Whole-of-life Value of Constructed Assets through Digital Technologies

Final Industry Report, Project 2.46

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This Final Industry Report summarises research carried out in SBEnrc Project 2.46 — *Whole-of-life Value of Constructed Assets through Digital Technologies*. The Project Report (available at http://sbenrc.com.au/research-programs/2-46) describes the research process and outcomes in a more comprehensive manner.

Preface

The Sustainable Built Environment National Research Centre (SBEnrc), the successor to Australia's Cooperative Research Centre (CRC) for Construction Innovation, is committed to making a leading contribution to innovation across the Australian built environment industry. We are dedicated to working collaboratively with industry and government to develop and apply practical research outcomes that improve industry practice and enhance our nation's competitiveness.

We encourage you to draw on the results of this applied research to deliver tangible outcomes for your operations. By working together, we can transform our industry through enhanced and sustainable business processes, environmental performance and productivity.

John V McCarthy AO
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Executive Summary

Building Information Modelling (BIM) is a rapidly emerging digital technology and process with the potential to greatly improve the efficiency and effectiveness of the design, construction, operation and decommissioning of constructed assets. To date, the implementation of BIM has largely focused on the design and, more recently, construction phases of the asset life cycle. However, the greatest benefits of BIM may lie in the operational phase. Implementation of BIM for asset/facility management, maintenance and operations will present a number of potentially disruptive challenges, such as integrating the BIM digital asset information model generated by a new asset with an existing asset management system.

This report summarises the outcomes of SBEnrc Project 2.46 *Whole-of-life Value of Constructed Assets through Digital Technologies*. This applied research project sought to:

1. Develop an online benchmarking tool to evaluate the benefits of using building information modelling (BIM)
2. Investigate the influence of 'disruptive' technologies on constructed assets

The first objective was achieved in the form of the BIM Value Benchmarking online tool launched in November 2017.[1] The second was achieved through a literature review examining the theme of 'disruptive innovation' and investigated the impact of BIM through two case studies. The outcomes of the research provide guidance to industry on implementation of digital technologies such as BIM.

The development of BIM Value Benchmarking highlighted some of the technical and procedural challenges of implementing an industry-wide benchmarking tool. Development of metrics that are intuitive, easily deployed and meaningful was made more complex by limited industry engagement in benchmarking and the prevalence of confidentiality concerns. The project team identified nine benchmarks applicable to the procurement phase of the asset life cycle. The success of BIM Value Benchmarking will depend upon the integrity of data entered into the tool and industry contributing sufficient data to create meaningful benchmarks.

[1] *http://bimvaluebenchmarking.natspec.org*

The two case studies examined different types of constructed assets: public housing and road infrastructure. These showed clear similarities with regards to the implementation of digital technologies such as BIM and digital engineering (DE). Both studies identified the alignment of existing asset management systems with BIM/DE models to be potentially disruptive of existing business practices.

Two conclusions emerge from this research:

1. The adoption of a benefits management framework may be an appropriate strategic response to disruptive technologies
2. There is a pivotal role for clients in driving innovation, including whole-of-project and whole-of-asset life cycle benchmarking

Introduction

In the coming decades, Australia and other countries will be facing challenges as a result of a changing climate and rapid technological progress. Throughout the life cycle of constructed community assets, new technologies such as BIM (Building Information Modelling) can provide benefits that are not yet being taken full advantage of and concurrently address some of these challenges.

This project sought to improve whole-of-life value of constructed community assets by creating an online tool to measure the value of BIM and to separately consider the impact of disruptive technologies on such assets.

This effort builds on earlier SBEnrc research including Project 2.34 'Driving Whole-of-life Efficiencies through BIM and Procurement'[2] outcomes, the publication of 'Delivering Value with BIM'[3] and creation of the knowledge website 'BIM Value'[4]. Project 2.34 had identified a lack of national and international benchmarking systems that promote understanding and set realistic goals for digital technologies such as BIM and their benefits to the whole-of-life value of constructed assets. This is particularly pronounced in Australia. As the Australian Productivity Commission in its 2014 infrastructure productivity report stated: *Benchmarking information in Australia is disappointingly limited, a deficiency which must be addressed in a future structure for infrastructure decision making as a whole*.[5]

The research methodology focused on developing and empirically testing a benchmarking system. As a result, this project launched 'BIM Value Benchmarking'[6] in November 2017 in partnership with NATSPEC.

The research also sought to understand strategic and procurement implications of new disruptive technologies expected to positively impact the way that community assets are delivered and managed. This resulted in a literature review of 'disruptive innovation' alongside two case studies investigating impacts of BIM/DE implementation in housing and transport infrastructure.

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[2] *http://sbenrc.com.au/research-programs/2-34-driving-whole-of-life-efficiencies-through-bim-and-procurement/*

[3] Sanchez A.X., Hampson K.D. and Vaux S. (2016) *Delivering value with BIM: A whole-of-life approach.* London: Routledge.

[4] *https://bimvaluetool.natspec.org/*

[5] Australian Government Productivity Commission (2014) *Public infrastructure. Productivity Commission Inquiry Report. Volume 2*. Canberra: Australian Government.

[6] *http://bimvaluebenchmarking.natspec.org/*


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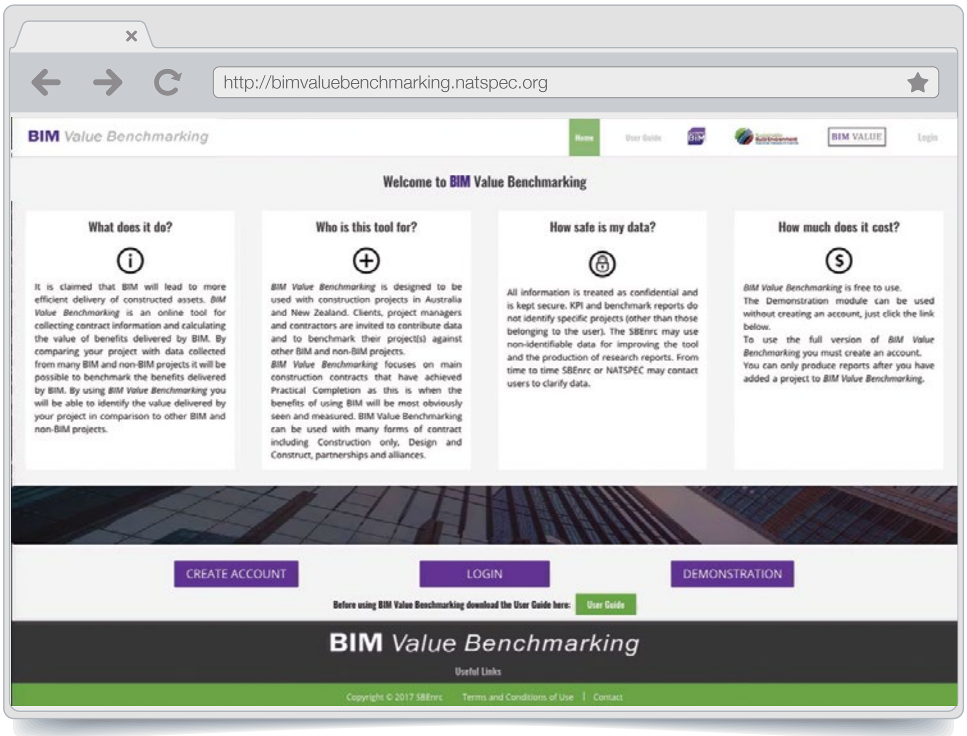
BIM Value Benchmarking

BIM Value Benchmarking is the free SBEnrc-developed online tool for measuring the value of using BIM. The tool was launched in Perth, Australia at the CIB/SBEnrc/Curtin University International Symposium on 15 November 2017 and went live on 20 November 2017.[7] It is hosted by NATSPEC[8], in a continuation of the arrangement for SBEnrc's earlier online tool, *BIM Value*.[9]



BIM Value Benchmarking builds on crowdsourcing principles to help the built environment industry collect contract information, calculate the value of benefits delivered by BIM to different types of projects and compare against non-BIM projects. Clients, designers, project managers and contractors are invited to contribute data and to benchmark their project(s) against other BIM and non-BIM projects.

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[7] *http://bimvaluebenchmarking.natspec.org/*

[8] NATSPEC is an Australian national not-for-profit organisation, owned by government and industry, whose objective is to improve the construction quality and productivity of the built environment through leadership of information.

[9] *https://bimvaluetool.natspec.org/*

Developing BIM Value Benchmarking

The challenges with benchmarking are discussed in detail in 'Delivering Value with BIM', wherein it is noted that metrics should be '*intuitive and able to be easily deployed*'. Forty-three metrics and fifty enablers were described in this earlier work, noting that the diversity of metrics may '*offer some clues on why industries often find it difficult to create standard metrics*'.

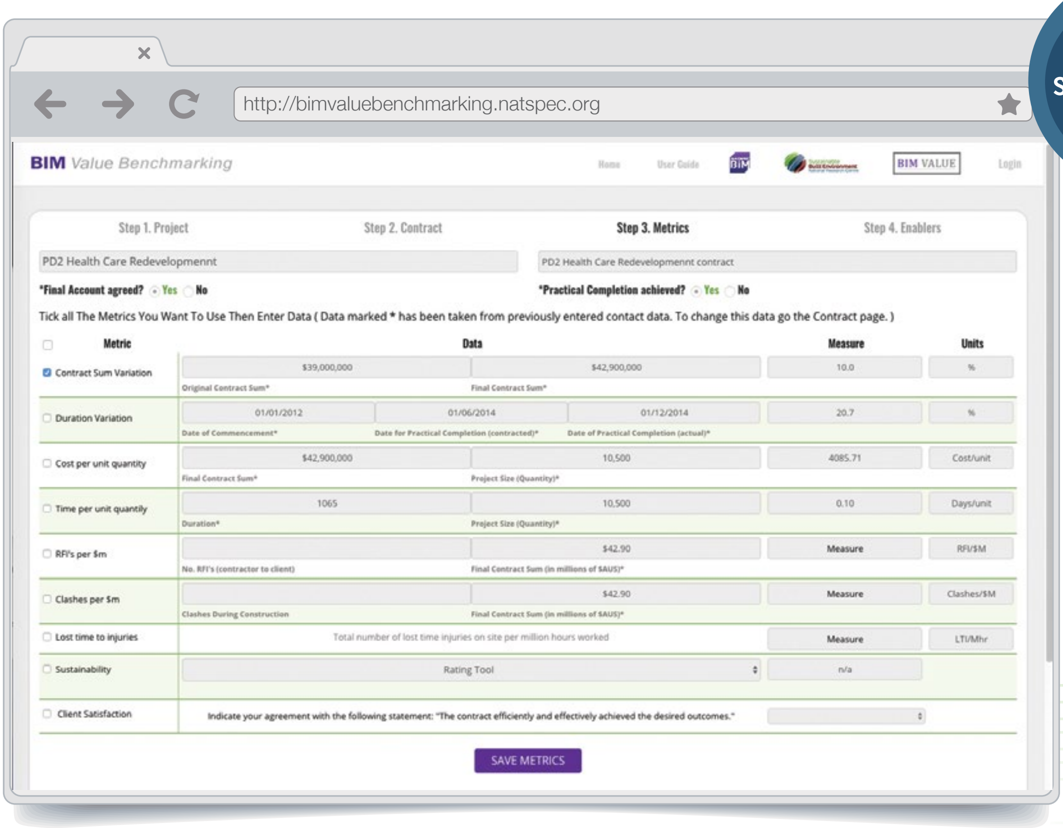
However, BIM Value Benchmarking had to be developed in a pragmatic manner, taking into consideration the realities of current practice and industry benchmarking difficulties. The following principles guided the development:

1. Keep it simple A critical success factor would be the ease with which users could collect and enter data into BIM Value Benchmarking and obtain reports. The mantra 'keep it simple' became a key driver in the development of BIM Value Benchmarking.
2. Develop a detailed User Requirements Specification (URS) A URS is a document used in software development to specify the system's functionality. It is a detailed document addressing user interfaces, data processing and outputs. Preparation of a URS requires the user to consider what outcomes are required and, as a consequence, the essential inputs and data processing protocols must be defined.
3. Focus on the procurement phase in the asset life cycle The use of BIM is primarily in the design and construction of assets: the project procurement and delivery phase. Therefore, BIM Value Benchmarking should focus initially on this phase.
4. Focus on individual contracts A project typically involves many separately contracted actors, some procured directly by the client, others engaged as sub-contractors. Benchmarking a whole project requires all actors to provide metric data with the consequence of incomplete data invalidating any benchmarks. Coordination of multiple actors is a challenge beyond the reach of an online tool. Therefore, it was decided to focus on single contracts and particularly the main contract that typically represents the largest commitment of resources and therefore the most likely to reveal the value of using BIM.
5. Use metrics for which information was likely to be readily available In line with the decisions above, only metrics that are commonly used in contracts were considered. Specifically, those relating to time, cost, quality and safety that require data readily available in contracts.
6. Limit BIM Value Benchmarking to Australia and New Zealand An international dimension brings additional complications of different currencies, languages, units of measurement and work practices. To avoid this, the scope was initially limited to the countries of SBEnrc's partners.

Metrics and benchmarking validity

The nine metrics selected for BIM Value Benchmarking are shown on the right.

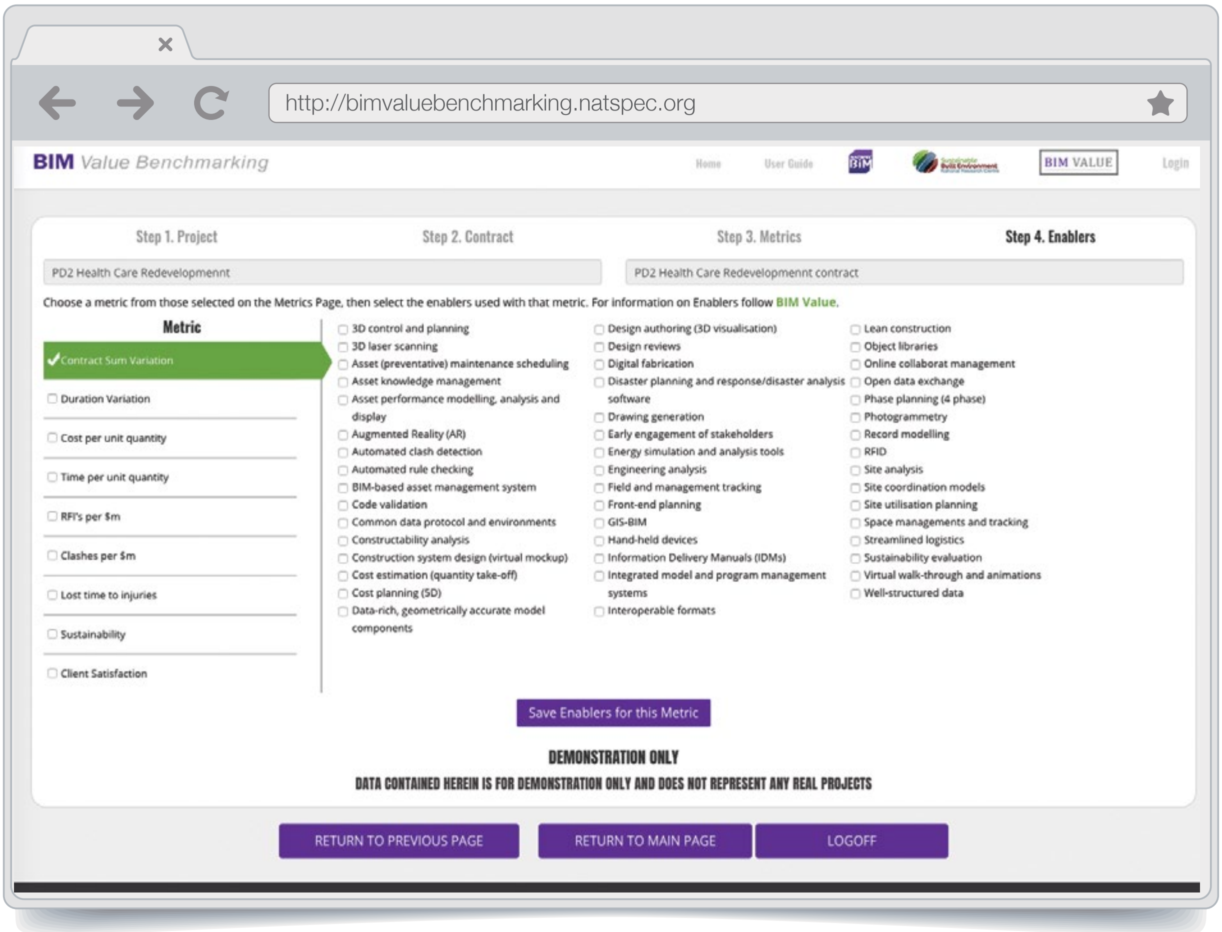
It is realised that the potential unit cost and unit time metrics lack sufficient context to be specifically comparable. For example: road kilometre laneway costs vary with the grade of road, the inclusion of bridges and other features. Similarly, unit time and unit cost measures for buildings vary with building type, for example the grade of office. It was decided to continue to collect metric data for these benchmarks in anticipation of a sufficient number of contracts being contributed and that, with the use of appropriate filters, these metrics would become relevant.



Use of BIM Value Benchmarking

The success of BIM Value Benchmarking is dependent upon the collection of sufficient data from BIM and non-BIM projects to calculate meaningful comparative metrics trending over time. This is reliant upon the voluntary contributions of industry. Consequently, it will be beneficial to promote the use of BIM Value Benchmarking with a marketing campaign to encourage industry to contribute data with the proactive assistance of the Project Partners. It will require a significant effort to overcome the reluctance of the construction industry to engage in benchmarking.

Data entered into BIM Value Benchmarking is not validated at the time of submission. Therefore, there is a risk of metrics being corrupted by unreliable data arising from entry errors or malevolent users. Should this occur, the reputational damage to BIM Value Benchmarking could compound the difficulties of voluntary data collection by acting as a disincentive to further contributions. Protocols to regularly review the reliability of data entered into BIM Value Benchmarking are being developed.



Future opportunities

If BIM Value Benchmarking is accepted and used by industry, then a number of options may emerge for future development.

Further investigation into existing asset management data sets and benchmarking methods used in other industries may provide ideas for developing the tool and sources of new data or comparative data. For example, cost indices published by various quantity surveying practices and industry organisations may provide a means of validating data entered into BIM Value Benchmarking. It may also be possible to establish the value, number and range of projects or contracts across the built environment industry and from this calculate the minimum number of data points needed to create valid benchmarks.

Creating an international version of BIM Value Benchmarking will need to address the work practices, measuring systems and units of measurement used in different countries. These will need to be better understood to validate and, if necessary, normalise benchmark comparisons between countries. An initial approach could be to allow countries to establish their own version of BIM Value Benchmarking. This would enable data to be collected with only minor alterations to the software (such as changing text from English to the native tongue as appropriate). Resolution of international differences could then be evaluated at a later date.

Addressing some of the difficulties encountered in the initial development of the tool, such as measuring projects or contracts and calculating benchmarks for several asset life cycle phases, involves issues of industry practice. It is unlikely that these can be resolved by simply adding more metrics to BIM Value Benchmarking. More sophisticated metrics bring with them challenges in terms of data collection and collation. Consideration could be given to developing separate tools for each phase of the asset life cycle and aligning this with benefits realisation practice. Such a move would necessarily encompass business and change management, and require a significantly different approach from simply capturing and processing metrics.

Innovation and Disruptive Technologies in Construction

Innovation refers to changing processes or creating more effective processes and products, and moving ideas into practice. The revolutionary nature of innovation was described by the economist Joseph Schumpeter in the mid twentieth century as a process of economic growth sustained by new products and means of production that supplant the existing[10]. More recently, Christensen published a theory of disruptive innovation in the 1990's that described how innovation has left well-established companies stranded in the past[11].

The project-based, low profit, high-risk nature of the construction industry is commonly cited as a disincentive to innovation. However, the potential for clients to drive innovation is also acknowledged and is consistent with previous research by the SBEnrc and its predecessor, the CRC for Construction Innovation[12].

Internally, the industry may be resistant to disruptive change but external factors may still create a wave of '*creative destruction*'[13]. A number of innovations from other industries have the potential to disrupt the operation of existing constructed community assets and the procurement process for new assets. A topical example is the technology of autonomous vehicles (AV). This technology has the potential to radically change the way people use vehicles and make new demands on road infrastructure for interactive signage and other technological changes.

The implementation of BIM can be viewed as a process innovation enabled by technology. An example of the disruptive power of BIM is emerging in the UK where the Government is driving the adoption of BIM by requiring its use in state procurement contracts. In this instance, the client is driving innovation. It may be that the source of creative destruction in the construction industry will be clients driving innovation with radical intent. However, the UK effort has been framed by close collaboration with industry, changes to legal, economic and operational frameworks, and a timetable for Small and Medium Enterprises.

The two following case studies investigate impacts of disruptive innovations likely to change the way constructed community assets are delivered and operated.

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[10] Schumpeter, J.A. (1942) *Capitalism, socialism and democracy*. London: Routledge.

[11] Christensen, C.M. (1997) *The innovator's dilemma: When new technologies cause great firms to fall.* New York: Harper Business.

[12] Brown, K. A., Hampson, K. D., Brandon, P. and Pillay, J. (2008) *Clients driving construction innovation: Benefiting from innovation.* Brisbane: CRC for Construction Innovation.

[13] *Creative destruction* describes the process of innovation changing the macro-economic system (Schumpeter)

Case study 1: Digitally engineering the future — opportunities for transport infrastructure

Context

VicRoads, the Victoria State road infrastructure agency, plans, develops and manages the arterial road network and delivers road safety initiatives and customer focused registration and licensing services in the State of Victoria, Australia. In 2015/16, VicRoads spent AU$1.92 billion on road asset management and improvements, including AU$600 million in capital works to enhance the State's road network[14]. The Victorian State Government, in its 2015/16 Budget, provided for the development of a process for selecting key projects to participate in a BIM/DE pilot study. The Victorian Government will use the results of the pilot study to inform a staged plan for BIM/DE implementation across infrastructure projects in the state[15].

From an international perspective, Europe is seen to be leading the implementation of DE and BIM. The United Kingdom[16], Finland[17] and Sweden[18] have each launched nation-wide plans for the adoption of DE and BIM.

International experience shows that:

1. Industry takes action when the government demonstrates clear leadership as a client and regulator
2. A national strategy facilitates the broader adoption of new technologies such as BIM/DE
3. Collaboration with industry is required to implement an effective strategy

Data

This case study sought to provide advice to VicRoads on the adoption of DE and BIM. The study involved:

1. A survey of nominated VicRoads staff to assess current awareness of DE
2. Interviews with key staff to better understand VicRoads plans for adopting DE
3. Literature review of approaches to DE to identify knowledge that might inform VicRoads actions

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[14] Vicroads (2016) *VicRoads annual report 2015/16*. Melbourne: Victoria State Government.

[15] Victoria State Government (2016) *Victoria's Future Industries Construction Technologies Sector Strategy.* Melbourne: Victoria State Government.

[16] Philp, D. and Thompson N. (2014) *Built environment 250: A report on our digital future.* London: Construction Industry Council.

[17] buildingSMART (2015) *Finnish BIM requirements for infrastructure released.* Available from: https://buildingsmart.fi/en/finnish-bim-requirements-for-infrastructure-released/

[18] Trafikverket (2017) *BIM.* Available from: https://trafikverket.ineko.se/se/bim.

Findings

Overall, VicRoads' current position is consistent with the adoption of DE in Australia more generally, which has otherwise been uneven across the states and territories and lacked a consistent national strategy. The endorsement by the Australian Transport and Infrastructure Council of National Digital Engineering Policy Principles[19] in November 2016 encourages a consistent approach between transport agencies and the sharing of knowledge. This is in line with the recommendations of SBEnrc Project 2.24 *Integrated Project Environments – Leveraging Innovation for Productivity Gain through Industry Transformation* (2014). The New South Wales State transport agency, Transport for NSW (TfNSW), is developing a detailed strategic approach to the implementation of DE and is currently running a number of state-wide pilot projects.

The VicRoads staff survey found a positive perception to the concept of BIM/DE and a good understanding of its potential usefulness. However, the level of skills and knowledge was found to be variable.

There was a strong belief that successful implementation of DE will depend on the leadership of senior management and creation of a dedicated implementation team. Respondents expressed concerns about the challenge of integrating DE with the wide variety of software used by VicRoads for asset management and operations. There was significant variation in the confidence of respondents in their own abilities and that of their teams to implement and use DE. Despite the uncertainty in some areas, the responses to the concept of DE were very positive. Provided that the concerns for staff regarding leadership and resourcing are addressed, there is strong support for the implementation of DE at VicRoads.

The interviews confirmed the findings of the survey and provided some supplementary information on the DE strategy being developed by VicRoads. The whole-of-life value created by DE is seen as an opportunity to develop asset information and management practices going beyond the basic function of modelling. An 'Asset Management Transformation Team' has been established within VicRoads to take this initiative forward.

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[19] Department of Infrastructure and Regional Development (2016) *National Digital Engineering Policy Principles*. Canberra: Australian Government.

Case study 2: Using COBie with existing housing asset information

Context

COBie (Construction Operations Building Information Exchange) is a tool for integrating digital asset information from a BIM model with a computerised asset management system. The significance of this is the potential saving of many hours of work that are traditionally spent manually transcribing as-built documentation and manuals into the asset owner's management system.

COBie can be presented as a spreadsheet workbook containing a suite of linked worksheets or tables (Figure 1). Each table addresses a particular characteristic of a constructed asset including: Facility (address), floors, spaces (rooms), zones (groups of spaces), and components and type (the elements of which the facility is built).

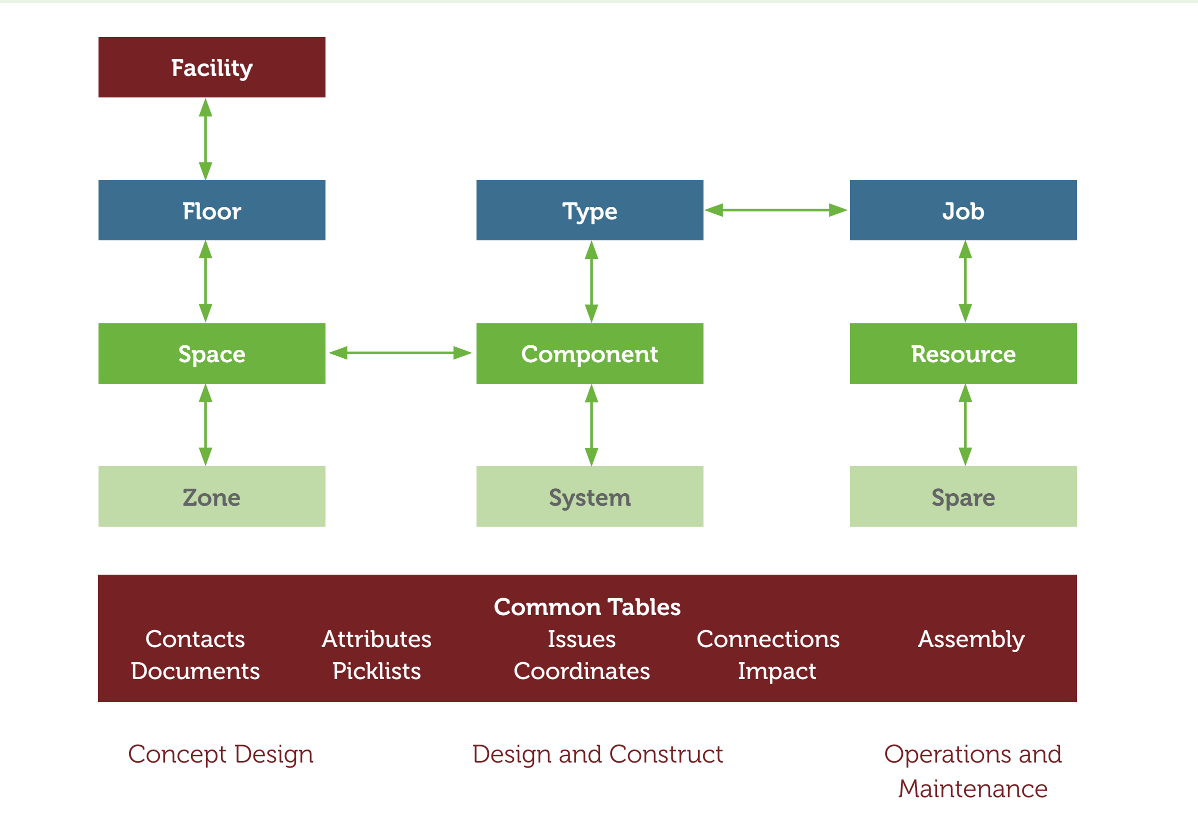

Figure 1: COBie tables and linkages

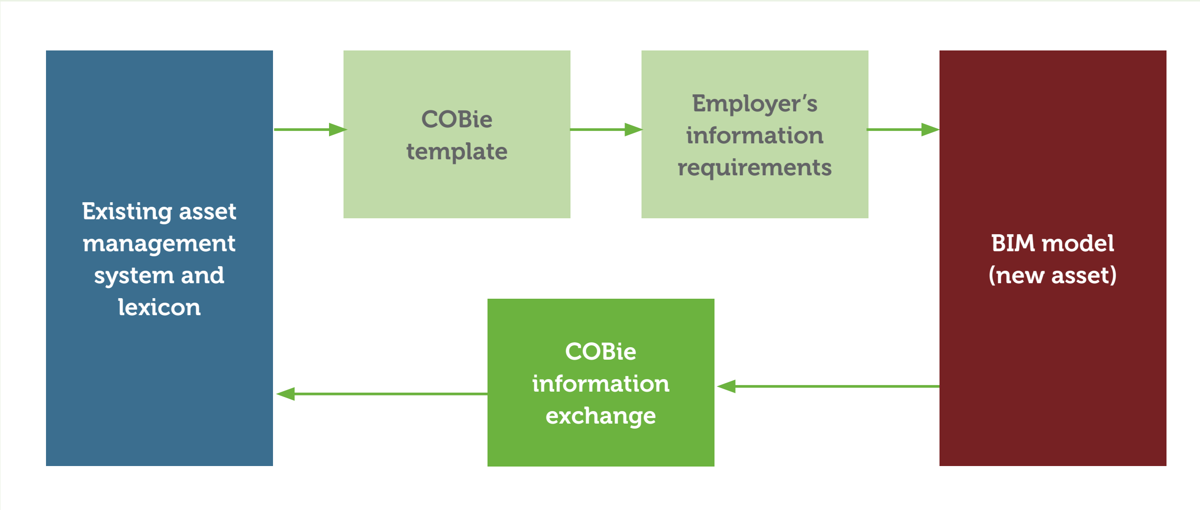

Figure 2: Role of COBie in asset information delivery

Data

This case study investigated the practicalities of translating the structure of an existing housing asset information database into a COBie format to facilitate the exchange of information with BIM models generated in the procurement of new housing assets. The study was facilitated by Queensland Department of Housing and Public Works, which manages over 50,000 public housing rental units and generously provided asset information.

Findings

BIM is a rapidly emerging digital technology and activity with the potential to greatly improve the efficiency and effectiveness of the design, construction, operation and decommissioning of constructed assets. To date, the implementation of BIM has largely focused on the design and, more recently, construction phases of the asset life cycle. However, the greatest benefits of BIM may lie in the operational phase. Implementation of BIM for asset/facility management, maintenance and operations will present a number of potentially disruptive challenges such as integrating the BIM digital asset information model generated by a new asset with an existing asset management system.

The prevailing practice is to provide as-built asset information in a mix of paper and electronic documents at Practical Completion. This is then manually transcribed into the asset owner's asset information system. Consequently, the BIM digital asset information model is 'frozen' at Practical Completion and the intrinsic value of the model is lost, together with any long-term benefits of BIM to asset management.

A key step in the implementation of BIM for whole-of-life asset management will be the automated exchange of digital asset information from the BIM model to existing asset management systems. To achieve this, the content and structure of asset information in BIM and the asset management system must be aligned. The use of a COBie template may provide the means for asset owners to specify how asset information should be structured. The completed template could then be used to facilitate a digital exchange process between a BIM model and existing asset management system (Figure 2).

In the US, the National Institute of Building Sciences working with the US Army Department of Public Works has demonstrated how COBie can be used to record information from an audit of existing constructed assets[20]. Research in Australia has suggested that, if BIM is to progress beyond the Practical Completion of new constructed assets, a 'benefits framework' needs to be established[21].

There has been some discussion in professional forums, such as BIM+, as to the value of COBie and suggestions that the integration of BIM and asset management systems will eliminate the need for an information exchange tool[22]. While in principle this may eventuate, it will still be necessary for asset owners to define their asset information requirements and to integrate BIM with existing asset management practices for which COBie may provide an appropriate methodology.

An important principle in the use of COBie is to maintain the structure of the tables so that the methodology can be applied and repeated across many and varied projects and assets. The case study found that the housing asset information did not readily align with the generic COBie workbook tables.

The housing asset information has evolved over many years and is structured in a manner that on occasion combines type, component, space, facility and other information in a manner that must be deconstructed to achieve alignment with the COBie tables. In addition, the housing asset information focuses on components of interest to the agency for purposes of maintenance and condition monitoring and does not represent all the materials and building elements of a public housing property to the level of detail envisaged in COBie.

COBie provides an established framework for asset information data exchange between contractor and client. However, the development of a COBie template based upon an existing asset management system lexicon is likely to be one of many potentially disruptive innovations arising from the adoption of BIM for asset/facility management. Consequently, the use a 'benefits management framework' enabling asset owners to clearly focus on end results and added-value may be critical to success.

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[20] Rojas, E., C. Dossick, and J. Schaufelberger (2009) *Developing best practices for capturing as-built building information models (BIM) for existing facilities.* U.S. Army Engineer Research and Development Center

[21] Love, P. E., Matthews, J., Simpson, I., Hill, A. and Olatunji, O. A. (2014) A benefits realization management building information modeling framework for asset owners. Automation in Construction, 37: 1-10.

[22] Hannell, A. (2016) *COBie is already an outdated method of data management*. BIM+
Available from: http://www.bimplus.co.uk/people/cobie-already-outdated-method-data-management/

Conclusions

The outcomes delivered through this project responded to ambitious industry development objectives. The separate parts of this project share two common themes:

1. The importance of using a benefits management framework to understand benefits sought and how they will be delivered through the adoption of digital technologies
2. The role of construction industry clients in innovation

BIM Value Benchmarking was made available to industry in November 2017[23]. This, however, is not the end of the journey. The success of BIM Value Benchmarking will depend upon collecting a sufficient volume of data on both BIM and non-BIM projects to create meaningful benchmarks. This requires ongoing engagement with industry over many years, the willingness of industry to invest time in collating data from completed projects, and the validation of data supplied and reports produced.

The exploration of disruptive technologies likely to change the way constructed community assets are delivered and operated led to consideration of what is meant by 'disruptive technology' and how innovation occurs in the realm of constructed assets. The concept of 'creative destruction' as part of an economic cycle in which the originality of entrepreneurs leads to new products and processes, appears to be more relevant to constructed assets within which innovation tends to follow an evolutionary and sustaining model, rather than one of crude disruption.

The case studies examined two instances in which strategies to implement BIM/DE are under consideration.

The study undertaken with the support of VicRoads took a broad view of the challenges of implementing BIM/DE in an organisation with well-established practices and multiple management systems. The research sought the views of a range of staff likely to be directly involved with the introduction of BIM or affected by its implementation. It was found that the potential for disruption to existing practices was recognised, although the specific implications were unresolved. Similarly, there was a general appreciation of the benefits BIM/DE might deliver. Further detailed case studies with this organisation and others are necessary to elucidate the benefits and impacts of the implementation of BIM/DE.

The second case study investigated the challenge of integrating digital information from BIM with an existing asset management system and lexicon, and was supported by Queensland Department of Housing and Public Works. The case study

[23] *http://bimvaluebenchmarking.natspec.org*

examined the prospects of producing a COBie template derived from existing QDHPW housing asset information. It was found that the structure of the information did not readily align with the COBie model. A conclusion was reached that integrating BIM with an existing asset management system is likely to be disruptive of the latter in the short term. Methodologies were proposed to enhance how COBie might be used through, for example, using pick-lists and attributes.

Existing asset management systems and lexicons may need to evolve further to align with digital technologies such as BIM. This may also offer opportunities to refresh long-established processes as determined by establishing a benefits management framework.

International experience shows that:

1. Industry takes action when the government demonstrates clear leadership
2. A national strategy facilitates the adoption of new information technologies such as BIM/DE
3. Collaboration with industry is required to implement this strategy

The role of clients as drivers of innovation therefore remains significant and echoes the findings of previous research by the SBEnrc and its predecessor, the CRC for Construction Innovation. Not only is there a pivotal role for clients in driving innovation, but also in driving whole-of-project and whole-of-asset life cycle benchmarking.

The adoption of BIM/DE in Australia generally has been uneven across the States and Territories and has lacked a consistent national strategy. The endorsement by the Australian Transport and Infrastructure Council of ‘National Digital Engineering Policy Principles’ encourages a consistent approach between agencies and the sharing of knowledge. The adoption of a national benefits management framework and BIM value benchmarking methodology would further support a national approach to delivering value with BIM.

An ongoing journey

Asset management in the built environment has been the subject of changing practice and research for years and is often complicated by inconsistency in measuring and monitoring the condition and performance of assets across the industry.

SBEnrc is now advancing with a new industry-driven project, with an overarching approach across housing, buildings and transport infrastructure. It seeks to develop a ‘Digital Asset Information Delivery Manual’ to support the operation and maintenance of key assets. Project 2.51[24] will determine enabling information management technologies and develop a framework for capturing, structuring and exchanging asset information digitally.

[24] Refer to SBEnrc Project 2.51 — *Developing a Cross Sector Digital Asset Information Model Framework for Asset Management* available at http://sbenrc.com.au/research-programs/2-51/

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