Project 2.82

DE-enabled asset life-cycle management

Measuring the benefits of BIM

Prepared by	Peng Wu and Jun Wang
Status	Final
Date	July 2022

Acknowledgements:

This research has been developed with support provided by Australia's Sustainable Built Environment National Research Centre (SBEnrc). SBEnrc develops projects informed by industry partner needs, secures national funding, project manages the collaborative research and oversees research into practice initiatives. Core Members of SBEnrc include ATCO Australia, BGC Australia, Government of Western Australia, Queensland Government, Curtin University, Griffith University, RMIT University and Western Sydney University. This research would not have been possible without the valuable support of our core industry, government and research partners.

Project Leader: Peng Wu, Curtin University

Researchers: Peng Wu and Jun Wang

Project Partners: Department of Communities, Housing and Digital Economy, Main Roads Western Australia, Department of Energy and Public Works

Citation: SBEnrc (2022) TITLE SBEnrc 2.82 – Digitally-enabled Asset Life-cycle Management. https://sbenrc.com.au/research-programs/2-82/

Executive Summary

With the recent advances in digital technologies such as building information modelling (BIM), digitalisation has attracted much attention in the construction industry. Despite the effort to promote BIM, the adoption of BIM has been challenging, possibly due to the fact that the value of BIM has not been demonstrated.

This review aims to demonstrate BIM value for different projects and two objectives are fulfilled:

1. To review and summarise potential BIM benefits by stakeholder and lifecycle phases for infrastructure and buildings with evaluation metrics; and
2. To demonstrate the value of BIM for different projects, especially small-scale built projects, underground projects, and heritage projects.

It is expected that the results can help stakeholders realise and manage value of BIM in various types of projects.

Table of Contents

1. Background

Digital technologies such as building information modelling (BIM) have obtained increasing momentum worldwide and are shifting the paradigm within the construction industry. The Queensland Health Project Information Requirements requires project delivery teams to complete a BIM metrics spreadsheet for the various project phases they are involved in. BIM has been identified to benefit construction projects in reducing errors and omissions (McGraw Hill Construction, 2014a), improving team communication (Sanchez et al., 2016a), enhancing energy efficiency (Eastman et al., 2011), reducing risks and improving safety (Khosrowshahi, 2017), increasing documentation effectiveness (Kjartansdóttir et al., 2017), and enabling more effective and accurate cost estimation (Khosrowshahi, 2017, Ullah et al., 2019), etc. However, the qualitative results are not illustrative enough for stakeholders to realise and manage the value of BIM. In addition, significant differences exist in the business value of BIM between various project types.

This review aims to demonstrate BIM value for different projects and two objectives are fulfilled:

1. To review and summarise potential BIM benefits by stakeholder and lifecycle phases for infrastructure and buildings with evaluation metrics; and
2. To demonstrate the value of BIM for different projects, especially small-scale built projects, underground projects, and heritage projects.

It is expected that the results can help stakeholders realise and manage value of BIM in various types of projects.

2. Method and Results

A literature review has been conducted and several key reviewed documents, including reports, academic papers, and domain experts' experience and views are listed in Table 1.

Table 1. Key reviewed documents

Project Type	Document Type	Organisation/Author	Year	Document Name
Built assets (public sector)	Report	PwC	2018	BIM Level 2 benefits measurement: application of PwC's BIM level 2 benefits measurement methodology to public sector capital assets
Built assets, including heritage assets	Report	Centre for Digital Built Britain	2019	Future capabilities report: the creation and through life management of built assets and infrastructure
Buildings and infrastructure	Online database	NATSPEC	2015	BIM value dictionaries (Benefits, Enablers, and Metrics)
Buildings and infrastructure	Book	Sanchez et al. of SBEnrc	2016	Delivering value with BIM
Buildings and infrastructure	Academic paper	Sanchez et al. of SBEnrc	2016	Delivering value with BIM: A framework for built environment practitioners
Buildings	Academic paper	Barlish and Sullivan	2012	How to measure the benefits of BIM—A case study approach
Not specified	Report	McGraw Hill Construction	2014	The business value of BIM in Australia and New Zealand: How building information modelling is transforming the design and construction industry
Not specified	Report	McGraw Hill Construction	2014	The business value of BIM for construction in major global markets: How contractors around the world are driving innovation with building information modelling
Not specified	Academic paper	Ullah et al.	2019	An overview of BIM adoption in the construction industry: Benefits and barriers
Small projects	Academic paper	Faghihi and Kang	2012	Benefits of Using BIM for Small Projects
Small projects	Academic paper	Sebastian et al.	2009	BIM application for integrated design and engineering in small-scale housing development: a pilot project in The Netherlands
Small projects	Domain experts' experience and views	Jodie Carson of NBS	2018	Can BIM successfully deliver small construction projects?

Project Type	Document Type	Organisation/Author	Year	Document Name
Underground projects	Academic paper	Chapman et al.	2020	BIM for the Underground–An enabler of trenchless construction
Underground projects	Domain experts' experience and views	Jane Marsh	2021	5 Ways Underground Construction Benefits from BIM Technology
Underground projects	Domain experts' experience and views	Geoff Zeiss	2012	Using BIM for infrastructure to improve urban aerial and underground facility records
Heritage assets	Academic paper	Pocobelli et al.	2018	BIM for heritage science: a review
Heritage assets	Academic paper	López et al.	2018	A Review of Heritage Building Information Modelling (H-BIM)
Heritage assets	Academic paper	Sampaio et al.	2021	Analysis of BIM Methodology Applied to Practical Cases in the Preservation of Heritage Buildings
Heritage assets	Academic paper	García-Valldecabres et al.	2021	HBIM work methodology applied to preventive maintenance: a state-of-the-art review

2.1 BIM value for general infrastructure and buildings

A number of studies have been conducted to provide an overview of the benefits of BIM (e.g., Hardi and Pittard, 2015, Diaz, 2016). However, the literature only provides qualitative results. Standard metrics for measuring business value such as return on investment of BIM are also needed so that stakeholders can better realise and manage the BIM value.

- Delivering value with BIM: a BIM value realisation framework

Sanchez et al. (2016a) and Sanchez et al. (2016b) under the Sustainable Built Environment National Research Centre (SBEnrc) developed a BIM value realisation framework that is applicable to both infrastructure and buildings based on the benefits realisation management (BRM) approach. It is proposed that BIM value can be realised through both end-benefits and flow-on benefits that are unintended and can be achieved when end-benefits have been obtained. By identifying the specific benefits stakeholders aim to achieve, corresponding enablers (tools and processes) and evaluation metrics are established to deliver and monitor the BIM value. Eight steps are proposed to be followed in this framework. These include: 1) defining end-benefits, 2) defining intermediary and flow-on benefits, 3) defining enablers, 4) assigning metrics, targets, and incentives, 5) integrating the metrics and targets into progress report documentation and processes, 6) workshop follow-up / feasibility and approval, 7) progress review and correction initiatives, and 8) ongoing active learning.

- Dictionaries for BIM value realisation (benefits, enablers, and metrics)

Based on the abovementioned research, dictionaries for 31 BIM benefits, 47 enablers, and 49 metrics have been established (NATSPEC, 2015). The Australasian BIM Advisory Board (ABAB) aims to pilot these BIM benefits metrics in various types and scale of government projects. An online decision-support tool has also been developed and is freely available at https://bimvaluetool.natspec.org. With this tool, it is easy and convenient to identify the potential BIM benefits that could be achieved by different stakeholders in various lifecycle phases. For each selected benefit, the corresponding enablers and evaluation metrics are provided to aid stakeholders with their value realisation processes. Another site that is useful for stakeholders to identify BIM value in various planning, design, construction and operation activities is the PennState College of Engineering BIM Uses, available at: https://bim.psu.edu/Uses/.

All the potential BIM benefits identified in the tool are summarised in Appendix A, with ten stakeholders and six lifecycle phases considered. Figure 1 shows a screenshot for simple demonstration.

No	BIM value/benefits	Client/Owner						Designer		
		Whole-of-life	Planning	Design	Construction	Operations	Decommissioning	Planning	Design	Construction
1	Asset management labour utilisation savings					×				
2	Better change management	×	×	×	×	×		×	×	×
3	Better cost accounting	×	×	×	×	×				
4	Better data/information capturing							×	×	×
5	Better environmental performance	×	×	×	×	×	×	×	×	×
6	Better programming/scheduling		×	×	×	×	×			
7	Better scenario and alternatives analysis	×	×	×	×	×	×	×	×	×
8	Better space management									
9	Better use of supply chain knowledge	×	×	×	×	×	×	×	×	×
10	Competitive advantage gain								×	×
11	Faster regulation and requirement compliance							×	×	×
12	Fewer errors	×	×	×	×	×	×	×	×	×
13	Higher customer satisfaction		×	×	×	×		×	×	×
14	Higher process automation	×	×	×	×	×	×	×	×	×
15	Improved communications		×	×	×	×	×	×	×	×
16	Improved coordination	×	×	×	×	×	×	×	×	×
17	Improved data and information management	×	×	×	×	×	×	×	×	×
18	Improved documentation quality and processes	×	×	×	×	×	×	×	×	×
19	Improved efficiency	×	×	×	×	×	×	×	×	×
20	Improved information exchange	×	×	×	×	×	×	×	×	×
21	Improved learning curve							×	×	×
22	Improved output quality	×	×	×	×	×	×	×	×	×
23	Improved productivity		×	×	×	×	×	×	×	×
24	Improved safety									

Figure 1. A simple demonstration of Appendix A

- Quantified BIM value

The abovementioned studies/reports have established comprehensive BIM benefits and metrics and provided a practical framework for BIM value realisation. Nevertheless, the value of BIM is not quantified. Barlish and Sullivan (2012) conducted one of the first studies on developing cost (or investment) and benefit (or return) metrics to measure the value of BIM. A 42% savings of change order cost, 50% frequency reduction of request for information (RFI) per tool, and 67% reduction of project duration were witnessed in case 1. In case 2, design cost increased due to 31% increase in A&E costs and 34% increase in 3D background model creator costs. On the contrary, construction cost is reduced as 5% savings of contractor cost were achieved. The design and construction phases together resulted in a 2% savings in their combined awarded scope compared to non-BIM scenario. McGraw Hill Construction (2014b) also reported that four out of ten BIM users achieved a positive return of investment (ROI) at 1%-25% while a quarter of users had negative to zero ROI.

In addition, PwC (2018) estimated and monetarised the benefits achieved through BIM using two cases, namely, the refurbishment of DoH headquarters at 39 Victoria Street and the Foss Barrier Upgrade projects. Different benefit categories (e.g., time savings and cost savings) in various life-cycle phases (e.g., design, build and commission, handover, asset maintenance, refurbishment, and operation) are separately estimated. The value achieved in the first case includes: £42,366 for time savings in design, £103,872 for time savings in build and commission, £84,520 for time savings in handover, £391,592 for cost savings in asset maintenance, £23,463 for cost savings in refurbishment, £2,943 for reduction of operating expenditure variance, and £28,151 for asset utilisation improvement. Similarly, the second case have benefited: £132,317 for time savings in design, £5,757 for time savings in build and commission, £6,500 for cost savings from improved clash detection, and £223,118 for potential cost savings in asset maintenance. It should be noted that BIM maturity level was identified in this report to have potential impact on the benefits obtained. In this study, the project with a higher BIM maturity level has gained a larger scale of benefits.

2.2 BIM value for small-scale projects

It was revealed in McGraw Hill Construction (2014b) that stakeholders' perception that BIM seems less efficient in small-scale projects than large-scale ones was delaying their use of BIM, especially in small and medium enterprises (SMEs). As such, a number of studies have been conducted to discuss whether BIM can deliver benefits for small-scale projects.

The following benefits are identified and summarised in Appendix B:

Better data/information capturing. Carson (2018) interviewed several practitioners with experience of using BIM in small-scale projects and identified the most significant BIM benefit to be better data capturing at the construction phase. With one model carrying all information and enabling 3D visualisation, data capturing and management is much easier with BIM. However, small-scale projects usually do not implement full BIM which incorporates classification, standards, and protocols due to the complexity. Therefore, benefits are mostly seen in data capturing but not information exchange.

Better communication and coordination. One feature of BIM is the joined processes which involve all key stakeholders in the design phase. This shift in collaboration pattern leads to better communication and coordination between different stakeholders. Normally, the earlier such coordination is introduced, the larger the value can be generated. This benefit also applies to small-scale projects.

Fewer errors and less rework. Due to the integrated design and early participation of stakeholders, many interface errors can be detected before on-site construction. This effectively reduces rework and thereby reducing the execution time and cost. In addition, as most SMEs are still managing to transit from 2D drawing to 3D CAD, such benefits of integrated design can be outstanding for them (Sebastian et al., 2009). Other benefits that may be realised by large projects such as improved supply chain management, scheduling, cost estimation, and information exchange are temporarily beyond their reach.

Reduced cost. Faghihi and Kang (2012) investigated the benefits of applying BIM to projects that cost less than $5M. It was found that detecting 10 clashes prior to the actual work on site can save $12,000 to $62,500 out of the total budget of $4.2M, which equals 0.3% to 1.5% of total cost.

Better environmental performance. Due to the reduced rework and repairs that can be achieved in small projects, material usage and waste can be lessen.

Better programming/schedules. BIM is also reported in Carson (2018) to improve forming and performing maintenance programs. With the as-built 3D BIM model, the maintenance team can retrieve required data for scheduling their maintenance programs and record their maintenance activities in a more convenient manner.

2.3 BIM value for underground projects

Although underground space is a crucial asset, information available for such environment is comparatively poor compared to the aboveground buildings and infrastructure. The lack of information poses great challenges for planning future buried infrastructure and performing construction activities to maintain, repair, upgrade, and install new underground assets (Chapman et al., 2020). Underground construction is also risky due to the uncertain environment and urban underground construction work can have a wide social impact. Therefore, the mostly mentioned BIM benefits for underground projects mainly focus on safety and their impact area:

Better space management. One of the most obvious benefits of BIM in underground asset management is better space management, by integrating both aboveground and underground data to show the surroundings and visualise buried infrastructure (Marsh, 2021). In this way interferences in design are easier to spot and excavation methods and workspace are more convenient to plan to avoid invasive construction.

Reduced risks and Improved safety. Conducting risk analysis with BIM using data such as heat distribution and layered imagery can directly improve the overall project safety. For example, a risk manager can use BIM to detect locations with fall hazard to underground workers. In addition, GIS along with underground construction technologies such as LiDAR or GPR has been proven useful in identifying and reducing unique risks for buried infrastructure, such as waterline systems (Marsh, 2021).

Better environmental performance. Traditional trench excavation usually has a destructive nature and does no good to its land surroundings. Using BIM in underground projects can refine and optimise trenchless operations, therefore, more environmentally friendly construction can be performed.

Improved communications and coordination. As 3D visualisation is much more intuitive than 2D drawings especially for the buried infrastructure, using BIM in underground projects largely improves the communication and coordination.

Better change management. Due to the visualisation function embedded in BIM, it is much easier to view and assess the change of designs especially for the buried infrastructure, which otherwise would be challenging to notice.

Fewer errors and reduced rework. Similar to other project type, BIM for the underground infrastructure enables the detection of interferences or clashes in the design phase and thereby avoiding rework in the construction phase (Zeiss, 2012).

2.4 BIM value for heritage assets

Currently, there have been quite a number of studies that investigate heritage BIM (HBIM). However, most, if not all, are focusing on feasibility and technical aspects possibly because of the many difficulties, for example, complex morphology and non-homogeneous features of heritage assets (Ciribini et al., 2015, Pocobelli et al., 2018), limited families of libraries (León-Robles et al., 2019), and lots of manual and time-consuming work currently (Pocobelli et al., 2018). Very few have investigated the value of BIM in heritage asset management.

Improved data capturing, communication, and documentation. The mostly mentioned benefit of HBIM is the convenience of data capturing, better information communication between stakeholders, and improved documentation (García-Valldecabres et al., 2021, Sampaio et al., 2021). This is understandable because continuous maintenance and historical and cultural property are distinctive features of heritage assets. As HBIM can be a centralized repository with updated information, it enables better document management, improved data retrieval for maintenance team and better communication across the management team. In addition, the visualised 3D model improves the communication to the public.

Centre for Digital Built Britain (2019) also identified the following benefits of automated heritage asset digitisation for the UK and the benefits radar is shown in Figure 2:

Reduced risks. The digital model with updated maintenance information reduces engineers' manual survey work and walk-down time, which thereby lowers the safety risks.

Reduced complexity. Using BIM in heritage asset management reduces the complexity in document management and the HBIM model is useful in communication and coordination when delivering new assets that require interactions with heritage assets for coordination.

Reduced cost. Although reduced cost is reported in Centre for Digital Built Britain (2019), it is only stated in a bullet point summary for preliminary research without further explanation. Without any evidence in other published literature or cases, this benefit needs to be viewed with caution.

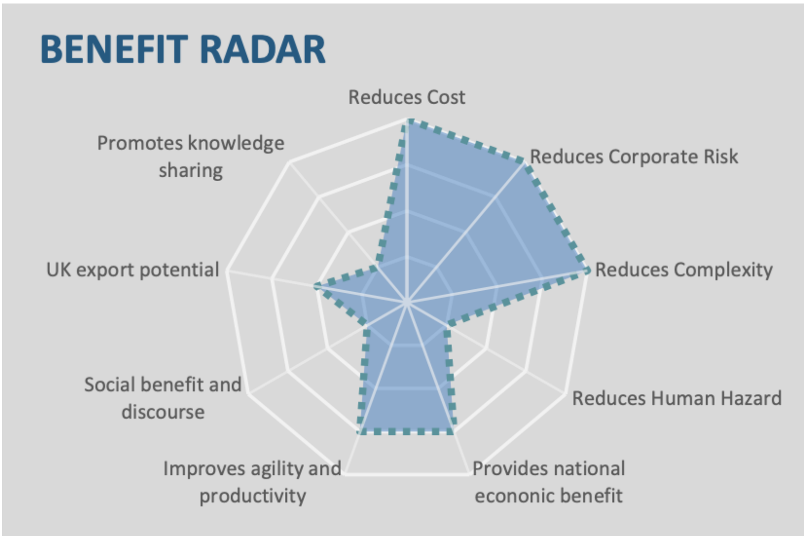

Figure 2. Benefit radar for automated legacy asset digitisation

(Reference: Centre for Digital Built Britain, 2019)

Conclusion

In this review, we examined the benefits of BIM and BIM value for different types of projects, including general infrastructure and building project and other specific types, including small-scale projects, underground projects and heritage assets.

As these BIM values are obtained through examining BIM case studies, it is believed that practitioners can understand how such values are achieved and eventually promote the use of BIM in these projects.

References

Barlish, K. & Sullivan, K. 2012. How to measure the benefits of BIM—A case study approach. *Automation in construction,* 24**,** 149-159.

Carson, J. 2018. *Can BIM successfully deliver small construction projects?* [Online]. Available: https://www.thenbs.com/knowledge/can-bim-successfully-deliver-small-construction-projects [Accessed Dec 22 2021].

Centre for Digital Built Britain 2019. Future Capabilities Report: The Creation and Through-Life Management of Built Assets and Infrastructure.

Chapman, D., Providakis, S. & Rogers, C. 2020. BIM for the Underground–An enabler of trenchless construction. *Underground Space,* 5**,** 354-361.

Ciribini, A., Ventura, S. M. & Paneroni, M. 2015. BIM methodology as an integrated approach to heritage conservation management. *WIT Transactions on The Built Environment,* 149**,** 265-76.

Diaz, P. 2016. Analysis of benefits, advantages and challenges of building information modelling in construction industry. *Journal of Advances in Civil Engineering,* 2**,** 1-11.

Eastman, C. M., Eastman, C., Teicholz, P., Sacks, R. & Liston, K. 2011. *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*, John Wiley & Sons.

Faghihi, V. & Kang, J. H. 2012. *Benefits of Using BIM for Small Projects* [Online]. Available: https://www.researchgate.net/publication/233762608 [Accessed Dec 22 2021].

García-Valldecabres, J., Galiano-Garrigós, A., MESEGUER, L. C. & GONZÁLEZ, M. C. L. 2021. HBIM work methodology applied to preventive maintenance: a state-of-the-art review. *WIT Transactions on The Built Environment,* 205**,** 157-169.

Hardi, J. & Pittard, S. 2015. If BIM is the solution, what is the problem? A review of the benefits, challenges and key drivers in BIM implementation within the UK construction industry. *Journal of Building Survey, Appraisal & Valuation,* 3**,** 366-373.

Khosrowshahi, F. 2017. Building information modelling (BIM) a paradigm shift in construction. *Building information modelling, building performance, design and smart construction.* Springer.

Kjartansdóttir, I. B., Mordue, S., Nowak, P., Philp, D. & Snæbjörnsson, J. T. 2017. *Building Information Modelling-BIM*, Civil Engineering Faculty of Warsaw University of Technology Warsaw.

León-Robles, C. A., Reinoso-Gordo, J. F. & González-Quiñones, J. J. 2019. Heritage building information modeling (H-BIM) applied to a stone bridge. *ISPRS International Journal of Geo-Information,* 8**,** 121.

Marsh, J. 2021. *5 Ways Underground Construction Benefits From BIM Technology* [Online]. Available: https://sourceable.net/5-ways-underground-construction-benefits-from-bim-technology/ [Accessed Dec 5 2021].

McGraw Hill Construction 2014a. The business value of BIM for construction in major global markets: How contractors around the world are driving innovation with building information modeling. *Smart MarketReport***,** 1-60.

McGraw Hill Construction 2014b. The business value of BIM in Australia and New Zealand: How building information modelling is transforming the design and construction industry. *Bedford, MA: McGraw Hill Construction*.

NATSPEC. 2015. *BIM value* [Online]. Available: https://bimvaluetool.natspec.org/decision-tree-tool/ [Accessed Dec 5 2021].

Pocobelli, D. P., Boehm, J., Bryan, P., Still, J. & Grau-Bové, J. 2018. BIM for heritage science: a review. *Heritage Science,* 6**,** 1-15.

PwC 2018. BIM Level 2 Benefits Measurement: Application of PwC's BIM Level 2 Benefits Measurement Methodology to Public Sector Capital Assets. PricewaterhouseCoopers LLP.

Sampaio, A. Z., Gomes, A. M., Sánchez-Lite, A., Zulueta, P. & González-Gaya, C. 2021. Analysis of BIM Methodology Applied to Practical Cases in the Preservation of Heritage Buildings. *Sustainability,* 13**,** 3129.

Sanchez, A., Hampson, K. & Vaux, S. 2016a. Delivering value with BIM. *Oxon: Routledge. Pg***,** 105-194.

Sanchez, A., Mohamed, S. & Hampson, K. Delivering value with BIM: A framework for built environment practitioners. Proceedings of the CIB World Building Congress 2016: Volume III-Building Up Business Operations and Their Logic. Shaping Materials and Technologies, 2016b. Tampere University of Technology, Department of Civil Engineering, 272-283.

Sebastian, R., Haak, W. & Vos, E. BIM application for integrated design and engineering in small-scale housing development: a pilot project in The Netherlands. International symposium CIB-W096 future trends in architectural manaement, 2009. 2-3.

Ullah, K., Lill, I. & Witt, E. An overview of BIM adoption in the construction industry: Benefits and barriers. 10th Nordic Conference on Construction Economics and Organization, 2019. Emerald Publishing Limited.

Zeiss, G. 2012. *Using BIM for infrastructure to improve urban aerial and underground facility records* [Online]. Available: https://geospatial.blogs.com/geospatial/2012/07/using-bim-for-infrastructure-to-improve-urban-aerial-and-underground-facility-records.html [Accessed Dec 2 2021].