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ADVANCING THE BIM-BASED FACILITY MAINTENANCE AND MANAGEMENT DATA ANALYSIS PLATFORM: A CLOUD-CENTRIC APPROACH

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Abstract

This study builds on the findings of our previous research, "Creation of a BIM-based facility maintenance and management data analysis platform", further developing an application to analyze facility management data using Building Information Modeling (BIM). As labor shortages grow in the expanding construction industry, streamlining tasks via digital transformation (DX) is becoming more urgent. BIM is viewed as a key tool for coordinating design and construction, yet full, organization-wide adoption remains challenging, possibly due to insufficient digital capability. By focusing on a headquarters facility's facility management (FM) and construction management (CM) tasks, this study investigates a BIM-based method for boosting organizational digital capability and confirms its effectiveness. While our earlier research integrated BIM models and facility data in a local environment—entirely dependent on BIM software installed locally—in the present research, we aim to construct a cloud platform that promotes organization-wide digital transformation, thereby reducing labor and enhancing efficiency in facility management.

In building this system, we first defined requirements and organized methods for linking BIM models with existing operational data. We then created a browser application using Autodesk Platform Services (APS) and examined how data management mechanisms function when integrated with Amazon Web Services (AWS). Specifically, we developed a browser application to visualize data such as repair frequency, electricity usage, and seat utilization, harnessing APS and uploading everything to AWS, enabling centralized management in the cloud. This paper discusses the insights gained from these initiatives as well as future challenges and prospects.

Keywords: BIM, Data Integration, Digital Twin, Existing Building, Facility Maintenance and Management

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1. Introduction

In the construction industry, demand for new buildings continues to rise while the labour force is shrinking; therefore, reducing the workload of existing operations through digital transformation (DX) has become an urgent issue. Building Information Modelling (BIM) is a leading DX technology and is already used widely in design and construction processes. Organisation-wide, comprehensive BIM utilisation, however, is still limited—most likely because digital capability inside companies has not yet been fully developed [2]. Taking the facility-management (FM) and construction-management (CM) tasks of a headquarters complex as an example, this study examines BIM-based methods designed to build digital capability across the entire organisation, and it evaluates the effects of introducing those methods.

1.1. Previous study

Our earlier work, "Creation of a BIM-based facility maintenance and management data analysis platform." successfully linked BIM models with facility-management data and visualised that data in a three-dimensional space. Nevertheless, several problems were identified, all stemming from the system's dependence on a local environment: only staff proficient with BIM software could operate the

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system, and data synchronisation could not be automated. The present study therefore redesigns the earlier data-visualisation system for cloud operation and aims to create a tool that facility-management personnel can use easily in the field.

1.2. Terms of definition

Jisc (2024) defines organisational digital capability as the holistic ability to leverage digital technologies to support core business operations while enhancing the digital skills of staff and stakeholders. There are two major approaches to building digital capability in an organisation:

- Improving overall digital skills.
- Creating an inclusive system.

Gaps between existing systems and users can be closed either by training users or by rebuilding the system side. This study focuses on latter second approach and aims to employ BIM as a unified life-cycle database for the headquarters' FM and CM operations by developing a cloud-based business-support application that links BIM with FM/CM data.

2. Current status of facility maintenance and management

2.1. Outline of this study

Based on the above, this study will proceed in the following four phases to verify the usefulness of facility management and the use of BIM in existing head office buildings.

- Define and create the BIM model requirements.
- Define and create the application requirements.
- Introduce and test the application in real or simulated operations.
- Evaluate the effects based on user feedback.

2.2. Site selection and organization of current status

This study focuses on the headquarters facility with a total floor area of approximately 8,000 square meters, for which a real estate management BIM model is created. Additionally, we organize the current operations and facility maintenance and management data of the target facility as shown in Figure 1 and discuss what elements are necessary for linking them with the real estate management BIM model.

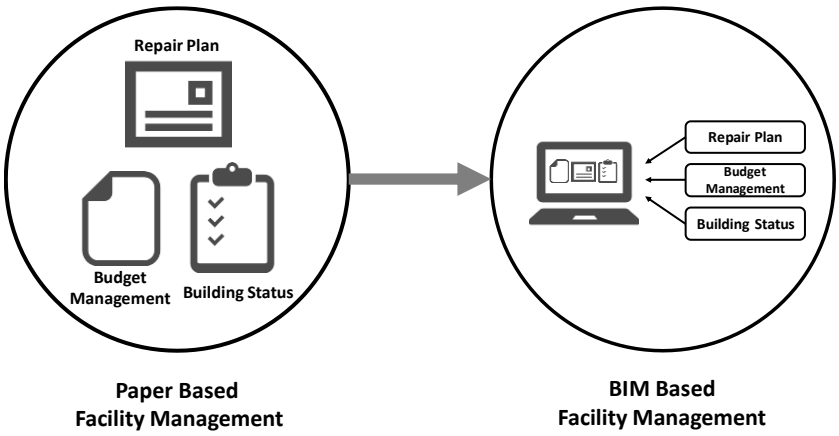

Fig.1. BIM implementation for organization of data based Facility Management and Maintenance

By linking each facility management data to the BIM model, cross-data analysis becomes easier, enabling efficient facility maintenance and management operations and providing a multi-perspective view in a three-dimensional space. This study will display three types of textual data and spatial data

owned by the target facility within a three-dimensional space. Below, we present the content of each data and the goals for data linkage.

- Electricity Usage Data

  The electricity usage (in kWh) for each floor is recorded hourly in a CSV file. The goal is to visualize the electricity consumption of each floor in a three-dimensional space. To achieve this, it is necessary to create models representing the space of each floor, so spatial objects resembling the actual office areas will be placed.

- Seat Utilization Data

  The occupancy status of each seat in the office's free-address area is recorded every 15 minutes in a CSV file. Since this data is recorded on a per-seat basis, it is necessary to create seat objects corresponding to each data point. The goal is to input the occupancy rate for each seat into the created objects and represent this in a three-dimensional space.

- Maintenance Record Data

  The details and timing of maintenance work carried out in the target facility are recorded for each project. The goal is to compile the content of the maintenance work by floor and create an environment where the data can be viewed as textual information in a three-dimensional space.

3. Development of the Real Estate Management BIM Model

3.1. Basic Concept for Constituting the Real Estate Management

The conditions required for the BIM model created in this study are summarized below:

- The BIM model should be capable of linking multiple facility maintenance and operation data owned by the facility and representing these data in a three-dimensional space through integration with the BIM model.
- The BIM model should allow for regular modifications due to repair and layout change works, with such modifications being minimal.
- Regardless of the size of the target facility, the BIM model should be of minimal data volume to ensure smooth facility maintenance and operation tasks.

On the above basis, we determined the Employer's Information Requirements (EIR), BIM Execution Plan (BEP), and Levels of Development (LOD). Table 1 shows the BEP defined for this study, and Figure 2 presents the completed BIM models of the two buildings. To create the real estate management BIM model, first define the EIR and BEP. EIR refers to the requirements definition and objectives formulated at the initial stage of the project and provided by the project's client. After defining the EIR, define the BEP, which refers to the detailed requirements definition for creating the actual BIM model. The BEP defined in this study is shown in Table 1 below.

Table1: The BEP defined in this study

Contents	**Definition**
Purpose of the Project	Visualization to optimize the maintenance and operation of the company's buildings. This aims to automate and upgrade maintenance and management operations in the future by integrating FM data held by the target facilities.
Scope of BIM Application	Using BIM as a platform for integrating building maintenance and operations data
BIM Software	Autodesk Revit 2024
Modeling Requirements	Spatical objects for data linking, FFE (Furniture, Fixture, Equipment)s, columns, beams, exterior walls, interior walls, floors and ceilings

3.2. Definition and Configuration of Spatial Objects and Levels of Development in BIM Model

Next, detailed consideration is given to the creation method of spatial objects necessary for data linkage in creating the real estate management BIM model. In this study, when linking the BIM model with the seat occupancy rate data owned by the target facility, identification on a per-seat basis is necessary. However, seat models placed from a single family cannot be individually recognized, making analysis on a per-seat basis impossible. Therefore, families were created for each seat to eliminate duplicate identification information, allowing for data linkage on a per-seat basis. Additionally, each family's name was set as "Floor_Seat Number" (e.g., 8F_1) to make identification easier during later data linkage tasks. This applies equally to electricity usage data and maintenance record data. For electricity usage data, spatial objects need to be created for each floor, so they were set as "Electricity Section_Floor" (e.g., Electricity Section_8F). For maintenance record data, they were set as "Floor_Maintenance" (e.g., 8F_Maintenance). Also, in creating the BIM model, the LOD for each object placed is set. LOD represents the detail level of shape and attribute information of BIM objects, indicated by numbers 100 to 500 following LOD. The higher the LOD number, the more detailed the model. This study uses the five levels of standards 100, 200, 300, 350, 400 defined by the BIM Forum LOD Specifications.

3.3. Creation of the Real Estate Management BIM Model

Based on the requirements and LOD defined in the previous sections, the real estate management BIM model is created. The model placement is performed in the order of columns and beams, floors, interior and exterior walls, ceilings, based on the member list described in the completion drawings. The comparison between the actual building and the completed model is shown in Figure 2 below.

Fig. 2. Exterior and interior renderings of the developed BIM model representing the target facility

4. Integration of FM Data into BIM model for the Real Estatement Management

4.1. Functional Requirements for a BIM-Based Facility Data Application

To begin the application development process, we first organized the current operational conditions and defined detailed requirements for each data type. The consolidated requirements for each dataset are summarized in Table 2.

Table 2: Consolidated Requirements for each dataset

Item	Seat Utilization Data	Energy Consumption data	Repair Records Data
Linked Data	Seat reservation system	Electricity billing data, smart meter data	Repair request records, construction completion reports

Visualization Method	Color-coded display of seat utilization rates on BIM model (e.g., red = high, blue = low)	Color-coded display of area-by-area energy consumption on BIM model	Heatmap display of the number of repairs by area on BIM model
Time Axis Support	Filterable by month, week, or day	Displayable by month or day	Selectable periods (e.g., past 1 year, past 3 years)
Data Update Method	Periodic automatic update or manual CSV upload	Monthly or daily data import	Monthly or ad-hoc updates
User Interaction	Clicking on a seat displays a time-series graph of utilization	Clicking on an area displays a time-series graph of energy consumption	Clicking on an area shows repair history list and defect details

As those datasets were stored and managed by each department separately, cross-analysis was previously impossible. Integrating them into the BIM is expected to yield benefits such as bulk procurement of building components across facilities and energy saving through building-specific benchmarks. In addition to the specific requirements for each data type, general functional requirements for the overall application were also conceptualized, taking into account future development and operational needs. While the application is still under development, these basic requirements have been outlined to ensure that the system will eventually support not only data visualization but also daily operational tasks, user accessibility, and information security. The basic requirements are summarized in Table 3.

Table 3: Basic Requirements for the Application

Perspective	**Requirement**
Data Integration	Ability to regularly link operational data and external files (e.g., CSV) related to each business task
BIM Model Integration	Ability to map and visualize various operational data spatially on the facility's 3D BIM model
Interactivity	Clicking on each seat or area should display detailed information and time-series graphs via pop-up
Time Axis Filtering	Ability to filter and display data by day, week, month, or year
Cloud Operation	Operates via Autodesk Platform Services (APS) and AWS, accessible from a web browser
Data Update Management	Interface allowing administrators to easily update data or automatic data ingestion functionality
Non-Technical User Interface	Designed for intuitive use by facility management staff without prior BIM operation experience
Security	Meets security requirements such as data protection, access control, and audit logging

4.2. Development and Deployment of the Browser-Based Application

Using Autodesk Platform Services (APS), we built a dynamic, browser-based system and deployed it to Amazon Web Services (AWS) for cloud-level data management. Figure 3 illustrates the system flow, and Figure 4 shows an example in which repair counts for each area are displayed in the BIM model.

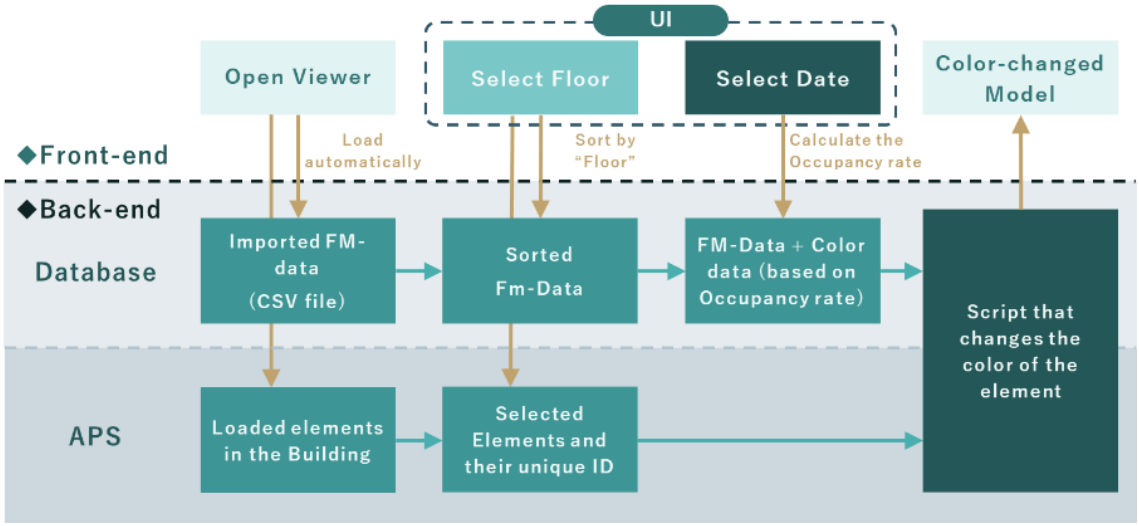

Fig. 3. System flow of seat usage visualization

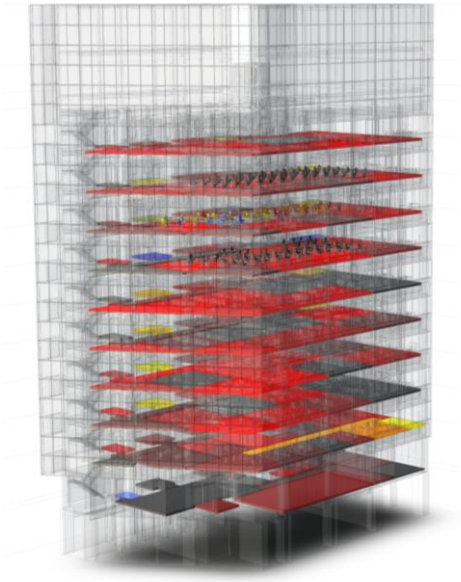

Fig. 4. Heatmap visualization of maintenance frequency on BIM model

5. Conclusion

The challenges identified in our previous research, such as the need for regular model data updates and dependence on a local environment, have been addressed through the utilization of Autodesk Platform Services (APS). Figure 5 shows the current state of the application development.

Moving forward, the highest priority is to complete the development of the application in accordance with the requirements defined in this study. After achieving this, we aim to refine the system through operational testing, including User Interface (UI) improvements and enhanced data integration efficiency. Furthermore, we envision expanding the system's capabilities to support multiple buildings, with the ultimate goal of providing a comprehensive digital tool that can solve a wide range of corporate real estate management challenges.

Fig. 5. Current situation of the application

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