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A NEW APPROACH IN IMMOVABLE ASSET MANAGEMENT USING 3D SPATIAL SPACE

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ABSTRACT

Effective asset management is crucial for organizations that provide high-quality services. However, the management of immovable assets often faces challenges due to time-consuming, tedious, and error-prone paper-based practices. To address these issues, the Malaysian government has introduced MySPATA (*Sistem Pengurusan Aset Tak Alih Kerajaan*), an electronic-based solution aimed at improving asset management. Despite its implementation, MySPATA has not fully resolved the complications associated with locating and managing assets. This study proposes integrating three-dimensional Geographic Information Systems (3D GIS) into the asset management system to enhance productivity and accuracy. This research focuses on Taman Kobena Hall, which is managed by Majlis Bandaraya Johor Bahru (MBJB), utilizing detailed LiDAR scanning and aerial photogrammetry to create an accurate 3D model of the building. The integration of 3D GIS into the asset management system using ArcGIS software enables efficient asset registration, detailed visualization, and comprehensive data querying. The findings demonstrate that 3D visualization significantly improves asset location tracking and reduces reliance on paper-based processes, thus promoting continuous asset updates. The study also addresses the strengths and limitations of this approach. While the initial creation and maintenance of detailed 3D models require significant time and resources, the benefits of improved accuracy, better decision-making, and enhanced visualization are substantial. This research provides robust proof of the concept of integrating 3D GIS in immovable asset management and offers valuable insights for broader applications in various industries.

Keywords: Asset management, 3D GIS, immovable assets, 3D visualization.

INTRODUCTION

The asset management system has been developed long ago in the hope of providing citizens with great service. However, asset management, specifically of immovable assets has been experiencing complications in its management, where it is found to be time-consuming, tedious, and error-prone due to its paper-based practice, which requires manual inspection (Md Aslam & Ahmad Tarmizi, 2018). This challenge is not unique to asset management, but is also seen in other sectors where digital technology and knowledge integration abilities are crucial for enhancing creativity and efficiency (Adeel et al., 2023). To address these complications, the government has introduced an electronic-based solution called the MySPATA (*Sistem Pengurusan Aset Tak Alih Kerajaan*), which is aimed at managing assets and facilities. However, MySPATA has been not much successful in resolving these issues.

MySPATA functions as a database for all immovable assets. Despite its introduction, the search for a better technology has continued. Research by Md Aslam & Ahmad Tarmizi (2018) has highlighted that the absence of 3D visualization would complicate the process of locating assets. Their research proposed the use of 3D models for visualization to improve the location tracking of an asset. This approach is supported by findings in other fields, such as the manufacturing industry in Malaysia, where management practices significantly impact organizational innovation, particularly in the digital age (Rehman et al., 2021).

Implementing 3D GIS elements in the asset management system could increase work productivity, as visualization aids in accurately locating asset positions. Compared to 2D visualizations, 3D visualizations offer better perspectives, reducing confusion caused by overlapping assets. Hence, developing a 3D asset management system might be a more effective approach, as it can visualize the current location of an asset more conveniently.

Asset management systems are specifically developed to manage an organization's assets. However, literature reviews report inefficiencies in current management practices. According to Aslam & Tarmizi (2018), contemporary asset management is time-consuming, bland, and prone to human error due to its reliance on paper-based, manual inspection practices (Berahim et al., 2015). This inefficiency necessitates the development of a new effective asset management system.

Efforts have been made to address these inefficiencies with electronic-based asset management systems. Despite the numerous benefits of 3D modelling, its application in asset management remains limited (Cavka et al., 2017). Therefore, a more effective system with 3D implementation is required to facilitate practical work and increase productivity. The development of a 3D asset management system is challenging, particularly in terms of documentation, which impacts asset productivity in operations and maintenance. It is important to appreciate that understanding the structure of 3D and its integration with asset management systems is essential to avoid complications (Matarneh et al., 2019). Similarly, the Malaysian construction industry's green site management practices has highlighted the importance of innovative solutions for improving energy and water consumption efficiency (Terh Jing et al., 2024).

This research aims to integrate 3D GIS into an immovable asset management system. It utilizes data from building models and asset information to create a database of assets, using ArcGIS software for data integration. This integration delivers a virtual environment of the building asset, enabling the positioning of assets and access to asset data.

LITERATURE REVIEW

3D Spatial Applications

The implementation of three-dimensional geographic information systems (3D GIS) has proven to be transformative across various industries, showcasing its versatility and effectiveness. This section will discuss successful applications of 3D spatial technologies in the construction and architecture industry, urban planning and smart cities, healthcare, and real estate. The discussion will help to draw parallels to the potential benefits in immovable asset management.

In the construction industry, the integration of Building Information Modelling (BIM) with 3D GIS has significantly improved project management and delivery. BIM allows for detailed 3D representations of buildings and infrastructure, facilitating better planning and coordination among stakeholders. For instance, Love et al. (2016) have demonstrated that using BIM in construction projects reduced errors, improved communication between teams, and resulted in substantial cost savings. BIM's ability to provide a visual and data-rich environment enables project managers to detect potential issues early, thus preventing costly delays and rework (Honic et al., 2023; Tan et al., 2023; Zubair et al., 2024). One notable example is the Crossrail project in London, which utilized BIM and 3D GIS to manage one of the largest infrastructure projects in Europe (Kurwi et al., 2017). The integration of these technologies allowed for precise planning and real-time updates, significantly enhancing project efficiency and safety. The project's success highlighted how 3D spatial technologies could manage complex construction projects and large-scale asset management effectively.

Meanwhile in urban planning, many planners have benefited from 3D GIS, especially in the development of smart cities. 3D models provide urban planners with detailed visualizations of cityscapes, enabling better decision-making regarding infrastructure development, zoning, and environmental impact assessments. Cities like Singapore have adopted 3D GIS for various applications, including flood risk management, urban heat island effect analysis, and optimizing public transportation routes (Ridzuan et al., 2024; Ujang et al., 2018). Singapore's Virtual Singapore initiative uses 3D GIS to create a dynamic and interactive city model that supports urban planning, disaster management, and public engagement (Haley, 1998; Silvennoinen et al., 2022; Syamimi et al., 2020). The 3D model allows for simulations and analyses that aid in the development of sustainable and resilient urban environments. This project demonstrates the potential of 3D GIS to revolutionize urban planning by providing a comprehensive tool for managing city infrastructure and assets.

In the healthcare sector, 3D spatial data is used for facility management, optimizing space usage, and tracking medical equipment. These implementations have led to improved operational efficiency and better patient care (Kuznetsov et al., 2022). For example, Atkinson et al. (2019) has highlighted the use of 3D GIS in managing hospital facilities, which allowed for more efficient space utilization and asset tracking, resulting in reduced operational costs and enhanced patient services. Another excellent example is the Mayo Clinic which has implemented a 3D GIS-based facility management system to track and manage its extensive assets across multiple campuses, and also to produce 3D forensic graphics (McGee et al., 2020). This system allows the clinic to efficiently allocate space, manage equipment maintenance, and plan future expansions. The success of this implementation underscores the benefits of adopting 3D GIS in healthcare facility management.

The real estate industry has also seen significant benefits from the application of 3D GIS, particularly in property management, sales, and marketing. 3D visualizations help stakeholders better understand property layouts and features, leading to increased sales and customer satisfaction. Integrating 3D models into real estate management provides a competitive edge by offering detailed property views and enabling virtual tours (Deng et al., 2019). The Zillow 3D home is a classic example (Cruz et al., 2021). Zillow, a leading real estate marketplace, has integrated 3D home tours into its platform, allowing potential buyers to explore properties virtually. This feature has enhanced the home buying experience, making it easier for buyers to make informed decisions. The adoption of 3D GIS in real estate illustrates how these technologies can improve property management and marketing efforts.

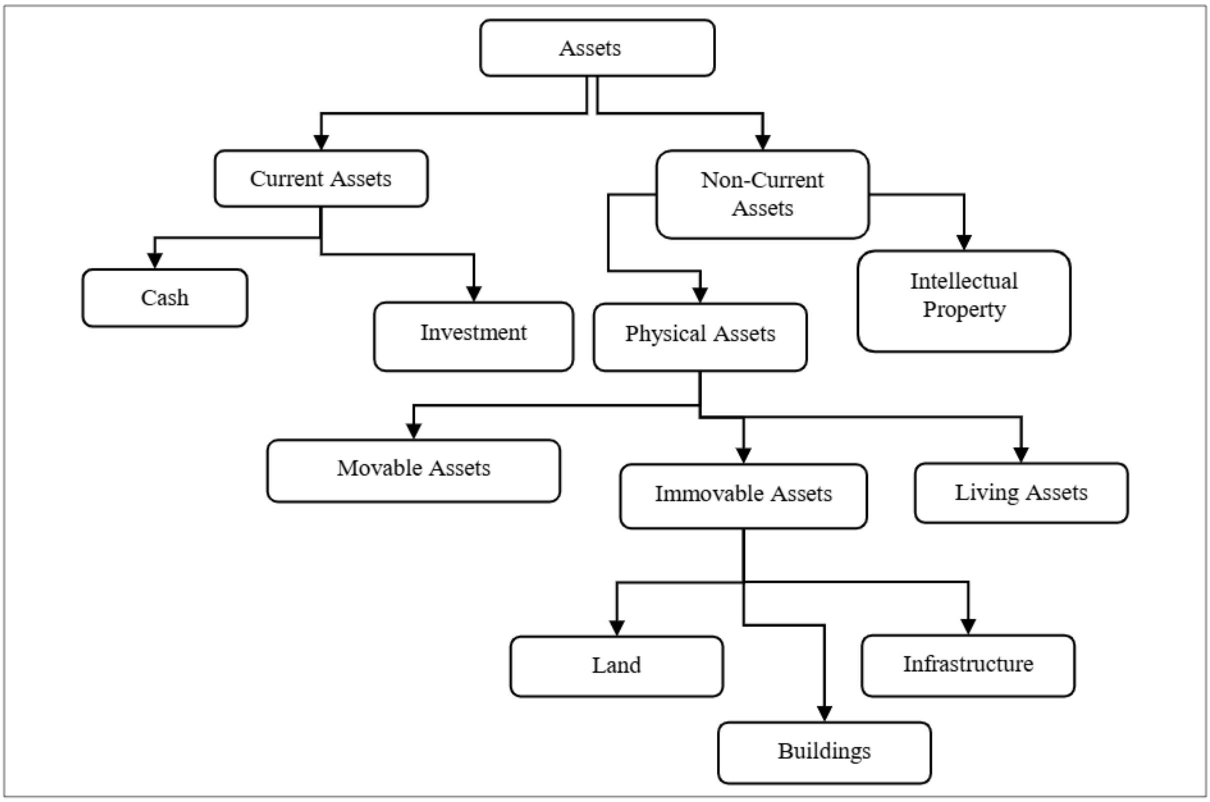
The successful applications of 3D GIS in construction, urban planning, healthcare, and real estate demonstrate the technology's versatility and effectiveness. The integration of 3D GIS into immovable asset management can similarly provide substantial benefits. For instance, 3D visualizations can improve asset tracking, facilitate better space utilization, and enhance decision-making capabilities. As evidenced by the foregoing discussion of exemplary case studies, adopting 3D spatial technologies can lead to significant cost savings, improved efficiency, and better asset management outcomes. The literature and case studies from various industries underscore the urgent need to integrate 3D GIS into immovable asset management. By leveraging the successes seen in construction, urban planning, healthcare, and real estate, the potential benefits of 3D GIS in asset management has become evident. These technologies can address current challenges, such as inefficiency and manual data handling, leading to more effective and streamlined asset management processes.

Asset Management

Asset management is developed mainly to get the management of assets under control. Controlled asset management will enhance work productivity and thus increase the quality of service of a specific organisation. The Malaysian government has created an asset management system that explains how assets are managed in detail. Figure 1 shows the breakdown of assets.

Figure 1

Classification of Assets



As illustrated in Figure 1, assets are further categorised into current assets, and noncurrent assets, which is then split into physical assets or nonphysical (intellectual) assets. At this stage, physical assets can be further distinguished as immovable assets, movable assets and living assets. Immovable assets consist of land, infrastructure, and building assets.

Asset management has nowadays become management in a digital environment – as over time, one is constantly communicating and keeping records in digital form. This digital approach is integrated with the conventional paper-based method used to keep the data on assets. Digital asset management has increasingly benefitted from the expansion of the global economy. It is said that with the management system being done digitally, it offers a great alternative to organising digital assets, which in return makes assets easier to find and get access to easily.

The benefits of having digital asset management are namely, having the ability to distribute assets, provide an easy and efficient way to find and retrieve assets. There is control ability, as it enables a selective party to have permission to view, use and modify assets, and lastly will enable users to keep track of assets. From the existing research in the field, a framework for digital asset management has been constructed.

Asset Management Life Cycle

Figure 2 illustrates the following eight asset life phases: need identification, planning, design, procurement or acquisition, commissioning or implementation, operation and maintenance, modification or upgrade, and decommissioning and disposal (Warner, 2014). The first phase is the justification of what kind of asset is needed that can bring returns on the investment made in a particular organisation. Next, planning is needed to decide exactly how assets are to be used and what is the goal. In the design phase, one is concerned with the need for any modification to the standard design of a give asset and to ensure that the modification is cost-effective.

In the next phase, the asset is purchased or leased and installed at its intended location. It is at this juncture that cost negotiation can be made. Commissioning occurs when the asset is ready to be assembled. In this phase, the organisation has to ensure that the installation must not damage the asset. After that, is the operation phase where the asset is operated and maintained as necessary. During the operation stage of the asset, some of the operations might have to be modified or upgraded to increase the efficiency of the asset. Finally, disposal has to be carried out as the end of the life cycle of the assets, some of them need to be retired for a number of reasons, for example the cost of maintenance might have become too high.

Figure 2

Asset Management Life Cycle (Warner, 2014)

In conjunction with the context of this research, there are some phases that have to be considered. First, the commissioning and implementation related, since all assets (building) are already operable. Moreover, operation and maintenance are also closely related, as the purpose of visualizing the building in 3D is to justify the effectiveness of building maintenance. For instance, it is easier and more time-effective to locate the specific room that needs maintenance because there are many different rooms in different floors.

Asset Management in Malaysia

In Malaysia, asset management is practised through the implementation of the Government Asset Management Policy (DPAK). The DPAK explains the direction, principle, and strategy to handle asset management that is complied with by all government agencies. The implementation strategies involved the following: administration, system and process, technology and human resource (JPAK, 2009a). The administration justifies the role and responsibilities of the officers and conducts research on the effectiveness of the management.

There are several processes involved in the strategies, and they are as follows: identifying assets, observing the uses of total asset management (PAM) practice, producing government asset management (PAK), evaluating the performance of asset services, and reporting the status of asset management. In addition, the government will also develop the asset management and monitoring system for standardisation and ensure that it is profitable. The government also encourages research and development programmes in the field of asset management. Finally, the strategies also aim to produce competent and highly skilled officers in order to manage and ensure that government assets are always in good condition so as to improve its service delivery to the public.

Procedure for Immovable Asset Management

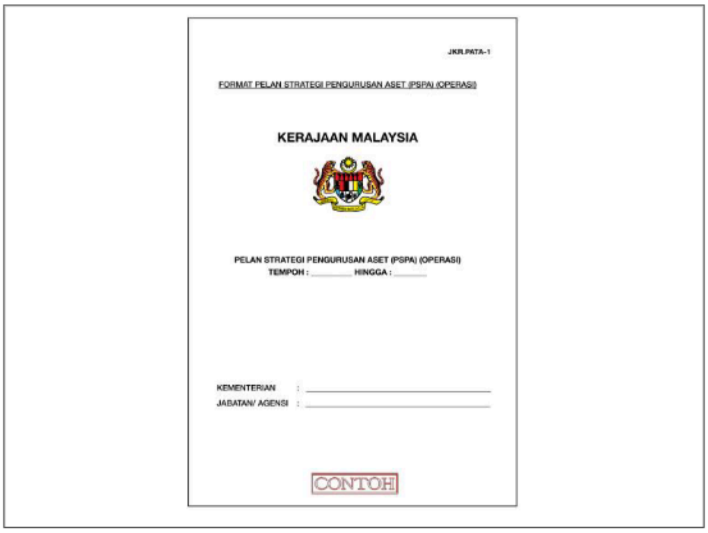
Procedure for Immovable Asset Management (TPATA) is provided by the federal government and is used to guide government agencies in managing various assets or property owned by the government. The TPATA focusses on the procedure of utilisation and disposal of immovable assets (Samsudin et al., 2020). There are seven modules that delineate the structure of governance and responsibilities, process of managing immovable asset, and reporting of asset information. The TPATA comprises seven phases in managing immovable assets, which are (i) strategic planning of asset management (PSPA), (ii) asset receiving and registration, (iii) asset operation and maintenance (OPA), (iv) asset condition and performance assessment, (v) asset restoration and improvement, (vi) asset disposal, and (vii) loss of asset (JPAK, 2017b).

Generally, the TPATA points out the method of immovable asset management in a life cycle from the beginning until asset disposal. Nevertheless, for the time being, the practised procedure based on the TPATA is focused on the usage and disposal of assets only. Firstly, the PSPA is a strategic planning that included the phase of asset usage and asset disposal. It is to ensure that the immovable asset management (PATA) can be implemented systematically. There are three sub-strategies which are, namely operational PSPA, budget estimation and allocation (ABM-PATA), and internal audit. The second phase is the receiving and registration of assets. It also includes three subphases, which are, namely asset receiving, asset premises registration (DPA) and special asset registration (DAK).

Next, the objective of the OPA is to ensure that the OPA can be carried out smoothly and transparently, as based on the asset operations and maintenance plan (POPA), the annual budget, and the regulations set. Activities in this phase are the divided into two, which are the preparation of the POPA and the implementations and reporting of the OPA (see Figure 3). The fourth phase of the TPATA is asset condition and performance assessment, which is to ensure that the performance of the asset is always in the optimum state. The next phase is asset restoration and improvement of assets. The main objective is to ensure that the asset that is upgraded follows the standard and function that has been set. The next phase is the disposal of the assets. It is important for all agencies to dispose of unusable immovable asset and ensure that they are disposed of correctly and systematically. Finally, the last phase is the loss of assets. The aim of this phase is to control the loss that that is borne by the government. Negligence on the part of any officer may result in a surcharge or disciplinary action.

Figure 3

Example of a Report for each Phase that is Prepared by Agencies (JPAK, 2012)



JKR.PATA-1

FORMAT PELAN STRATEGI PENGURUSAN ASET (PSPA) (OPERASI)

KERAJAAN MALAYSIA

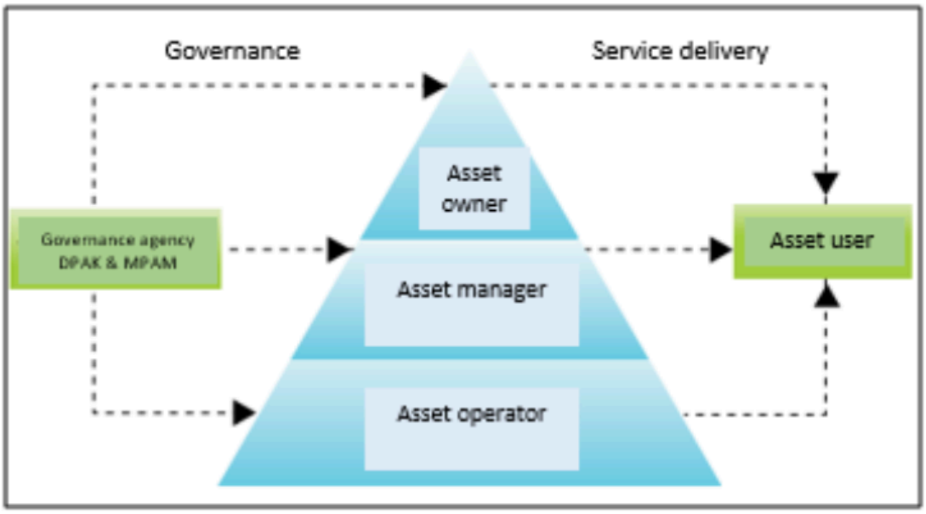
PELAN STRATEGI PENGURUSAN ASET (PSPA) (OPERASI)
TEMPOH : ________ HINGGA : ________

KEMENTERIAN : ________
JABATAN/ AGENSI : ________

CONTOH

Figure 4

Structure of Government Asset Management Responsibility (JPAK, 2012)



Immovable Asset Management

The implementation of immovable asset management (PATA) requires the coordination of activities between the owner, manager, and operator asset (see Figure 4). In every agency, the asset owner has to establish a Facility Management Unit (UPF) as the asset manager and form a group comprising personnel that will act as the asset operators based on the Comprehensive Asset Management Manual (MPAM) (JPAK, 2009b).

Role of the Government Asset Management Committee (JPAK)

The JPAK is a high-level committee that will focus on strategic matters related to asset management. The JPAK will report on the progress of implementation and improvement of government asset management to the integrity committee. The JPAK is chaired by the Chief Secretary of the Government. The Public Work Department (JKR) is the secretariat of the JPAK. The JPAK is responsible for determining the direction in the implementation of government asset management. In addition, the JPAK formulates policies, strategies, action plans and guidelines to implement government asset management policies, particularly on matters such as standards, security, procurement, and human resource development. The JPAK also coordinates the implementation of government asset management policies between ministries, departments, and agencies at the federal level.

Finally, the JPAK provides periodic reports on progress in implementation and suggestions for improving government asset management. Meanwhile, the role of the secretariat of the JPAK is to coordinate the agenda, prepare the minutes of meetings, and all administrative duties related to the JPAK. It also acts as a governing body and enforces the implementation of the TPATA. Finally, it will report the results of the monitoring of the management of immovable assets to the office of the chairman of the JPAK.

Role of the Facility Management Unit (UPF)

The PATA requires standardisation between the owner, manager and operator. Every asset owner in each agency has to create a facility management unit (UPF) as the asset manager, and organise a team of maintenance staff. The roles and responsibilities of the officers who are involved in the structure of the PATA are as follows:

- Technical Facility Officer (PTF) – who leads the technical team in facility management and immovable asset maintenance.
- Registry and Data Facility Officer (PDF) – who controls and monitors the implementation of the acceptance and registration of assets.
- Operational Facility Officer (POF) – who carries out the activity in each phase of the asset life cycle based on the DPAK.
- Inspectorate Facility Officer (PIF) - who controls and monitors activities of compliance with acts, regulations, procedures, scope of relevant facility management contract conditions based on a total asset management (PAM) approach.

Current Status of Asset Management (MySPATA)

MySPATA is an electronic asset management that is in line with the strategic planning developed by the DPAK. MySPATA was created by the Malaysian Administrative Modernisation and Management (MAMPU). MySPATA has been developed to collect and manage all the necessary data about the federal government, including building and infrastructure assets (Behnam & Kenley, 2019). Furthermore, an immovable asset coding system has also been established and developed (Aziz et al., 2013). According to the 2015 MySPATA record, there are 39,284 registered federal facilities and assets in Malaysia that are frequently used by the public.

Figure 5 shows the function of the system to establish an effective registration of immovable assets. In addition, it is to ensure that asset management is practised systematically, holistically and sustainably to achieve optimal asset benefit. Moreover, it also ensures an easier implementation of the evaluation and monitoring of immovable assets.

Figure 5

The MySPATA Interface (JPAK, 2017a)

Before this standard, there were various data collection methods and there was no specific guideline for collecting an asset's location data. As a result, the data collection was inaccurate, inconsistent, and unsystematic. Although MySPATA was introduced to facilitate the data collection of government building assets and maintenance data, this system could not yet be used at the time because the system integration involved a lot of data (Razali et al., 2020). Another issue related to MySPATA was that no spatial information was provided. In addition, no visualisation was attached to the information to describe the current condition or status of the asset. Asset maintenance is a complex process that requires a significant amount of information flow and a quick call-to-action; therefore, asset managers always find themselves putting out fire because they do not have access to a unique platform with centralised information (Infraspeak, 2018). Therefore, the development of MySPATA is considered bland and time-consuming as its application only stores and displays asset information (Nasir et al., 2020).

Therefore, asset management of immovable assets, has been experiencing some management issues as it was found to be time consuming, tedious and error prone due to its paper-based practice, where manual inspection is required (Md Aslam & Ahmad Tarmizi, 2018). Furthermore, it was clear that the practice makes the positioning of an asset difficult to locate as there was no guidance without then ability of visualisation, specifically in the form of 3D modelling, as this feature had not yet been integrated. Visualisation is a technology that will provide in much greater detail asset information by adding a height dimension. This added dimension gives a visual that represent the scale of real-world objects. Previously, GIS visualisation is always based on 2D data (Mohd & Ujang, 2016). Thus, it limits the usage in some application which requires height information. Since then, 3D has been incorporated with height dimension to enable a more detailed visualisation (Azri et al., 2019; Keling et al., 2017).

Recent advancements in the field of smart city asset management have highlighted the importance of integrating advanced technologies such as 3D GIS and graph databases to enhance a more efficient and predictive maintenance. Idris et al. (2024) explored the integration of versioning and asset lifecycle management in 3D assets, emphasizing the role of version control in maintaining accurate and up-to-date asset information. Their research has demonstrated how versioning can significantly improve asset tracking and lifecycle management, ensuring that all changes to assets were meticulously documented and easily retrievable. This approach has not only enhanced the accuracy of asset data, but also facilitated better decision-making and resource allocation in smart city environments. Similarly, Hairuddin et al. (2024) has explored the potential of graph databases in smart asset management, focusing on the enhancement of predictive maintenance capabilities in Industry 4.0. By leveraging the interconnected nature of graph databases, their research has provided insights into how predictive maintenance could be optimized, leading to reduced downtime and improved asset longevity.

Further contributions to the field include the study by Muhammad Zaly Shah et al. (2023), who modelled the reoccurrence of events in an event-based graph database for asset management. This study has highlighted how event-based modelling could be utilized to predict and manage asset maintenance schedules more effectively. In addition, A. A. M. Nasir et al. (2022) have provided a comprehensive overview of the current status of asset management in Malaysia. Their findings underscored the challenges and opportunities in implementing advanced asset management systems in the region. Another significant contribution was made in the study by A. A. i. Nasir et al. (2022), which was a research on managing indoor movable assets using CityGML for smart city applications. This study has illustrated the practical application of 3D GIS technologies in managing movable assets within indoor environments, highlighting the benefits of 3D visualization and spatial data integration in improving asset management practices.

3D Object Modelling

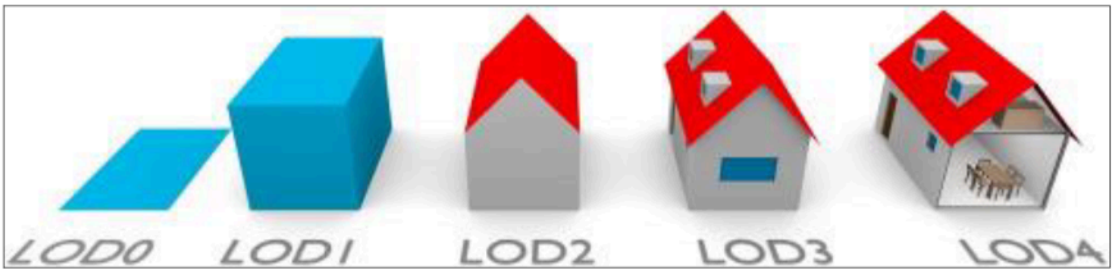
3D visualisation offers different levels of details. The level of detail (LoD) is a term used to describe the design complexity of a model. According to a study by Benner et al. (2013), the level of details could be divided into five (5) levels, as follows: LoD0, LoD1, LoD2, LoD3 and LoD4. All these levels have been defined in earlier studies following Benner et al. (2013).

In the world of three-dimensional (3D) modelling, a new version of the standard in CityGML has been introduced to users, which is the CityGML3.0. The previous version, CityGML 2.0, has been improvised, giving rise to the new CityGML3.0. Some aspects of the previous version have been improved, such as the modules and the level of detail (LoD) of the 3D building model. The new modules have added the following features: dynamizers, versioning, and point cloud to the existing modules. The CityGML core and generics have been revised. This revision will be further discussed because the complexity of the models is one of the factors to be emphasised when developing and presenting a 3D building model physically, whereby different building model complexity offers a varying level of detail that can affect a given study. For example, different levels of details of the building model can manipulate wind flow throughout a study area.

The CityGML3.0 version, unlike the previous version CityGML2.0, uses five primary LoDs: LoD0, LoD1, LoD2, LoD3, and LoD4. All these LoDs have a level of detail of the building model or the complexity of the building model. LoD0 represents the footprint of the building to be modelled, LoD1 is for block representation, which means that only the building block is presented using this level of detail, and LoD2 comprises the building model with the roof representation. Meanwhile, LoD3 displays the building with the roof surface, as exhibited in LoD2, but with other facade details and the final LoD, LoD4 is the same as LoD3; however, there is extra information or components added which are the interior structures such as the building furniture (Bahu et al., 2013; Biljecki et al., 2015). The representation for each LoD can be found in Figure 6.

Figure 6

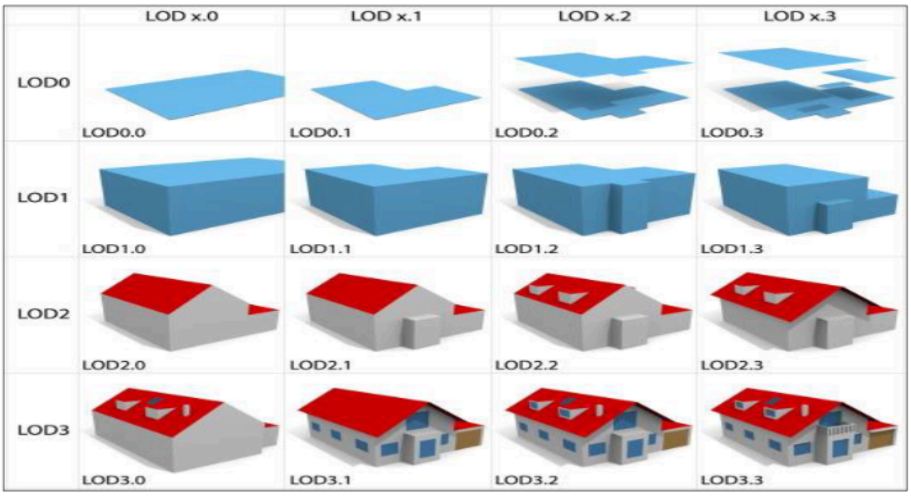
The Detailed Representation of each of the LoD Introduced in CityGML2.0 (Sun et al., 2018)



The significant change made in CityGML3.0 is that the number of primary LoDs has been reduced to only four LoDs, whereas as pointed out earlier, the previous version consisted of five main LoDs. The four LoDs are LoD0, LoD1, LoD2, and LoD3. As was in the earlier version, LoD0 represents the building footprint, and LoD1 is on the building block representation. The difference is found in LoD2 and LoD3, whereby the interior structures included in LoD4 of CityGML2.0 have been brought into these two new LoDs [10]. The details of the exterior design for LoD2 and LoD3 remain the same. However, as in the study by Biljecki et al. (2016), the more detailed structures and surfaces that existed on the building model could be further presented by providing each main LoD, the sub-version of it (see Figure 7). This is due to the fact that it will allow for a more stringent specification and limited modelling freedom. It should be noted that the detailing is focused only on the geometry of the exterior building and is implemented on the CityGML3.0 standard. For example, each LoD can have four more sub-level to differentiate the representation of the 3D model, which is LoD1.0, LoD1.1, LoD1.2 and LoD1.3 (using LoD1 as an example).

Figure 7

Sub Level of Details for LoD0, LoD1, LoD2 and LoD3 (Biljecki et al., 2016)



For LoD0, the sublevel that can be included are LoD0.0, LoD0.1, LoD0.2, and LoD0.3. These four sub-LoDs all show the building model as a footprint, for instance, LoD0.0, which shows the simplified footprint as a square with four vertices regardless of the shape of the building base. Furthermore, LoD0.1 is a simple footprint, but it takes into account changes in the geometry of the building base, where part sizes of more than 4 metres are recorded in this LoD0.1 model. Somehow, it is different for LoD0.2 and LoD0.3; there is an inclusion of more than 2-meter part size of building base and top surface, where LoD0.2 shows a single surface but multiple surfaces for LoD0.3. However, because the presented structure only exists in two-point five-dimensional (2.5D), there is no complete vertical dimension generated that can offer the volume of the model; thus, this LoD is not suitable for modelling the 3D building model.

The following LoD is LoD1, which comprises LoD1.0, LoD1.1, LoD1.2, and LoD1.3. The main concept in this detail is the representation of the building block. However, each sublevel displays various types of the building block. These sub-levels are simply an extrusion of all sublevels of LoD0 to enable 3D representation. For LoD1.0, it is a simple building block, but it to be seen as an extrusion from LoD0.0. Also, LoD1.1, LoD1.2 and LoD1.3 are presenting models of extrusion of LoD0.1, LoD0.2 and LoD0.3, respectively. Unlike LoD0, this level of detail is capable of conducting a study in the 3D environment, as it allows a complete 3D representation of the building model.

In addition, a more detailed representation can be obtained from LoD2. This LoD contains LoD2.0, LoD2.1, LoD2.2, and LoD2.3, in which the model to be presented is made up of individual buildings and detailed roof surfaces. The first sub-LoD, LoD2.0, illustrates a building block model with included building parts in 4-meter size and attached to the roof surface. Meanwhile, LoD2.1, LoD2.2, and LoD2.3 all represent the same building block as LoD2.0, but with the inclusion of 2-meter-size parts. The difference for these three is that LoD2.1 is embedded with the roof surface only; LoD2.2 is the same as LoD2.1; however, additional roof details such as a chimney are included. Also, for LoD2.3, it is presented the same as the preceding sub-level, but with the inclusion of an overhanging roof that is like a building in the real world.

Furthermore, LoD3.0, LoD3.1, LoD3.2, and LoD3.3 can be subdivided from the primary LoD, which is the LoD3. The model representation in LoD3.0 is similar to that of LoD2.2. However, this LoD allows for a more complicated model with roof details, such as a chimney greater than a meter in size and a roof opening. Additionally, LoD3.1 is an LoD that can model individual buildings with all parts merged, an overhanging roof and openings on the walls and balconies if present. As for LoD3.2 and LoD3.3, the last two sub-LoDs, these two are the most detailed LoDs whereby all criteria, such as the individual building with parts in 4 and 2-meter sizes, overhanging roof, roof details, opening on roof and wall, and balconies, exist. However, there is one distinction between these two LoDs; LoD3.3 can have additional characteristics such as a building façade, roof, or window structure of less than 20-centimeters in size.

In conclusion, there are 16 LoDs, each of which comprises four sub-LoDs derived from the four primary LoDs. The 16 levels of detail are as follows: LoD0.0, LoD0.1, LoD0.2, LoD0.3, LoD1.0, LoD1.1, LoD1.2, LoD1.3, LoD2.0, LoD2.1, LoD2.2, LoD2.3, LoD3.0, LoD3.1, LoD3.2, and LoD3.3. Although there are many sub-LoDs, the distinctions in their characteristics and structures can be clearly observed.

With respect to the situation in Malaysia, the asset management system does not offer visualisation, and the use of only the digital asset management system is not enough, as manual inspection is still to a great extent required (Md Aslam & Ahmad Tarmizi, 2018). However, a research by Pärn et al. (2016), has stated that asset management is gradually catching the interest of academics and practitioners in exploring the beneficial effects of 3D (or also known as BIM) implementation in digital modelling. This development shows that with 3D modelling implemented in other fields like asset management, there can be a great possibility to produce great benefits.

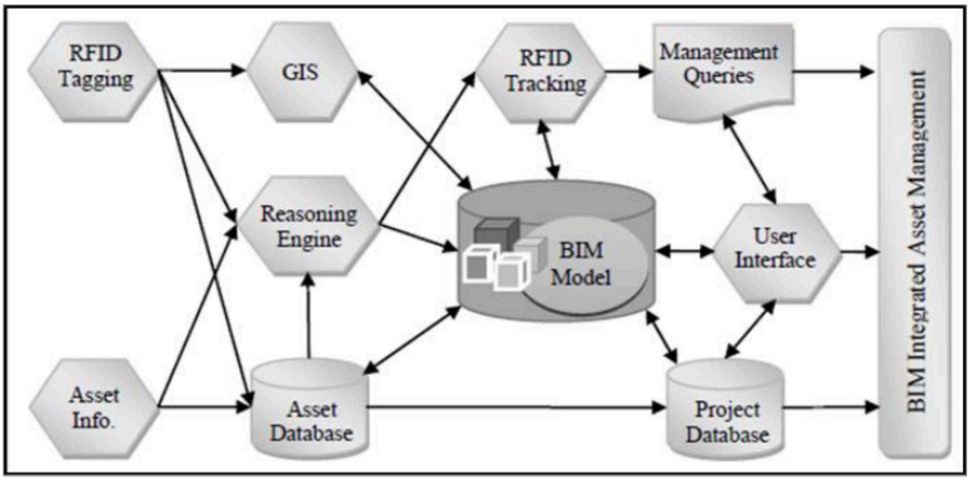
Another research by Love et al. (2016), a study on asset management in asset infrastructure has stated that "the adoption of system information modelling must be put forward towards a better future". This also shows the need to develop an asset management system integrated with modelling. It is believed that in the asset management area, there is also a need to implement a 3D GIS element within an asset management system.

Building Information Modelling (BIM)

The conventional asset management approach consists of manual inspection based on paper and has proven to be time-consuming, inefficient, and vulnerable to human error. Although 3D (or BIM – Building Information Modelling) technology has emerged in information management, its use in asset management specifically in assets is extremely low. Previous research, as highlighted above, has identified a framework describing a smart BIM record model which collects all assets and models them in a BIM. From the framework of the BIM model, the management of an asset which involves the following: operation, maintenance, servicing, repair and replacement, proves to have a labour-intensive asset inventory, involves time and requires unnecessary tool acquisition with informed decisions.

Figure 8

Framework of Smart Record Model (Md Aslam and Ahmad Tarmizi, 2018)



The framework created in the research on BIM for asset management is as shown in Figure 8. The RFID (Radio Frequency Identification) Tagging means tagging assets with electronic chips and antennas with the aim of making it possible to locate the assets. The RFID is linked to a User Interface (UI) t and this will enable the visualization of the asset in 3D. Assets are interrogated in the BIM with a reasoning engine where the engine reads the BIM format of a 3D model integrated with assets. GIS is used to obtain the location of the asset and position the assets in the BIM model. UI will boost asset information extraction, link with the BIM, and store them in the database.

The only problem with previous research is that the framework created has not yet been tested. Thus, there is still no evidence if the framework proposed for asset management in 3D model will eventually work or fail.

Another related research conducted by Love et al. (2016), stated that documentation prepared with 'As-Built' Computer-Assisted Design (CAD) is more than often will contain inadequate, inaccurate and or redundant information, adversely affecting the quality and efficiency of the asset during operation and management. Therefore, due to these complications, an evaluation is performed to detect errors and omissions contained in 'As-Built' electrical documentation. This is determined by comparing the information in CAD with the development of the System Information Model (SIM).

Figure 9

Development of SIM Showing a Drawing in 3D (Love et al., 2016)

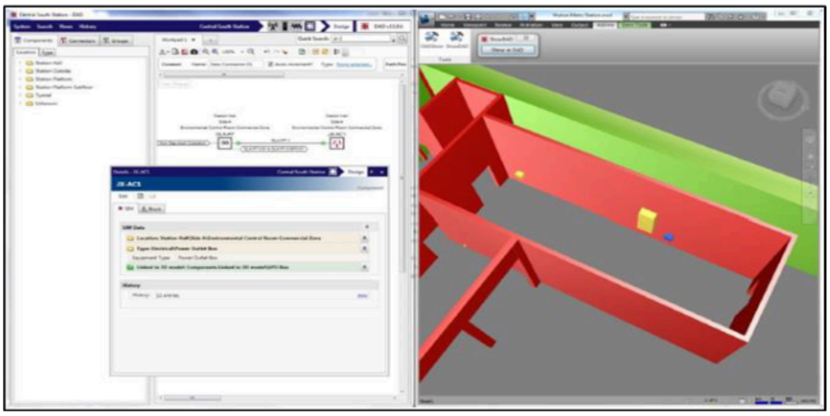
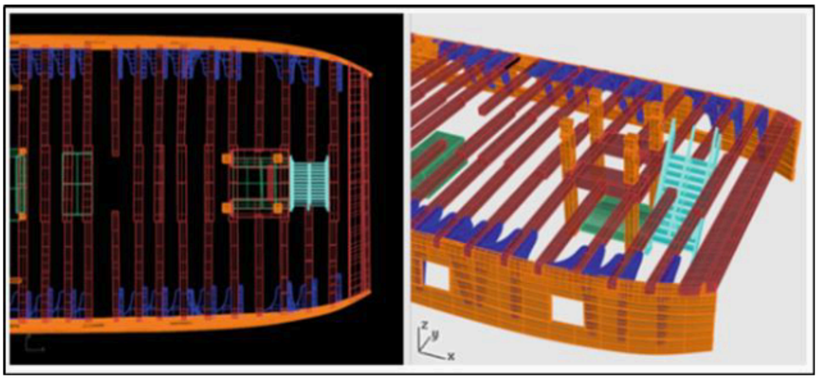


Figure 9 shows the development of the SIM interface. Drawings are modelled in 3D which gives better visualisation for a more efficient work. From this research (Love et al., 2016), it was found that SIM was capable of offering a good medium and method in development and documentation, therefore, leading to better efficiency and cost benefits. However, the said research is not related to asset management; it is tested within the context of an underground railway station. Thus, there is still no successful 3D model in the asset management system.

Figure 10

View of Upper Gundeck with VIM Application (Atkinson, 2019)



Another research by Atkinson et al., in 2019, was a study on the use of the BIM in conducting a 3D survey of a historic marine ship. The study had conducted a 3D survey to capture data and modelled captured data to see the effective management of historic ships and vessels, and other historic marine and maritime assets. This complex modelling of historic ships had used the VIM (Virtual Information Modelling) application which had generated point-cloud data from a laser scanning survey. Figure 10 shows the result of the modelling of the plan and the isometric view of the upper gundeck of the ship.

METHODOLOGY

This section discusses the methodology used in the present research. They are sections about data acquisition, data preparation and database design, and the data building and implementation process. The explanation of the stages is then covered in more detail in the sub-chapters.

Data Acquisition

Data acquisition involved obtaining detailed information about the Taman Kobena Hall, including building models, asset data, and user requirements. The researchers conducted a user requirement analysis (URA) with the Majlis Bandaraya Johor Bahru (MBJB) to ensure that the study addressed the MBJB asset management needs. The data needed are the building model of the hall, asset data, as well as information of the hall and asset code collection. This information is crucial in building a database and integrating 3D into it. Another type of information collected is the user requirement analysis for the system. Table 1 shows the tabulation of the information collected.

Table 1

User Requirement Analysis

Organization	Majlis Bandaraya Johor Bahru (MBJB)
Activity	Monitoring of Halls under MBJB
Current System	Using manual system: Data are stored manually in files. Using a file-based system: Drawings of floor plan and site plan are kept in CD/AutoCAD
Existing Problem	Accessing data becomes tedious as data are stored manually in files
Desired Changes/ System	Providing accessible data Providing an effective way for user to access data

The site of the research was the Dewan Muafakat Johor Taman Kobena, located in Tebrau and the asset was monitored by the Majlis Bandaraya Johor Bahru (MBJB) (as is shown in Figures 11 and 12). This newly renovated hall, typically used as a banquet venue for events and functions, provided an excellent case study for immovable asset management. The user requirement analysis (URA) for this research was conducted with the MBJB to ensure the study's relevance to their asset management needs. The Taman Kobena Hall was selected due to its recent renovations, making it an ideal candidate for advanced asset management strategies. The hall's 3D model was meticulously constructed from scratch, utilizing detailed LiDAR scanning for the building facade and aerial photogrammetry for the roof surfaces, resulting in a highly detailed and accurate representation of the building. This level of detail ensures that the 3D model reflects the real-world structure with precision. The Taman Kobena Hall serves as a prime example of building asset management and provides a robust proof of the concept for integrating 3D GIS in asset management. This case study highlights the practical benefits of advanced spatial technologies in managing building assets and offers valuable insights that can be replicated in other similar projects.

Figure 11

Location of the Taman Kobena Hall

Figure 12

Taman Kobena Hall

Data Preparation and Design

Data was prepared by refining and editing the 3D model to ensure accuracy. The 3D model of the Taman Kobena Hall was constructed using LiDAR scanning for the building facade and aerial photogrammetry for the roof surfaces. This process provided a highly detailed representation of the building. With close reference to the database acquired, a conceptual database was designed to deliver asset data accordingly, which was aligned with the existing asset database system. A conceptual database was designed to integrate 3D data with the existing asset management system. The physical database was then constructed using the ArcGIS software. Relationships between related attributes were created to facilitate data retrieval and management. Figure 13 shows the conceptual database design in this research. In line with the existing database management system, the database was designed to suit the integration of 3D into the database. The logical model was constructed after the conceptual mode. Figure 14 shows the logical model with added data type and character length for the required field.

Preparation in terms of the 3D model is done in refining and editing of the model to suit well with the building and integration phase. Any changes required were done here in this phase before proceeding to the next phase. Furthermore, in this phase it was important to build the ID for assets existing in the building. The construction of an asset ID was based on the asset code collection. With these data prepared, the next phase was conducted.

Figure 13

Conceptual Database Design

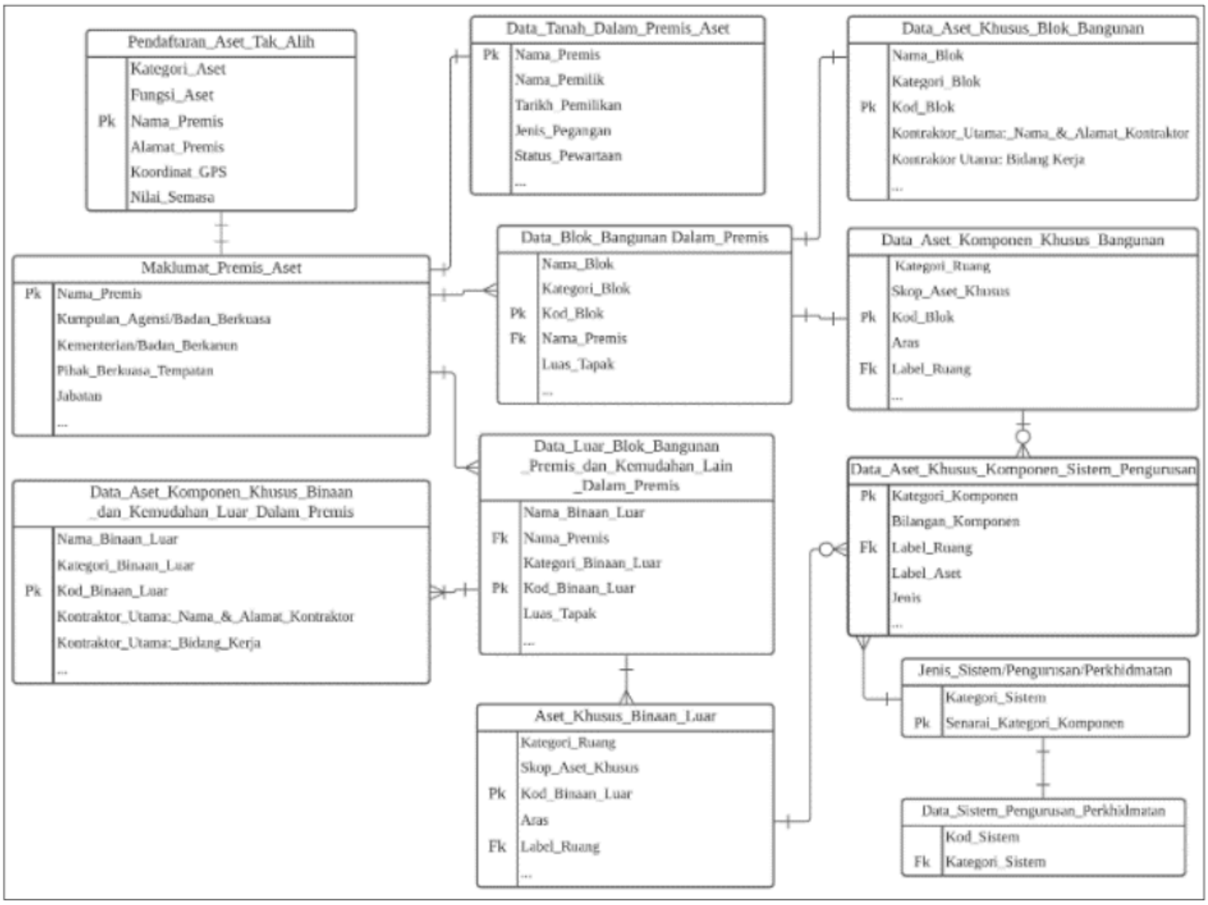
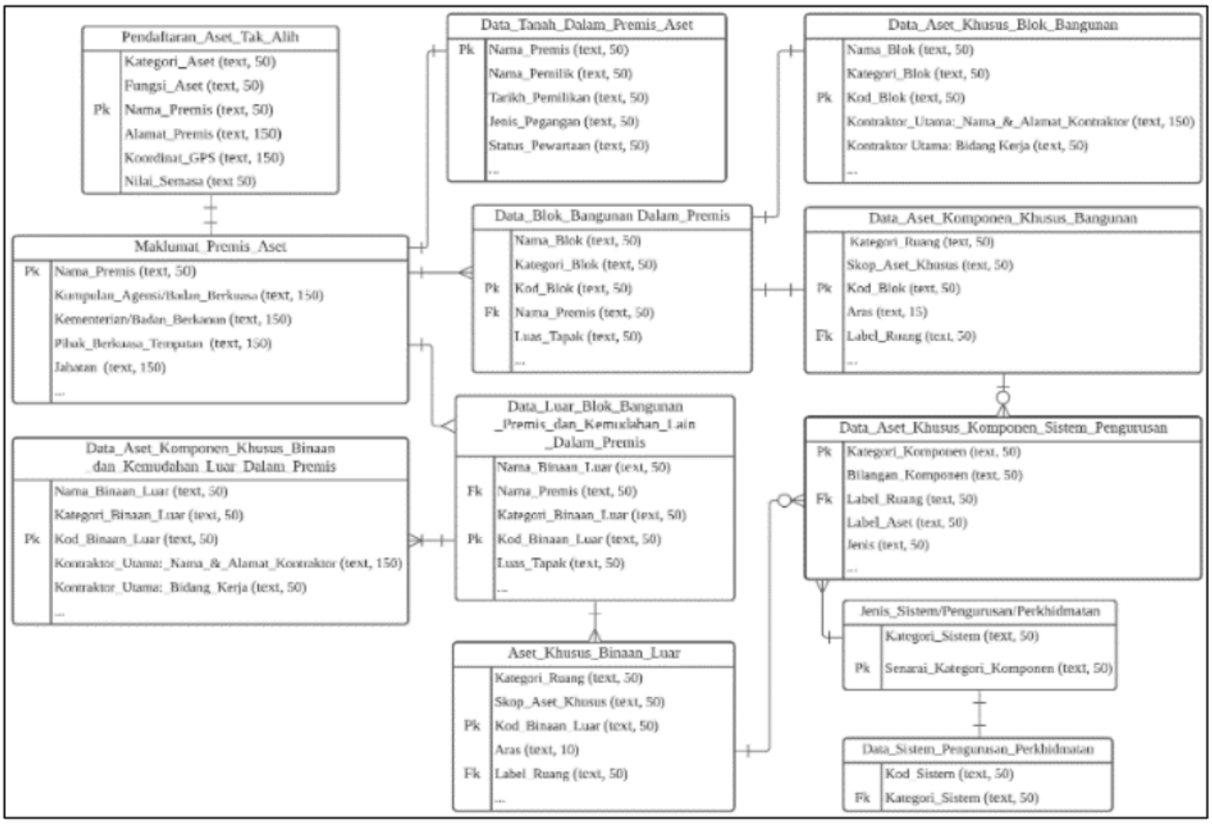


Figure 14

Logical Database Design



Building and Implementation Process

The 3D integrated database was tested using the ArcGIS ArcScene software to ensure functionality and accuracy. Users can register new assets, query asset data, and visualize asset locations, thus providing a practical tool for asset management. In this building and implementation phase, the building of the database was performed. With reference to database design, the building of the physical database into the system was carried out. Figure 15 shows a table taken from the physical database in the ArcGIS software of the Pendaftaran Aset Tak Alih.

Figure 15

Physical Database Design

Field Name	Data Type
OBJECTID	Object ID
Field	Text
KategoriAset	Text
FungsiAset	Text
NamaPremis	Text
AlamatPremis	Text
KoordinatGPS	Text
NilaiSemasa	Text

The editing of the code created accordingly was used to build up and install into system. Together in this phase, relationships between related attributes were also created. After the data was constructed, the 3D integrated database could then be tested.

RESULTS AND DISCUSSIONS

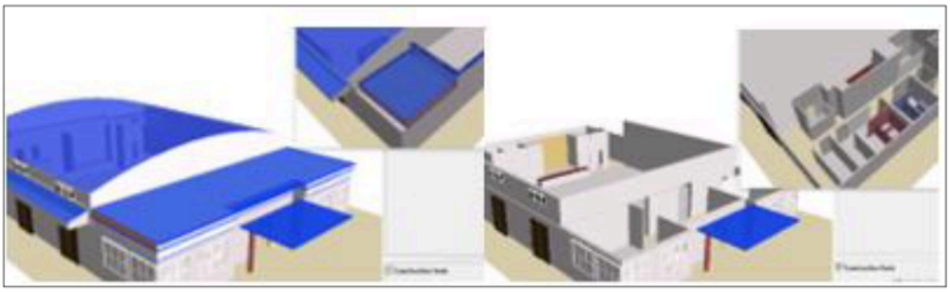
This section contains documentation of results from the processed data. It discusses the output of the 3D integrated database. Thus, it also includes testing and analysing of the output created using the ArcGIS ArcScene software.

3D Building Output

Figure 16 shown below is the assembled 3D model of the building hall. The illustration on the left shows the constructed exterior model and the illustration on the right, shows the interior of the building.

Figure 16

Constructed Model Output



Registering New Assets

Given the advantage of using desktop-based software, users can easily register new assets. To do that, the user must have some information of the new asset and where the new asset is located. Users are also able to customize the asset with visualisation, creating data as if the asset is for real. The process of adding data is as shown in Figures 17 and 18.

Figure 17

Locating Asset and Information

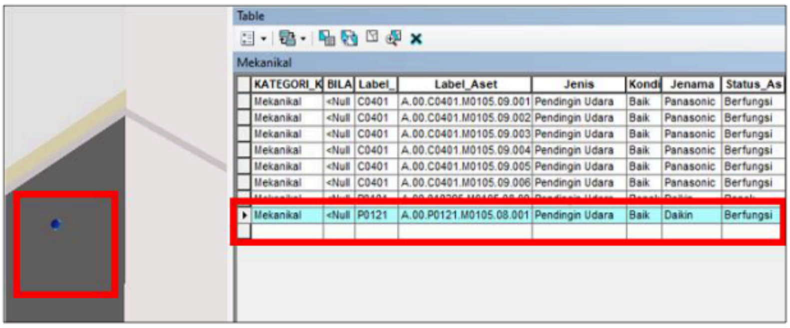
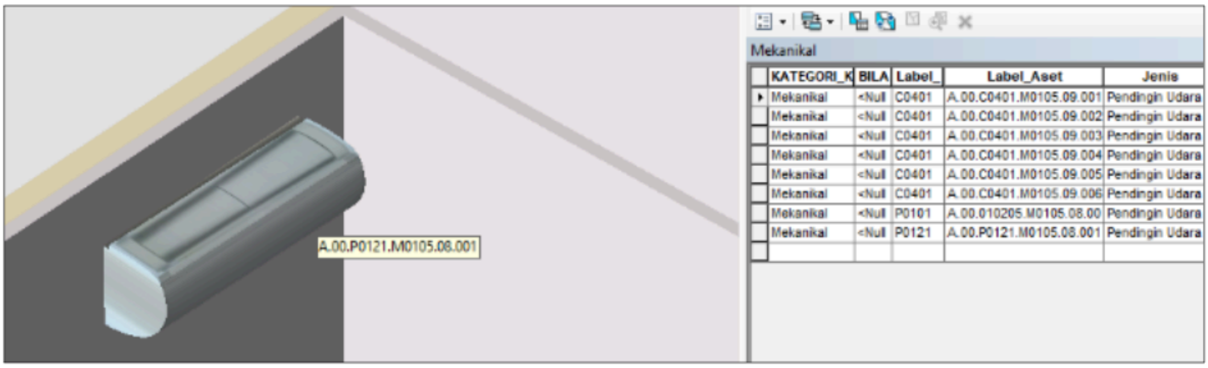


Figure 18

Visualizing Added Asset



The advantage of using this desktop-based application is that it enables users to add new data on their own. The process of registering new data is also much simpler, whereby assets can be registered directly as new input to the database. Having an asset code simplifies the registration work as it skips the need to search and enter the new building information. Since changes can be made, users are free to the perform any update of the assets in the database. This advantage will enable one to keep the data updated when changes are made. However, adding in visualisation requires some adjustment in that users need to spend more time to modify the asset size and orientation.

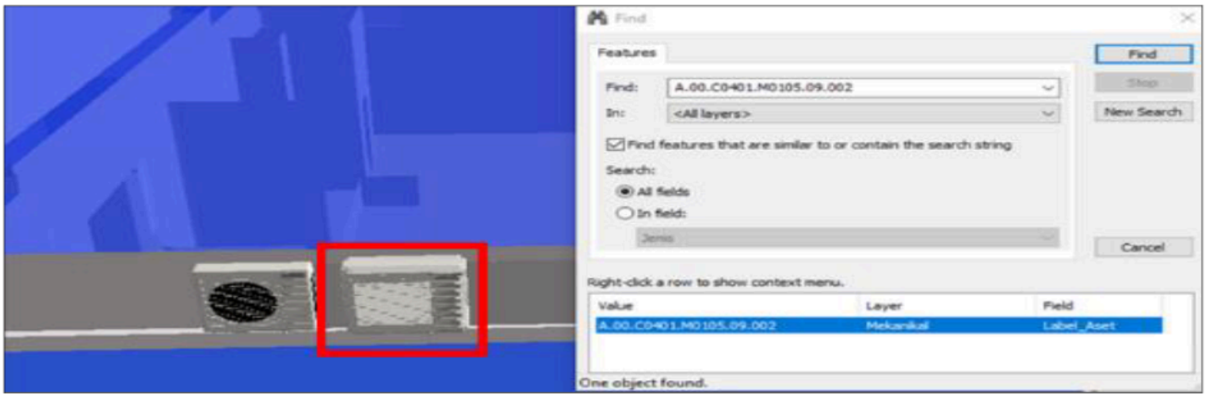
Query Asset Data

Query with the Find Tool

With the find tool, a query can be made by entering the asset information as input. Figure 19 shows the code-scrolled flashed asset. The Find tool is able to search for assets and enable users to view the asset location.

Figure 19

Find Tool

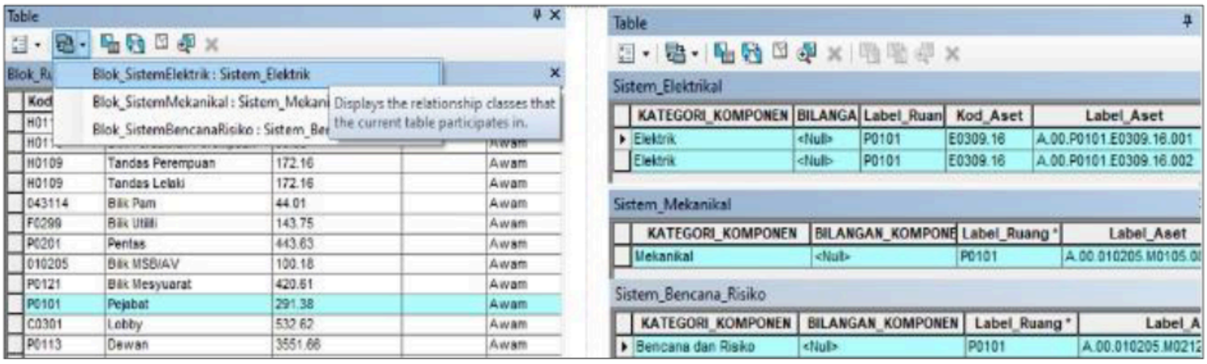


Query Assets in Space/ Room

When there is a need to get some component data of a room, for example the available asset components in the office, GIS is able to access the information about assets available inside the office. Figure 20 below shows the room selected in an attribute table. The table next to it shows the available assets associated with the office selected.

Figure 20

Asset Associated with Office



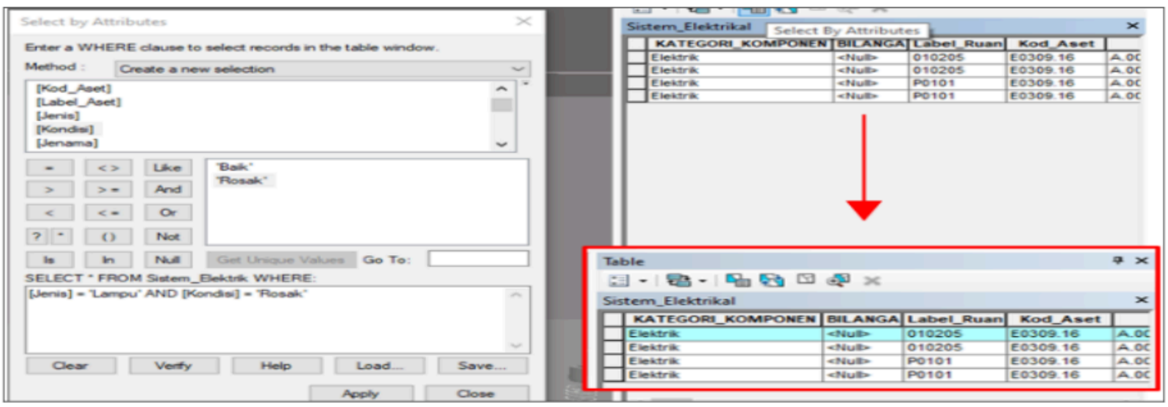
As illustrated in Figure 20, the connection between the tables enables the data retrieval of the asset components from a specific room. This is an advantage as it enables one to retrieve assets available in a room without having to manually find them. Since each component is also tabulated by a system category, this helps users to easily find out the category of the asset component that exists in a room. However, given that assets components are categorised by its own system, the total of all asset components combined needs to be calculated manually.

Query Assets by Attribute

There are situations where accessing a specific component is required, for example 'find the lamp which needs to be maintained'. Then, GIS can show which lamp needs maintenance and visually highlights it in the attribute table.

Figure 21

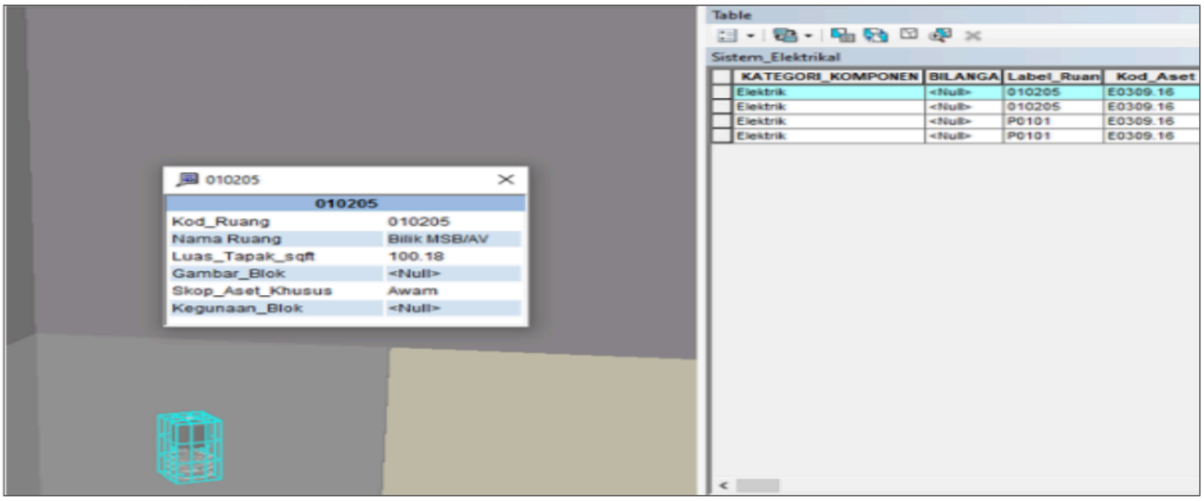
Query by Attribute



This query is possible because when the specification of the query using an attribute is met, the lamp which met the requirement will be highlighted as is shown in Figure 21. Having found the queried asset, the location of the lamp can be shown and visualised. Figure 22 shows the location of the lamp that needs maintenance being highlighted.

Figure 22

Location of Queried Asset

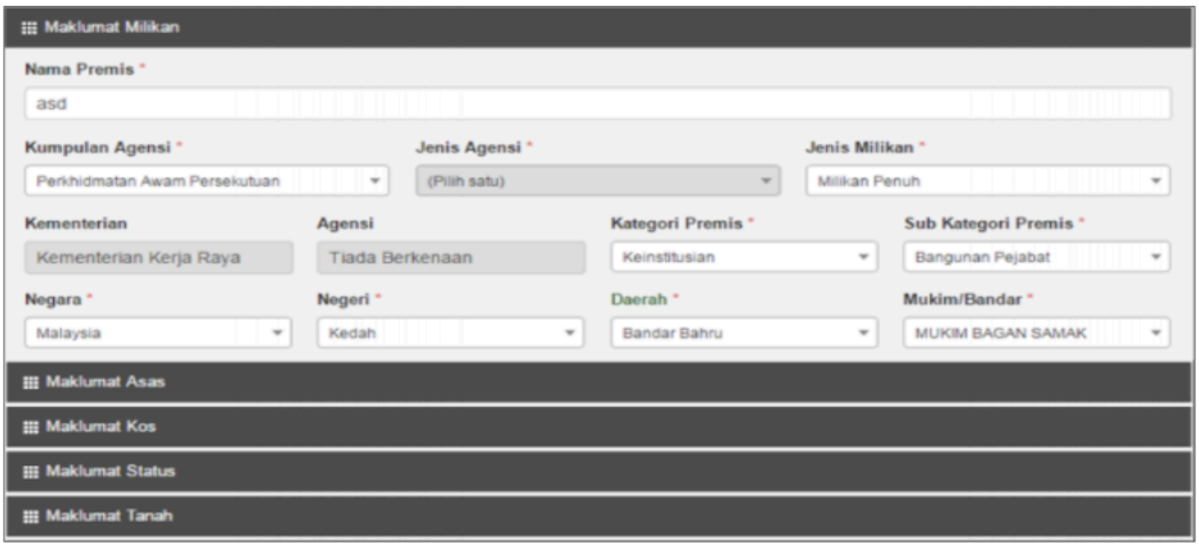


Comparison between 3D, 2D and Paper-based /Data-based

There are a few differences seen when comparing between previous existing database and database with developed 3D visualisation. Compared to the existing asset management system, data are stored in a new database system. As illustrated in Figure 23, it is seen that the system uses a full database system to store data.

Figure 23

Existing Database (Malaysia, 2017)



As much as it is convenient in storing data in the old system, when comparing asset database with 3D visualisation, the former somehow has a disability. For a start, the 3D integrated database contains more information (Azri et al., 2016). It holds not only the information of assets, but also information about the location of assets. Although the defect may seem simple, it is what causes it to be a less successful asset management approach. This problem leads to other drawbacks, such as the failure to locate assets, failure of data updates, and losing track of assets. To compare 3D visualisation with 2D visualization, 2D visualization may somehow look enough for some situation, but unlike 3D visualization, height dimension cannot be interpreted. As 3D is capable of visualising height dimension, thus giving it a more realistic virtual view of data inside an area.

CONCLUSION

In this study, a 3D GIS approach was developed to enhance asset database management using the ArcGIS software. The approach will allow users to register new assets, retrieve asset information through various query methods, and visualize asset locations. This development has significantly improved asset management efficiency and accuracy. By integrating 3D visualization into the asset database, the present study has sought to address the challenge of locating assets and facilitates continuous updates, ensuring that the data remains current and reliable. Queries on single data points, related data, and attribute-based selections are enabled, providing a comprehensive and practical tool for asset management.

This study contributes to the theoretical understanding of integrating 3D GIS into asset management systems by highlighting the role of spatial visualization and database interoperability in enhancing asset tracking and decision-making. It has established a framework for using 3D GIS to address traditional challenges associated with paper-based or 2D asset management approaches. The research also advances the discourse on the scalability of spatial technologies, particularly in integrating building information with geospatial data for robust, real-time asset management. By bridging the gap between traditional asset management theories and emerging geospatial technologies, this study sets the groundwork for future exploration of dynamic and predictive asset management models.

The findings offer significant practical implications for organizations and industries that manage immovable assets, particularly in government, urban planning, and facilities management. The integration of 3D GIS enhances the ability to track asset locations with precision, reduces dependency on paper-based systems, and provides tools for real-time data retrieval and visualization. Asset managers can now register and update assets more effectively, streamline maintenance workflows, and improve resource allocation. Furthermore, the interactive nature of 3D visualization enables stakeholders to perform spatial analysis and scenario planning, supporting informed decision-making in dynamic environments.

For government agencies, the study demonstrates a pathway to modernize asset management policies, particularly in aligning with initiatives like Malaysia's MySPATA. For urban planners and facility managers, the approach addresses operational inefficiencies by providing a centralized, interactive database for managing complex infrastructures. Moreover, the system’s capability in querying and visualizing assets ensures that maintenance needs are promptly addressed, reducing downtime and enhancing service delivery.

While the benefits of integrating 3D GIS into asset management are substantial, the approach has limitations. The initial creation and assembly of detailed 3D models are resource-intensive, and maintaining the system requires continuous updates, particularly in environments with frequent asset changes. Future research should explore automation techniques for updating 3D models, integrating predictive analytics for maintenance scheduling, and expanding the approach to include IoT-enabled sensors for real-time data capture.

In conclusion, the integration of 3D GIS into asset management provides a transformative tool for visualizing and managing assets in a virtual environment. This approach enhances the accuracy and efficiency of asset tracking while offering scalability to adapt to various asset management needs. The implementation represents a significant advancement in the field, promising improved outcomes for asset management practices and paving the way for the broader adoption of spatial technologies across industries.

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