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CREATION OF A BIM-BASED FACILITY MAINTENANCE AND MANAGEMENT DATA ANALYSIS PLATFORM

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Abstract: While Building Information Modeling (BIM) is an important tool for digitization in the architecture industry, its introduction rate in the field of facility maintenance and management is still low. Accordingly, this study aims to spread BIM to this field. The introduction of BIM enables centralization of facility data that has been managed separately in two-dimensional data and allows analysis across data in three-dimensional space. This study includes three phases. Phase 1 is to create a BIM model of the head office building in Japan as an example, phase 2 is to link the BIM model with the building data, and phase 3 is to create an analysis environment based on the data-linked BIM created. The BIM model is linked to three sheets of data using Dynamo; data showing the seating ratio of the seats in the free-address office owned by the facility, the amount of electricity used, and the repair work history of the building. Finally, an analysis environment is created for using the BIM model with data linkage in actual facility maintenance and management operations. As the platform created in this study now makes it possible to analyze multiple sets of data in a three-dimensional environment, it is expected to provide multifaceted solutions through analysis across multiple datasets.

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

1. INTRODUCTION

In recent years, as the construction industry moves toward digital transformation (DX), the adoption rate of Building Information Modeling (BIM) in facility maintenance and operation management remains lower than in other operations. This is attributed to the high barrier to entry for facility maintenance and operation managers in using BIM. This study aims to promote the widespread use of BIM in facility maintenance and operation management by creating a facility management BIM model using an existing headquarters facility as an example. Furthermore, by linking the created BIM model with the facility maintenance and operation data owned by the headquarters facility, we establish a BIM-based practical environment for facility maintenance and management operations and discuss the effects of its implementation in this sector.

2. CURRENT STATUS OF FACILITY MAINTENANCE AND MANAGEMENT

2-1. Outline of this study

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

(1) After organizing the details of facility management and operations currently being conducted and defining the Employer Information Requirements (EIR) and BIM Execution Plan (BEP), the actual models are created accordingly. Furthermore, each process, including determining the level of detail for each model, is organized.

(2) Link the BIM model created in phase (1) with the numerical and spatial data among the facility maintenance management and operation data owned by the facility.

(3) Create a working environment for using the facility management BIM model completed in phase (2) in an actual operation.

2.2. Site selection and organization of the current status

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

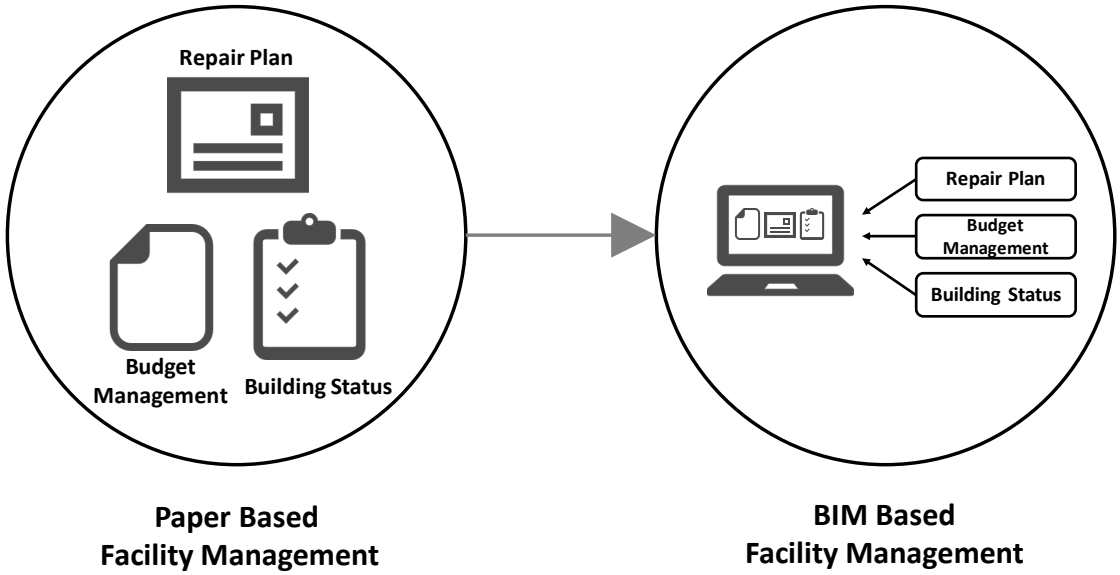


Figure 1: BIM implementation for the organization of data-based Facility Management and Maintenance

Although these data are stored in Excel files, cross-data analysis is difficult because they are saved separately and managed by different departments. Linking each facility management data to the BIM model thus facilitates cross-data analysis, enabling efficient facility maintenance and management operations, providing a multi-perspective view in a three-dimensional space. In this study, three types of textual data and spatial data owned by the target facility are displayed within a three-dimensional space. Below, we present the content of each data and the goals for data linkage.

(a) 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, spatial objects resembling the actual office areas will be placed to represent each floor.

(b) 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 these data are recorded on a per-seat basis, creating seat objects corresponding to each data point is necessary. The goal is to input the occupancy rate for each seat into the created objects and represent this in a three-dimensional space.

(c) 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. STRUCTURE OF THE FACILITY MANAGEMENT BIM MODEL

3.1. Basic Concept for Constituting the Facility Management

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

(a) The model should be capable of linking multiple facility maintenance and operation data owned by the facility as well as representing these data in a three-dimensional space through integration with the BIM model.

(b) The model should allow for regular modifications due to repair and layout change works, with such modifications being minimal.

(c) Regardless of the size of the target facility, the model should be of minimal data volume to ensure smooth facility maintenance and operation tasks.

The elements that make up the facility management BIM model considered under the above conditions include the walls, columns, floors, beams, roofs, stairs, ceilings, and Furniture, Fixtures, and Equipment (FFE), spatial objects for data linkage, and the exterior and surrounding sites, which are discussed in the following. First, among the main structural parts such as walls, columns, floors, beams, roofs, stairs, beams and stairs are not directly necessary for the BIM model created in this study. However, as beams are important components representing the structure of the building, their inclusion is necessary. Beams are important not only for this reason but also to help users grasp the space in three-dimensional space when analyzing the model's interior and exterior walls, floors, and roofs. Next, ceilings and FFE are necessary elements constituting office space, so they will also be created. Finally, the exterior and surrounding sites will be created for use in design considerations for future renovation works.

3.2. Definition of Requirements for Creating the Facility Management BIM Model

To create the facility management BIM model, first the EIR and BEP are defined. 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, the BEP is defined, which sets out the detailed definition of requirements for creating the actual BIM model. Table 1 represents the BEP defined in this study.

Table1: BEP defined in this study

Contents	Definition
Purpose of the Project	Visualization to optimize the maintenance and operation of the company's buildings. Aiming 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 Revit2024
Modeling Requirements	Spatial objects for data linking, FFEs, columns, beams, exterior walls, interior walls, floors and ceilings

3.3. Creation of Spatial Objects

Subsequently, the creation method of spatial objects necessary for data linkage in creating the facility management BIM model is considered in detail. 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 not possible. Therefore, families were created for each seat to eliminate duplicate 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) for easier identification during later data linkage tasks. This applies equally to electricity usage data and maintenance record data. For electricity usage data, as spatial objects need to be created for each floor, they were set as "Electricity Section_Floor" (e.g., Electricity Section_8F). Maintenance record data were set as "Floor_Maintenance" (e.g., 8F_Maintenance).

3.4. Setting of LOD

In creating the BIM model, the Level of Detail/Level of Development (LOD) for each object placed is set. LOD represents the detail level of the shape and attribute information of BIM objects, indicated by numbers 100 to 400 following LOD, where 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. [1]

3.5. Creation of the Facility Management BIM Model

Based on the requirements and LOD, the facility management BIM model is created. The model placement is performed in the order of columns and beams, floors, interior and exterior walls, and ceilings, based on the component list described in the as-built drawings. Figure 2 shows the comparison between the actual building and the completed model.

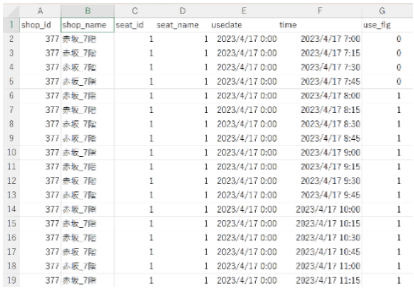
Figure 2: Comparison between the actual building (left) and the rendered BIM model (right)

4. INTEGRATION OF THE FACILITY MANAGEMENT BIM MODEL WITH FACILITY MAINTENANCE AND OPERATION DATA

4.1. Consideration of Data Integration Methods

This section discusses the methods for integrating the completed facility management BIM model with facility maintenance and operation data. First, the selection of data integration software is considered. The basic process involves organizing each set of facility maintenance and operation data saved in CSV files and outputting the results on Revit. Dynamo, Excel macros, and Unity are

considered software options for organizing each facility maintenance and operation data. However, this study adopts Dynamo for data integration, as it is capable of meeting the demands for detailed manipulation linked with data and regular data updates required for the BIM model created in this study. The following figure 3 shows part of the data used in this study.



	A	B	C	D	E	F	G
1	shop_id	shop_name	seat_id	seat_name	usedate	time	use_flg
2	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 7:00	0
3	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 7:15	0
4	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 7:30	0
5	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 7:45	0
6	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 8:00	1
7	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 8:15	1
8	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 8:30	1
9	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 8:45	1
10	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 9:00	1
11	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 9:15	1
12	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 9:30	1
13	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 9:45	1
14	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 10:00	1
15	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 10:15	1
16	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 10:30	1
17	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 10:45	1
18	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 11:00	1
19	377	赤坂_7階	1	1	2023/4/17 0:00	2023/4/17 11:15	1

Figure 3: Seat usage data

4.2. Specific Methods for Integrating Each Data Set with the Facility Management BIM Model

4.2.1. Specific Method for Integrating Electricity Usage Data

The process of programming in Dynamo to link each spatial object with electricity usage data is organized. The basic flow of this program is as follows:

(a) Refer to the electricity usage data file.

(b) Calculate the total electricity usage for each floor per day.

(c) Link the specified spatial object with the electricity usage.

(d) Perform coloring based on the numerical values of the spatial object and output the total usage numbers to the object's parameters.

Figure 4 represents the results of data integration following the above process.

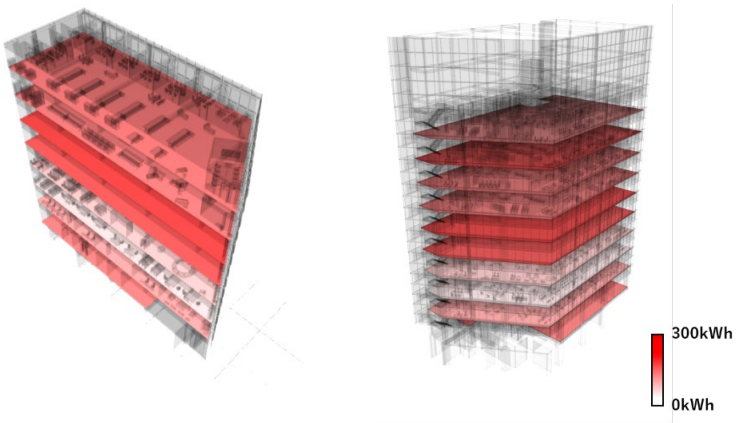


Figure 4: Situation of spatial objects color-coded by electricity consumption

4.2.2. Specific Method for Integrating Seat Utilization

The flow of Dynamo programming for linking seat-specific utilization data per day and daily seat utilization data on a per-seat basis is as follows:

Seat-specific utilization data per day:

(a) Refer to the seat utilization data file.

(b) Calculate the utilization data for each seat.

(c) Link the specified seat object with the seat utilization rate.

(d) Perform coloring corresponding to the utilization rate on the seat object and output the total usage numbers to the object's parameters.

Daily utilization data on a per-seat basis:

(a) Refer to the seat utilization data file.

(b) Calculate the daily utilization data.

(c) Output to the specified Excel sheet.

Figure 5 represents the situations of data integration in the above processes.

Figure 5: Situation of seat objects color-coded by each seat's utilization rate

4.3. Creation of the Data Analysis Environment

Based on the BIM with integrated data, a data analysis environment for actual facility maintenance and operation tasks is created. Initially, the facility maintenance and operation data integrated into the facility management BIM model in this study are "electricity usage data per floor" and "seat-specific utilization data per date". The process of integrating these data is completed by simultaneously running each Dynamo program created in the previous chapter. Figure 6 represents the results of displaying these two sets of data simultaneously in a three-dimensional space.

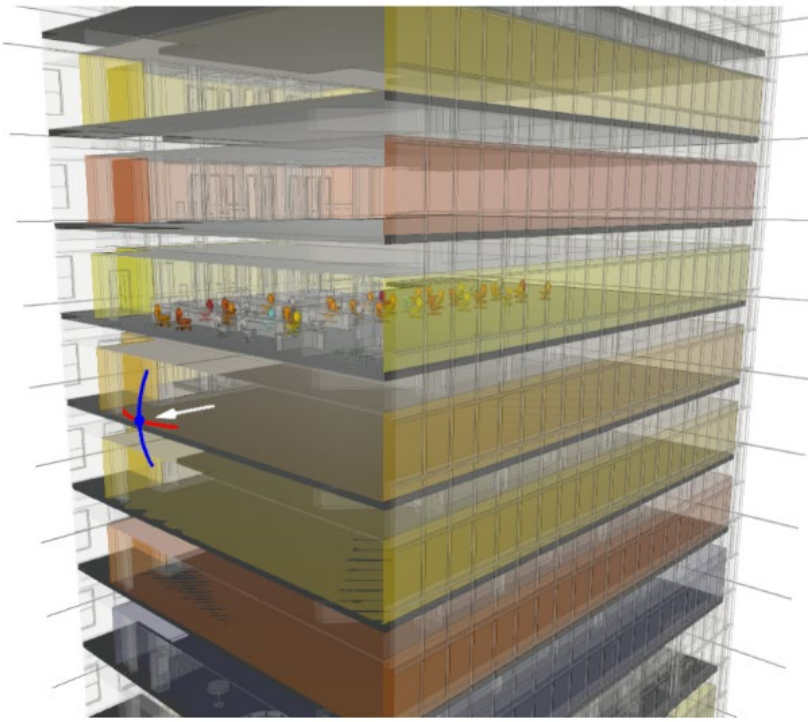


Figure 6: Situation of the integration of electrical usage data and seat usage data in the BIM model

Next, for the “date-specific seat utilization data” that were not integrated, a simple Business Intelligence (BI) tool displaying seat utilization trend graphs, seat layout diagrams, and seat numbers was created in Excel. Finally, the situation of the final analysis environment, which allows the execution of a series of programs with minimal tabs, is visualized in Dynamo Player. The result is shown in Figure 7.

Figure 7: Situation of the Integration of BIM model and FM data for use by facility maintenance and management operators

5. CONCLUSION

5.1. Data Implementation in Progress

As an additional feature to this facility management BIM, building repair records reflected by section and color-coded by frequency is currently being implemented. The flow of Dynamo programming for linking maintenance record data is as follows:

(a) Refer to the maintenance record data file.

(b) Extract maintenance record data by section.

(c) Link the specified maintenance record model with the maintenance record data.

(d) Display the maintenance records in the specified model's parameters and perform color coding according to the number of repairs.

Figure 8 presents the situation of data integration following the above process.

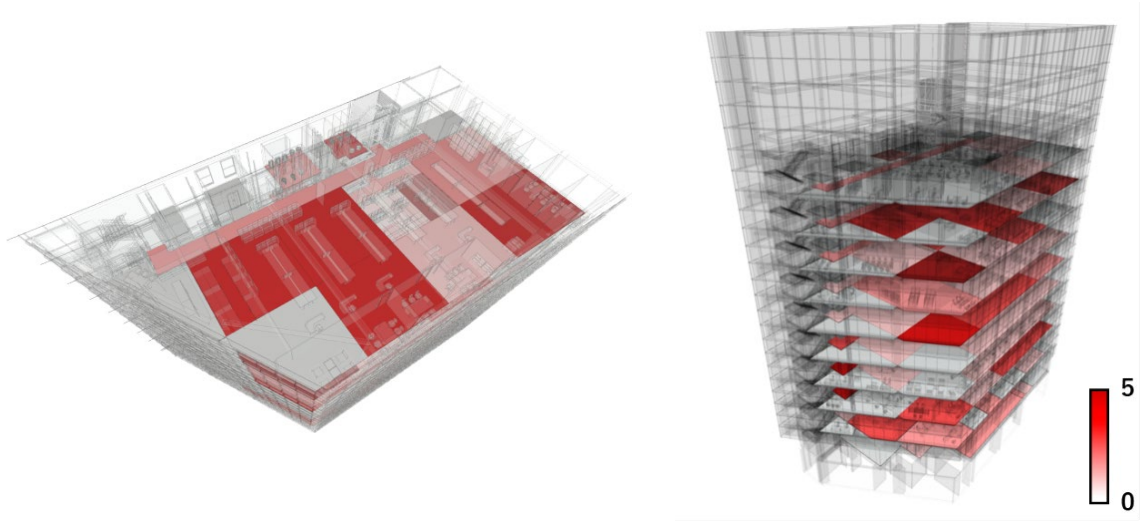


Figure 8: Situation of spatial objects color-corded by the maintenance times data on each area

Currently, virtual data is used for linkage, and actual data will be linked in the future.

5.2. Future Prospects

The facility management BIM created in this study, equipped with the functionality of an analysis environment, presents challenges due to dependence on the Revit environment, model data update responsiveness, lack of data variety and user interface (UI) operability. In the future, creating a UI that allows for the manipulation of BIM models and data analysis online could enable operations independent of the user's BIM usage experience, potentially promoting the adoption of BIM in facility maintenance and operation tasks.

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