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# Unlocking 3D BIM's Potential: 3DSMS for Efficient Space Management

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## ABSTRACT

In today's world, data is king. Businesses, organizations, and even individuals are generating massive amounts of data every day especially in this era of industrial revolution 4.0. The application of information moved too fast and the conveyance process from one platform to another become one of the biggest challenges that need to cater especially in between Building Information Modeling (BIM) and the space management sector. Due to inadequate interoperability issues between these information systems, significant financial losses will happen. Therefore, this study was conducted (i) to examine the status quo of the implementation of information management technology used in space management and to recognize emerging issues and (ii) to identify technical solutions to these problems based on a proposed framework. The ingenuity of this study is the overall design and functionalities of various components of an integrated BIM-space management portal solution that have not been so thoroughly defined by any previous studies concerning the current results in both theory and practice. The results demonstrate the offered solution by 3D Space Management System (3DSMS) to the current space management issues that are mostly related to the information connection and structure. This study also contributes to the existing body of knowledge in multiple aspects such as (i) it pinpoints the essential data needed for efficient space management and outlines the Levels of Detail (LoD) required for various project phases, (ii) it tackles the compatibility problems frequently faced when merging BIM with other systems and (iii) it introduces a thorough 3DSMS equipped with features for visualization, querying, and many more.

*Keywords:* BIM, integration, space management, technical solution, 3DSMS

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## INTRODUCTION

Space management is defined as a mechanism to assess space needs, recognize shortcomings, equitably assign usable space to users, track use, support users facing conflicts with space utilization, and fix space issues (Piras et al., 2024). Compared to other organizations, the implementation of space management in higher learning institutions (HLIs) is important because teaching and learning spaces need to be receptive to the leading university's evolving requirements; and flexibly built and planned depending on the role to facilitate efficient use (Jutaim et al., 2023). Therefore, the utilization of space and facilities in HLIs has to be prioritized and effectively handled or it would negatively impact both the end-user of the space and their administrative functions (Jutaim et al., 2023). Inefficient space management can result in substantial financial burdens for institutions, leading to increased costs related to unnecessary expansions, excessive energy usage, and the need for frequent, costly maintenance of underutilized spaces. Additionally, administrative challenges arise, including increased scheduling conflicts and inefficiencies in space allocation, which impede daily operations and hinder long-term planning objectives (Basiru et al., 2023).

The emergence of the Building Information Modeling (BIM) paradigm has significantly reshaped information management practices across the construction industry, aiming to enhance coordination and communication (Mustorpha & Mohd, 2019; Cao et al., 2022). BIM has proven its potential in addressing challenges stemming from inefficient and insufficient information production and management throughout the building life cycle, including space management. Higher Learning Institutions (HLIs) particularly benefit from effective space management systems, as they enable cost-effective resource allocation and support evolving academic requirements. Without a standardized, interoperable system, institutions may struggle with resource misallocation and high operational costs, underscoring the importance of adopting robust digital solutions for space management (Cao et al., 2022). Despite the growing adoption of BIM, space management in higher learning institutions remains hampered by poor interoperability and data silos. The inability to seamlessly convey information between BIM models and space usage systems results in resource misallocation, scheduling conflicts, and increased operational costs. This paper addresses this critical gap by proposing a novel 3D Space Management System (3DSMS) that leverages BIM-GIS integration to improve spatial decision-making and optimize institutional operations.

Nonetheless, recent studies show that there are some issues regarding the implementation of BIM for streamlining space management activities such as (i) lack of guidelines (Ma et al., 2020), (ii) lack of adequate technologies for collecting current facilities' BIM models (Trevik & Nilsson, 2017; Ikuabe et al., 2020), (iii) lack of non-consistent terminologies and taxonomies (Pishdad-Bozorgi et al., 2018), (iv) no clear criterion for the standards in BIM applications (Nawari, 2019; Ding et al., 2022) and (v) no metric to assess the details and the amount of information the space management teams require (Matarneh et al., 2019).

This paper is focused on qualitative work based on the concepts of fundamental philosophy. It mainly addresses on how to optimize information transfer from BIM to space management so it can be an effective approach for space management. An overview of the BIM implementation literature for space management is presented, an example of such systems is identified, and its components and features are evaluated in relation to the results of the literature review. The contribution of this study is twofold. Firstly, it summarizes the status quo of the construction of information management technologies used in the activities of facility operation and to identifies prevalent problems and impediments. Secondly, it formulates technological solutions based on an exemplary cutting-edge technical solution to address these problems. This article also contributes to the existing body of knowledge in several ways. Firstly, it identifies the key information required for effective space management and specifies the LoDs necessary for different stages of a project. Secondly, it addresses the interoperability issues often encountered when integrating BIM with other systems. Lastly, it presents a comprehensive 3D space management system (3DSMS) that includes tools for visualization, querying, and others.

While previous works have acknowledged the potential of BIM in facilities and space management, few have operationalized a unified, web-based BIM-GIS platform tailored for real-time space allocation. However, the novelty of this study is situated in its integration of institutional timetable data into a 3D BIM-GIS framework using a Many-to-One semantic coupling model. Unlike prior works, the 3DSMS does not merely visualize space but operationalizes dynamic academic-semantic data into 3D digital environments, enabling real-time, query able analytics aligned to actual institutional workflows. This study contributes a technically robust solution through 3DSMS, closing this gap by demonstrating its practical implementation within an academic setting and providing a replicable model for other institutions. Recent advancements in BIM-GIS integration, cloud-based spatial analytics, and real-time data frameworks have significantly shaped the capabilities of facility and space management systems. For instance, the integration of Digital Twins into campus facilities has begun to revolutionize space optimization strategies by enabling real-time monitoring and predictive analytics (Han et al., 2022). Studies like Valinejadshoubi et al. (2022) emphasize the use of sensor-based occupancy data in conjunction with BIM for adaptive facility scheduling and energy optimization. These developments suggest a shift towards a more dynamic, data-driven ecosystem in facility management that aligns closely with the objectives of the 3DSMS framework. In this context, 3DSMS not only addresses the persistent interoperability challenges but also reflects current industry advancements by enabling real-time spatial analytics through the integration of BIM-GIS and web-based APIs.

## EXISTING TECHNOLOGICAL BIM-SPACE MANAGEMENT INTEGRATION SOLUTIONS

The integration process is important in this Industrial Revolution (IR 4.0) era and is part of IR 4.0 components (Yusoff et al., 2023). There are significant financial losses that occur due to insufficient integration or interoperability between information systems in the building industry, especially in the space management sector (Lau et al., 2018). In general, five (5) key solutions have been used as technological solutions to simplify the transition of knowledge from BIM to space management applications. Firstly, is the utilization of spreadsheets as fundamental tools for text indexing has facilitated the seamless transfer of data from Building Information Modeling (BIM) to space management software. Wisniewski et al. (2019) highlight how basic hyperlink indexing tools within spreadsheets serve as technical solutions for this purpose. Primarily, the establishment of a connection between the spreadsheet and BIM features is essential. This linkage often relies on unique IDs assigned to BIM features, serving as anchors to correlate information with the spreadsheet.

On the other hand, in accordance with Construction Operations Building information exchange (COBie) guidelines, spreadsheets serve as platforms for data exchange, synchronization, and hyperlinking. As Matarneh et al. (2019) explain, COBie, an open standard for data transmission, utilizes formats like EXCEL spreadsheets to disseminate managed asset information effectively. Third key solution is through the Industry Foundation Classes (IFC) format emerges as a standard medium for exchanging information in the realm of openBIM data schemes. The IFC format serves as an open data exchange standard, enabling interoperability between BIM software and other digital platforms used in construction and space management (Pärn et al., 2017). While IFC offers straightforward semantics for stakeholders, Mustorpha and Mohd (2019) caution about its static nature, hindering its universal application across all facility life cycle phases. Challenges persist regarding the integration of IFC into space management, including limited supplier options for IFC-compatible product information and issues like large file sizes and information relevancy (Azzan et al., 2019). Forth key is by coupling Computerized Space Management Systems (CSMS) with BIMs via Application Programming Interfaces (APIs) has become pivotal. The APIs can facilitate the transfer of BIM information to space management software, often via web portals, which serve as platforms for implementing BIM data.

Lastly, proprietary middleware software, such as FM: Interact, EcoDomus, and Onuma Systems, offers alternative avenues for information integration. These middleware solutions, though costly, are favored by major organizations like NASA and GSA. Notably, the 'BIM for FM Portal' framework, introduced by Edirisinghe et al. (2017) and Pinti et al. (2022), has gained traction for its simplicity and versatility. This portal accommodates various space management frameworks, particularly focusing on Computerized Maintenance Management Systems (CMMS). Its modular design allows flexibility for different applications, presenting a relatively cost-effective solution (Shalabi & Turkan, 2017).

## RESEARCH METHODS

This section will discuss the proposed technical GIS solution for optimizing information transfer from BIM to space management medium. This proposed technical solution called 3D Space Management System (3DSMS) has been applied to Kompleks Inspirasi campus building at Universiti Teknologi MARA (UiTM) Shah Alam as a prototype with focus on the syllabus and timetable. The framework of this technical solution is in Figure 1. The proposed technical solution was separated into five (5) main parts. These include the information input, coupling platform, space utilization, space management, and facility management part.

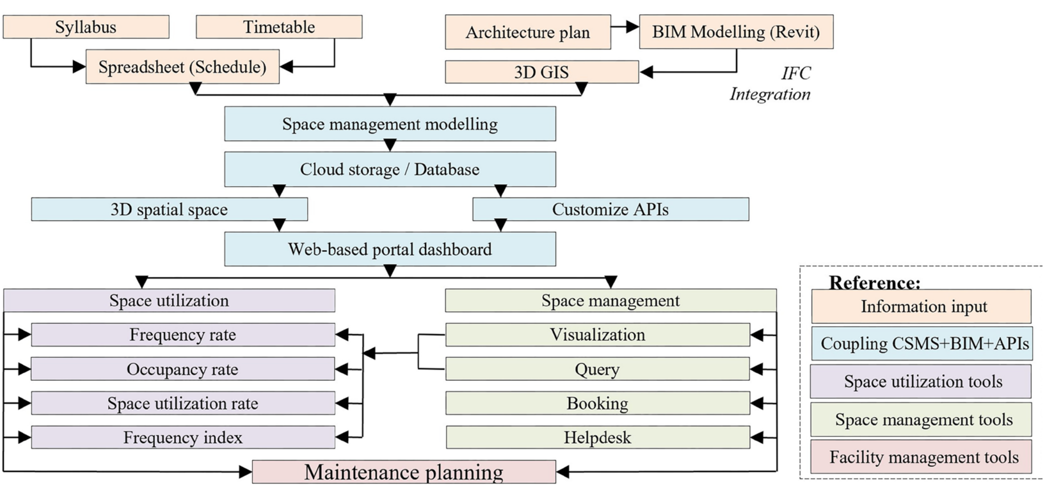


Figure 1. Proposed 3DSMS technical solution framework

### Information Input Part

For the information input part, there were two (2) main types of information involved. These are attribute information and spatial information.

### *Attribute Information*

The attribute information is crucial for campus space management because it is an indicator to identify the space usage of a specific unit or asset. This proposed 3DSMS technical solution combined the information from the syllabus and timetable extracted from the Integrated Course Registration and Scheduling System (ICReSS) of UiTM into a spreadsheet schedule. The spreadsheet schedule contained ten (10) information fields required to validate the space usage as listed in Table 1.

Table 1
*Proposed information field*

| Item | Field name | Data type | Example information | Remarks |
| --- | --- | --- | --- | --- |
| 1 | Course | Text | GLS652 | Course code |
| 2 | Group | Text | AP2203C | Class group |
| 3 | Start | Text | 1700 | Time |
| 4 | End | Text | 1800 | Time |
| 5 | Day | Text | Monday | Gregorian day |
| 6 | Mode | Text | Full Time | Course mode |
| 7 | Status | Text | First Timer | Student status |
| 8 | Rooms | Text | G-A503 | Room number |
| 9 | No of student | Text | 30 | Total number of students |
| 10 | Space ID | Text | 1 | Unique ID for spatial space |

### *Spatial Information*

The spatial information is used as an anchor for campus space management to tie the attribute information into 3D visualization. The 3D visualization is important to serve as a reference to the users especially since most of campus buildings are multi-story buildings. The level of details (LoD) from the 3D BIM model is used widely as a managing model so that all the information from the real world can be easily identified in digital form (Mustorpha & Mohd, 2019).

The 3D BIM model for the proposed 3DSMS technical solution was developed from architectural plans, specifically using Level of Detail (LoD 3) from the Construction Industry Development Board (CIDB) BIM Standards. LoD 3 captures essential details like walls, windows, and doors, providing the necessary granularity for accurate space planning and management within multi-story buildings (Mustorpha & Mohd, 2019). The developed 3D model was integrated into the 3D GIS through IFC as an exchange information medium. An example of an integrated BIM model is in Figure 2.

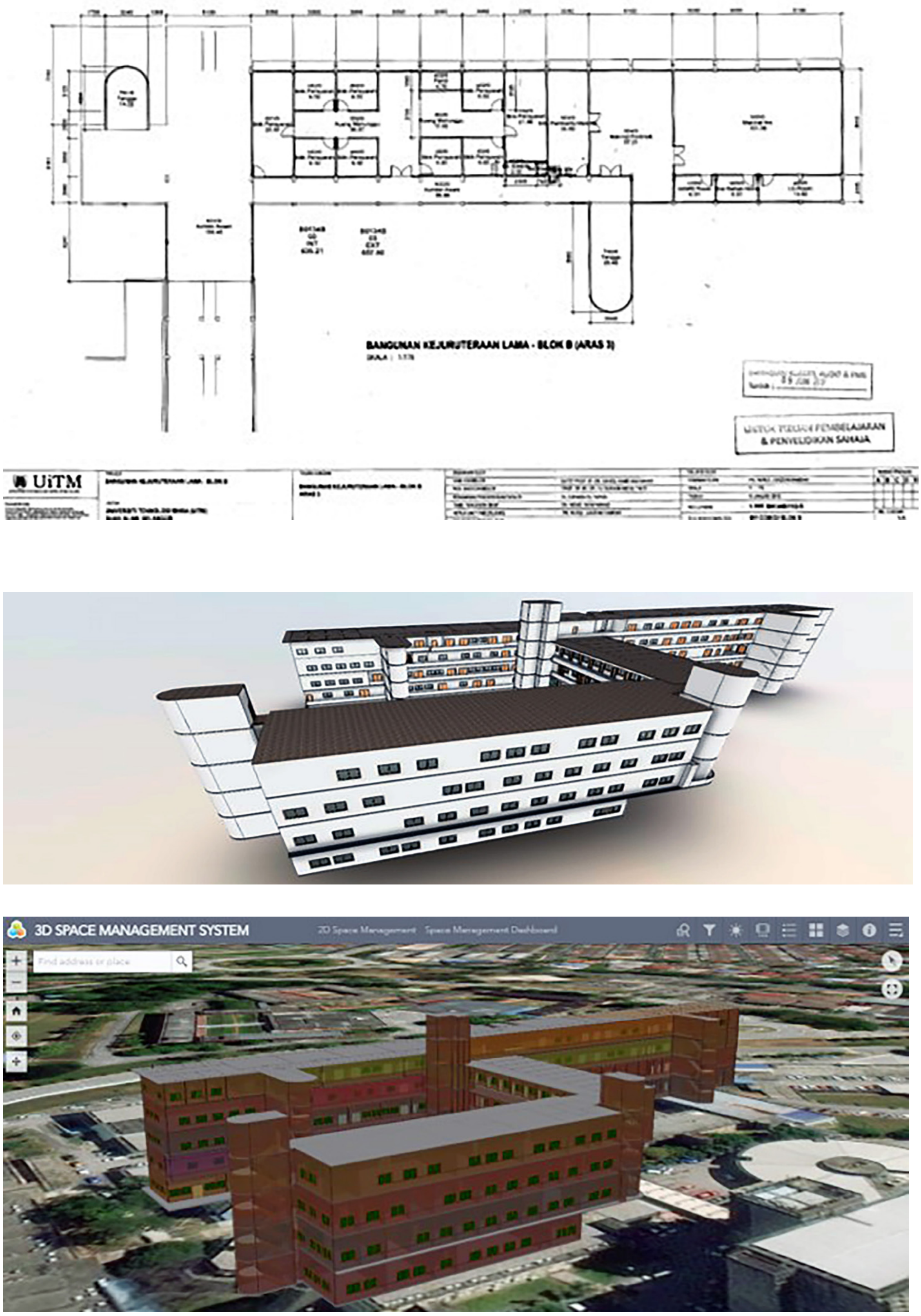


*Figure 2.* Spatial integration sources (a) architecture plan, (b) BIM model, and (c) 3D GIS model

## Coupling Platform Part

The coupling platform part involved the combination process between two (2) information to generate a specific space management modeling, and to import it into a database for the development process. This part was separated into two main phases: coupling and development phase.

### *Coupling Phase*

For the coupling phase, the process of merging attribute information from the ICReSS, and spatial information integrated from BIM were conducted to generate space management modeling. A relationship between the space ID from the attribute information was tied with space unique ID from the 3D modeling to make sure the information was linked to each other. The information relationship used was "Many-to-One" as there were many of attribute information from one specific space that needed to be tied with one specific space of spatial. The relationship combinations concept of information is shown in Figure 3.

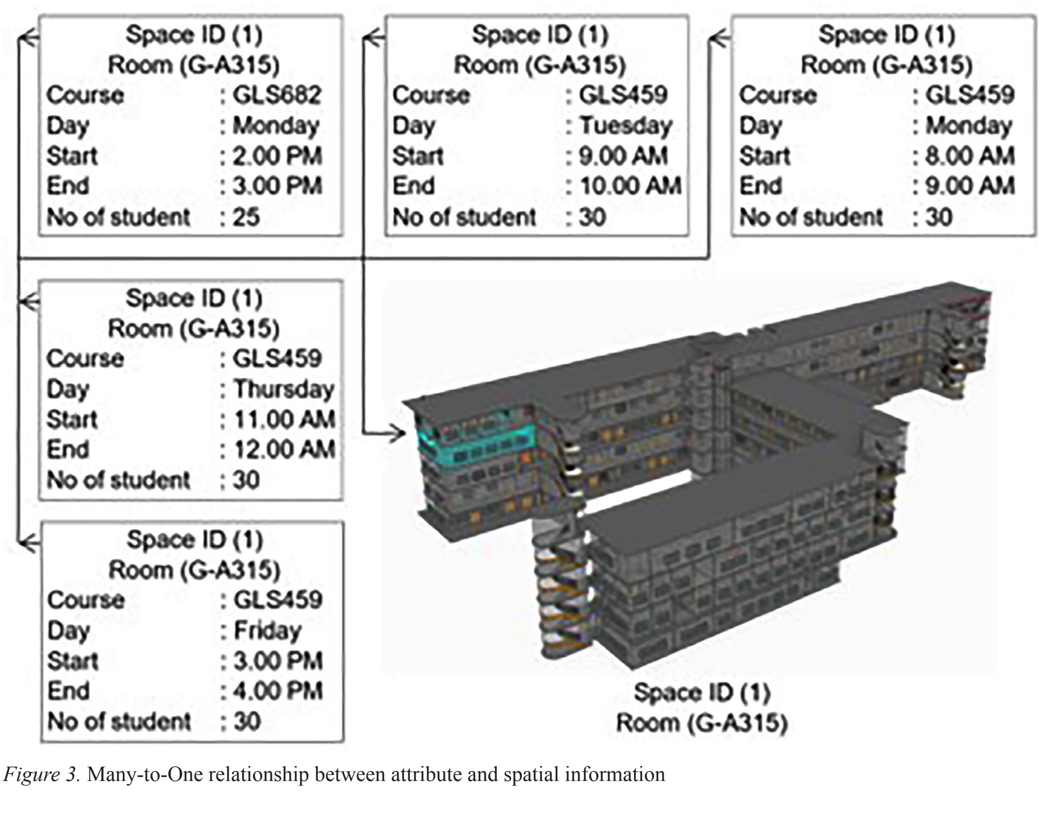


*Figure 3.* Many-to-One relationship between attribute and spatial information

### *Development Phase*

For the development phase, the process started with uploading the generated space management model and its relationship into the database, which in this case study was the ArcGIS Online cloud database. The uploaded 3D space management modeling was visualized through a web scene, and the generated web services were used to customize it into 3D web application APIs. The customized process was conducted by using JavaScript language through the ArcGIS API for JavaScript platform.

### Space Utilization Part

The space utilization part focused on the space utilization tools to indicate the quantitative information of a specific space usage. It was important to identify the level of utilization for each space by the user for the current semester schedule (Ani et al., 2012; Solla et al., 2020). The measurement tools used were based on four (4) types of indicators. These indicators are frequency rate, occupancy rate, space utilization rate, and frequency index.

### *Frequency Rate (FR)*

The frequency rate (FR) is recorded based on the usage time of the space physically. This record is important to understand the frequency of space being utilized. It can be calculated based on the space allocated hours during the week ($H_A$) and total hours used within a week ($H_U$). The formula as in Equation [1].

$$FR = \left( \frac{H_U}{H_A} \right) \times 100 \qquad [1]$$

### *Occupancy Rate (OR)*

Occupancy rate (OR) is used to identify the occupancy percentage of each space. It is calculated based on the total number of students used within a week ($T_{SU}$), total room capacity ($T_{RC}$), and total hours used within a week ($H_U$). The formula as in Equation [2].

$$OR = \left( \frac{T_{SU}}{T_{RC}\ x\ H_U} \right) \times 100 \qquad [2]$$

### *Space Utilization Rate (SUR)*

Space utilization rate (SUR) is used to indicate the utilization percentage for space. It is calculated based on the frequency rate and occupancy rate. The formula as in Equation [3].

$$SUR = \frac{FR\ x\ OR}{100} \quad [3]$$

***Frequency Index (FI)***

Space frequency index (FI) is used to determine the frequency of use of spaces that are particular according to the scale of use namely minimal, optimal, and maximal use of critical applications as seen in Table 2. It is identified by the combination of the schedule data and the spaces used at the campus. It is calculated based on the frequency rate (FR) and the space allocated hours during the week ($H_A$) according to the space usage frequency. The calculation formula follows Equation [4].

$$FI = \frac{FR}{H_A} \quad [4]$$

Table 2
*The frequency index determinants (Ani et al., 2012)*

| Index | Range | Usage indicator | Percentage consumption variations |
|---|---|---|---|
| 1 | 0-1 | Minimal | 0% - 15% |
| 2 | 1-2 | Optimal | 51% - 75% |
| 3 | 2-3 | Maximal | 76% - 100% |
| 4 | 3-4 | Critical | >101% |

**Space Management Part**

The space management component of the proposed 3D Space Management System (3DSMS) encompassed tools vital for handling qualitative space information, serving as the cornerstone for user control. These tools comprised a visualization window, query tool, booking tool, and helpdesk.

The visualization window enabled users to observe the 3D space management model populated with spatial data, particularly crucial for multi-story buildings to facilitate easy spatial identification from a real-world perspective. It provided access to spatial details and various floor plans derived from Building Information Modeling (BIM). Additionally, it listed information pertinent to teaching spaces, such as classrooms, including space, floor, area, capacity, and building unit. The query tool facilitated user searches and multiple queries based on the 3D space management model, allowing planning and retrieval of attribute or spatial location information for specific spaces. Both visualization and query tools were integrated with space utilization data to offer additional references for users.

The booking tools empowered users to reserve specific spaces for various purposes, enabling direct visualization of space location in 3D. These tools paralleled the functionality of the eRuang System utilized by UiTM, with the added feature of 3D spatial capabilities. Finally, the helpdesk tools were designed to aid users in obtaining information and generating reports through the web application. Integrated with the admin email address, they ensured immediate alerting of reported cases to the admin.

The semantic coupling mechanism implemented through Many-to-One mappings between class schedule entries and 3D spatial identifiers offers a practical approach to semantic interoperability. This enables space usage analytics grounded in actual semantic content such as the scheduled time of classes and the number of students enrolled, harmonized within the 3D spatial environment.

### Facility Management Part

Lastly, the facility management part was developed to allow users to identify the overall rate of space usage as well as helping users to plan maintenance activities. It was crucial for the management to recognize the information of space usage prediction before planning the maintenance activities.

## RESULTS AND DISCUSSIONS

The proposed 3DSMS technical solution was a web-based portal solution that served all CSMS tasks, and easily and efficiently incorporated and synchronized the underlying academic schedule building information databases with the 3D building models at the same time. The most critical field issues derived from the literature are discussed in this section.

In the realm of BIM, the integration of spatial data into space management practices has emerged as a significant challenge. The complexity of this integration often leads to inefficiencies and inaccuracies that can impact the overall project outcomes. Our proposed technical solution, the 3DSMS, aims to optimize the conveyance of information from BIM to space management, addressing these challenges head on.

The first challenge we address is the identification of relevant information (Ma et al., 2020). Space managers often struggle to determine which information is critical for effective space management. The 3DSMS leverages 3D building models with spatial information, directly addressing space management requirements. By integrating attribute data, such as course schedules, with BIM, we ensure that relevant information is readily available. This approach not only streamlines the space management process but also enhances the accuracy and reliability of the information used. Furthermore, the second challenge is specifying the LOD for BIM models (Nawari, 2019). Deciding on the appropriate LoD can be complex, given the varying requirements of different stages of a project. The 3DSMS utilizes LoD 3 BIM models, striking a balance between detail and efficiency. This ensures accurate representation without overwhelming users with unnecessary details. By focusing on the most relevant aspects of the BIM model, we can optimize the use of resources and improve the efficiency of space management.

BIM models also often contain extraneous data that are irrelevant to space management, posing another challenge (Pishdad-Bozorgi et al., 2018). Our approach focuses on constructing BIM models specifically tailored to space management needs, filtering out unnecessary information. This not only simplifies the space management process but also reduces the risk of errors and inconsistencies. Besides that, industry-wide standards and data structures vary across different BIM sources, leading to another challenge (Nawari, 2019). The 3DSMS adheres to local and commonly used industry standards, such as CIDB BIM Standards and IFC, ensuring consistency and interoperability. This standardization facilitates the integration of BIM with other systems and enhances the overall efficiency of space management. Finally, ensuring that attribute information aligns with BIM authoring tools is a significant challenge (Matarneh et al., 2019). The 3DSMS maintains a unified database derived from the BIM model, ensuring seamless integration between attribute data and spatial information (Trevik & Nilsson, 2017). This approach not only simplifies the space management process but also enhances the accuracy and reliability of the information used.

To enhance our discussion, we draw insights from related studies. NASA effectively determined ineffective space usage and developed optimal strategies using space-based information (Pärn et al., 2017). Our 3DSMS approach aligns with NASA's goal, emphasizing efficient space utilization. Similarly, Northumbria University's BIM implementation improved workforce efficiency and geometric accuracy (Pishdad-Bozorgi et al., 2018). The 3DSMS extends this concept by integrating BIM with space management, enhancing overall efficiency. Furthermore, BIM facilitated dynamic energy efficiency evaluation at California State University, Fresno (Wong et al., 2018). The 3DSMS could similarly predict space usage patterns, aiding maintenance planning.

In conclusion, our proposed 3DSMS bridges the gap between BIM and space management, offering an innovative solution for efficient information transfer. By addressing key challenges and drawing insights from existing research, we contribute to the advancement of space management practices. We believe that the 3DSMS has the potential to significantly impact the field and look forward to further research and development in this area.

## Comparative Evaluation of 3DSMS

Table 3 presents a comparative analysis of 3DSMS and two widely-used commercial facility management platforms. The key differentiator of 3DSMS lies in its semantic integration of timetable data within 3D BIM-GIS environments tailored to institutional needs. As shown in Table 3, 3DSMS outperforms FM:Interact and Onuma in critical areas, including schedule integration, academic-specific design, and 3D querying capabilities. Unlike FM:Interact and Onuma, which often rely on costly licenses and provide generic templates, 3DSMS is purpose-built for academic institutions and can be deployed through open-access APIs. This approach enhances both cost-effectiveness and scalability, particularly for public-sector applications.

Table 3
*Comparative features of 3DSMS and commercial facility management platforms*

| Feature | 3DSMS | FM:Interact | Onuma |
|---|---|---|---|
| Schedule integration | √ | X | X |
| 3D Query | √ | Limited | √ |
| Academic-specific design | √ | X | X |

## Impact of 3DSMS on Space Management at UiTM Shah Alam

The deployment of the 3D Space Management System (3DSMS) at UiTM Shah Alam marked a significant advancement in optimizing campus space utilization, providing both administrators and facility managers with a comprehensive tool for data-driven decision-making. Through the integration of BIM with GIS-based 3D spatial modeling, the 3DSMS enabled real-time monitoring of space usage patterns, helping administrators to identify, predict, and respond to varying space demands across the academic calendar. This case study highlighted several quantifiable outcomes that underscore the system's effectiveness.

Following the implementation of 3DSMS, the campus saw a notable 15% improvement in space utilization rates, particularly in high-demand areas such as lecture halls and laboratories. By analyzing real-time occupancy and frequency data, administrators were able to maximize the use of these spaces by redistributing schedules, leading to a more balanced and efficient allocation of rooms. This optimization minimized instances of overcrowding while ensuring that underutilized spaces were effectively repurposed, aligning resource use with actual needs (Ani et al., 2012).

The visualization and data integration features of 3DSMS facilitated a more streamlined scheduling process, enabling proactive identification and resolution of potential scheduling conflicts. Within one semester, the number of scheduling conflicts decreased by approximately 20%, freeing up valuable administrative resources that were previously dedicated to manual adjustments (Jutaim et al., 2023). By providing real-time data and spatial insights, 3DSMS not only reduced operational disruptions but also decreased the administrative workload associated with space allocation and rescheduling.

Another significant impact observed was in the area of facility maintenance and cost management. By prioritizing maintenance efforts based on actual space usage data, UiTM Shah Alam was able to reduce maintenance costs by an estimated 10%. High-use areas that experience greater wear were targeted for timely maintenance, preventing costly repairs associated with deferred upkeep. This data-informed approach allowed facility managers to extend the longevity of infrastructure and optimize the allocation of maintenance resources, reducing both immediate and long-term costs (Wong et al., 2018).

The long-term insights provided by 3DSMS contributed to more informed strategic planning for the institution. By analyzing patterns in space usage over time, UiTM Shah Alam was able to make data-backed decisions regarding the repurposing or reconfiguration of spaces to meet evolving academic demands. This capability is particularly valuable for academic institutions, where fluctuating student populations and curriculum changes necessitate adaptable spatial solutions (Cao et al., 2022). The data provided by 3DSMS empowered campus planners to anticipate future needs, thereby ensuring that spaces remain functional, adaptable, and aligned with institutional growth.

In summary, the 3DSMS implementation at UiTM Shah Alam demonstrated substantial improvements across multiple dimensions of campus space management. The system's ability to merge BIM and 3D GIS data into a single, accessible platform enhanced space utilization, reduced administrative burdens, and delivered cost savings, all while supporting long-term strategic planning. These practical outcomes not only validate the effectiveness of 3DSMS but also illustrate its potential as a model solution for similar institutions aiming to improve space efficiency and resource management through advanced digital integration.

## CONCLUSIONS

According to our study, a lack of guidance and effective technology to acquire the BIM models of the existing facilities were the most critical problems when applying BIM for streamlining space management activities. It involved working with non-consistent terminology, correctly describing and determining specifications in BIM applications, and identifying the details needed for space management and required level of detail. IFC is currently developing open formats for sharing building knowledge to ensure interoperability between the wide spectrum of proprietary resources and systems, and effective and sustained usage over the entire life cycle of the building.

Concerning the status quo of the subject field, previous study has not extensively defined the overall design and functionality of the various components of an integrated

BIM-GIS method based on a portal solution both in theory and reality. The technical solution proposed in this study through 3DSMS has the potential to optimize the information integration from BIM to space management medium, and to utilize the IR 4.0 technologies for the greater good. The 3DSMS technical solution demonstrates practical value, as seen in its application to UiTM Shah Alam, by enabling a more efficient, data-driven approach to space management. By reducing scheduling conflicts, improving resource allocation, and cutting costs, 3DSMS serves as a model solution for institutions seeking to modernize their space management practices.

Although this case study focused on a single institution, the methodology and framework of 3DSMS are scalable and adaptable across HEIs and other large public facilities, particularly in emerging economies. The use of open-source APIs and flexible semantic bindings ensures that institutions with limited financial or technical capacity can replicate or extend the system according to local needs, supporting broader space governance and infrastructure planning objectives.

Beyond its localized implementation, the study introduces an operational semantic harmonization strategy via unique ID pairing and space-time coupling. This approach could be replicated across different institutional typologies, contributing incrementally to the discourse on pragmatic semantic interoperability in BIM-GIS systems.

However, to complement the findings of this study on the efficient use of BIM for space management through 3D GIS-based system, further research with a focus on facility management is needed, particularly the space management and regulatory aspects of building information handover.

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