UNIVERSITI TEKNOLOGI MARA

DEVELOPMENT OF AN INTEGRATED 3D GIS-BIM FRAMEWORK FOR SMART CLASSROOM SPACE OPTIMIZATION SYSTEM

SHARIFAH NURUL AIN BINTI SYED MUSTORPHA

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ABSTRACT

In recent years, the need for multi-dimensional geoinformation has increased to provide more realistic representations and enhance operational awareness for both external and internal building infrastructures. Space management, a branch of facilities management, focuses on managing building space infrastructure effectively. However, its implementation in Higher Education Institutions (HEIs) is rarely discussed, especially in addressing the cost of wasted space and issues related to space optimization. Since providing space is costly, HEIs must ensure the best possible service delivery to support their core functions. Most HEIs struggle with limited space availability to accommodate academic programs, and even the existing spaces are often underutilized. Challenges in implementing space management include the unavailability of reliable information, the absence of centralized data management, and the use of ineffective systems and methods. Therefore, this study was conducted to design and investigate the use of a multi-dimensional Geographic Information Systems (GIS) application based on an integrated Building Information Modeling (BIM) model for optimizing classroom space utilization. The research began with a literature review focused on current 3D geospatial technologies and space optimization tools in facilities management to establish key research directions. The study identified seven key issues in current space management practices: difficulties in identifying essential information, ambiguity in specifying required Levels of Detail (LoD), the inclusion of non-useful design and construction data, inconsistencies in classification standards, mismatches in field information, lack of direct integration with schedule data, and reliance on manual, time-consuming querying processes. Three methods of BIM to GIS were tested and assessed based on geometric and semantic accuracy to determine the most suitable 3D model for implementation. A Many-to-One data relationship was applied to connect timetable data with spatial information within a geodatabase. Three multi-platform prototypes, 2D, 3D, and dashboard visualizations were developed and evaluated in a case study. The findings show that the integrated 3D GIS-BIM framework successfully addressed major issues in current space management systems. Notably, its enhanced space utilization transparency, enabled real-time visualization, improved data accessibility, and supported better decision making for space planning. The flexibility of 3D modeling to support both 2D and 3D environments proved vital for operational efficiency. This research offers a practical solution for HEIs to manage space more effectively, reduce inefficiencies, and promote sustainable infrastructure governance.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

In contemporary society, individuals spend the majority of their time whether actively working or resting within built environments. These structures have evolved into complex, man-made ecosystems composed of interdependent physical infrastructure, digital systems, and human activity (Ammar et al., 2022). With the rapid advancement of digital technologies, the design, operation, and maintenance of such environments have become increasingly sophisticated. Managing these intricate ecosystems now demands integrated platforms capable of handling spatial, semantic, and operational data at scale (Luo et al., 2023).

Facilities Management (FM) has emerged as a multidisciplinary domain that focuses on the post-construction phase of buildings. It aims to ensure functionality, comfort, and sustainability by integrating people, place, process, and technology (Rosario da Silva et al., 2024). FM professionals are responsible for managing a range of critical systems utilities such as water, electricity, air conditioning, and safety measures while ensuring occupant well-being and operational efficiency (Opoku & Lee, 2022). Despite its strategic importance, the FM landscape continues to be constrained by fragmented data sources, non-scalable legacy tools, and disconnected platforms (Jiang et al., 2023).

This is particularly evident in Higher Education Institutions (HEIs), where the management of physical space plays a vital role in supporting teaching, learning, and research functions. In many institutions, spatial data is managed across multiple platforms such as 2D CAD files, Excel spreadsheets, and scanned documents resulting in duplication, inefficiencies, and delays in data updating and retrieval (Ammar et al., 2022). The manual nature of these processes limits the institution's ability to respond to dynamic space demands, especially when dealing with frequent changes in course timetabling, enrolment, and space usage.

The increasing complexity of university campuses, combined with growing demands for accountability, sustainability, and resource optimization, calls for a more integrated and digital approach to FM. Multi-dimensional visualization tools,