Session 6.3: Smart Initiatives in SBE (2)

Transforming Building Information Modelling to Sustainable Building Asset Management

LEE Che-kit[a], CHAN Ping-sun[b], CHAN Hor-yin[c], YUEN Piu-hung[d]

[a] *The Electrical and Mechanical Services Department, Government of the HKSAR, Hong Kong SAR, cklee@emsd.gov.hk*
[b] *The Electrical and Mechanical Services Department, Government of the HKSAR, Hong Kong SAR, pschan@emsd.gov.hk*
[c] *The Electrical and Mechanical Services Department, Government of the HKSAR, Hong Kong SAR, stevehyc@emsd.gov.hk*
[d] *The Electrical and Mechanical Services Department, Government of the HKSAR, Hong Kong SAR, phyuen@emsd.gov.hk*

ABSTRACT

Building Information Modelling (BIM) technology has rapidly emerged in recent years in architecture, engineering and construction (AEC) industry to reduce design and construction efforts through enhanced multi-disciplinary coordination, however, its application in the long building lifecycle of operation and maintenance (O&M) stage is little investigated. Whilst research studies and real-world applications of BIM in building facility management (FM) and asset management (AM) have put emphasis on data exchange between BIM and FM/AM software, this paper presents a novel system framework and our development works for transforming BIM to sustainable building asset management by seamless integration among BIM model, AM system and multiple electronics systems/tools.

Furthermore, the proposed framework provides a visually intuitive way to access heterogeneous O&M information of assets such as photos, attributes, equipment relationships, manuals, drawings, maintenance records, live view of Closed Circuit Television (CCTV) System, real-time sensing data from a Building Management System (BMS) and wireless ad-hoc sensors, as well as location information from a Real Time Location System (RTLS) in one single integrated mobile platform. All these information is accessible simply by asset repository, manoeuvring throughout a BIM model, or even a handheld Radio Frequency Identification (RFID) scanning tool.

Having selected our headquarters building as a showcase project, an integrated BIM-AM System with four key generic user models has been developed to implement the proposed framework. The results have successfully demonstrated the system capabilities in not only facilitating daily O&M works and effective asset management but also responsive incident handling, thus enhancing building sustainability.

Keywords: *asset management, smart building, information integration*

1. INTRODUCTION

Tracing and identification of building facilities using 2D computer-aided design (CAD) drawings are complicated and inefficient particularly where there are overlapping layered services. Inconvenient cross-reference among different 2D CAD drawings also hinders a clear visualisation of concerned service like duct and pipe works of Heating, Ventilation, and Air Conditioning system. A better visualisation of service drawings is therefore always desirable from O&M perspective. In recent years, BIM, a digital model and process being conceived as an object-oriented CAD system supporting the representation of building elements in terms of their geometric and functional attributes as well as their inter-object relationships, has rapidly emerged in AEC industry to facilitate early coordination among different disciplines, leading to significant shrink of construction schedules and project costs.

However, the approach and application of adopting BIM for sustainable building asset management is yet to be investigated. Whilst there are many research studies and real-world applications of adopting BIM in FM/AM, most of them focus on data population from BIM to FM/AM software [1,2,3,4] either by proprietary add-ins, open BIM standard in IFC format [5], or a spreadsheet / an XML file for Construction Operations Building Information Exchange (COBie) [4,6,7]. Albeit that there are researches involving information exchange between BIM and FM/AM system with BMS integrated [8] and integrating RFID technology with BIM [9], they are in essence not considered as full and seamless integration among BIM, FM/AM software and multiple O&M systems in terms of their integration diversity and extent, as compared with our developed BIM-AM System. Owing to the utmost importance of information accessibility for efficient O&M, asset related information that can be obtained by maintenance engineer should not be limited to static asset attributes of each building element residing in the BIM model. To close the gap between direct adoption of BIM and day-to-day O&M practice for sustainable asset management, we have investigated the appropriate approach for integrating/interfacing BIM with a variety of O&M systems/tools.

This paper aims to show that, by leveraging the underlying principle of BIM in facilitating effective information exchange and storing in an interoperable and reusable way, a novel framework exploiting BIM in integrating AM and a variety of O&M systems/tools has been successfully implemented with a view to streamlining building O&M. Such a BIM-AM System has been piloted in our headquarters building to evaluate its O&M effectiveness. The pilot results have broken new ground in the application of BIM and could potentially fill a void in the market. The BIM-AM System features multiple O&M tools in a single integrated application, offering real-time O&M information sharing/retrieving and exchange capabilities, thus making system handover and O&M much more efficient and effective. It is envisaged that the BIM-AM System would be an enabling tool for sustainable building asset management.

2. SYSTEM FRAMEWORK

As far as our knowledge goes, full and seamless integration of BIM with an AM system as well as a variety of O&M systems/tools including BMS, CCTV system, RFID scanning tool, and RTLS has not been realized. Figure 1 depicts the proposed system framework in which the dotted line indicates the integration that may have been implemented in some other FM/AM software applications whereas the solid line indicates the full and seamless integration that was first implemented by us in 2014.

Under this framework, AM system is considered as an O&M software application for building asset management, preventive maintenance and corrective maintenance management including workflow for fault reporting, handling and monitoring. One of the most distinctive differences is that the AM system in the proposed framework serves as a middleware to integrate/interface with other systems/tools whereas other research works take BIM as a middleware for information exchange with other systems/tools, thus increasing the integration complexity. This is because direct integrations between BIM and other systems/tools would result in high complexities in the Application Programming Interface (API) developments on BIM software and the systems/tools. Moreover, BIM cannot replace the role of AM system in storing and upkeeping AM-related information as well as performing other comprehensive AM features. Another distinctive difference between our works and other researches is that the visual integration between BIM and AM system is in a seamless and intuitive manner, in the sense that the BIM-AM System allows locating and visualising any particular asset with its real-time asset information by maneuvering freely throughout the BIM model in one single integrated system, instead of mere data exchange between BIM and AM system.

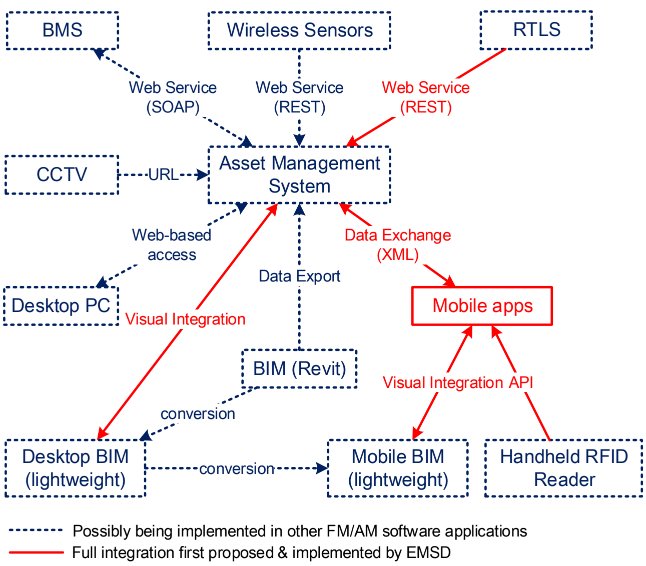


Figure 1: The novel framework for BIM-AM System

2.1. Visually intuitive cross-reference among real-world, BIM model, and static asset information

The BIM-AM System enables visually intuitive cross-reference of real-world physical objects to BIM model and even to asset attributes, maintenance records, asset relationships, system topologies, manuals (including animated repair manuals, if any) and system drawings at a mobile terminal. As shown in Figure 2, a VAV box can be visualised and quickly located in its approximate real-world physical location, enabling easy cross-reference to a BIM model for pre-diagnosis.

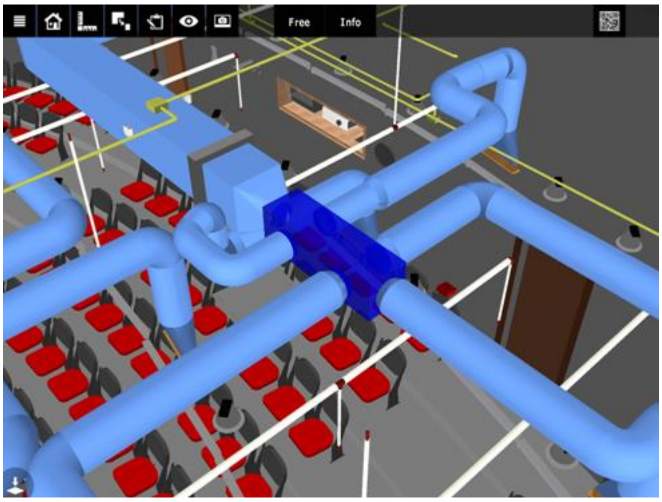


Figure 2: Georeference of a VAV box in a BIM model

System topology generation was purposely developed to visualise the asset relationships within a particular system for further cross-referencing among assets information during fault locating. The system topology as shown in Figure 3 provides a graphical view of the asset relationships of the VAV box within the overall system.

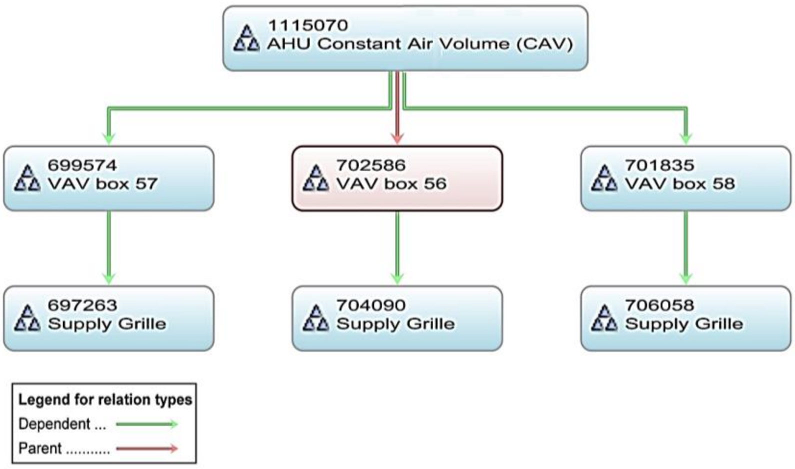


Figure 3: System topology visualising the asset relationships of a VAV box within the overall system

In addition, we have established our BIM-AM asset templates for Mechanical, Electrical, and Plumbing (MEP) installations. Apart from typical system specific attributes, the standardised asset templates also contain the information of asset relationship, wireless tag ID and geometric related attributes for system topology generation, RFID/RTLS application, and BIM visualisation respectively.

2.2. Pre-diagnosis and condition monitoring based on real-time asset information from BMS, wireless ad-hoc sensors, and CCTV system

Integrating BIM-AM System with BMS and fixed CCTV system for accessing real-time remote site information with control functions at a mobile terminal could facilitate efficient offsite pre-diagnosis and possible rectification. Based on the pre-diagnosis, maintenance engineer would be able to bring necessary tools / spare parts to the site in one go. Figure 4 is the mobile screen capture showing the real-time BMS monitoring sensor values of an Air Handling Unit (AHU).

Code	Meter	Reading date-time	Reading value
1028778	DAHU706.TSP2, Return Temp Set PT (EMSD)	10/12/2015 15:22	24
1028779	DAHU706.PSP, Static Pressure Set PT (EMSD)	10/12/2015 15:22	430
1028781	DAHU706.PSP, Static Pressure Set PT (EMSD)	10/12/2015 15:23	445
1028786	DAHU706.TSP2, Return Temp Set PT (EMSD)	10/12/2015 17:50	27
1028787	LTG_RM7153, Rm 7153 Lighting Control (EMSD)	10/12/2015 09:52	1
1028789	LTG_RM7153, Rm 7153 Lighting Control (EMSD)	10/12/2015 09:54	100
1028832	VAV7F_55FDS, VAV Damper Status	16/12/2015 21:23	38.13
1028834	VAV7F_55FLW, VAV Flowrate	16/12/2015 21:23	0

Figure 4: BMS monitoring interface of an AHU in the BIM-AM system

In addition, wireless ad-hoc sensors, such as temperature sensor, humidity sensor, power metre, and wireless camera over WiFi, Bluetooth, and cellular networks, were developed for prompt installation and monitoring. These wireless ad-hoc sensors are considered useful in incident handling, condition monitoring, generation of pre-fault alerts, or energy management. Figure 5 shows the live feed of a wireless camera available at the mobile terminal for monitoring the subject plant room area. In this pilot, web services have been employed for the data communication from BMS and wireless sensors to the AM system and vice versa.

Figure 5: The live feed of a wireless camera in the BIM-AM system

2.3. Efficient locating of fixed and movable assets

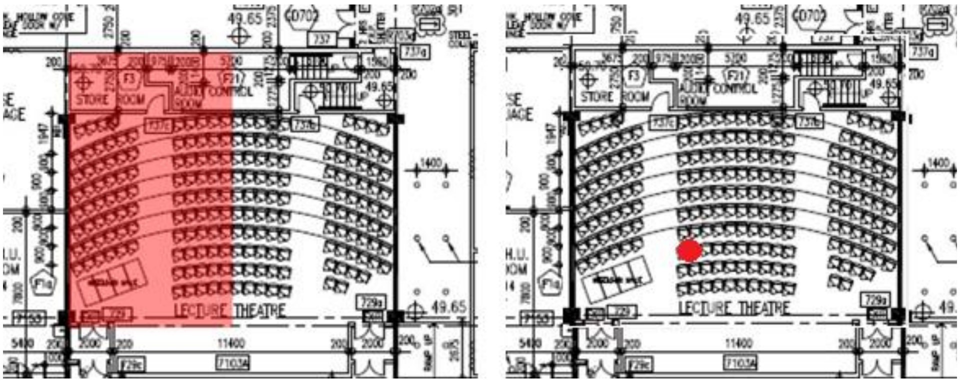
Having integrated the mobile terminal platform of BIM-AM System with a handheld RFID scanning tool, maintenance engineer could efficiently and effectively locate critical equipment for further enquiry of asset information even if the equipment is hidden above a false ceiling or underneath a raised floor. Figure 6 shows a mobile screen capture of RFID scanned results listing nearby assets.

ScannerName HW SW Battery 0%
29 Scan Search By ID

Equipment ID ⇅	Description ⇅	Location ⇅	System Type ⇅	Signal ⇅
000258	AHU supply 1.4 - 2.8 m3/s	LOBBYZone 1	HVAC	90 %
000244	Airco Unit	AHU RoomZone 4	HVAC	80 %
000243	Emergency lighting decentrally fed	Common AreaZon...	LIGHT	70 %
000253	Splitting system VAV	Hub RoomZone 5	HVAC	60 %

Figure 6: RFID scanned results listing nearby assets

To extend the locating feature from fixed assets to movable assets such as working platform and biomedical equipment, RTLS over WiFi and Ultra-Wide-Band (UWB) technologies, as shown in Figures 7(a) and 7(b) respectively, were piloted in EMSD HQs building. The latter was adopted and installed because of higher positioning accuracy.



(a) (b)

Figure 7: (a) RTLS over WiFi; (b) RTLS over UWB

2.4. Efficient and effective O&M workflow management

Coupled with four key generic user interfaces for client, helpdesk, supervisors and frontline, the BIM-AM System can facilitate efficient and effective O&M workflow in fault reporting, handling and monitoring not only for in-source but also out-source arrangement. As shown in Figure 8, the user interface for the maintenance engineer provides readily accessible asset information, such as asset attributes, maintenance record, equipment relationship, system topology, manual, and system drawing as well as creating service request and cross-referencing to BIM model. Additionally, the System can timely notify users to fill in an electronic pre-work safety check form such that the safety compliance can be easily achieved.

Moreover, the System can cater for highly dynamic and versatile interactions among different parties in the client, maintenance contractor and our organisation by assigning respective features to different parties to facilitate efficient and effective O&M services, supervision and communication at all times.

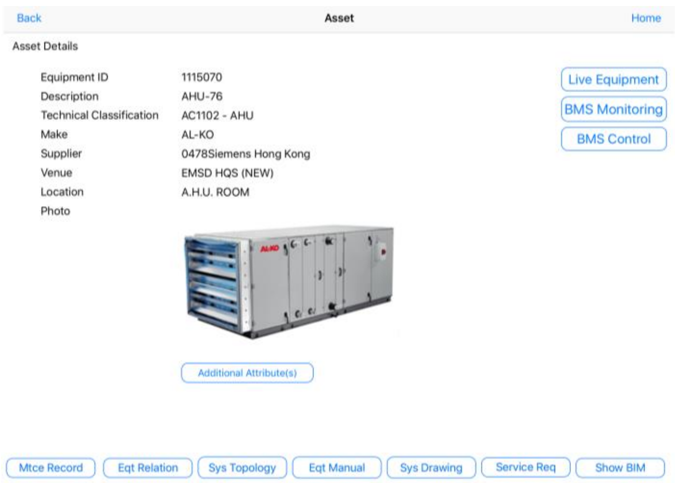


Figure 8: User interface for the maintenance engineer at the mobile terminal

3. DEMONOSTRATION

Simulated maintenance showcases using an AHU model, a fire sprinkler system model, an emergency lighting model, and a general lighting model in the BIM-AM System were recorded in videos for demonstration purpose [11]. The results demonstrate that the BIM-AM System can improve productivity in fault response, workflow management, safety compliance, retrieval and appending of maintenance record, access of asset details, relationships and manuals, and so on. Significant time-saving of more than two hours can be achieved on fault localization in a typical air conditioning fault situation as compared with the current practices. In fiscal year 2015/2016, the total number of maintenance orders was about 639,000 in all buildings maintained by the EMSD. Projecting the potential time-savings without real trials would lead to inconclusive findings, but the benefits of the full rollout are foreseeable.

4. CONCLUSION

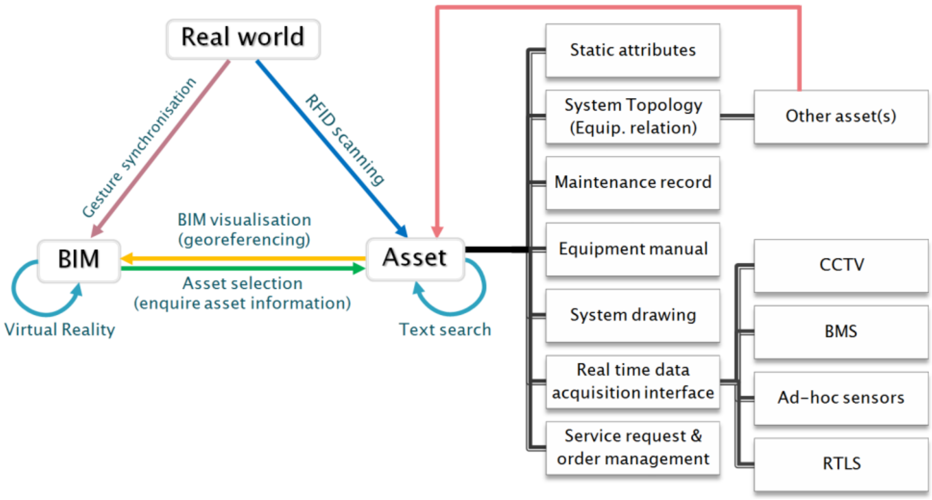


Figure 9: A graphical summary of BIM-AM System features

We have proposed a novel system framework exploiting BIM in asset management and realized the concept in an integrated BIM-AM System featuring multiple O&M systems/tools in one single platform. A graphical summary of the System features is exhibited in Figure 9. The integrated platform has proved effective in streamlining workflow, facilitating responsive incident handling and sustainable asset management. The tool has great potential to bring major benefits including long-term cost savings in the O&M building lifecycle. Though the successes arising from the framework and pilot BIM-AM System are only on a limited scale, we hopes the integrated BIM-AM System would not only benefit our services in operating and maintaining about 5,800 government buildings, but also encourage and facilitate the construction industry in Hong Kong to better deploy this new technology for sustainable building asset management, particularly O&M services, ultimately benefitting the public.

REFERENCES

[1] Schevers, H.A., Mitchell, J., Akhurst, P., Marchant, D.M., Bull, S., McDonald, K., and Linning, C., 2007. “Towards digital facility modelling for Sydney Opera House using IFC and semantic web technology”, Journal of Information Technology in Construction, 12, pp. 347-362.

[2] Sabol, L., 2008. Building Information Modeling & Facility Management, Washington, DC: Design + Construction Strategies.

[3] Ding, L., Drogemuller, R., Akhurst, P., Hough, R., Bull, S. and Linning, C., 2009. “Towards Sustainable Facilities Management”, in Newton P., Hampson K. and Drogemuller R. (Eds). Technology, Design and Process Innovation in the Built Environment. Taylor & Francis, pp. 373 - 392.

[4] Teicholz, P.M., 2013. BIM for facility managers, (IFMA, Ed.), Wiley, Hoboken, N.J.

[5] Lewis, A., 2013. “Case Study 5: State of Wisconsin Bureau of Facilities Management, Division of State Facilities, Department of Administration”, IFMA (Ed.), BIM for Facility Managers, Wiley, Hoboken, N.J., pp. 250-293.

[6] Aldaham, O., Gonzalez, J., Grant, I., Harper, K., Kruger, A., Nannis, S. and Snedeker, L., 2013. “Case Study 1: Mathworks”, IFMA (Ed.), BIM for Facility Managers, Wiley, Hoboken, N.J., pp. 147-163.

[7] Beatty, R., Eastman, C. and Kim, K., 2013. “Case Study 2: Texas A&M Health Science Center”, IFMA (Ed.), BIM for Facility Managers, Wiley, Hoboken, N.J., pp. 164-184.

[8] Aspurez, V. and Lewis, P., 2013. “Case Study 3: USC School of Cinematic Arts”, IFMA (Ed.), BIM for Facility Managers, Wiley, Hoboken, N.J., pp. 185-232.

[9] Motamedi, A., Soltani, M. and Hammad, A., 2013. "Localization of RFID-equipped assets during the operation phase of facilities." Advanced Engineering Informatics, pp. 566-579.

[10] Abiola, A.A., Chimay, J.A. and John, I.M., 2012. "An RTLS-Based Approach to Cyber-Physical Systems Integration in Design and Construction," International Journal of Distributed Sensor Networks, vol. 2012, Article ID 596845.

[11] Videos of Building Information Modelling - Asset Management (BIM-AM), Electrical and Mechanical Services Department, HKSARG [online]. Retrieved from: http://www.emsd.gov.hk/en/engineering_services/project_management_consultancy/highlights_of_work/bim_am/index.html [Retrieved on 30 September 2016].