Using BIM for ongoing Building Operations throughout a Building's Lifecycle

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Abstract

The use of BIM technology in the operational phase of a building's lifecycle is taking hold as building owners look for new ways to take advantage of BIM and improve the effectiveness of their facility operations. Following the successes of the use of BIM in design and construction, there is growing interest in how the digital asset information held in building models from the design and construct projects can be best used to advantage in the operational life of the building. Building owners also are asking how building models for existing buildings can be created, and the assets used throughout the operational phase.

Asset information is the key area of digital asset management. Such information is needed to ensure that the overall set of data can be used for effective management over the asset lifecycle. Previously, much early work in BIM focuses on geometry and geometric construction information which is useful for design and construction. Through time, as the assets move to the maintenance and operation stage, more asset attributes are needed to make informed decisions. It is therefore necessary to ensure that detailed asset information for each asset lifecycle stage is clearly mapped.

The aim of this paper will be to evaluate, through analysing a real BIM project-case study, the value of digital space and asset information throughout the asset lifecycle and specifically in the building operations phase.

Keywords: BIM, asset information requirements, lifecycle asset management, BIM operations and maintenance, BIM facilities management.

1. Introduction

In the lifecycle of construction projects, there are many involved actors who need to share information. The management of this information in the lifecycle is often inefficient and error prone. Through the different phases, information gets lost, is misinterpreted, copied to other formats and structures, stored in different locations and comes with an implicit structure or no structure at all [1]. BIM models are transforming how buildings are designed and constructed, and can facilitate multi-disciplinary coordination, and integrate 3D design, analysis, cost estimating, and construction scheduling. By extending the model into the post-occupancy period, BIM models can also be used to support facilities management and building operations, and offer a consolidated interface for information regarding all aspects of building operational performance [2]. However, most of the projects in research, industry or public authorities focus on the planning or construction phase, the practical use of BIM in the operational phase within Facility Management (FM) is still relatively rare [3].

Knowing that the operational phase of a building is the main contributor to the building lifecycle cost and that estimates show that the lifecycle cost is five to seven times higher than the initial investment costs and three times the construction cost [4], it is vital to further explore how BIM can be better utilised to serve the operational phase of the asset's lifecycle. BIM is defined as the process of generating, storing, managing, exchanging and sharing building information in an interoperable and reusable way [5]. BIM is also a socio-technical system promising the ability to create models that combine data which was traditionally spread across multiple documents and databases along with the ability to share information between different models [6].

2. Method

This research paper emerged from SBEnrc[1] industry-led research Project 2.51[2]: Developing a Cross-sector Digital Asset Information Model Framework for Asset Management. The Authors led and managed a national series of industry and academic discussions during the project's life over a period of 19 months since April 2017. Through this project, the Authors explored the question 'what type of asset information is needed for BIM/DE to add value to an asset's lifecycle and specifically the operational phase'. Project 2.51 tackled asset management in the digital engineering space over three important sectors in Australia; the housing sector, the buildings sector and the transport infrastructure sector. Literature review including a comprehensive review of current asset management standards and practices in Australia, UK, US, EU and globally has shaped the direction of this research. Ten case studies across Australia were referenced as project outputs to test the theoretical framework of this project. Five outputs were generated out of this project; The Digital Asset Information Management (DAIM) – A Guide and Manual, Case Studies Report, Research Report, a YouTube video and a Good Practice Guide.
The authors will be referring to various research material from Project 2.51 throughout this research paper. This paper will inform a future research direction.

3. Non-digital asset management

According to buildingSMART, asset management is the systematic process of deploying, operating, maintaining, upgrading and disposing of assets efficiently and effectively [7].
When traditional documentation (drawings, specifications, as-built) is available for a project then the necessary asset information can be extracted from this. However, extraction is a time consuming and

[1] SBEnrc: Sustainable Built Environment National Research Centre
[2] SBEnrc Project 2.51: https://sbenrc.com.au/research-programs/2-51/

error prone process if the documents are on paper or were scanned from paper [8]. Data can be extracted more readily from documents prepared in CAD or other drawing software, if the software supports ‘blocks’ as library objects.

Information on the location and type of an asset needs to be extracted from the drawings and then combined with the non-geometrical information from the specification to complete the asset schedules. Ideally, this would all be extracted from the as-built documentation, but this is often not reliable. Onsite validation is normally required [9].

4. Digital asset management

The biggest difference between traditional deliverables and BIM deliverables is structured data [10]. According to the Institution of Civil Engineers [8], the contribution of BIM to asset management can include: Asset register or inventory; Topographic data on the assets, and quantities derived; Asset condition data; Asset capability information; Asset performance service levels, failure rates, etc.; Life expectancy data of equipment and materials; Descriptions of potential interventions for maintenance or renewal, and their costs; Contextual data, such as climate and surroundings;

BIM and asset information can work together to make informed decisions in areas such as bringing existing assets into BIM, developing new assets in BIM, operating and managing existing or new assets [11].

5. BIM from design to facilities management

One of the challenges that building owners implementing lifecycle BIM face is the difference between the Building Models created for design and construction and the Building Models needed for operational use. However, with planning and proper procedures, building data can and should flow from one phase to the next. BIM information generated and captured during the lifecycle of a facility can be used in FM [4]. It is useful to identify at least four types of Building Models [12] as seen in Figure 1:

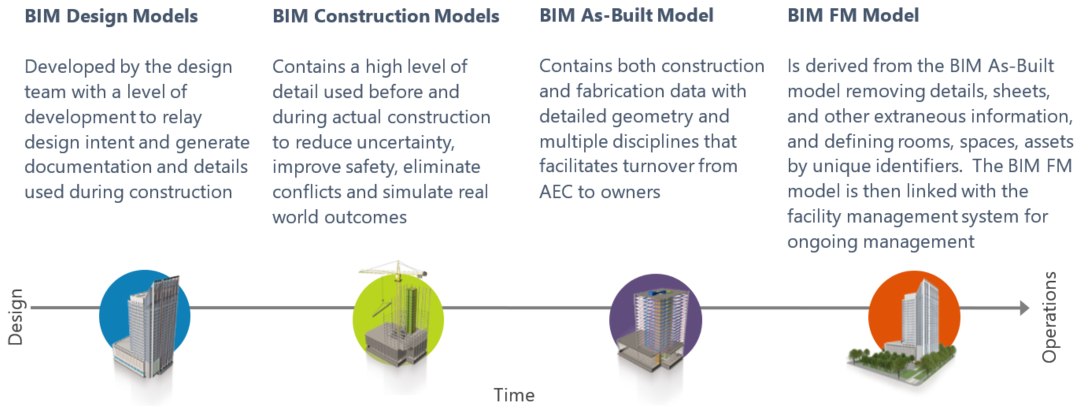

Figure 1: Building Models from design through to facility management

A brief explanation of the difference between these models is below [9]:

- ### BIM Design Models

BIM design models are created by architects and engineers with the objective of first defining the conceptual design and ultimately producing more detailed construction documents. Materials and equipment of building or infrastructure are defined generically, allowing the contractor the freedom to competitively bid and price equivalent alternatives. For example, air handling units are described by general dimensions and performance requirements by the engineer without knowledge of who the selected manufacturer will be.

- **BIM Construction Models**

Contractors and subcontractors will use these models to aid in staging and detection of potential conflicts using clash detection before encountering the issues in the field, as well as for material take-offs (estimating) and procurement. BIM Construction Models typically contain a high level of detail used before and during construction to reduce uncertainty in the construction process. Additional benefits include enhancing safety on the job, limiting conflicts and the simulation of real world outcomes.

- **BIM As−built Models**

This is created by the building construction contractor, subcontractors and suppliers. Traditionally this information has been provided as a set of paper working drawings that were annotated to reflect change orders and field changes and was accompanied by equipment cut sheets and shop drawings depicting specific equipment selection.

In the BIM era, this information needs to be entered back into the BIM Model by the contractor or a specialist in building commissioning. Information in the BIM as−built Model will include details, annotations, dimensions, building or infrastructure sections, schedules and elevations. The BIM as−built Model will also include material and equipment properties as determined during the construction process. The BIM standards are critical for defining the information that is required. The building and infrastructure projects owner should retain the as−built model as the authoritative source and a reference for the building as−constructed.

- **BIM-FM Model**

The BIM-FM Model is derived from the BIM As−built Model. When creating the BIM-FM Model, a number of modifications should be made: extraneous information is removed, including construction details and working drawing sheets; where linked models have been used to separately represent building core, building shell and tenant improvements, these are merged into a single model; occupancy room numbers are derived from construction room numbers, with numbers matching building signage; office spaces, workstations and offices are defined separately from rooms and are numbered with an occupancy numbering system. This is key to matching office occupants to desks, cubicles and offices and is also essential for management of work orders; building equipment items are numbered with unique asset IDs; the BIM-FM Model is linked to the facility management system, which tracks ongoing work orders, maintenance operations, occupancy information, equipment and material replacement costs and other data related to building operations.

The BIM Model is the authoritative source for the physical aspects of a building or infrastructure project including the structural system, walls and doors, room finishes, lighting, power, plumbing, fire protection and HVAC systems. It is not designed to manage data for ongoing operations and occupancy; this information is best handled by a facility management system. The general term ‘facility management system’, is commonly known by one of the following designations: Computer−Aided Facility Management (CAFM) System: these are systems integrated with CAD or BIM and are used to track space and maintenance; Computerised Maintenance Management System (CMMS): these are systems designed to track remedial and scheduled maintenance; Integrated Workplace Management Systems (IWMS): these are systems that manage space, maintenance management, real-estate information and leases, move management, strategic planning, project management, room bookings and other facility functions and are deployed on an enterprise rather than departmental basis.

6. Asset information in the building lifecycle to support BIM

This section is adopted from SBEnrc Project 2.51 '*Developing a Cross Sector Digital Asset Information Model Framework for Asset Management – Digital Asset Information Management (DAIM) – A Guide and Manual'* [9] and '*Developing a Cross Sector Digital Asset Information Model Framework for Asset Management – Digital Asset Information Management (DAIM) – Research Report'* [13].
To enable the owner safely and effectively operate new assets and refurbished assets, asset information requirement should be stated clearly at the stage of project handover when the asset is transferred from one organisation to the other.
Asset information is composed of Data (Graphical data and Non-graphical data) and Documents as shown below is Figure 2.

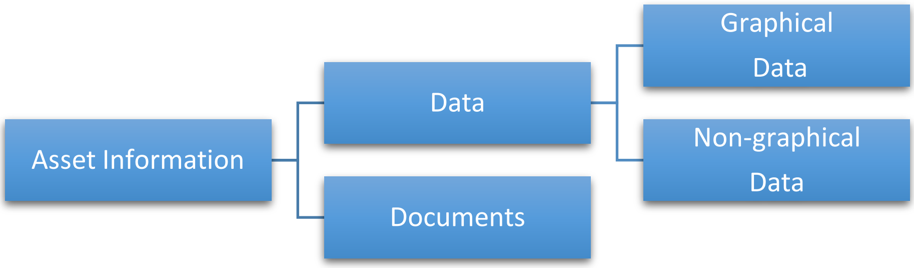

Figure 2: Asset information components

Graphical Data describes an asset graphical attributes involving actual attributes in terms of location (physical and geospatial attributes), position and spatial attributes. On the other hand, Non-graphical Data consist of configuration (physical and functional data identify and provide static reference of manufacturer details, asset construction, asset procurement, technical characteristics), condition data (past and current condition data, such as information on residual life, operational data (operational data related to usage, tonnage, restrictions and criticality), maintenance data (stipulate management and recording of maintenance activities), organisational data (illustrate the framework referring to responsibilities of the owner, operator and maintainer) and financial data (record costing of the whole project lifecycle from capital acquisition, operation, maintenance to disposal).

Besides above-mentioned data, asset documents, composed of manuals, plans, photos, drawing, models, certificates, licences and schematics, store and satisfy requirements of asset handover. Considering convenience of asset information handover, all CAD drawings and models should be defined and submitted with standard form of handover requirements.

Asset information is generated across the asset lifecycle. Figure 3 demonstrates the four stages of asset lifecycle.

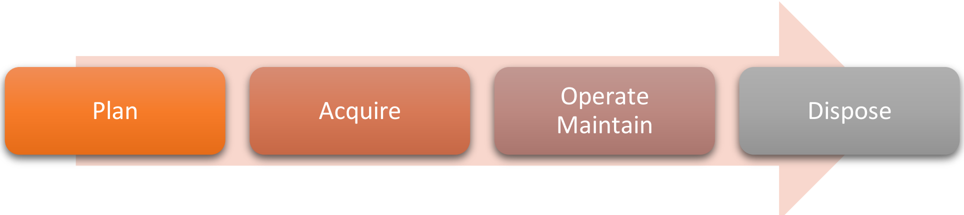

Figure 3: Asset lifecycle stages

During this asset lifecycle, asset information should be assessed unceasingly to ensure data and documents quality, supporting and substantiate asset information to meet asset information requirements. The asset information quality shall be determined by six categories: completeness, correctness, consistency, clarity, integrity and uniqueness.

Asset information requirements should be collected and managed at the stage of Plan and Acquire. Providing and updating the following detailed asset information requirements facilitates asset handover, commissioning, operation and maintenance:

1. Plan stage:
   Asset information at this commencement phase shall be recorded and submitted, which includes; requirements specification, feasibility, environmental, geotechnical reliability, availability, maintainability and safety (RAMS), system safety assurance plan and hazard log.

2. Acquire stage:
   a) Configuration data, includes; asset register identifier, construction or build, asset status, date commissioned and design life, design information, supplier or vendor data, failure modes, effect and criticality (FMECA), test and commissioning results, warranty data, survey data, heritage data, and spare parts inventory.
   b) Location data: includes; physical geographic and geospatial referencing data, and environmental data.
   c) Organisational data: includes; asset ownership, asset maintainer, asset operator, third party agreements, land ownership, deeds and agreements.
   d) Operational data: includes; asset criticality and assessment criteria (design), operational settings such as circuit breaker trip setting, hazards – confined space and restrictions, risk level, energy usage, special requirements to operate and maintain.
   e) Financial data: includes; capital acquisition cost and operate and maintain cost.
   f) Other documents: includes; maintenance standards and technical maintenance plans (TMPs), maintenance manuals, operating manuals, drawings – includes concept, approved for construction and as-built drawings, schematics, plans and cad files, and models, regulatory – includes licensing and special conditions, certificates and compliance, reports – includes design assumptions and calculations, inspection and test reports, commissioning reports and safety assurance reports

Above mentioned asset information requirements are required for new assets as well as renewal or refurbishment of existing assets. In addition, asset information shall be continually assembled throughout whole lifecycle including operation, maintenance and disposal phases.

3. Operate and Maintain stage: At the stage of operation and maintenance, the following asset information requirements shall be acquired and managed:
   a) Configuration data: includes; asset status.
   b) Condition data: asset condition and assessment criteria, and remaining life.
   c) Operational data: includes; asset criticality and assessment criteria, asset utilisation and capacity – includes performance requirements.
   d) Maintenance data: includes; maintenance activities data (preventive service schedules), work orders for maintenance activity, defects, work breakdown structures, unit rate estimates, duration, maintenance activity records – includes measurements, adjustments and calibration records, and material used.
   e) Failure or incident management data: includes; time – includes time failed, time attended, time rectified and time in service, and defect and asset related to failure or incident.
   f) Financial data: includes; maintenance cost – includes labour, material, plants and equipment and contract, and capital value.
   g) Other documents: includes; photos, reports, and concession provided to maintenance activity.

4. Disposal stage: In regard to disposal stage, asset specific decommissioning information shall be captured and managed as below:
   a) Maintenance data: includes; maintenance disposal activities, and work orders for maintenance activity.
   b) Financial data: includes; disposal costs – includes labour, material, plants and equipment and contract, and residual capital value.

Literature review up to this point has shown the importance of mapping and providing the correct data and asset information at every stage of an asset's lifecycle and how BIM is of benefit to the AECO (Architectural, Engineering, Construction and Operations) industry. The latter will be tested next in a real-BIM case study.

7. Case Study: James Cook University Biosecurity Building (Townsville, Queensland, Australia) [14]

7.1 Project overview

James Cook University (JCU), Figure 4, in northern Queensland, has over 360 buildings and 230,000m² of floor area modelled in Autodesk Revit, linked with their Integrated Workplace Management System (FM:Interact). The University has adopted BIM through the design, construction and operations phases of all new building projects.

Beginning with a CAD/paper-based project management and handover process, JCU identified the need for a BIM-enabled design and continuous data management process. By introducing new technologies, processes and standards, JCU took control of data from the design development stage all the way through to handover; ensuring that they had access to the data they needed, when they needed it and in a format they could use.

At the operations stage, the University leveraged the increased availability of space data to improve operational efficiencies and rationalise the University's built footprint.

Figure 4: James Cook University Biosecurity Building

7.2 Challenges

In recent university projects, and without a BIM-based process, JCU relied heavily on manual coordination efforts during the construction and handover phases which meant that often conflicts that should have been picked up in the design phase were not discovered until later in the project, leading to delays and cost increases.

At handover, momentum was lost as the operations team struggled to collect the information necessary to properly manage the defects and operations phases of the building lifecycle. Sourcing the right data in useable formats proved difficult, which led to the double handling of data as it was manually entered into management systems.

Improving processes while utilising BIM seemed like the logical next step for the University, as greater emphasis was placed on the cost of projects and operations. Faced with aggressive schedules and tighter budgets, managing the building lifecycle had become an area where there were potential benefits to be realised.

7.3 Solutions

Starting from scratch, JCU put together a BIM/FM Working Group to research and examine BIM usage in other organisations and identify the basic requirements that would be the foundation for JCU's project.

Data collection and analysis included:

1- Digitising of record drawings
2- On-site truthing and measure-ups
3- Conversion of CAD drawings
The steps above provided the base Revit models while:

4- Optical Character Recognition (OCR) scanning of records relating to the buildings and projects provided the preliminary data.

The data collection process carried out over a few months across the university facilities management department provided a series of existing point base level.

7.4 Approach

Having determined what data they had, the BIM/FM team then identified what they wanted. Initially setting out a staged set of BIM specifications, JCU could specify different requirements based on project value or service provider capabilities.
To ensure maximum compatibility with associated systems, JCU specified deliverable requirements for Revit version, Level of Detail (LOD), family naming conventions, categorisation and associated parameter naming.

On major projects, building model submission was expected regularly throughout the design development, construction and at handover. In addition to improving coordination between disciplines, as the detail levels of the models improved, stakeholders were able to prepare for occupancy as preliminary data flowed through to linked systems. Not only were the project teams seeing less expensive and time-consuming changes in the construction phase, but the transition to operations proved to be smoother than expected.

7.5 BIM for FM

The increasing integration of the building models with JCU systems presented its own opportunities. One area identified by the BIM/FM team was data integrity in the model at each handover. As the amount of data in each model increased rapidly, it became a major task to manually check for compliance with the standards and specifications. There was still also a significant cost in manually updating models handed over to JCU, to a BIM/FM ready state; particularly the data. Revit included some basic standard checking but a more robust solution was needed. Working with ASt[3], JCU began trialling BIMAssure for analysis of project models. Focusing on the rapid creation of shared,

[3] ASt: Advanced Spatial Technologies Pty Ltd

standardised rules-based analyses, JCU design staff were able to perform these checks simply by publishing the model to the BIMAssure cloud vault. The model located in the cloud, enabled multiple users on the project to carry out checks on the data, corrections made, and updates synchronised back into Revit on the desktop.

In addition to adopting BIM for projects, the University was also expanding the scope of its Integrated Workplace Management System (IWMS), FM:Interact. Having mapped Revit parameters to the Integrated Workplace Management System (IWMS) system's database, a bi-directional integration with the Revit models meant that as soon as the model was published to the system, the operational data was available to management and front-line operational staff, with all functionality provided through a web browser.

7.6 Results

With the building asset data in the IWMS, cleaning, security, maintenance, IT and timetabling staff had the information necessary to do their jobs on their desktop or mobile device immediately. The building fabric data contributed to quicker and more accurate cleaning tenders, IT staff had access to physical network traces before performing works, and room inventories and capacities became suitable for use in JCU's timetabling system.

Data analysis in this case study informed more efficient FM practice, which led to a more comprehensive understanding of the University's building stock and has contributed to offset the reduction in government funding. The space types were mapped, allowing for cost modelling of the University's activities carried out versus the maintenance costs associated with those spaces. With an additional feed of Human Resource data, the University began modelling more efficient space allocations, comparing the staff assigned to a building with the amount and type of space in that building; the result being that the University could reduce the total built footprint while improving services to students.

7.7 Case study conclusions

The use of BIM to support asset management at James Cook University has had a significant impact. The increased coordination between disciplines has resulted in fewer delays while the ability to produce visualisations within the context of the campus has improved overall engagement with the University community. Informed by the case study data collection and analysis, arguably the greatest change though, has been in operations, where improved visibility of building asset data has streamlined operations, greatly improved the consistency of data used amongst operational units and helped promote a positive awareness of FM operations throughout the organisation.

James Cook University has embraced the capabilities of BIM to improve organisational decision making and enhance planning exercises. BIM data has contributed to the University's 10-year development planning, 'Strategic Asset Management Plan', 'Activity Based Cost Modelling' and various space rationalisation projects.

8. Conclusions

Despite the fact that the growing ecosystem of digital tools has increased the risk of interoperability issues [15], [16], which is a future problem the digital engineering (DE) industry needs to deal with and is outside the scope of this paper, BIM has proved very powerful database for continuous development of the facility as well as enabling sharing of concepts and solutions amongst stakeholders [17], [18]. This is particularly true when it comes to benchmarking across 'whole-of-asset lifecycle', monitoring through the use of an asset management framework can demonstrate the benefits and value delivered through the adoption of digital technologies [19].

BIM provides immense benefits to the AECO industry. These benefits span from increased coordination between project stakeholders, decrease of project delays, better community engagement, efficient and effective organisational decisions based on solid data, strategic planning and cost reduction amongst many other benefits. However, without the right type of asset information requirements at each stage of the building's lifecycle and data being in the right structure and format, BIM will function as a platform to archiving data and serve as a 3D modelling software similar to CAD and other softwares.

The operational stage of the asset lifecycle is the longest and the costliest, as indicated in the literature above. Digital engineering, including BIM, is an effective solution to manage the facilities services over the asset's life. For this to happen, awareness of clients and building owners is crucial. Looking at initial cost of implementing BIM tools only without the realisation of the benefits, cost reduction and subsequently return on investment these tools can deliver over the asset life has not been realised. Industry-led research and collaboration between the supply chain's players, supported by case study research and analysis analysis to capture and present value is the way ahead to better adoption of BIM/DE tools.

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