of the data collected depends on various factors, such as the resolution of the scanner and the distance between the scanner and the object being scanned [11]. The basic equation for terrestrial laser scanning is as follows:

$$R = c * t / 2 \tag{1}$$

Where $\boldsymbol{c}$ is the speed of light, $\boldsymbol{t}$ is the time of flight of the laser pulse from the scanner to the object and back, and $\boldsymbol{R}$ is the distance between the scanner and the object. By using this equation and measuring the time of flight of the laser pulse, the scanner can calculate the range of the object [12]. By scanning the object from multiple positions, the scanner can create a point cloud that represents the object's surface geometry. This point cloud can then be processed to create a 3D model of the object [13].

Regarding methodology, TLS involves using a laser scanner, which is placed at various locations within the scanned area. The scanner sends out laser pulses, which bounce off the surfaces of the objects within its range. The time taken for the laser pulse to return to the scanner is used to calculate the distance between the scanner and the object [14]. This process is repeated from various positions to capture the entire area of interest. The resulting data is then processed to create a point cloud, which can be used to create a 3D model [15]. Based on the horizontal and vertical angles $(\boldsymbol{\varphi}, \boldsymbol{\theta})$ of the laser beam, the position of the reflecting point $(\boldsymbol{Xp}, \boldsymbol{Yp}, \boldsymbol{Zp})$ can be determined using Formula (2),(3),(4) concerning the coordinate system of the instrument (Figure 1).

$$X_p = R \sin\theta \cos\varphi \tag{2}$$
$$Y_p = R \sin\theta \sin\varphi \tag{3}$$
$$Z_p = R \cos\theta \tag{4}$$

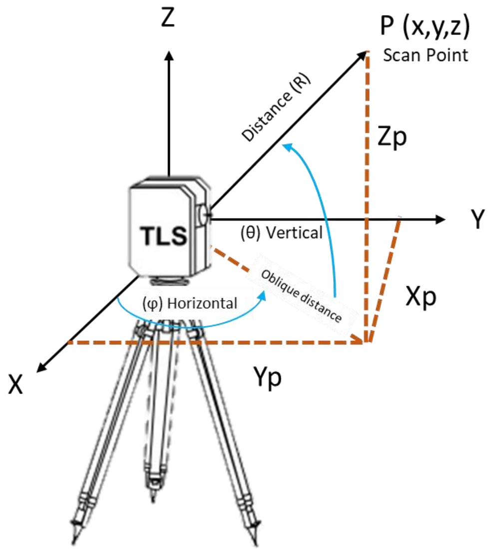

Figure 1. Working principle of a laser Scanner

The technique has been used in various applications such as construction, surveying, and mapping. In asset management, TLS can create detailed 3D models of assets such as buildings, infrastructure, and furniture [16], [17]. 3D asset registries contain information about physical assets such as buildings, equipment, and furniture. The registry typically includes information such as each asset's location, type, condition, and maintenance history [18]. By creating a 3D model of the assets, the registry can provide a more comprehensive overview of the assets, which can help in planning and maintenance tasks [19].

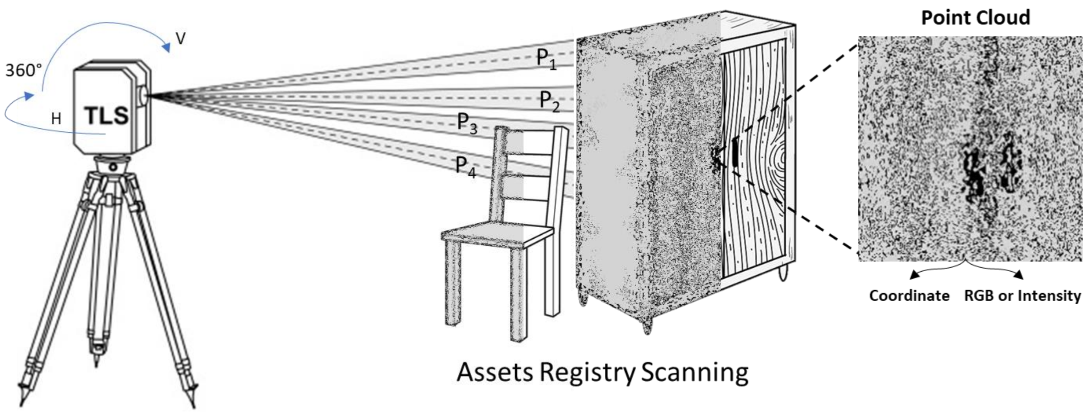

Figure 2. Scanning illustration of Assets Registry

TLS has emerged as a promising technology for creating 3D asset registries. Its ability to create accurate and detailed 3D models of indoor environments makes it a valuable tool for asset management tasks [20]. Figure 2 show the illustration of Assets Registry Scanning. There is a need for overlapping in scanning to get the perfect 3D shape [21]–[23]. This scanning produces point cloud data with coordinates (position) and RGB or Intensity (color) [24], [25]. Various techniques in measuring distance can be employed to determine the separation $(\boldsymbol{R_{Dist}})$ between the scanner and the object (P_1) and (P_2), as shown by Formula (5).

$$R_{Dist} = \sqrt{\left(X_{p_2} - X_{p_1}\right)^2 + \left(Y_{p_2} - Y_{p_1}\right)^2 + \left(Z_{p_2} - Z_{p_1}\right)^2} \quad (5)$$

B. Research Method

The methodology used in this research includes several steps to obtain and process the necessary data for creating a 3D asset registry using terrestrial laser scanning. First, data were collected using a Faro Terrestrial Laser Scanner to scan the objects of interest, such as chairs, tables, cabinets, and furniture. In this case, the location is the Geodesy Engineering building, ITN Malang campus. During the scanning process, the surrounding area of the object was cleared to facilitate the processing of point cloud data. Second, the radial method obtained coordinate data of control points from static GPS observations. The weather condition was favorable during the observation period, ensuring high-quality data. The obtained data were used as control points in the georeferencing process to ensure that the object's coordinates in the model were the same as in the field. Third, total station measurements were taken to support the georeferencing process by shooting retro points that have been established in the building. Fourth, data about the assets in the building, such as dimensions and information about each asset, were collected using measuring tools and observation. The collected data was used to model the assets' size and shape. After obtaining the data, several steps were performed to process the point cloud data:

1) The point cloud data was imported into the TBC software to ensure the data was compatible with the modeling process.
2) The data registration process was conducted to merge multiple-point cloud data.
3) Filtering was performed to remove the unnecessary point cloud data.

Finally, the modeling process was conducted using the processed point cloud data. The point cloud data was used to create 3D models of the building and its assets. The number of point cloud data used for each model varies depending on the modeled asset. The resulting 3D asset registry provides additional information about the assets and complements the building model.

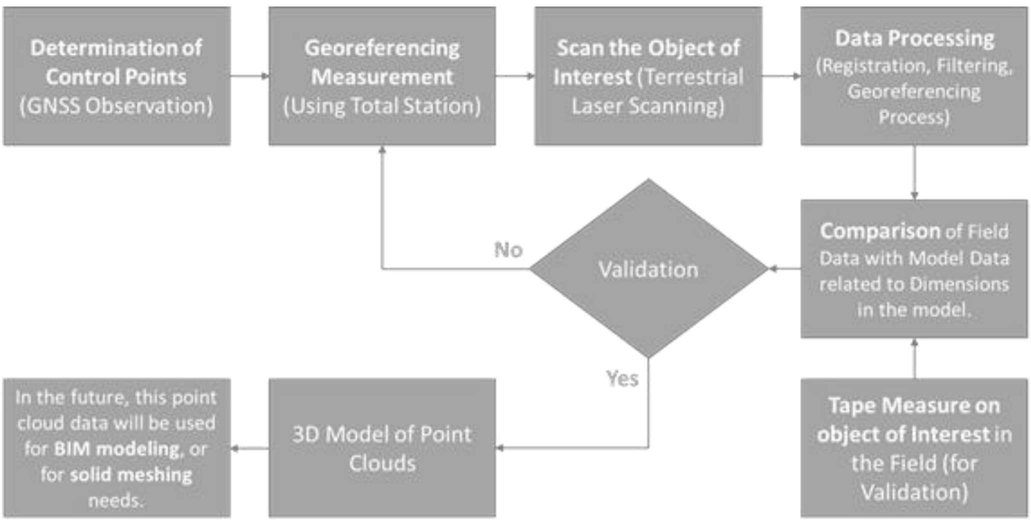

Figure 3. Flowchart of methodology

C. Result

The study results show that terrestrial laser scanning is an effective method for 3D asset registry. The scanning process captured detailed data on various assets such as chairs, tables, cabinets, and other furniture. The point cloud data obtained from the TLS scanning was then processed through several stages, including registration and filtering, to obtain accurate and usable data. The use of GPS observation and total station measurement also helped to ensure the accuracy of the data. TLS measurements take less than 5 minutes with a density of 1.2 mm.

The resulting 3D models of the assets could accurately represent the objects in the real world, with dimensions and details captured in high resolution. The models were also georeferenced using GPS observations and total station measurements, allowing for precise location data to be attached to each asset. The study demonstrates the potential of terrestrial laser scanning as a tool for 3D asset registry in various settings. The accuracy and detail provided by the scanning process can benefit facilities management, asset tracking, and other applications.

The 3D asset registry was created by processing the data obtained from terrestrial laser scanning using the Faro scanner. The resulting Point Cloud data underwent several processing stages, including input into the TBC software, multiple scan data registration, and filtering unused Point Cloud data. The processed data was then used for modeling the objects and assets in the ITN Malang campus, including chairs, tables, cabinets, and other furniture. The 3D asset registry created from the TLS data provides a detailed representation of the objects and assets on the campus (see Figure 4). Each asset is accurately modeled and positioned in the Point Cloud, allowing for precise measurements and space analysis. The registry also includes information about the assets, such as their dimensions and type, providing a comprehensive overview of the campus facilities (see Table 1).

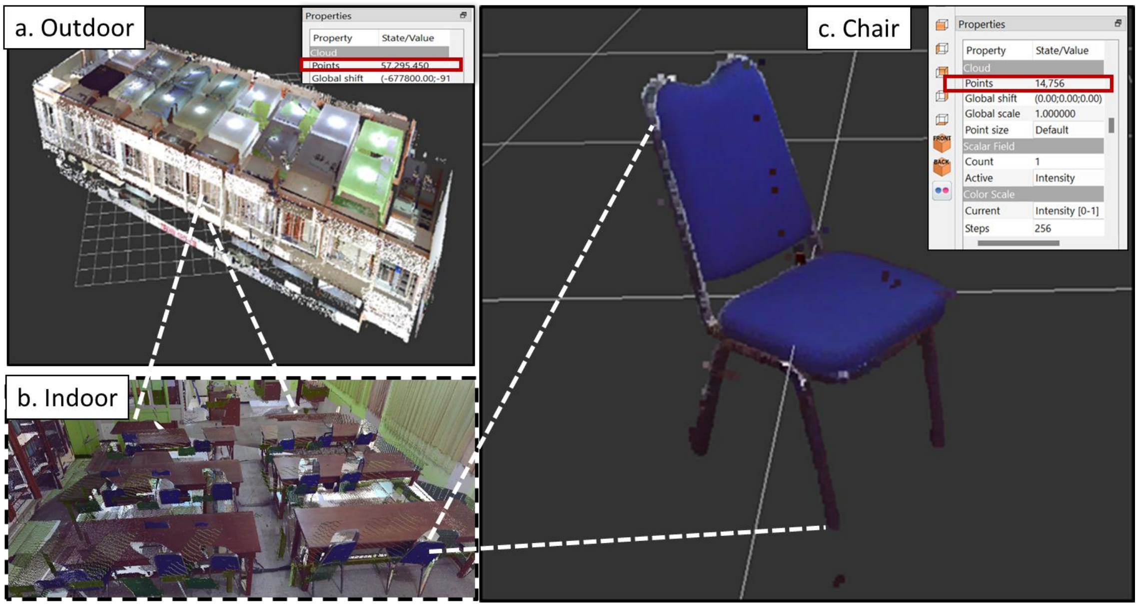

Figure 4. Scanning Results; (a) Outdoor Environment of Geodesy Building, (b) Indoor Environment, (c) Facility of Geodesy Environment Assets

Based on the methodology outlined, terrestrial laser scanning has created a highly accurate and detailed 3D asset registry of the Gedung Program Studi Teknik Geodesi Institut Teknologi Nasional Malang (ITN Malang). The accuracy achieved in the scanning process was ensured by using GPS for the control points and Total Station to support the georeferencing process. The resulting Point Cloud data was then processed using various software tools to create detailed 3D models of the various assets within the building. Filtering techniques helped ensure that only relevant Point Cloud data was used in the modeling process, which further contributed to the accuracy and level of detail achieved.

The level of detail achieved in the 3D asset registry is relatively high, with the models accurately representing the physical characteristics and dimensions of the various assets scanned. This level of detail can be handy in various applications such as facility management, asset tracking, and maintenance. However, it should be noted that the accuracy and level of detail achieved depend on the scanning equipment used, as well as the skill and expertise of the operators. Therefore, it is essential to ensure that the equipment is regularly calibrated and operators are appropriately trained to ensure consistent and accurate results.

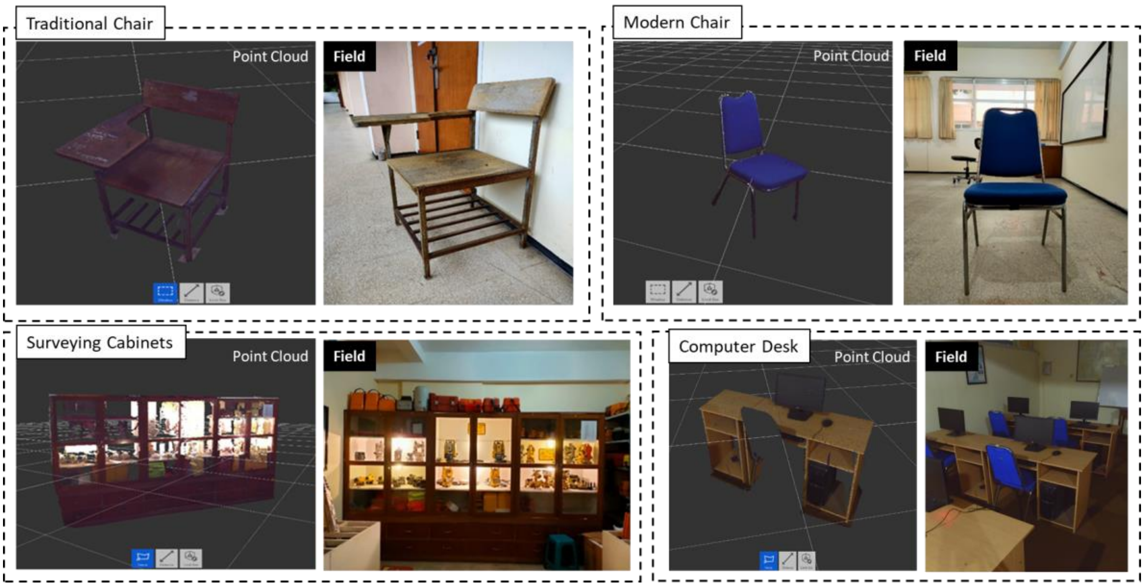

Figure 5. 3D Assets Registry Models

Based on a comparison of the model created from Point Cloud data with Field Data using a measuring tape, numerous samples examined got results with the accuracy shown in Table 1. These results are quite accurate for recording indoor assets and more efficient than a paper-based asset register and measurement using simply a measuring tape. The findings of the 8 samples evaluated for average accuracy (MSE) were length (2 mm), width (1 mm), and height (2 mm), while the overall accuracy (RMSE) of asset measurements with the number of samples given was length (5 cm), width (3.2 cm), and height (4.9 cm).

These findings suggest that using TLS with 3D model outcomes that can be seen from all directions, including dimensions, coordinates, and intensities, is more effective and efficient when handling very large and complex facility management.

Table 1. Comparison of Point Cloud Data with Field Data

Name	Model Dimension (m)			Field Dimension (m)			Results (m)		
	L	W	H	L	W	H	σL	σW	σH
Desk ½ Bureau	1.125	0.697	0.790	1.211	0.650	0.750	0.007	0.002	0.001
Long Desk	2.470	0.615	0.765	2.460	0.628	0.753	0.000	0.000	0.000
2 Doors Glass Cabinet	1.285	0.500	1.645	1.200	0.440	1.750	0.007	0.003	0.011
4 Doors Glass Cabinet	2.415	0.500	1.645	2.410	0.451	1.690	0.000	0.002	0.002
Whitebo ard	2.438	0.160	1.237	2.450	0.160	1.223	0.000	0.000	0.000
Blue Fukuda Chair	0.475	0.417	0.914	0.480	0.410	0.900	0.000	0.000	0.000
Book Cabinets	2.082	0.311	1.732	2.006	0.300	1.800	0.005	0.000	0.004
Surveyin g Cabinets	3.625	0.528	2.160	3.620	0.522	2.150	0.000	0.000	0.000
						MSE	0.002	0.001	0.002
						RMSE	0.050	0.032	0.049

While terrestrial laser scanning technology has proven to be effective for creating a 3D asset registry, some potential issues and challenges may arise during the scanning process. Some of these issues and challenges include:

1) Weather conditions: The accuracy of the scanning data can be affected by weather conditions such as rain, fog, or extreme heat.
2) Limited scanning range: The laser scanner's range is limited; therefore, multiple scans may be required to capture the entire asset or object of interest.
3) Obstacles: Objects in the surrounding environment, such as furniture or people, may obstruct the scanning process and limit the accuracy of the data captured.
4) Time-consuming process: Scanning can be time-consuming, especially when dealing with significant assets or objects.
5) Data processing: Processing the large amounts of data collected during the scanning process can be a challenge, and may require specialized software and technical expertise.
6) Cost: The use of terrestrial laser scanning technology can be expensive, especially when scanning significant assets or multiple objects.

Addressing these potential issues and challenges requires careful planning and execution of the scanning process. For example, selecting a day with good weather conditions, planning the scanning process to avoid obstacles, and using specialized software and technical expertise to process the data collected can help to mitigate these issues. Additionally, considering the cost-benefit analysis may be necessary to determine if terrestrial laser scanning technology is justified for a particular project.

D. Discussion

Terrestrial laser scanning has several benefits for creating 3D asset registries. One of the main advantages is its ability to capture a large amount of data in a short amount of time. This allows for quick and accurate measurement of objects (Table 1) and the ability to create detailed 3D models of assets (Figure 5).

Another benefit of terrestrial laser scanning for 3D asset registries is the ability to perform non-destructive measurements. This means that the scanning process does not damage the object being measured, which can be essential for preserving historical or valuable assets. However, some potential drawbacks exist to using terrestrial laser scanning for 3D asset registries. One challenge is the cost of the equipment and software required for scanning and processing the data. This can be a significant investment, particularly for smaller organizations or projects with limited budgets. Another potential area for improvement is the level of expertise required to operate the equipment and software effectively. Skilled technicians are needed to position and operate the scanner properly and to process and interpret the resulting data. This can be a limiting factor for organizations with limited personnel or resources. Lastly, there can be limitations in the accuracy and level of detail achieved with terrestrial laser scanning. Factors such as weather conditions, surface reflectivity, and distance from the object being scanned can all impact the quality of the data collected. Additionally, certain types of objects, such as those with complex shapes or reflective surfaces, may be more difficult to accurately capture with terrestrial laser scanning.

While there are some challenges and limitations to using terrestrial laser scanning for 3D asset registries, its benefits can make it a valuable tool for accurately measuring and modeling assets in a non-destructive manner. Terrestrial laser scanning is a powerful technology for creating 3D asset registries. However, there are other technologies available for asset management. Other technologies include photogrammetry, LiDAR, and mobile mapping. Photogrammetry involves using photographs taken from different angles to create 3D models. It is a cost-effective technology that can produce high-quality results. However, it requires good lighting conditions and can be affected by shadows and reflections. LiDAR uses laser beams to measure distance and create 3D models. It is a highly accurate technology that can work in low-light conditions. However, it is more expensive than photogrammetry and may require specialized equipment. Mobile mapping involves mounting cameras and other sensors on a vehicle and driving around the area of interest to capture data. It is a fast and efficient technology that can cover large areas quickly. However, it may produce a different level of detail than terrestrial laser scanning or LiDAR. Each technology has its strengths and weaknesses, and the choice of technology will depend on the project's specific needs. For asset management, the level of detail required and the available budget will be key factors in selecting a technology.

The use of terrestrial laser scanning for 3D asset registries is a relatively new and rapidly evolving technology, and several areas could benefit from future research. One area that needs further investigation is the development of automated feature extraction algorithms to extract specific assets from point cloud data. This would reduce the need for manual annotation, making the asset registry process more efficient. Another area for future research is the integration of TLS with other technologies, such as photogrammetry and BIM, which could lead to a more comprehensive asset management system.

Furthermore, future research can focus on optimizing the scanning process, such as developing faster and more accurate scanning equipment and improving the registration and alignment of point cloud data. Additionally, the research could also explore the use of TLS for monitoring the condition of assets over time, allowing for predictive maintenance and cost savings. Finally, there is a need for research into the legal and ethical implications of 3D asset registries, including data ownership, privacy, and protection. The potential applications of TLS for 3D asset registries are vast, and future research will continue to push the boundaries of what is possible with this technology.

E. Conclusion

The study highlights the potential of using terrestrial laser scanning for creating 3D asset registries, which can significantly improve asset and facilities management. The high accuracy and level of detail achieved through the scanning process provide a more comprehensive understanding of the assets and their condition. This information can be used for maintenance planning, space management, and renovation projects, among other things. The 3D asset registry also provides a powerful visualization tool for communication with stakeholders, allowing them to see the facility's current state and plans in a clear and accessible way. Seeing the results of the average accuracy reveals a value less than or equal to 2 mm for each object, thus it provides recommendations in recording assets including structures and facilities inside them.

Furthermore, the study also identifies the potential challenges and limitations of the technology, such as the need for trained personnel, the cost of equipment, and the processing time required to create the 3D models. Therefore, it is important to carefully weigh the costs and benefits before using terrestrial laser scanning for asset management. The findings of this study have important implications for asset and facilities management, highlighting the potential of terrestrial laser scanning as a valuable tool for creating comprehensive 3D asset registries.

Future research in this area could focus on developing and refining techniques for improving the accuracy and level of detail of 3D asset registries created using TLS. This could involve investigating new methods for processing and analyzing point cloud data or exploring the potential of new technologies, such as augmented reality and machine learning to enhance the capabilities of 3D asset registries. Additionally, further research could explore the potential of integrating 3D asset registries with other asset management and facilities management systems, such as computer-aided facilities management (CAFM) or building information modeling (BIM). This could involve investigating how 3D asset registries can be used to enhance the effectiveness of these systems or exploring the challenges and opportunities involved in integrating 3D asset registries with other technologies and processes.

Finally, the research could also focus on investigating the economic and environmental benefits of using 3D asset registries for asset management and facilities management. This could involve conducting cost-benefit analyses of implementing 3D asset registries in different contexts or investigating how 3D asset registries can improve sustainability and reduce environmental impacts in facilities management.

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