# Construction of BIM-FM Data Linkage Methods Based on Real Estate Ownership Forms and Implementation in Management Systems

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**Abstract**

**In the field of Facility Management (FM), the increasing complexity of operations and the demand for Environmental, Social, and Governance (ESG) compliance require strategic, lifecycle-oriented data management. However, current practices often suffer from information fragmentation and a lack of integration between spatial and FM data. This study addresses these issues by developing a cloud-based Building Information Modeling (BIM)-FM integration system that offers decision support to 2 specific real estate ownership forms: Corporate Real Estate (CRE) and Real Estate Investment Trust (REIT). By defining distinct management requirements for each type, we constructed a system using Autodesk Platform Services (APS) that dynamically links 3D BIM models with external management databases without overburdening the BIM files. The proposed system was verified through a prototype applied to office buildings in Tokyo. The results indicate that the system improves operational efficiency in CRE by visualizing cost sources and enhances governance in J-REITs by providing investors and asset managers with transparent, real-time access to granular property data. This approach establishes a practical model for utilizing BIM in the maintenance phase to maximize real estate value.**

**Keywords –**

**BIM; Cloud; CRE; Digital Twin; Decision Support System; FM; REIT**

## 1 Introduction

### 1.1 Research Background

In recent years, facility maintenance and construction management operations have become increasingly complex due to the extension of facility lifespans and multifunctionality. Additionally, there is a growing demand for strategic management that considers the entire building lifecycle, including responses to Environmental, Social, and Governance (ESG) management and carbon neutrality. This has heightened the importance of management methods that capture various tasks cross-sectionally and handle information continuously, going beyond preservation and operation.

On the other hand, information handled in these operations often remains recorded on paper or managed individually by departments, causing information fragmentation, update delays, and personalization, which hinders rapid decision-making. Building Information Modeling (BIM) is an effective means to solve these issues.

BIM functions as a database integrating spatial and attribute information, enabling unified management throughout the lifecycle.

Nevertheless, most existing research and practices regarding BIM focus on information sharing during the design and construction phases, and concrete operational models for the facility management phase have not been established. In particular, sufficient consideration has not been given to the fact that the quality of decision-making and necessary data granularity differ depending on the purpose of real estate ownership.

Therefore, this study classifies real estate ownership forms into CRE and REIT and constructs a BIM-FM integration system based on their respective management requirements. The purpose is to contribute to the maximization of real estate value in a stock-based society.

### 1.2 Previous Research

Previous research [1] attempted to construct an environment where facility managers without specialized skills could intuitively utilize BIM data. Specifically, a prototype of the system was developed using Autodesk Platform Services (APS). Figure 1 illustrates the platform developed in the previous study.


Figure 1. System developed in the previous study

In that study, targeting existing office buildings in Tokyo, a data linkage method was established to associate different forms of FM data—such as power consumption, seat usage, and repair records—with room IDs and seat IDs on the BIM model. This system enabled the visualization of energy consumption and spatial occupancy rates for each floor as a heatmap on a web browser without requiring specialized BIM software. This demonstrated the utility of the system as an integrated visualization system for building information by reducing the technical barriers to BIM utilization.

### 1.3 Research Objectives

The prototype constructed in previous research focused on the technical verification of 3D data visualization. However, it didn't sufficiently examine the lack of sustainability in update operations due to reference data relying on local environments, nor did it assess its suitability for decision-making processes in actual real estate management. In particular, sufficient consideration was not given to the fact that the requirements and judgment indicators sought by managers differ fundamentally depending on the form of real estate ownership.

Therefore, this study inherits the technical foundation of the previous research while securing operational sustainability by fully migrating the data management infrastructure to the cloud and newly introduces management requirements based on real estate type. The objective is to develop a more practical decision-making support model by implementing specific business logic into the system—such as operational efficiency in CRE and profitability evaluation in REIT—going beyond information visualization.

### 1.4 Research Methodology

This study is divided into the following three-stage process. First is the definition of management requirements based on real estate types. Target properties are selected from CRE and REIT, and the data granularity and technical requirements necessary for decision-making in each category are clarified.

Second is the construction of a BIM-linked system. Based on the cloud visualization technology developed in previous studies, a database structure and ID linkage logic satisfying the defined requirements are implemented.

Third is verification and evaluation. The developed system is applied to medium-sized office buildings in Tokyo, representing both CRE and REIT. The utility of the system for decision support and operational efficiency is verified in scenarios from both CRE and investor perspectives. Table 1 shows the chapter structure and content of this paper.

Table 1. Chapter structure and content of this paper

| | | |
|---|---|---|
| 1. Introduction | 1.1 Background<br>1.2 Previous Research<br>1.3 Objectives<br>1.4 Methodology | |
| 2. Requirements Definition | 2.1. Real Estate Classifications in Japan | |
| | CRE<br>2.2.1. Workflow Analysis<br>2.3.1. Requirements Definition | REIT<br>2.2.2. Work Analysis<br>2.3.2. Requirements Definition |
| 3. System Development | 3.1 System Architecture<br>3.2 Data Design<br>3.3 Visualization Design | |
| 4. Verification | CRE<br>4.1. Workflow Verification | REIT<br>4.2. Workflow Verification |
| 5. Conclusion | 5.1. Summary<br>5.2 Future Outlook | |

## 2 Requirements Definition

### 2.1 Classification od Real Estate Types and their Domestic Asset Scale

According to the Cabinet Office's Annual Report on National Accounts (FY2023 estimates) [2], the total value of "non-financial assets" (real assets including land, buildings, and structures) in Japan's national wealth has reached approximately 3,065 trillion yen. Based on the ownership entity, these assets are broadly classified into three categories: "Households," "Public Real Estate (PRE)," and "CRE".

Their ownership forms are broadly classified into two categories: PRE and CRE. In this study, grasping the asset scale of each category is important for estimating the social ripple effects of system implementation.

1. PRE
   This refers to assets owned by the national or local governments, such as government buildings, public housing, and educational facilities. The estimated asset scale is approximately 769 trillion yen. However, as the management principle is public welfare, this is excluded from the scope of this study.
2. CRE (broad defined)
   This refers to real estate owned by private enterprises. According to the Cabinet Office data, the total asset scale reaches approximately 786 trillion yen. In this study, we further classify this broad CRE into two types based on the purpose of ownership:

   - Operational Assets (narrow defined)
     Real estate owned for business activities (headquarters, factories, logistics, etc.). This accounts for the majority of the stock (approx. 762 trillion yen), where cost optimization is the primary goal.

   - Investment Assets (REIT)
     Real estate operated for rental income or capital gains. While the asset scale of J-REITs is approximately 24 trillion yen, this sector requires high transparency and accountability to investors.

In this study, we specifically target CRE, which has a large asset scale and high ripple effects on economic activities, and REIT, which is a growth area, to construct a BIM linkage model optimized for their respective management requirements.

## 2.2 Issues in Existing Real Estate Management Operations

### 2.2.1 Scope and Issues of Real Estate Management in CRE

CRE management operations consist of business processes that circulate within the enterprise. Issues and reports extracted from the site are aggregated to the property administration and FM departments and are processed as optimization measures for management resources, such as cost management and layout planning. The business content is broadly divided into the following three categories:

1 Management and Administrative Tasks:
Contract management, quality control, office receipts and disbursements, and complaint handling.

2 Operational Tasks:
Energy management, parking management, FFE (Furniture, Fixtures, and Equipment) management, environmental hygiene and cleaning, and general information and security.

3 Maintenance Tasks:
Equipment maintenance, exterior maintenance, building maintenance, construction planning and supervision.

Based on the organization of these tasks, there are two primary issues in CRE real estate management.

The first issue is the fragmentation of information and increased management costs. As mentioned above, tasks such as contract management, energy management, and equipment maintenance differ in nature, and in many cases, the departments in charge or the outsourced vendors are also compartmentalized. Consequently, data such as repair history, energy usage, and contract conditions are scattered, creating a situation where unified management is difficult. As a result, this becomes a factor in delaying judgments regarding cost reduction and quality maintenance from an overall optimization perspective.

The second issue is the personalization of maintenance operations. At building and equipment maintenance sites, there is a strong tendency for decisions to be made based on the empirical rules of skilled personnel. Since know-how regarding anomaly detection and preventive maintenance is not formalized as data, there is an inherent risk that operational quality will decline due to staff turnover or retirement. Furthermore, the shortage of Building Management (BM) personnel due to the declining birthrate and aging population may also contribute to the deepening of this issue.

### 2.2.2 Scope and Issues of Real Estate Management in REIT

J-REIT operations have a multi-layered structure consisting of the Site (PM), Operation (AM), and Investors. The business content is broadly divided into the following three categories:

1 Management and Financial Tasks
Lease contract management, tenant contract management, deposit management, budget and balance management, billing and payment management, and fund planning.

2 Operational Tasks
Energy management, parking management, FFE management, and environmental hygiene and cleaning management.

3 Maintenance Tasks
Equipment maintenance, exterior maintenance, building maintenance, construction planning and

supervision.

Regarding the issues in REIT management, information fragmentation, delayed decision-making, and the personalization of tasks—identified in the previous section on CRE—are considered common challenges. However, a specific issue unique to REIT is the limitation of reporting operations to the AM. In conventional paper-based monthly reports, vast amounts of operational data generated on-site were aggregated on a monthly basis and submitted in static media such as PDFs. However, the lack of direct access to raw data and means of verification prevents AMs and investors from objectively evaluating the validity of Capital Expenditure (CAPEX) and operating costs. Under increasingly sophisticated disclosure requirements, this hinders the ability to logically and immediately prove the effectiveness of investments or their contribution to improving asset value.

## 2.3 System Requirements Definition

### 2.3.1 Requirements Definition for CRE

Based on the previous section, we defined the specific system requirements for CRE.

1 Operational Workflow Transformation

In the conventional operational flow, different departments such as General Affairs, Property Administration, and Accounting managed data in their respective ledgers. For a Facility Manager to grasp the current status, a lot of man-hours were required to collect Excel files and drawings from these vertically segmented departments and to manually cross-reference them. After the introduction of this system, data from different sources is automatically integrated via spatial information; therefore, manual data verification becomes unnecessary, enabling operational efficiency and a transition to a higher standard of management.

2 Data Integration Requirements

- Power Consumption
  Time-series data of electricity usage recorded every 15 minutes on each floor from BEMS or smart meters.
- Construction and Repair Data
  Past repair history, costs, construction details, and long-term repair plans.
- Seat Occupancy Rate
  Utilization status per seat extracted from existing office seat reservation systems.

3 Key Functions:

- Cost Heatmap
  Visualizes the density of power and repair costs by color-coding them on the space to identify areas of energy waste.
- Occupancy Monitoring
  Identifies dead spaces with low usage frequency based on seat occupancy data to provide decision-making material for layout changes.

### 2.3.2 Requirements Definition for J-REIT

Based on the previous section, we defined the specific system requirements for REIT.

1 Operational Workflow Transformation

In conventional PM operations, basic data reported from the sites such as inspection records, repair history, and energy performance—were scattered without being linked to physical spatial information. Consequently, when PMs reported asset status to Asset Managers (AMs), it was difficult to quantitatively demonstrate the causal relationship between profitability and physical condition. Therefore, explaining equipment deterioration risks and life-extension effects—the basis for CAPEX proposals—required significant man-hours to manually re-aggregate dispersed data and supplement the logical structure. After the introduction of this system, the flow shifts to one where data in diverse formats from BM is automatically integrated on the cloud via common spatial information. This allows PMs to immediately visualize the factors causing fluctuations in Net Operating Income (NOI) in correlation with repair history and equipment status. Consequently, it makes an environment for fulfilling accountability at a higher level, enabling PMs to present risk avoidance effects and return on investment of CAPEX to AMs logically and with high resolution.

2 Data Integration Requirements

- Power Consumption
  Monthly meter reading data used for tenant billing.
- Construction/Repair Data
  Detailed construction order history including CAPEX/OPEX classification, and long-term repair plans.
- Contract Information
  Rent roll (rent, contract period, tenant information, security deposits, etc.).

3 Key Functions

- Construction Planning and Budget Management
  Visualizes construction results that caused budget variances and future repair plans in 3D space to support judgments on the validity of construction implementation.

- Contract Information Visualization

Visualizes vacancy information in 3D space to visually grasp vacant sections or sections approaching contract expiration, thereby supporting leasing activities.

In this study, we adopted a unified system architecture that satisfies these distinct requirements using a single platform foundation. The specific design of this common platform is detailed in the next chapter.

# 3 System Construction Methodology

## 3.1 Overall System Design and Architecture

To address the detailed technical design and operational workflow, a comprehensive schematic of the system architecture, database schema, and data update workflows is provided in Figure 2. As illustrated, the architecture consists of four layers. The Database Layer (Google Cloud BigQuery) stores the spatial master and operational records in separate tables, managed with key identifiers such as Spatial Object ID. The Backend API Layer (Node.js/Express) exposes endpoints (e.g., GET /api/construction/projects, GET /api/rooms/all) to process requests from the frontend layer. The BIM model is updated only during major renovations, while the Property Manager uploads financial and operational data (e.g., rent, energy, repair logs) on a regular basis, such as monthly or annually.

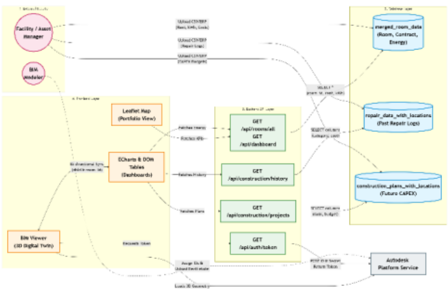

Figure 2. Comprehensive system architecture, database schema, and update workflows

## 3.2 Database Composition

### 3.2.1 Master Data Design

In designing the master data, the policy was adopted to limit the information held within the BIM model to the minimum IDs necessary for linking with the external database. Previous research has attempted methods of inputting management attributes and some non-geometric information into properties within the BIM model. However, updating frequently fluctuating information on BIM software each time requires specialized licenses and operational skills, which becomes a major factor causing update delays and discrepancies with actual conditions during the operation phase. To avoid this issue and minimize the future editing burden on the BIM model, this system uses BIM schedules to extract only the Spatial Object ID. These are defined as the primary keys for the spatial master in the system-side database. Fluid management information such as rent unit price, contract period, and tenant name is entirely managed on the cloud database side and dynamically linked via the Spatial Object ID. This establishes an environment where attribute information updates that do not involve shape changes can be executed immediately and inexpensively from a web browser without going through the BIM model.

### 3.2.2 Spatial Object ID Scheme

To accurately link spatial elements within the BIM model with management information in an external database, a unique identifier is essential. Previous BIM implementation case studies [3] have cited inconsistent tagging as a factor that hinders asset data integration, demonstrating the effectiveness of an ID scheme that hierarchically combines physical location and system classification.

Based on these findings, this system adopts a spatial ID naming rule consisting of the following five levels, hereafter referred to as "room_id" in this study, designed to optimize spatial identification and filtering efficiency in database queries. Table 2 summarizes the detailed definitions and examples of this scheme.

Table 2 Spatial Object ID Naming Levels

| Object ID Naming Levels | Description |
|---|---|
| **Level 1: Floor Code** | Floor level indication where the space is located. (e.g., "2F" for Second Floor) |
| **Level 2: Large Zone Name** | AreaName: Functional classification of the major zone. (e.g., "OfficeZone", "Staircase") |
| **Level 3: Large Zone Number** | Two-digit number identifying specific major zones. (e.g., "01", "02") |

| | |
|---|---|
| **Level 4: Small Zone Name** | Descriptive name of the specific functional unit. (e.g., "MeetingRoom", "Workspace") |
| **Level 5: Small Zone Number** | Two-digit number identifying specific zones. (e.g., "01", "02") |

The codes for each level are join~~t~~ed using underscores (_) as delimiters to construct the final format as follows:

[Floor]_[LargeZoneName]_[LargeZoneNumber]_[SmallZoneName]_[SmallZoneNumber]

In this study, this room_id is assigned based on structural spans to serve as a unchanging spatial unit. In the database, tenant contracts and other management data are managed as a collection of these associated room_id units. To ensure the continuity of historical data during floor plan changes caused by contract renewals or interior reconfigurations, the system responds by updating the assignment of these persistent room_id units to the corresponding management records. This room_id is stored as a Revit instance parameter, functioning as the primary key for external database integration.

### 3.2.3 Data Formatting

Raw data imported from accounting systems or PM reports are lists of numbers that do not possess spatial coordinates. In this system, a data formatting pipeline using SQL join processing was constructed to assign the ~~IfcGuid~~ DBID to this data via the spatial master defined in the previous section. The DBID is an internal integer identifier generated by APS, which is strictly required to select, color, or manipulate specific 3D objects within the web viewer. Specifically, queries were designed to execute joins against the spatial master table extracted from BIM, using floor information and section names contained in the raw data as foreign keys. Through this processing, for example, for a construction record such as "2024-Month X, AC Repair Cost, Office 1", the ~~IfcGuid~~ DBID corresponding to Office 1 is automatically mapped. In the event of a mismatch between the room_id and the external data due to input errors in the raw data, the DBID returns a null value. Since it is only necessary to verify these data matching errors during the initial stage of defining the spatial model, these missing data are not displayed on the dashboard. However, these null values can be checked in the frontend console.

## 3.3 Data Visualization Algorithm

The role of the visualization algorithm is to convert values in the database into visual attributes perceptible to the user. Internally, the system utilizes the aforementioned DBID to match the retrieved database records with specific 3D objects in the APS Viewer, rendering them based on the following logic. For coloring spatial objects on the BIM model, two methods are used depending on the nature of the data: Discrete Value Mapping and Continuous Value Mapping.

1 Discrete Value Mapping

Applicable Data:

Contract status, construction status (planned/completed), etc.

Logic:

Determines whether the data string perfectly matches a specific condition.

2 Continuous Value Mapping

Applicable Data:

Power consumption, rent unit price, etc.

Logic:

Normalizes numerical values to a range of 0.0 to 1.0 based on maximum and minimum values and maps them to a color hue circle.

The calculation is performed using Equation (1).

$$x_{norm} = \frac{x_i - x_{min}}{x_{max} - x_{min}} \qquad (1)$$

$x_{norm}$: The normalized value (ranging from 0.0 to 1.0).
$x_i$: The individual data value of the target object.
$x_{min}$: The minimum value within the dataset.
$x_{max}$: The maximum value within the dataset.

The calculated normalized value *x(norm)* is substituted into the color ramp function *f(x)* to determine the RGB value.

# 4 Verification

## 4.1 Case Study for CRE

### 4.1.1 Overview of Target Facility

To verify the utility of the proposed system, a prototype system was constructed and applied to two representative office buildings in Tokyo, each corresponding to a different ownership form.

In this study, we verified the system's effectiveness in solving the issues of information fragmentation and difficulty in status grasping faced by CRE. The target facility is a medium-sized office building located in Minato-ku, Tokyo, selected to simulate a typical corporate asset. Details of the building are below.

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- Scale: B1/10F
- Total Floor Area: Approx. 7,800 m²
- Structure: Steel (partly CFT)

#### 4.1.2 Verification of Effectiveness Scenario

The system's effectiveness was verified through a scenario integrating energy management and maintenance tracking. First, Figure 3 shows that selecting a specific date on the dashboard simultaneously displays electricity usage and seat occupancy rates for each floor. This visualization allows facility managers to immediately identify inefficient zones where energy is consumed despite low occupancy. In the context of CRE, this directly supports space optimization decisions, such as identifying target areas for layout coordination or adjusting HVAC operational hours, thereby fulfilling the primary goal of operational cost minimization.

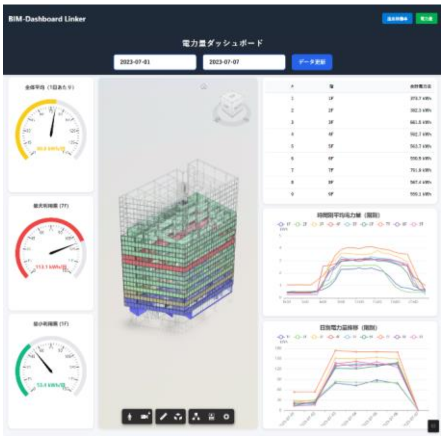


Figure 3. Visualization of energy consumption data

Second, regarding repair history, floors were color-coded by repair frequency in the 3D viewer. As illustrated in Figure 4, it was confirmed that selecting a specific floor displayed a list of past construction records, and clicking a record immediately highlighted the corresponding section while showing detailed specifications. This seamless transition from macro-level status grasping to micro-level detail verification demonstrates the system's capability to resolve information fragmentation and significantly reduces the time required for cause identification.

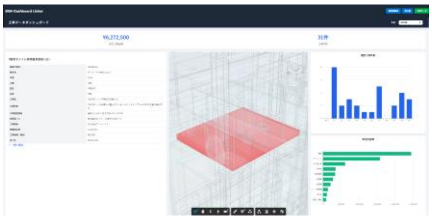

Figure 4. Visualization of repair history and details

### 4.2 Case Study for REIT

#### 4.2.1 Overview of Target Facility

In the second case study, we verified the system's effectiveness in solving the issues of untransparent information and accountability faced by REIT management. The target facility is an existing office building located in Shinjuku-ku, Tokyo, selected to simulate an investment property under asset management. Details of the building are as below.

- Scale: 9F
- Total Floor Area: Approx. 6,000 m²
- Structure: SRC

#### 4.2.2 Verification of Effectiveness Scenario

The system's effectiveness was verified through a scenario where PM and AM utilize a unified information environment. First, operational data such as electricity usage and construction history trends were visualized on the management dashboard. Figure 5 shows the management dashboard for construction history and KPIs. This interface enables intuitive tracking of the building's physical condition and budget status over time. For REIT management, this bridges the gap between physical deterioration and financial impact, enabling AMs and investors to make data-driven decisions regarding the validity of CAPEX proposals and to prioritize renovations that directly contribute to maintaining asset value and maximizing NOI.

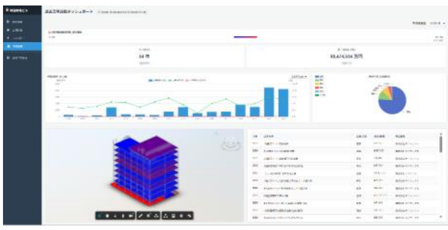

Figure 5. Visualization of construction history data

Furthermore, regarding leasing management, contract status was mapped directly onto the 3D model. Figure 6 shows the visualization of contract data and specific section details. In this view, it was confirmed that users could visually identify vacancy risks and, by clicking specific sections, immediately access detailed contract terms.

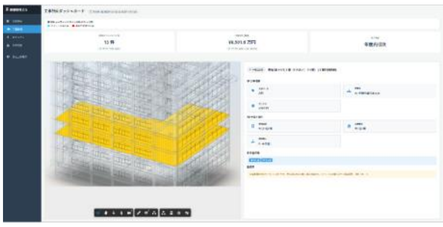

Figure 6. Visualization of contract data and specific section details

### 4.3 Summary of Verification Results

To evaluate the accuracy of the ID linkage method, the mapping results from both case studies are summarized in Table 3. ~~Finally, the verification results for both case studies are summarized in Table 4.~~

A total of 665 operational records for CRE and 259 for REIT were mapped to the spatial objects extracted from their respective BIM models. As a result, the system achieved a 100% success rate across all categories.

Table 3. The mapping results from both case studies

| | | Valid Records | Successfully Linked | Success Rate (%) |
|---|---|---|---|---|
| **CRE** | **Energy & Contract** | 189 | 189 | 100% |
| | **Construction History** | 429 | 429 | 100% |
| | **Construction Plan** | 47 | 47 | 100% |
| **REIT** | **Energy & Contract** | 147 | 147 | 100% |
| | **Construction History** | 52 | 52 | 100% |
| | **Construction Plan** | 60 | 60 | 100% |

Furthermore, the practical verification results for both case studies are summarized in Table 4, which outlines the key issues and main outcomes for each scenario.

Table 4 Summary of verification results

| Case | Issue | Main Outcome |
|---|---|---|
| **Case 1: CRE** | Data Fragmentation | Demonstration of streamlined workflows for identifying cost sources and analysing space usage.~~Reduced time for identifying cost sources and analyzing space usage.~~ |
| **Case 2: REIT** | Information Asymmetry | Provision of a unified platform to support explanation capability and transparent decision-making.~~Improved explanation capability and transparent decision-making.~~ |

## 5 Conclusion

### 5.1 Summary

In this study, we developed a prototype system that integrates BIM and financial data on a web browser to address the issues of information fragmentation and reporting opacity in real estate management. Through a case study applied to office buildings in Tokyo, we technologically verified the system's effectiveness in two specific aspects: accelerating the identification of cost sources for CRE and ensuring data transparency and accountability for REITs. The results demonstrated that dynamically linking spatial information with management data via the cloud is a valid technical approach for supporting decision-making and resolving information asymmetry. However, this research is currently limited to functional verification within specific scenarios. Establishing measurable baselines to quantitatively evaluate the actual reduction in operational time and the degree of improvement in decision-making remains a subject for future research.

### 5.2 Future Outlook

#### 5.2.1 Expansion to Portfolio Management

The current system targets the visualization of a single property, but operational practices require unified management of the entire portfolio consisting of dozens to hundreds of properties. As a future outlook, we aim to extend this system to support multi-asset management and implement functions to cross-sectionally compare and analyze the operation status and repair risks of multiple properties. This enables decision-making support from a management perspective, such as maximizing NOI for the entire portfolio.

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### 5.2.2 Application to Investor Relations (IR) and Improvement of Market Evaluation

We are also considering utilizing this system for information disclosure to external investors. To achieve this, it is necessary to select the information to be disclosed and design data access restrictions. Since the primary objective of investors is to manage asset value and cash flow, the data is provided at a different level of granularity while sharing the same underlying data source as the PM. Although the contracts, energy usage, construction history, and construction plans visualized in this study remain the subjects of visualization, to protect tenant privacy and confidential information, the system will visualize large-scale renovations exceeding a certain threshold and display general floor-by-floor energy costs, occupancy rates, and rent-based revenue trends using heatmaps. Additionally, access restrictions are enforced at the frontend presentation layer. When accessing the application, the JavaScript side checks the user's login role. If the role is an investor, the frontend converts the view and restricts the rendering of detailed data tables.

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