

BIM Experience in Design of New Public Mortuary

Ir Wallace S. F. LEUNG, Senior Building Services Engineer, Architectural Services Department
Ir Paul P. K. YU, Senior Building Services Engineer, Architectural Services Department
Ir Keith K. Y. CHENG, Building Services Engineer, Architectural Services Department

Abstract

Promotion and adoption of innovative technologies to drive for higher production efficiency and to relief the burden of inadequate site laborers in the construction industry is an important works of the Hong Kong Government. Application of Building Information Modelling (BIM) technology in major capital works projects has become a standard requirement following the Technical Circular issued by the Development Bureau in December 2017. Architectural Services Department (ArchSD) has been well preparing for this challenge. In 2015, the project to build a new Public Mortuary at Fu Shan, Sha Tin was identified as one of the pilot projects for trial adoption of BIM starting from its design stage. This paper will share ArchSD's experience in the application of BIM in the design of mechanical, electrical and plumbing (MEP) installations including design collaboration of various specialized systems like air-conditioning/ventilation for autopsy suite and analysis of photovoltaic system for renewable energy generation in this project. The BIM data management structure, level of development (LOD) of MEP objects, model production process and consideration for asset management after building occupation would also be briefly introduced.

Key Words: BIM, collaboration, Level of Development, buildability

Technical Paper

1. Introduction

Building Information Modelling (BIM), an innovative and powerful parametric modelling tool, is receiving increasing attention for implementation in construction industry. The Hong Kong SAR Government is proactively promoting the adoption of this advanced technology to drive for higher production efficiency and to relief the burden of inadequate site laborers in the construction sector. In past few years, Architectural Services Department adopted BIM technology in a number of pilot projects. Following the detailed policy directive issued by the Development Bureau in December 2017, the application of BIM is now a standard requirement in major capital works projects.

There have been revolutionary changes in building design and construction process since the emergence of BIM. Building form analysis, solar analysis and also 3D visualization can be delivered at earlier design stage. Collaboration, such as clash detection and resolving conflicts amongst multi-disciplinary stakeholders, and quantities take-off can be achieved by using BIM. The changes and risks during construction can be reduced as a result contributed by the modelling on buildability via successful collaboration using BIM. The use of BIM can be further extended to asset management (AM) and an integrated AM system with BIM can undoubtedly provide a comprehensive and effective platform for optimization of operation and maintenance (O&M) throughout the building lifecycle.

One of the BIM pilot projects, a new Public Mortuary at Fu Shan, Sha Tin, was identified by Architectural Services Department (ArchSD) in 2015 for more extensive BIM application starting from its sketch design stage. This paper aims to share the experience in the application of BIM in the design of Mechanical, Electrical and Plumbing (MEP) installations including design collaboration of various specialized systems like air-conditioning/ventilation for autopsy suite and analysis of photovoltaic system for renewable energy generation in this project. The BIM data management structure, level

of development (LOD) of MEP objects, model production process and consideration for asset management would also be briefly introduced.



Figure 1 – 3D rendering of new Public Mortuary (aerial view)

2. Project Background and BIM Deliverables

The new Public Mortuary is located on a sloping site. It consists of both public and restricted zones which have different design requirements to cope with their building functions. There are 8 nos. autopsy suites and 31 nos. autopsy workstations in total and these facilities are the core of a mortuary building, where routine Coroner's cases, homicide cases and suspicious deaths are investigated. With stringent requirements in architectural, structural and building services design for autopsy suites, BIM is envisaged as an efficient tool to enhance the building design and construction processes.

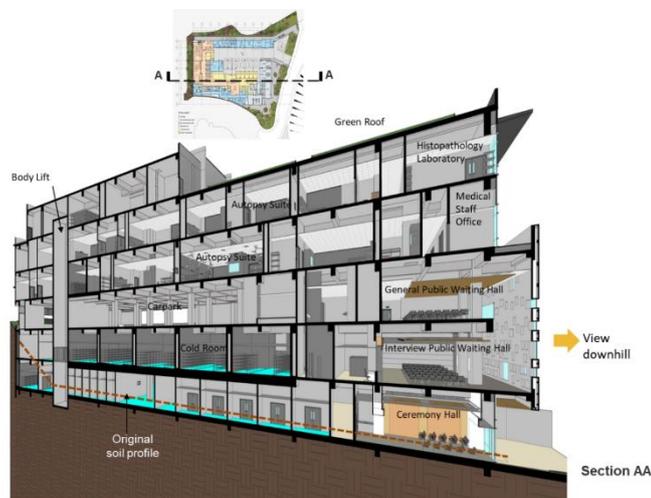


Figure 2 – BIM model of new Public Mortuary (sectional view)

This new mortuary project is undertaken by a team of in-house professionals from different disciplines in ArchSD. A BIM consultant has been engaged for assisting the adoption of BIM for this pilot project through provisions of regular training and workshops on the advanced modelling skills and BIM workflow to our architect, engineers and technical officers. At the beginning of the sketch design stage of this project, the BIM deliverables are defined with collaboration amongst the design team members. The major BIM deliverables are listed below:-

<i>Sketch Design Stage</i>	<i>Detail Design Stage/ Tender Stage</i>	<i>Construction Stage/ Operation Stage</i>
<ul style="list-style-type: none"> - Glare study of PV panels reflection to the neighborhood - Site Analysis - Solar Analysis - Slope Cut and Fill Review 	<ul style="list-style-type: none"> - 3D visualization and design collaboration at Autopsy Suite - CFD analysis at Autopsy Suite - BIM integrated lighting design - Clash analysis - Model authoring - Precast unit study - Material quantities take-off for cost estimation - Operation and maintenance planning 	<ul style="list-style-type: none"> - Clash analysis - Virtual prototyping and virtual mock-up - Site construction programme modelling (5-D) - Plant rooms spatial study for maintenance purpose - Data rich as-built model for asset management

Table 1: BIM deliverables at different project stage

An integrated autopsy suite is federated in BIM such that resolution of one module can benefit all the others. By using BIM, 3D coordination can be achieved and the maintenance concern can be easily addressed at earlier design stage as the BIM allows effective collaboration between MEP installations and architectural/structural design elements in this type highly complexity project. Design clashes amongst various disciplines can be detected and resolved in design stage to enhance the buildability and minimize abortive works at construction stage. Thus reducing time in overall construction programme and saving in construction cost is expected from the BIM technology application.

3. BIM Application in the Design of MEP installations

3.1 Glare Study of Photovoltaic System

The Hong Kong SAR Government is promoting the use of renewable energy technologies for sustainability development. Photovoltaic (PV) system will be provided in this new public mortuary building. Key design parameters affecting the energy generating performance of the PV system are the orientation and tilt angle of the PV panels. Since the new mortuary is a low-rise building and being surrounded by some high-rise residential buildings, the potential glare nuisance due to sunlight reflection from the PV panels should be assessed carefully and the PV layout design should minimize the impact to the neighborhood.

BIM has been adopted at the sketch design stage to assess the glare due to PV panels. The glare study is visualized from the model for verifying whether the PV system design would induce adverse effect to the neighborhood due to solar light reflection or not (Figures 3 and 4).

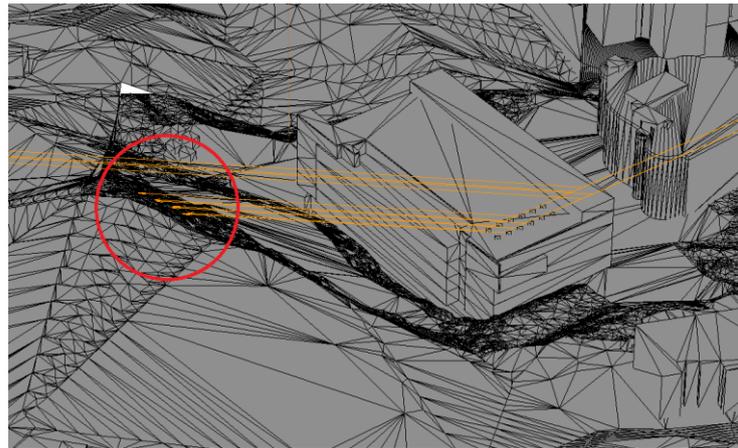


Figure 3 – Reflection of sun glare at 0700 on Summer Solstice in June

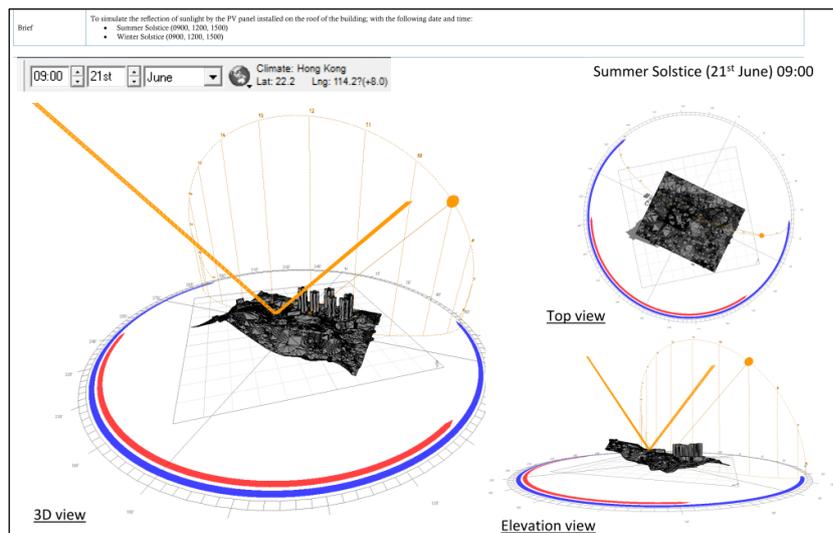


Figure 4 – Simulation of solar ray and its reflection path of PV panels at Summer Solstice and Winter Solstice to check if any adverse effect to neighborhood

3.2 3D Visualization and Design Collaboration

Autopsy suite is a major building facility where routine Coroner’s cases, homicide cases and suspicious deaths are investigated to support the operation of a mortuary building. In this project, there are 8 nos. autopsy suites and 31 nos. autopsy workstations in total. The project team considered that the spatial relationship and potential conflicts amongst architectural, structural and MEP elements should be critically reviewed prior to construction as each autopsy suite demands a well co-ordinated working environment including essential elements like the autopsy workstations and associated building services installations with specific operational requirements.

A federated model for the autopsy suite has been developed for better design coordination, clash avoidance and clash detection for critical zones/areas in an autopsy suite such as the ceiling zone and service duct clearance along autopsy workstations. Co-ordination workshops amongst architects, structural engineers, building services engineers and BIM consultant are held in order to work out the zoning and rules for combining services at critical sections. The clashes amongst architectural, structural and MEP elements are detected, visualized and resolved accordingly. In addition, the clearance among key

elements and spaces for maintenance have also been assessed. Design collaboration using BIM technology enables faster and earlier response time for design reviews and also vastly reduces the risk for abortive site works.

Figures 5 to 8 demonstrate the BIM collaboration processes.

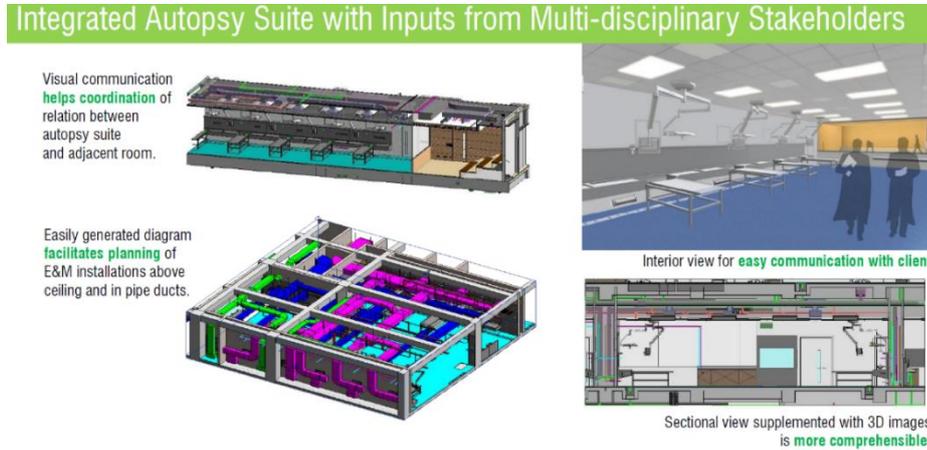


Figure 5 – BIM enhances visual experience and communication in design collaboration

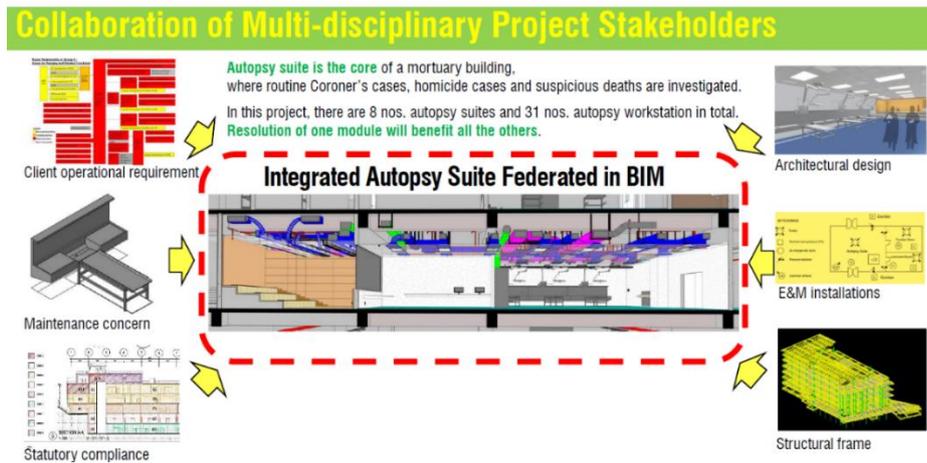


Figure 6 – Collaboration among multi-disciplinary stakeholders using BIM

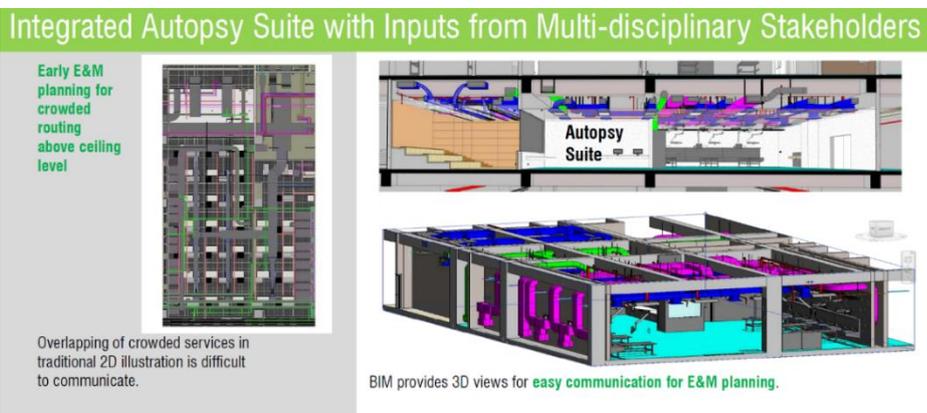


Figure 7 – MEP design coordination of autopsy suite using BIM

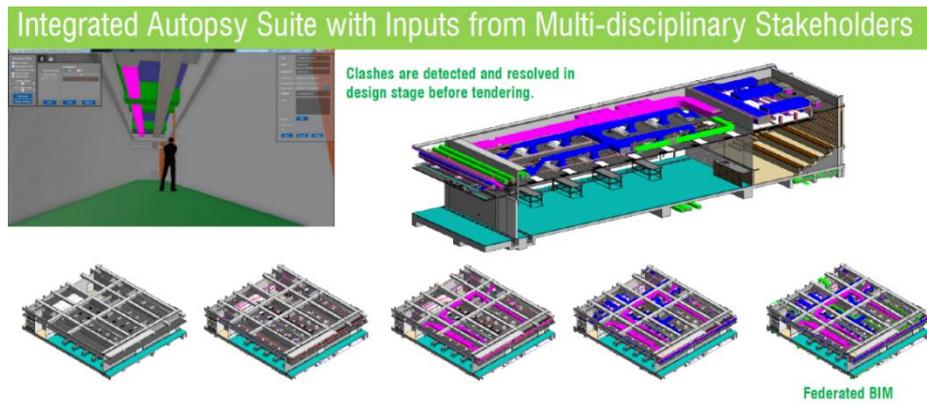


Figure 8 – Clashes analysis using BIM

3.3 Computational Fluid Dynamics (CFD) Analysis at Autopsy Suite

An effective ventilation system to minimize airborne contamination is vital for staff working in autopsy suites even though personal protective equipment (PPE) are provided to them. Uni-directional flow ventilation system has been designed in such a way that clean air will be supplied from ceiling, passing the breathing zone of staff working at the autopsy tables and then extracted at low level whereas the contaminated air and putrid odors is trapped in the uni-directional flow of air supply.

With the application of BIM-compatible Computational Fluid Dynamics (CFD) simulation tool, the ventilation system airflow pattern of the autopsy suites have been simulated and analyzed. The boundary conditions are assigned in the CFD tool, which include airflow rates, positions of air grilles, temperatures, etc. The CFD study enables the designer to visualize and analyze the airflow and heat transfer patterns in the autopsy suite in a more effective way. Through the powerful simulation engine, the performances of the ventilation system under different air grilles design arrangement are simulated, assessed and then optimized. Figures 9 to 14 briefly highlighted the CFD study.

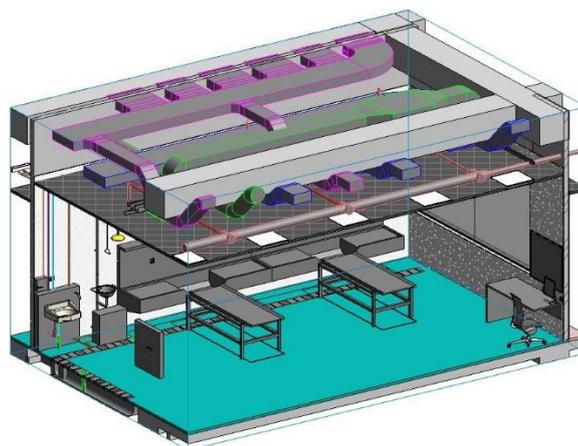


Figure 9 – BIM model of an autopsy suite

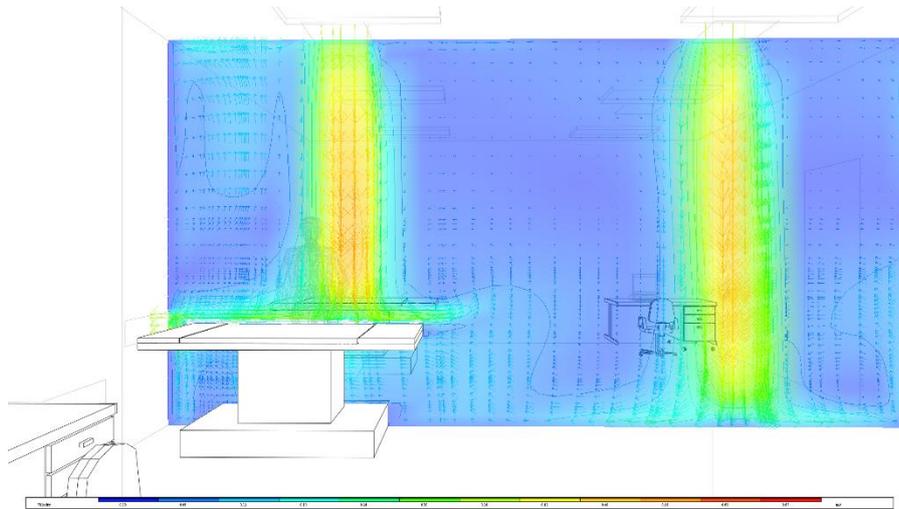


Figure 10 – Airflow pattern analysis for autopsy suite (sectional view) – [Case 1: Exhaust air grille situated at a lower level next to autopsy table. Contaminated air was extracted effectively.]

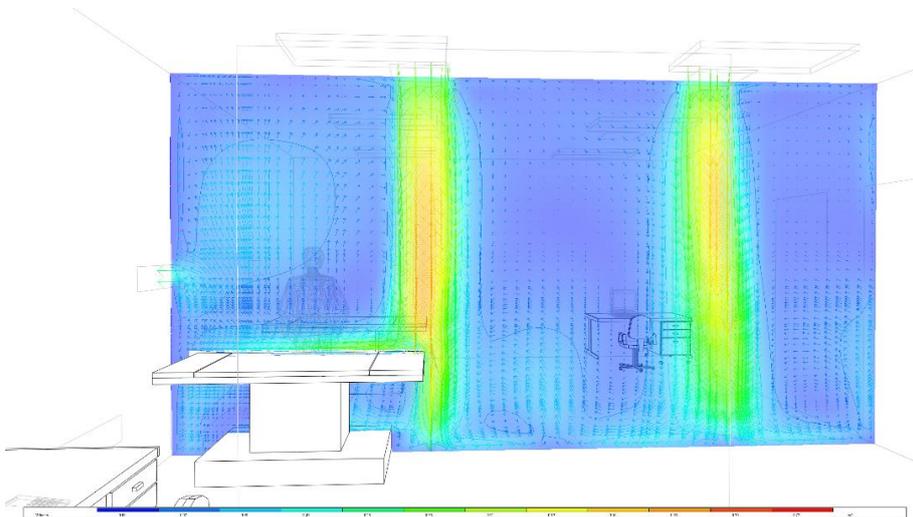


Figure 11 – Airflow pattern analysis for autopsy suite (sectional view) – [Case 2: Exhaust air grille situated above the autopsy table. Contaminated air will flow across the staff breathing zone]

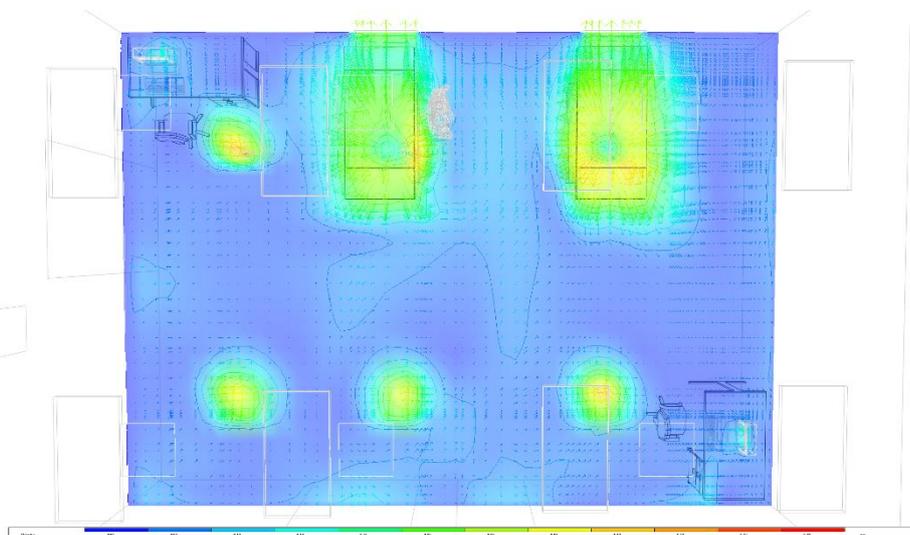


Figure 12 – Airflow pattern analysis for autopsy suite (top view)

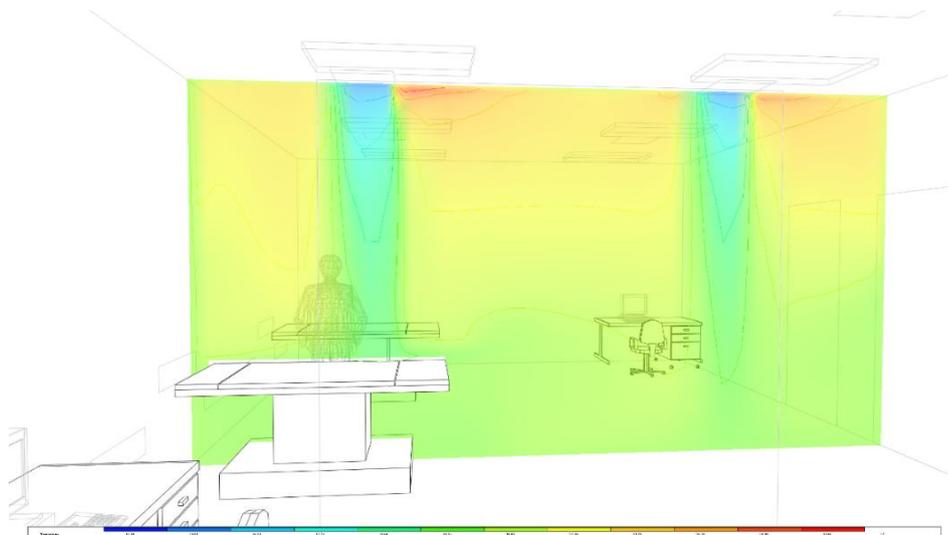


Figure 13 – Temperature profile analysis for autopsy suite (sectional view)

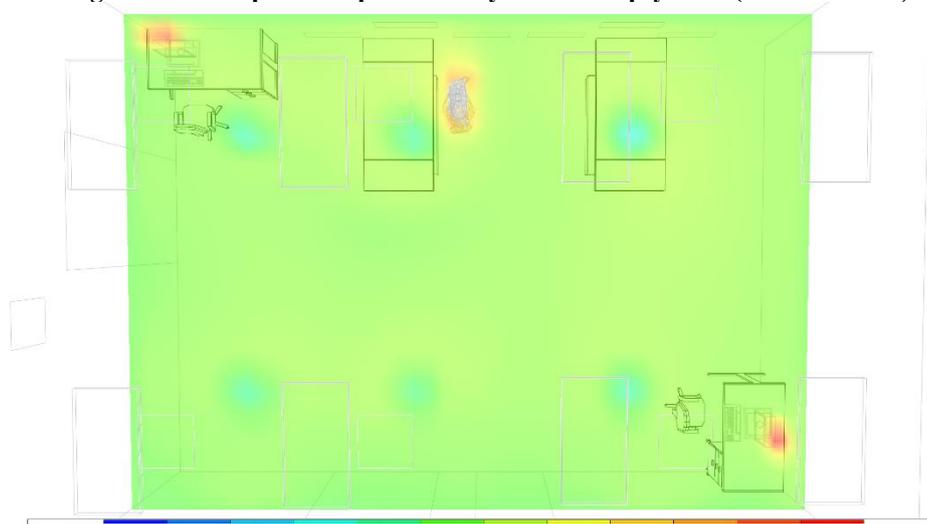


Figure 14 – Temperature profile analysis for autopsy suite (top view)

3.4 Benefits and Challenges of BIM Application

BIM application in MEP design substantially enhances the spatial awareness amongst members of the design team and co-ordination/discussion with the building users through visualization of MEP installations and their spatial relationship with other building elements as reflected in the federated BIM model. Collaboration on the design review becomes more interactive, the response time is greatly reduced and the results is more convincing. BIM not only allows holistic coordination on the ceiling depths, service and equipment supports arrangement; improved accuracy of coordination and planning, but also enable better evaluation on the buildability and maintainability. Conflicts can be discovered and remedied during the design process well before the fabrication and construction stage thus reducing the time to handle numerous requests for information (RFI) and subsequent need of site instructions for variation works. Also, innovative construction method such as prefabrication and modularization of tightly integrated MEP system becomes achievable and this can reduce waste in construction materials and effectively address the burden of inadequate site laborers in the construction industry in Hong Kong. The use of BIM can be further extended to asset management (AM) to

enhance building operation and maintenance (O&M) throughout the building lifecycle.

Based on the experiences from this pilot project, we are of the view that the successful BIM application greatly relies on the design team's earlier efforts on BIM adoption planning. The good planning should involve a comprehensive BIM Execution Plan and a structured Common Data Environment (CDE) for BIM collaboration. In view that the use of generic MEP objects in the BIM model at earlier design stage may not accurately reflect the operational parameters of the actual equipment being scheduled, the level of development (LOD) of the MEP objects in the BIM model should be regularly reviewed and updated once more detailed design parameters are available so that the accuracy of the model and its simulation studies can be progressively improved.

Unlike architectural design work, engineering design of MEP installation usually starts from schematic logic prior to the spatial design. For example, the designer would first outline the electrical power distribution schematic before working on the power distribution routings. Since the market available BIM software tools at present may not have the capability to logically link up between the schematic design and the spatial design information, it is understandable that a hybrid environment, i.e. use of 2D design tools to outline the logical schematic design and use of BIM software tool to exercise 3D spatial design would still be maintained for the time being.

4. Considerations for BIM Model Production for MEP installations at Fu Shan Public Mortuary

The following sections reveal the detail development of BIM model production for MEP installations for the project.

4.1 BIM Data Management

A unified data management structure should be established for efficient BIM collaboration and information exchange among design team. The data framework for segregation of data within a designated set of folders can be referenced to the BS1192:2007 +A2:2016 – Code of Practice for the Collaborative Production of Architectural, Engineering and Construction Information. At the start of the project adopting BIM, the design team should agree and state in the BIM Execution Plan the details of data management arrangement, which should at least include the CDE arrangement, project folder structure, collaboration arrangement (such as model linking), software platform, model division arrangement, file /object naming convention, level of development (LOD) at various work stages and the model presentation style (such as colour scheme, line types, etc.).

4.2 Level of Development (LOD) of MEP Objects

With reference to the CIC's BIM standards (Phase One) and the American Institute of Architects (AIA)'s G202-2013 BIM Protocol Form, the general coordination with other model elements in terms of size, location and clearance to other model elements can be achieved by using LOD 200. Generally, LOD 200 has been adopted at the design stage of the pilot project. In some critical areas such as autopsy suites, LOD 300 is adopted such that specific coordination (such as the air-conditioning/ventilation equipment in

autopsy suite) with other model elements can be achieved to enhance the effectiveness of design collaboration. Given that the higher LOD phase requires more specialized technology as well as increased skillsets to properly address the finite details within the 3D BIM model, the acceptable LOD should be defined prudently at early stage of each project according to a number of aspects such as BIM deliverables, project stage, allowable time and budget. Based on the project experience, the interpretation of the MEP specific LOD criteria is suggested in Table 2.

LOD	Criteria of MEP Objects
100	The object is graphically represented in the model with a symbol or rough 3D shape for indication of its existence. Identification of the object should be indicated.
200	The object is graphically represented within the model as a generic system, object or assembly with approximate quantities, size, rough shape, location and orientation. Identification and preliminary design information should be included.
300	The object is graphically represented within the model as a specific system, object or assembly in terms of quantity, size, approximate shape, location and orientation. Identification and detailed design information should be included.
400	The object is graphically represented within the model as a specific system, object or assembly in terms of quantity, size, approximate shape, location and orientation in according to manufacturer's data . Identification and manufacturer's information should be included.
500	The object's graphically represented within the model as a specific and site verified system, object or assembly. The objects should be verified for their existence for as-built record purpose. Accuracy of the object location and setting-out should be within 150mm or other range subject to approval. The 3D geometry details of the object is not necessary to be higher than LOD 400. As-built information of the objects such as identification, manufacturer name, model number and asset management information, etc. should be included.

Table 2 – Suggested LOD Criteria for MEP Objects

An example of the object geometry shapes and the corresponding object information for a water pump set at different LODs are suggested in Table 3 and 4.

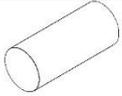
LOD	Example Image	Description
100		Schematic Model The water pump set is modelled to indicate its existence for scheme design purpose
200		Generic Model A generic water pump set in which the approximate size, dimensions and details are not specific
300		Specific Model A specific water pump set in which the approximate size, dimensions and details are specific for individual design application area
400		Specific Model A specific water pump set in which the manufacturer size, dimensions and details are specific for individual application area
500		As-built Model A field verified and specific water pump set in which the manufacturer size, dimensions and details are specific for individual application area

Table 3 – Example of Object Geometry Image for a Water Pump Set

Information	Unit	Information at LOD				
		100	200	300	400	500
Identification	Text	R	R	R	R	R
Reference number	Text	-	R	R	R	R
Type	Text	-	R	R	R	R
Water flow rate	l/s	-	-	R	R	R
Water supply pressure	kPa	-	-	R	R	R
No. of electrical phase	Text	-	-	R	R	R
Motor voltage	V	-	-	R	R	R
Motor frequency	Hz	-	-	R	R	R
Motor active power	kW	-	-	R	R	R
Motor IP rating	Text	-	-	-	R	R
Supplier	Text	-	-	-	-	R
Manufacturer (pump)	Text	-	-	-	-	R
Manufacturer (motor)	Text	-	-	-	-	R
Brand (pump)	Text	-	-	-	-	R
Brand (motor)	Text	-	-	-	-	R
Model number (pump)	Text	-	-	-	-	R
Model number (motor)	Text	-	-	-	-	R
Country of origin (pump)	Text	-	-	-	-	R
Country of origin (motor)	Text	-	-	-	-	R
Other asset management information	-	-	-	-	-	R

Remark: R – Required

Table 4 – Example of Information Requirements at Various LOD for a Water Pump Set

4.3 Information Requirements for MEP Asset Management

The use of BIM can be further extended to asset management (AM) and operation and maintenance (O&M) throughout the building lifecycle. Furthermore, an integrated AM system with BIM can undoubtedly provide a comprehensive and effective platform for optimization of operation and maintenance. To assist the development of BIM enabled AM, the Electrical and Mechanical Services Department (EMSD) has published the BIM-AM Standards and Guidelines in November 2017. The document provides detailed guidelines on the information requirements of as-built BIM model for MEP installation at the handover stage which are essential for the further integration to the BIM-AM system prototype developed by EMSD.

ArchSD has been working in collaboration with EMSD and include the information requirements of as-built BIM model in this public mortuary building project in order to promote the application of BIM for asset management. Other pilot studies for more advanced BIM-AM operation for MEP assets are also initiated, amongst which include the use of Radio Frequency Identification (RFID) to assist the locating of covered MEP assets, interface between the BIM-AM system and the Building Management System (BMS) for real-time monitoring and checking of MEP system operating data.

5. Conclusion

This paper briefly introduced the BIM applications and experiences in an ArchSD's

project at design stage. The experiences confirm that the use of BIM and associated computer tools for design analysis and multi-disciplinary collaboration at earlier design stage can greatly enhance the efficiency of design process. Also, the use of BIM for clash analysis can effectively resolve design conflicts among various disciplines, thus enhancing the buildability of the project at construction stage. For effective adoption of BIM, the importance of a well prepare BIM Execution Plan and a CDE to facilitate the design collaboration process are highlighted. With the lack of common LOD specifications for MEP objects nowadays, the interpretations, 3D geometry images and the information requirements of MEP objects at various LODs are also suggested for reference. The high potential use of BIM technology in the building's operating cycle for asset management also provide numerous development opportunities. With the growing applications of BIM and associated innovative technologies, the momentous evolution of building design, construction and asset management processes would be one of the major challenges for the industry.

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