


Digitalisation in action: creating the future from BIM to a Digital Twin for enhanced building operation and maintenance

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ABSTRACT

The Electrical and Mechanical Services Department (EMSD) is advancing its digital transformation from Building Information Modelling (BIM) to BIM-Asset Management (BIM-AM) to create a Digital Twin for building Operation and Maintenance (O&M). Since 2015, the organisation has been developing and customising its BIM-AM System for enhancing its O&M. In 2019, it launched the Government-Wide IoT Network (GWIN), dedicated IoT infrastructure for near real-time monitoring of Electrical and Mechanical (E&M) assets. To streamline O&M workflows, the organisation has also explored technologies like the Cave Automatic Virtual Environment (CAVE) and smart glasses, utilising Virtual Reality (VR) and Augmented Reality (AR). Since 2020, the organisation has initiated a government-wide asset digitalisation exercise, covering over 450 government venues to support smart building initiatives. Additionally, the organisation has aimed to establish the first on-premises Common Data Environment (CDE) compliant with ISO 19650 for the Government of the HKSAR, alongside the development of an Asset Information Management Platform (AIMP) and Virtual Desktop Infrastructure (VDI) to facilitate BIM-AM adoption. This paper will discuss the integration of these technologies in creating a Digital Twin for effective building O&M.

KEYWORDS Building Information Modelling, Asset Management, BIM-AM, Digitalisation, Digital Twin, Internet of Things, Common Data Environment

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1. Introduction

In recent years, the organisation has started to digitalise the E&M assets in government buildings and venues, striving for a new vision coined “E&M 2.0”. The application of BIM for asset management, namely the BIM-AM System, was developed as one of the digitalised engineering solutions, and the organisation formulated the departmental BIM-AM standards and guidelines for internal use and reference by the trade. The benefits of BIM-AM technologies have been well recognised by other government departments and the trade in recent years. In 2016, a Hong Kong patent was granted for the BIM-AM System streamlined building O&M Services with the Building Management System (BMS), Closed Circuit TV (CCTV) System, Radio Frequency Identification (RFID) System and Real-Time Location System (RTLS).

While BIM use for asset management has not been commonly adopted in O&M practice due to the lack of BIM models for existing buildings, the organisation initiated a government-wide asset digitalisation exercise to revitalise the E&M asset of existing government venues, preparing for BIM-AM adoption. Since September 2020, asset digitalisation has been conducted in over 450 existing government venues. The asset data and digitalised documents were managed efficiently in a structured manner using AIMP and an ISO 19650-compliant CDE for BIM-AM adoption. The AIMP is a tool developed to verify the input format of asset information and provided the function

of information exchange with other systems using Construction Operations Building Information Exchange (COBie) XML files.

In the journey of BIM-AM development, the organisation also developed a number of BIM tools, such as VDI and BIM model checker, to facilitate BIM-AM adoption. Several advanced innovative technologies were also adopted to realise a Digital Twin from BIM for enhanced building O&M. Examples such as wearable 3D laser scanning, the integration with IoT applications based on GWIN, CAVE and smart glasses will be further described in this paper.

2. Literature review

In recent years, integrating real-time data acquisition interfaces, e.g., Building Management Systems (BMS) and wireless sensor networks, with Facility and Asset Management (FM/AM) systems has attracted considerable attention. Studies reveal that this integration leads to enhanced operational efficiency and sustainability. By providing continuous streams of data on factors like energy consumption, occupancy, and environmental conditions, real-time systems allow for the dynamic optimisation of building resources, leading to reduced energy costs and a smaller environmental footprint (Jalaei & El-Sayegh, 2022; Rahman et al., 2023). This enables a move away from fixed maintenance schedules toward condition-based and performance-verified asset management, ensuring better

governance and compliance (Atkin & Brooks, 2024). Albeit that there is much research literature studying the benefits of integrating real-time data acquisition interfaces with FM/AM systems, fault localisation is not emphasised. In addition, visual integration between building facilities and spatial information, e.g., 2D/3D drawings and BIM models, was not included in these studies.

The use of BIM should not be limited to building design and construction processes, but also be extended to FM/AM and O&M stages by seamlessly conveying the necessary asset information from an as-built BIM model. Undoubtedly, there is enormous potential in regard to BIM's value. By virtue of the utmost importance of information accessibility for efficient fault localisation in O&M, the asset-related information that can be obtained by maintenance engineers should not be limited to static asset attributes of each building element residing in the BIM model. While there are many research studies and real-world applications of BIM in FM, most of them tend to focus on information transfer from BIM to FM systems (Quinn et al., 2024; Tsay et al., 2022). In these studies and applications, they have focused on the mere data population of facilities information from an as-built BIM model to an FM/AM system via Revit Add-ins, open standard in IFC format (Otranto et al., 2025), or a spreadsheet or an XML file for COBieLite (Pärn et al., 2023). Moreover, there are real-world projects involving information exchange between BIM and FM/AM systems with BMS integrated into the same system (Mayurachat et al, 2025) as well as studies on integrating RFID technology with BIM for fixed assets (Biswas et al., 2023) and interfacing Real-Time Location Systems (RTLSSs) with BIM for movable assets (Shi et al., 2024). However, these real-world applications are, in essence, generally not considered as true and full integration as to the integration diversity and extent whereas the system architecture that we have proposed and implemented is a full integration of BIM, AM in particular in the system topology, RFID technology as well as a variety of real-time data acquisition interfaces including BMS, wireless sensors, CCTV system, and RTLSS in one single system.

3. The BIM-Asset Management (BIM-AM) Framework

3.1. BIM-AM System

Our BIM-AM is a novel architecture for managing building facilities information by exploiting the information interoperability and reusability among BIM, system topology, RFID and real-time data acquisition system interfaces including BMS, IoT sensors and CCTV systems. Both native mobile applications and web-based applications were developed based on this architecture. It provides a standard approach for transforming an as-built BIM, i.e., Project Information Model (PIM) to an Asset Information Model (AIM). As shown in Figure 1, the organisation has

conducted trials and developed use cases to exploit the benefits of adopting a BIM-AM System compared with the traditional O&M workflow for fault reporting (EMSD, 2016a, 03:30), offsite pre-diagnosis (EMSD, 2016b, 01:51) and on-site reporting (EMSD, 2016c, 02:38). Compared to traditional O&M paper-work workflow, the BIM-AM System facilitates facility maintenance by integrating real-time integrated Building Management System (iBMS) data together with asset attribute information and 3D BIM models to create a smart fault management workflow. When equipment fails, the system automatically generates a fault alert with precise 3D location mapping, equipment manuals and maintenance details, enabling offsite engineers to conduct accurate pre-diagnosis using the BIM-AM system before dispatching technicians to attend on site.



Figure 1. Mobile application of the BIM-AM System.

3.2. Asset Information Management Platform (AIMP)

AIMP is a self-developed platform with a web-based interface and mobile application to manage asset information of more than 25 E&M systems and over 200 equipment types.

Some examples of the systems, and equipment involved, include but are not limited to: Lift and Escalator (LAE) systems with electric lifts (ELs), hydraulic lifts (HYLs), and escalators (EPCs); LV Switchboard (LAS) systems comprising switchgear (SWG), harmonic filters (HARs), and capacitors (CAPs); HVAC systems covering air-side components like Air Handling Units (AHUs), Fan Coil Units (FCUs) and VAV boxes (VAVs); Fire Services (FSs) installations including Sprinkler Heads (SPRs), Automatic Fire Detection and Alarm Systems (AFAs), and Pressure Reducing Valves (PRVs). The systems are meticulously categorised with standardised equipment codes to ensure consistent identification across all maintenance operations, enabling precise fault reporting and asset management throughout the facility's lifecycle.

The platform is also used for creating asset relationship and document-to-asset mapping, which is unable to be input into BIM models in a human-readable format. The AIMP supports the information exchange between BIM models, CDE, BIM-AM Systems, and our Enterprise Resource Planning (ERP) system. In the new workflow, only minimal attributes for object references (i.e., Asset Code and Zone Tag No.) are required in BIM models. All attributes will be inputted into an Excel spreadsheet. Subsequently, our self-developed BIM tools will export the extracted attributes from IFC or native BIM format into COBieLite format. Both the comprehensive attribute spreadsheets and the COBieLite file containing minimal attributes will be uploaded to an Asset Information Management Platform (AIMP), which enables our BIM-AM system to automatically link objects with their asset attributes. For accessing the equipment documents and information, the BIM-AM system will also connect to the API of the CDE and ERP to retrieve the files. It also acts as a portal for submission of BIM-AM deliverables by contractors and data validation by third-party checkers, such as checking for any missing data and incorrect data format, etc. A user-friendly mobile application of AIMP for on-site asset data validation with the features of QR code scanning and site photo uploading has also been developed.

3.3. Common Data Environment (CDE)

A CDE is a digital information platform designed to serve as a single source of truth for project information, fostering collaboration throughout the project lifecycle. Our department has been developing a CDE focused on managing and sharing BIM-AM-related information. This includes asset data, equipment catalogues, BIM models, drawings, O&M manuals, and other documentation.

With integrated workflow management, our CDE ensures consistent and streamlined access to vital information for all BIM-AM deliverables.

The CDE was designed to comply with the ISO 19650 for information assurance of Project Information Models (PIMs) and Asset Information Models (AIMs). Based on the ISO 19650 standards and the organisational BIM-AM requirements combined with organisational workflow and process, the platform stores BIM- and asset-related information on specific metadata and information states, including system, discipline, location, suitability, authorisation codes, etc., for all file collection. Any creation, updates or deletion of information is recorded with revision control and audit trails within the file collection. In September 2022, the organisation published two new guidelines: Guidelines for the Handover of E&M Installation to the EMSD and BIM-AM Acceptance and Upkeeping Guidelines for the EMSD (EMSD, 2022) based on the new CDE workflow as shown in Figure 2. In addition, our CDE is an on-premises solution, which minimises cybersecurity risks for adoption in restricted venues.

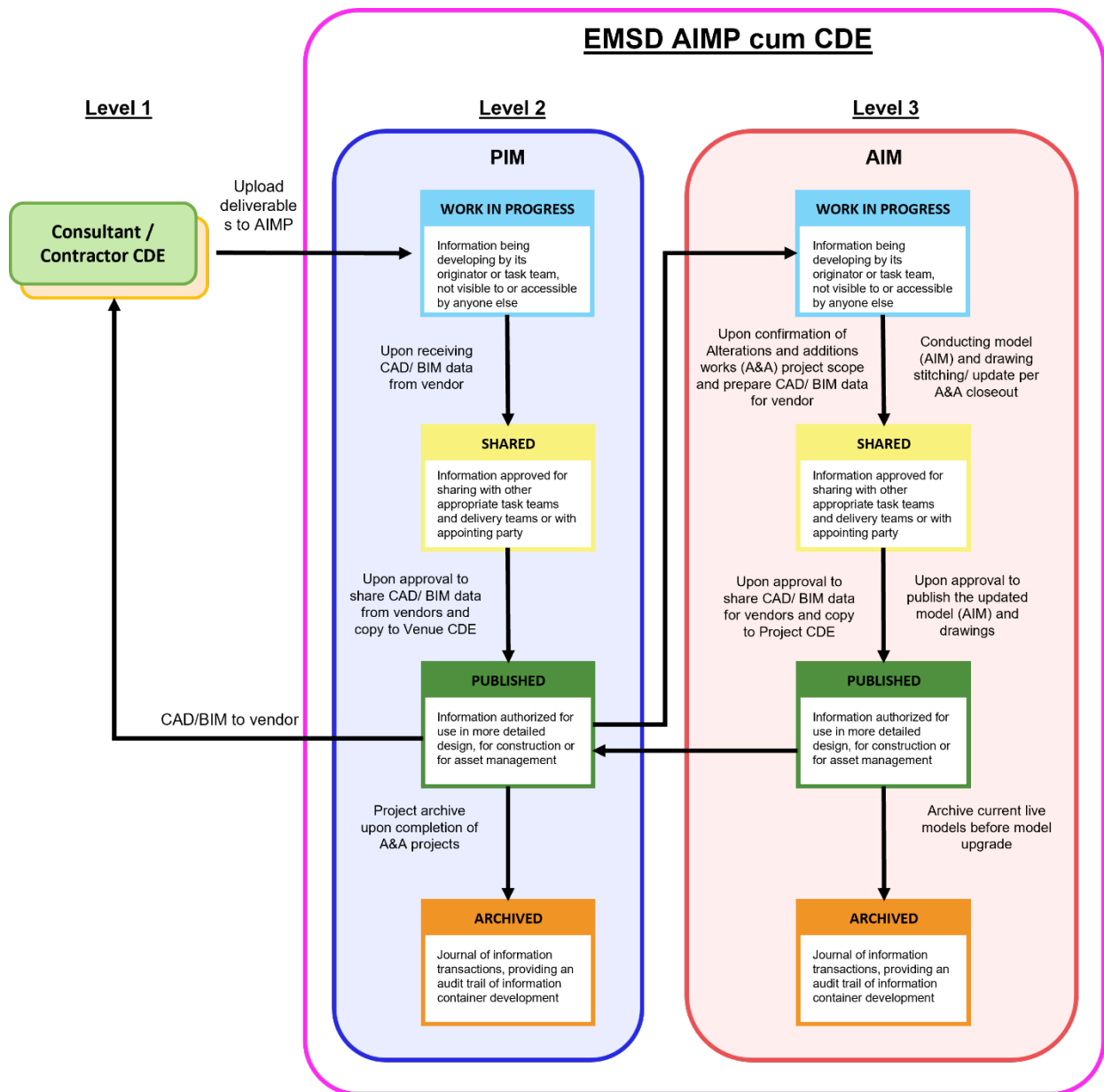


Figure 2. Overall workflow of departmental Common Data Environment.

3.4. BIM-AM Framework

Integrated with the AIMP and BIM-AM System, the CDE provides a single data reference supporting automated data synchronisation among related systems, which also facilitates collaboration between project and maintenance team members throughout the project lifecycle by improving the creation, sharing and issuing of BIM- and asset-related information. Therefore, the information integrity in a BIM-AM System can be assured. The information exchange among AIMP, CDE, BIM-AM system and our ERP system is shown in Figure 3.

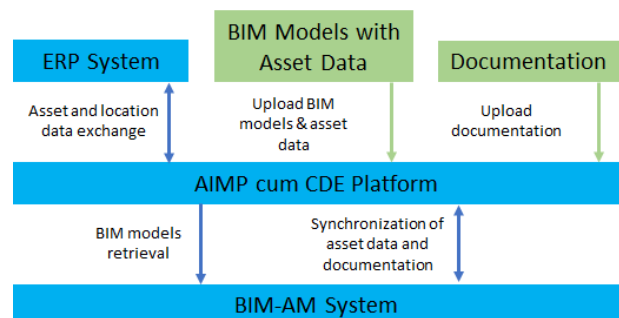


Figure 3. Information exchange among various systems.

Over the years, the organisation has adopted the AIMP to manage BIM-AM deliverables for importing to BIM-AM Systems. The platform is further enhanced and integrated with the ISO19650-compliant CDE. The CDE provides Application Programming Interfaces (APIs) for BIM-AM Systems to retrieve the documents or files stored in the centralised storage, and the AIMP makes use of a message queue (MQ) to notify the CDE and BIM-AM System for any changes in asset data and files. On the other hand, when there are any updated files and asset data from either CDE or BIM-AM, these changes are synchronised with the AIMP via an API which acts as a central system to communicate these changes with other related systems. The AIMP also communicates with our ERP system for data exchange of location and asset information.

The system interfaces among AIMP, CDE and BIM-AM System have completed the BIM-AM Framework as a total solution to facilitate asset management ensuring the data integrity and interoperability across various systems. With such comprehensive system integrations, different stakeholders are able to access the integrated and most up-to-date asset information concurrently on web-based applications or mobile applications of the BIM-AM System.

4. Adoption of smart technologies

4.1. Asset Digitalisation

Asset data and digitised documentation are of utmost importance for BIM-AM adoption in existing buildings to achieve smart O&M. In 2020, the organisation initiated a government-wide asset digitalisation exercise for E&M assets, including affixing RFID tags on major E&M equipment as shown in Figure 4, inputting asset information, digitalising maintenance manuals, etc., in more than 450 existing government venues. As at September 2022, around 24,900 RFID tags were installed on site and over 109,000 E&M assets involving more than 2,080 E&M systems were digitalised.



Figure 4. RFID tag installed at an E&M asset.

To support on-site data verification in existing venues, users can make use of the AIMP mobile application to update asset data if there are any discrepancies found on site and upload site photos using mobile devices for the record. Moreover, a new technology of wearable 3D laser scanner was also adopted in site surveys for constructing 3D models of existing venues. The scanned point cloud models and the textured 3D mesh as shown in Figure 5 served as the basis for the construction of a BIM model which was then uploaded to the BIM-AM System for visualisation. Based on the estimation from the software application of the wearable 3D laser scanner, it could effectively save up to 30% of site survey time as compared to the traditional ones. As for the restricted areas where a site survey is not allowed, the organisation invented the “BIM-AM lite” modelling methodology in which 3D objects were placed on the 2D floor plan for BIM model construction.

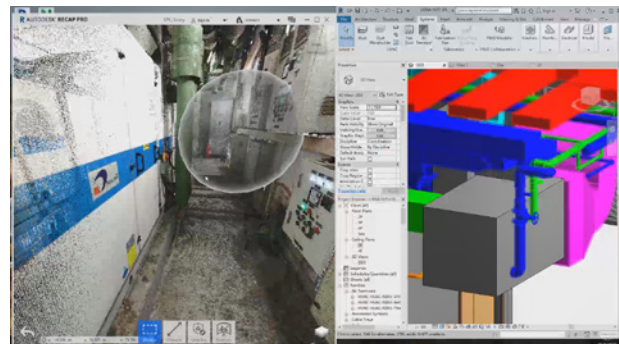


Figure 5. Point Cloud from a Wearable 3D Laser Scanner.

4.2. BIM tools for BIM-AM adoption

Further to the BIM model construction, the editing and viewing of BIM models typically require high-end computers installed with BIM authoring software. Due to the increasing usage of BIM in projects, it is important to evaluate the levels of BIM usage within the organisation for cost-effective resource allocation and reducing the manual checking process in BIM. The organisation developed the following tools to facilitate BIM-AM adoption.

(1) Virtual Data Infrastructure (VDI)

To optimise BIM resource allocation, the organisation offers high-end computers shared over the network. With the deployment of VDI, users may access computers with a much higher processing power and pre-installed BIM authoring software on an as-needed basis. The computing resources and software license are provided on demand over the virtual desktop infrastructure, allowing flexibility and lowering the total cost of ownership.

(2) BIM Model Checker

In September 2022, the organisation published the BIM-AM standard and guidelines version 3.0 (EMSD, 2022) which specified the BIM model and asset data requirements. A BIM software plugin was developed by the organisation for automatic BIM model checking against the organisational BIM-AM requirements, e.g., asset codes, equipment codes, project parameters, equipment schedules, and unit and symbol setting in the BIM models. This tool reduces the time for manual checking and may be used by the contractors to conduct quality checks of the BIM models before their submission to the project team.

4.3. Integration between the BIM-AM System and IoT to create a Digital Twin

In addition to digitalising static asset data, the emergence of IoT technologies offers a means to collect massive volumes of data for remote monitoring to support Digital Twin adoption in smart buildings. Since 2019, the organisation has been developing a dedicated IoT network, namely GWIN to deploy smart IoT sensors to digitalise E&M assets in government buildings and venues as well as supporting other smart city applications. With the integration of near real-time sensor data captured by GWIN, the BIM-AM System was enhanced to support the remote monitoring function for E&M equipment in achieving smart building O&M.

In smart toilet application (EMSD, 2020, 00:48), IoT sensors are installed in toilets to collect near real-time information which can be presented in the BIM models for remote monitoring as shown in Figure 6. The usage of consumables such as liquid soap and toilet paper can be monitored based on the data of level sensors for in-time refilling. Cleaning schedules and maintenance services may be optimised with reference to the data collected on the people queue, and people count. The health status of E&M equipment, such as hand dryers and ventilation fans, can also be monitored by detecting the vibration pattern of the equipment. Environment sensors reflect the odour level and interact with the air control system. IoT technology supplements the information which is not covered by the existing building management system to optimise toilet management so as to achieve better resource utilisation and higher end-user satisfaction. It also enables data analysis for further spatial, resource and energy optimisation opportunities to augment O&M effectiveness.

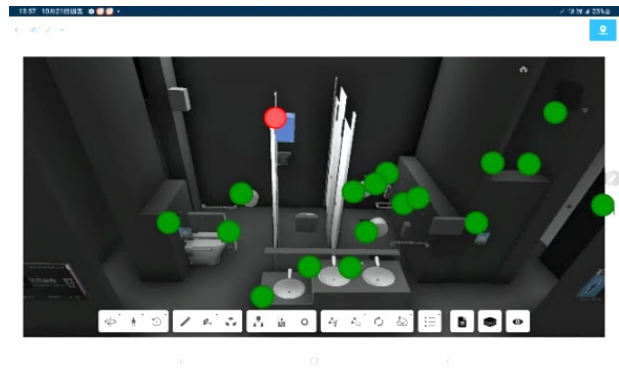


Figure 6. BIM-AM for Smart Toilets.

4.4. Integration between the BIM-AM System and Integrated Building Management System (iBMS) for creating a Digital Twin

Since 2019, the organisation has been progressively installing the iBMS to monitor the condition of venue facilities (e.g., electrical, mechanical, air-conditioning and building services systems). Additionally, the organisation has integrated a BIM-AM system with multiple iBMS, IoT sensor data, and building energy analytics to create a Digital Twin, as illustrated in Figure 7. This advanced application allows for real-time anomaly detection within the facilities, enabling colleagues to stay informed about the status of key systems. As a result, they can quickly identify issues, deploy manpower for troubleshooting, and efficiently notify and respond to customer needs.



Figure 7. Integrating iBMS with the BIM-AM System to create a Digital Twin.

The digital twin with BIM-AM is more than a virtual representation of a physical system. It is envisaged that the digital replica of the physical twin can be used to create living digital simulation models. These models can unearth possible insights and evaluate any peculiar patterns such that special attention can be paid to certain aspects to enhance asset management.

4.5. Virtual Reality and Augmented Reality technologies

Virtual Reality (VR) is a mature technology being widely adopted in the entertainment and gaming industry to simulate the real world environment so as to provide an immersive experience without obscuring the real world. However, the application of this visualisation technique in the Architecture, Engineering, and Construction (AEC) industry is still gearing up to realise its benefit throughout the building life cycle (Ossama et al., 2020). In the renovation projects of the outdoor piazza and customer service centre (EMSD, 2019, 04:42) at the EMSD Headquarters, BIM models were adopted at the design stage and were integrated with the CAVE system for design review. In this case, the design team was able to assimilate into a virtual environment to preview the interior and exterior design, layout as well as spatial arrangement in order to perfect the design solution as shown in Figure 8.

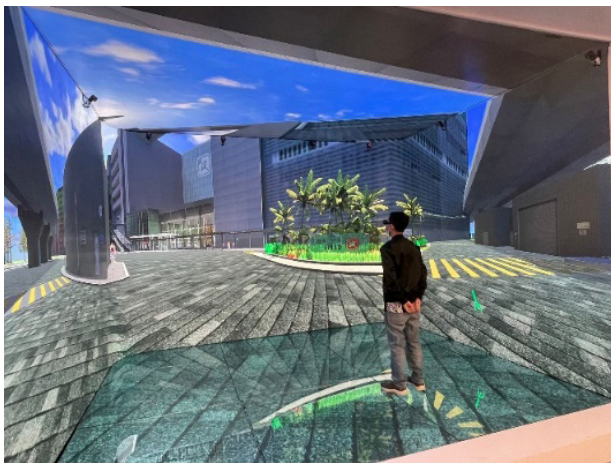


Figure 8. Use of CAVE in design review.

With this system, maintenance colleagues can also practise simulation maintenance in zones that are not easily accessible (such as operating theatres at the hospital as shown in Figure 9), to grow familiar with the environment and repair procedures, thus better preparing for the actual maintenance work in due course.



Figure 9. Use of CAVE in O&M Training.

Furthermore, the organisation has been exploring how to apply AR to enhance the O&M workflow. The technology involves the superpositioning of digital information over the physical environment for a better visualisation experience. Traditionally, when frontline colleagues seek support from the backend office, in general they communicate via phone call. The quality and efficiency of communication among both parties are limited. With the aid of smart glasses coupled with AR technology, remote assistance can be achieved thereby allowing both parties to have two-way real-time video communication. On-site colleagues not only can free up their hands for work, but also refer to maintenance documents or images sent by back office colleagues via smart glasses. With the integration with BIM models, the operators can also see through the false ceiling and locate E&M equipment as shown in Figure 10 for better correlation of BIM models with the actual site condition.



Figure 10. Integrating Smart Glasses with BIM.

4.6. Challenges and Limitations in System Development

Despite the significant potential of an integrated BIM-AM platform, its development and practical implementation face considerable challenges and limitations that can hinder widespread adoption in the private sector. A primary obstacle is the difficulty in creating tailor-made integrations with existing ERP systems. ERP platforms are the financial, logistical and job management backbones of most organisations, yet their rigid, transaction-based data structures are fundamentally in a separate domain as compared with the BIM equipment data, like equipment number, manufacture information, and warranty. This integration makes it exceptionally difficult and costly to create seamless, bidirectional workflows, often resulting in data silos where the BIM-AM system cannot automatically trigger work orders in the ERP, or where financial data on asset replacement remains disconnected from the digital twin. Furthermore, the handover workflow developed for transferring as-built information may not be suitable for

other organisations. The aforesaid integrated workflow of AIMP, CDE, BIM-AM and ERP is often too complex and impractical for other organisations to adopt directly for their actual operational needs.

5. Benefits in implementing BIM-AM

By implementing BIM-AM, the O&M workflow can be greatly improved in terms of effectiveness and efficiency. In a typical O&M workflow, the asset data and maintenance information are stored in various locations, for example, asset data in the asset management system, O&M manuals in handover folders, maintenance records in a work order system, etc. The maintenance colleagues need to spend much time searching for the required information in various systems for their maintenance works. By adopting BIM-AM, all the relevant asset data with maintenance information can be easily managed in an integrated system. Maintenance colleagues can also manage the E&M assets anytime and anywhere with the use of the BIM-AM mobile application to perform remote fault diagnosis, remote monitoring and fast asset locating. Based on the BIM-AM pilot at the EMSD Headquarters, it is proven that at least a 15% time saving can be achieved for fault localisation in a typical air-conditioning fault situation.

6. Way forward

6.1. Artificial Intelligence

Throughout the digitalisation journey, the organisation has adopted new technologies and developed system platforms to digitalise, manage and visualise the asset information for smart building O&M. We are currently exploring the development of advanced applications of digital twins with the integration of the Building Semantic AI system for predictive maintenance and system optimisation. This technique involves developing the programmes of the AI services portable across buildings in a shorter timeframe, bringing about the optimisation of system operation and energy savings. For example, metadata from BIM and iBMS will be used as the input parameter. An AI algorithm will be developed to calculate the correlation between the input and energy output to create semantic knowledge graphs and build a digital twin to simulate the situation of the Electrical & Mechanical (E&M) equipment. By interpreting the relevance of digitalised E&M operation information of many buildings through an integrated semantic standard, this approach is feasible to reduce the time for digitalisation of the E&M systems by around 70% (EMSD, 2021).

6.2. Lesson Learnt

BIM adoption involves a cultural change and new normal in the engineering industry. The organisation has developed a training plan to prepare all colleagues of different ranks to equip themselves with the required BIM knowledge and skills to achieve the goal of “BIM for everyone”. We have also encouraged the O&M teams to explore the BIM-AM use cases according to their operation needs for sharing internally as well as with the other government departments and trades. Similar to the wide adoption of smartphones nowadays, we believe that “BIM for everyone” will come true one day with the close collaboration between the different stakeholders in the construction industry.

7. Conclusion

The BIM-AM System has been proved efficient in streamlining the O&M workflow in recent years. With the use of the BIM-AM mobile application, maintenance work does not necessarily start on site. Instead, the maintenance colleagues could perform remote monitoring, asset locating and remote fault diagnosis, once there are any reported faults received. On the other hand, a variety of system integrations have developed the BIM-AM application into a complete solution with workflow management. While the AIMP serves as a submission portal with validation gateways for BIM-AM deliverables submitted by contractors, the CDE is a single source of truth platform with a structured workflow and asset information management for collaboration among multiple parties. With the introduction of new corporate systems for project and asset management workflow, the organisation has also formulated multiple guidelines to share the new acceptance and handover workflow based on the ISO19650-compliant CDE.

Moreover, the organisation has explored and conducted trials to apply cutting-edge technologies in the area of smart O&M over the years, including IoT sensors in GWIN, VR and AR in CAVE and Smart Glasses, etc. Technology integration has been a key success factor for the organisation, especially for the complicated and multiple varieties of existing O&M workflows. In the future, more studies will be conducted on innovative solutions, e.g., AI and data analysis for the advancement to “E&M 3.0”, with a view to improving public services and strengthening our role not only as a regulator for E&M systems, but also as a “Government’s Innovation Facilitator”.

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