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Improving Efficiency of University Campus Facility Management Using Digital Twin

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Abstract: Universities own several campuses and many buildings within the campuses. During the operation & maintenance phase, some of the buildings have architectural components and MEPFs that must be maintained. In the authors' study, university campus Facility Manager uses paper drawings and paper documents for operations and maintenance of MEPFs, and building components, which are managed by human power. In this study, As-Built 3D model of school buildings, was developed by 3D scanning with MatterPort Pro2 camera. A digital twin of the school building was developed from integrating the As-Built 3D model with a COBie Sheet information that defines the building and facility components for FMr. This developed digital twin was used to verify the efficiency of conventional Facility Management (FM) operations. The specific procedures are as follows.

(1) Conducted an interview survey on FM of conventional university campuses to organize the current operations.
(2) The following building items, which are annual inspection items, were extracted from the conventional FM operations being performed, Speakers, fire alarms, fire doors, guide lights, air conditioning, and fire extinguishing equipment.
(3) Since these items listed above are currently documented in different formats, the authors organized them into a database using COBie format.
(4) The components of the organized COBie format and the As-Built 3Dmodel were integrated to complete the digital twin.
(5) To verify the effectiveness of the digital twin, experiments were conducted on information search in current FM operations and workflows using the digital twin.
(6) We also verified the effectiveness of the AS-Built 3D model by comparing between the As-Built 3D model and the BIM model.

Finally, we discussed how process innovation through digitalization of FM operations contributes not only to the improvement of daily operations, but also to the productivity improvement of university management.

Key words:, Facility Management, COBie, Digital Twin, Point cloud,3D stereo Camera

1. INTRODUCTION

Digital technology is rapidly becoming popular in the AECO industry. Various digital proposals are being made not only in the design and construction phases, but also in the operation and maintenance (O &M) phases. On the other hand, building owners still use paper drawings and paper reports in the O &M phase, which is analog and resource-oriented management. In this study, a digital twin of school buildings on a university campus was developed by integrating an as-built 3D model of a university captured by a 3D stereo camera and a COBie format that defines building components target toward FM workflow. The developed digital twin will be used to verify the efficiency of conventional FM work.

2. Research Methods

A comprehensive review of prior studies was undertaken to delineate the positioning of this research. As the initial phase, interviews with facility managers were conducted to elucidate the methodologies employed in maintaining the condition of building assets. Subsequently, the necessary items for legal inspections were structured in COBie format. Concurrently, a 3D scan of the university building was executed. Finally, the components arranged in COBie format were allocated within the designated spaces to finalize the digital twin. The efficacy of FM utilizing the digital twin was subsequently verified (refer to Figure 1).

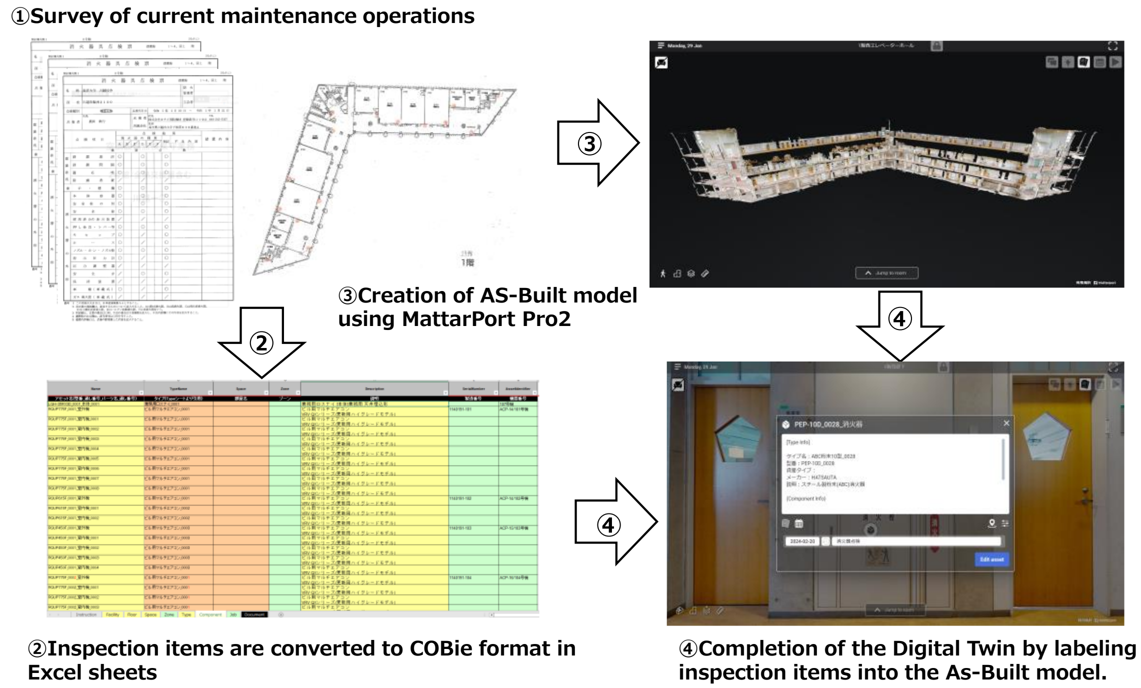

Fig1. O&M workflow using digital twin.

3. Previous Studies

These studies encompass a diverse array of topics, including the calculation of Return on Investment (ROI) with BIM-FM, BIM technology applications in FM, BIM guidelines for owners, COBie utilization, legal considerations, and more. However, this study focuses on FM utilizing BIM, excluding the incorporation of point cloud data and 3D stereo cameras. References [2] and [3] contain studies specifically addressing COBie, highlighting its structural significance and utility. Despite the existence of COBie format, navigating them for relevant information retrieval remains challenging, necessitating the integration of spatial information. This study endeavors to enhance the operational efficiency of FM by integrating building geometry data from point clouds and images with maintenance and management information facilitated by COBie.

4. Survey of current FM operations in University Campus

An interview survey was conducted with FMr to understand O&M of Toyo University campus. A total of 35 buildings are managed at the Kawagoe campus. Among the 35 buildings, this study focused on Building 2, which contains classrooms, drawing rooms, and laboratories.

The current maintenance work is divided into three major categories. The O&M tasks are summarized in Figure 2.

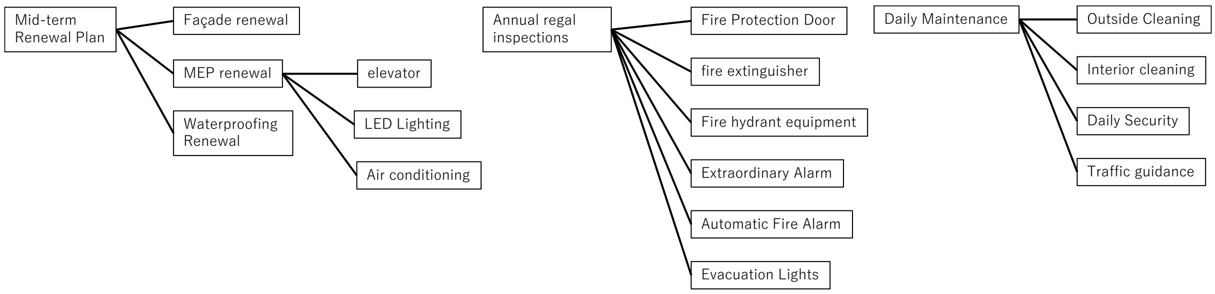

Fig2. The current operation & maintenance work

The first is maintenance, which includes construction work. This is called the mid-term plan. This plan includes maintenance and management operations involving works such as renewal of exterior walls (painting and tiles), renewal of the waterproof layer on the rooftop, renewal of air conditioning equipment, renewal of EVs, and conversion of lighting to LEDs. This plan picks up construction work that includes construction work to be done over the next five years and prioritizes it. The budget for this year is based on this mid-term plan. There is no long-term maintenance and repair plan, only a plan for the next five years. The second group is the work related to legal inspections. This maintenance work is required by the Building Standard Law and the Fire Defense Law and must be performed once a year. The items to be inspected include air conditioning, fire extinguishers, fire hydrants, emergency power supplies, automatic fire alarm systems, fire doors, fire dampers, and guide lights. Each item is inspected once a year and a paper inspection report are submitted by subcontractor. The third group is daily management. This group is daily maintenance, which includes the cleaning of tree branches and fallen leaves outside the building and the daily cleaning of the building's interior. It was confirmed that high-level strategies and decisions on maintenance and management are made by the head office of the university, and that FMr is only responsible for the formulation of mid-term plans and daily maintenance. Currently, two employees oversee O&M. And the MEP subcontractor and the building subcontractor are contracted to perform O&M. We also confirmed that the documents used for legal inspections are paper documents and 2D drawings. (Figure 3)

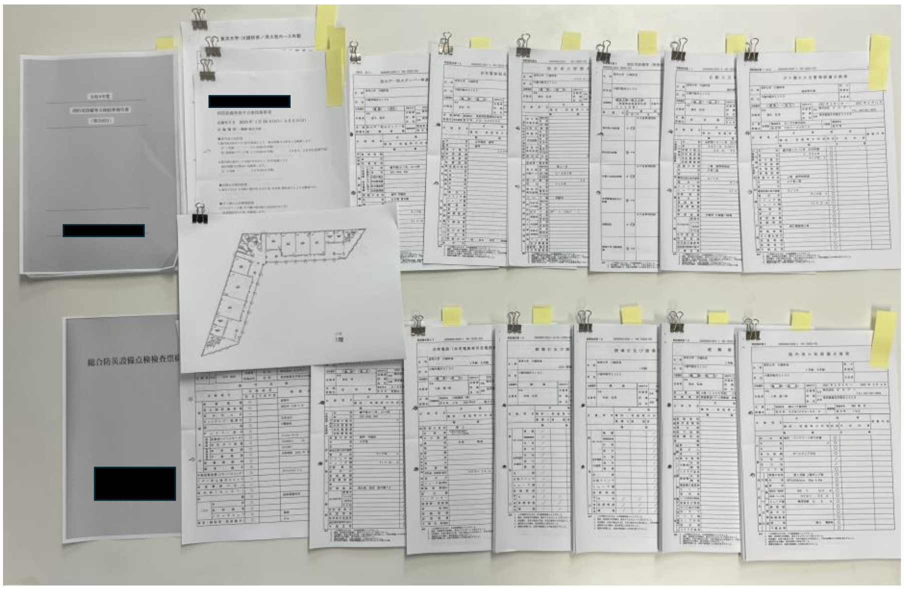

Fig3.2D drawing and paper documents used for legal inspections

Paper documents were collected for the following inspection items: air conditioning, fire extinguishers, fire hydrants, emergency power, automatic fire alarm systems, fire doors, fire dampers, and guide lights. Using the collected documents, a digital twin was created for FM related to legal inspections to verify the effectiveness.

5. Organize maintenance items using COBie

In preparation for creating the digital twin, data on various items obtained from the interview survey - including air conditioning, fire extinguishers, fire hydrants, emergency power, automatic fire alarm systems, fire doors, fire dampers, and guide lights - was meticulously organized using the COBie format. COBie stands as an international standard for data specifications, facilitating the transfer of Building Information Modeling (BIM) information to maintenance management systems. Notably, in the UK, COBie submission is compulsory under "BS 1192-4" for information handover in public building projects. The COBie template, available in Excel format and comprising 20 sheets, provides a structured approach for entering facility information. This structured data enables efficient searching for the location and type of equipment within the facility. A total of 112 components were meticulously inputted into COBie, adhering to the specified rules outlined in Table 1.

Table 1.COBie input example

COBie	Data Input Example
Facility	Building 2
Floor	2nd Floor
Space	2456
Zone	fire protection zone
Type	fire extinguisher
Component	ABC powder 10type
Job	Inspection
Document	Inspection report

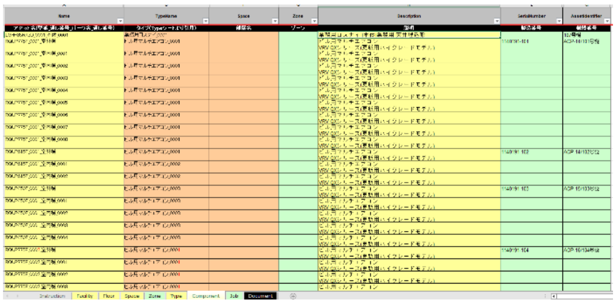

Fig4.COBie Sheet

5.1. Room name duplication problem

An issue arose during the entry of data into the COBie sheet. Various reports from different contractors pertaining to air conditioning, fire extinguishers, fire hydrants, emergency power, automatic fire alarm systems, fire doors, fire dampers, and guide lights indicated differing room names for identical locations, as illustrated in Table 2 below. In our study, we successfully standardized the room names by leveraging the As-Built model, as detailed subsequently.

Table 2. Room name duplication

Item	Space Name from different contractors	Space name in this study
emergency power	Building 2, n Floor	Building 2, n floor, north corridor
automatic fire alarm systems	Building 2, n Floor m district	
fire doors, fire dampers	Building 2, n Floor Fire Door A Staircase B	
guide lights	Building 2, n Floor indoor corridor	

6. Creating an As-Built model using MattarPort Pro2

In parallel with the COBie-based organization of maintenance items in Chapter 5, a 3D scan of the Building 2 on the Kawagoe Campus was performed using the MattarPort Pro2 camera, a 3D stereo camera that simultaneously captures point clouds using depth sensors and 360° panoramic images. This time, approximately 800 points were scanned for Building 2. The 360° panoramic image enables visualization of MEPs and fixtures, and the point cloud data enables measurement of area. In this verification, all four floors of corridors and one classroom in the building 2 building were scanned.

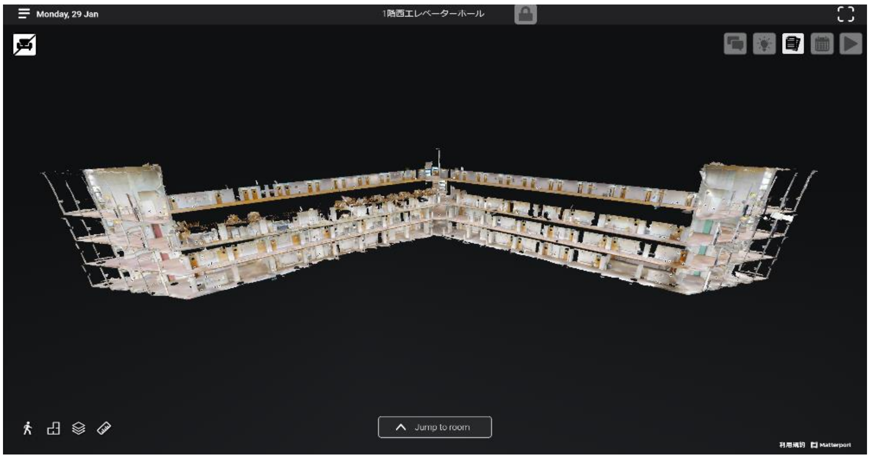

Fig 5. As-Built model using MattarPort Pro2

7. Input of components into As-Built model

In Chapter 5, 112 maintenance items that had been managed on paper were structured using COBie sheets.In Chapter 6, building information that had been managed in 2D drawings was scanned in 3D using MatterPort Pro2 camera to create the As-Built model. In this chapter, we integrate these data and input maintenance management items into the As-Built model to complete a digital twin for O&M of school buildings on a university campus. The digital twin has three functions: (1) reference to highly searchable assets, (2) maintenance management by issuing tickets, and (3) schedule management. The system uses SIM-ON [5], a cloud service developed by SIMLAB.

7.1. Asset input method

First, the maintenance items collected in Chapter 5 were registered in a three-dimensional space. The name of the registered item (called "Asset") is the name of “component” sheet of COBie. Information related to COBie's Type, and System was also input. For Spece, the names registered in COBie were input as asset location information in As-built 3D model. As a result, a digital twin that integrates the location information of O&M assets and as-built models was completed. As a secondary function, PDFs of instruction manuals are also uploaded to the asset, making them easily searchable. In addition, images of the assets and videos of inspection procedures can be viewed. (Fig.6)

7.2. Ticket Issuance

This system is designed to streamline the process for building users to report issues by issuing tickets and leveraging cloud technology to promptly notify the designated facility manager. Specifically, when a user detects an issue with the air conditioning system, the system notifies the relevant facility manager of the problem. FMr can then utilize this system to identify the cause of the issue, eliminating the need for on-site visual confirmation and reference to the handling manual. This enables FMr to shorten the time required for facility recovery work.

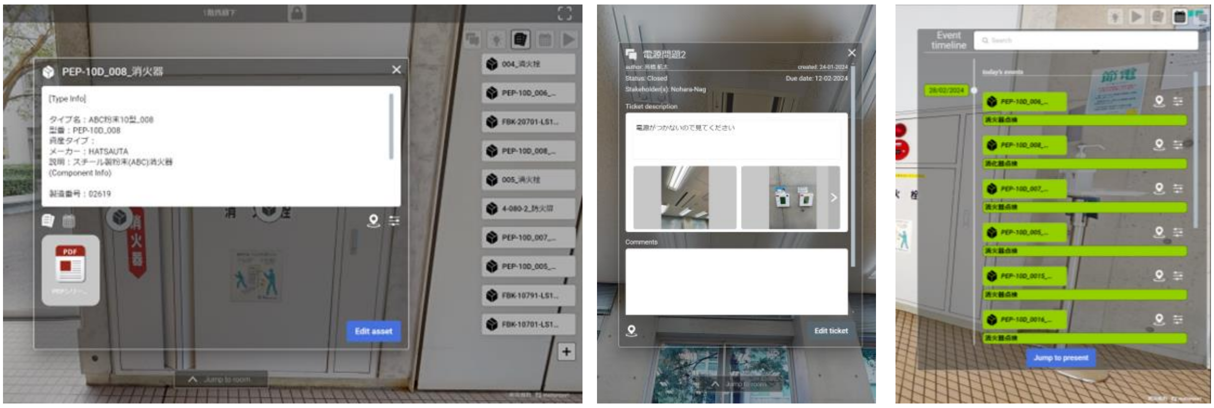

Fig 6. Asset's COBie information, ticket issuance, and inspection schedule

7.3. Maintenance schedule

In Section 7.1, inspection schedules can now be inputted for all assets. This digitalization process means that inspection schedules for numerous building assets, previously managed manually on paper, can now be efficiently accessed, and checked.

8. Effectiveness Verification

In previous steps, we developed a digital twin for O&M of school buildings on a university campus. In this chapter, we evaluate the effectiveness of this system compared to traditional maintenance management practices. Two types of verification were conducted: one involving the manual search for information in paper inspection reports, and the other utilizing the digital twin method to access information through the system.

8.1. Verification of trouble simulation

This verification process occurs when an air conditioner malfunctions, prompting the facility manager to be contacted through the ticket issuing function in the digital twin. The cause is then predicted based on the handling manual, followed by on-site investigation, and contacting the contractor. After confirming the equipment specifications, identifying the cause, adjusting the schedule, restoring the equipment, and generating a restoration report, the process is completed. The table below outlines the effectiveness verification details. The conventional method required 5 hours and 50 minutes, whereas the digital twin method only took 2 hours and 36 minutes, representing a 55% reduction in work time.

Table 3. Verification of trouble simulation

Action	Conventional	Duration	DigitalTwin	Duration
<Report of Event> Student contacts facility personnel.	From the classroom, move to the administrative office. Call the facilities manager and report explain the actual location of the equipment on site.	0h07m	Contact FMr on SIM-ON (iphone).☒	0h01s
<Expectation of cause>. Facility representative investigates the cause before contacting the vendor.	Locate the HVAC equipment instruction manual and anticipate the cause.	0h03m	FMr understands the problem on the digital twin, opens the manual on SIM-ON, and anticipates the cause.	0h02s
<Cause Identification> Identified from the "If something is wrong" section of the instruction manual.☒	Identify cause from on-site survey	0h30m	Identify cause from on-site survey	0h30s
<If the cause is unknown Contact the vendor.	Contact contractor by email or phone. (Show and attach drawings of the air conditioner in question)	0h20m	Contact the contractor using SIM-ON	0h01s
<Contractor - Identify the specifications of the equipment.> Check the specifications of the equipment to determine the cause or to get an idea of the cause.	Schedule on-site survey by e-mail	0h30m	Identification from asset information on SIM-ON	0h10s
	Visit the site and check the equipment	1h30m	Predict the cause	0h05s
<Contractor - restore>	Schedule on-site restoration work by e-mail	0h30m	Schedule restoration work using SIM-ON	0h15s
	Site visit, restoration	1h30m		
			Site visit, restoration	1h30s
<Report> Notify the student who reported the problem or the entire student body of the cause and recovery.	Prepare posters	0h40m	Notification on SIM-ON	0h01s
	Posting of posters at the site	0h10m		
	Total	5h50m	Ttotal	2h36s
	Work time reduced by approx. 55%			

8.2. Verification of inspection schedule searching speed

The subsequent verification involved finding a broken guide light and checking the results of its previous inspection. Essentially, this verification aimed to assess inspection times. The results are presented in the table, showing 11 minutes and 52 seconds for the conventional method and 56 seconds for the digital twin method. The digital twin method reduced work time by approximately 92%.

Table 4. Verification of inspection schedule searching speed

Action	Conventional	Duration	DigitalTwin	Duration
<Discovery of Event> Found guide light blinking.	On-site Inspection	-	On-site Inspection	-
<Inspection of equipment> Confirm previous inspection results	Find previous reports and confirm results for applicable equipment	4m22s	Check the results of the previous inspection from the corresponding asset information on SIM-ON (iPhone)	0m46s
<Arrangement> Confirm next inspection schedule.	Confirm timing of next inspection from the annual plan for periodic inspections	7m30s	Check the next inspection date on SIM-ON (iPhone)	0m10s
	total	11m52s	total	0m56s
	Work time reduced by approx. 92%			

9. Consideration

In this study, we have verified the efficiency of O&M by developing a digital twin. The following is a consideration of the validation.

9.1 BIM or Point Cloud with panoramic photo images?

There exists a trade-off between utilizing BIM and point cloud technology for constructing 3D models in O&M practices. For BIM to effectively serve O&M purposes, it necessitates being consistently updated and accurately maintained. However, managing the intricate geometry and properties of MEPF systems within BIM can be time-consuming. In essence, ensuring that the BIM model accurately reflects the current state of the building presents challenges. In contrast, employing point cloud technology to develop as-built models offers the advantage of easily capturing the current geometry of the building. However, this approach has its drawbacks. Notably, when updates occur, the building must be scanned again, and there is a notable limitation in accessing information about concealed areas.

9.2 How to use the COBie format.

COBie stands as a crucial format for organizing essential information during the maintenance phase of a building. However, a challenge arises as this information is stored within an Excel sheet, leading to difficulties in discerning the relationship between components and their respective spaces. To address this issue, our study relies on the as-built model for building space information, wherein components are meticulously labeled. This approach ensures that the spatial relationship between components and their corresponding labels is digitized, facilitating highly efficient and comprehensive searches.

9.3FM Organizations and Digital Information

Finally, we consider the organization that performs FM. Organizational change is important to promote digitalization. In conventional FM work, subcontractors have information on buildings, equipment, and costs. On the other hand, building owners do not have the information. In other words, building owners do not need to be actively involved in FM because the company that performs O&M contracts long-term work. There is no competition at work there. With the solution in this study, inspection items and building geometry information can be understood by the building owner. The ROI and cost reduction will be possible through proactive management by the owner.

10. Conclusion

The following are the findings of this study. Interviews were conducted with FMr at the university campus. It was confirmed that the current situation is that paper drawings and inspection reports are managed and not digitized. Inspection items were captured by 3D scanning of buildings using COBie format and integrated to create a digital twin for O&M with high searchability. The effectiveness verification confirmed the improvement in search productivity. Future items to be considered include energy consumption, real-time temperature management, and power usage management, and will be expanded using IoT technology. The goal is to make it possible to streamline not only O&M operations but also the management business of university campuses.

ACKNOWLEGEMENTS

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