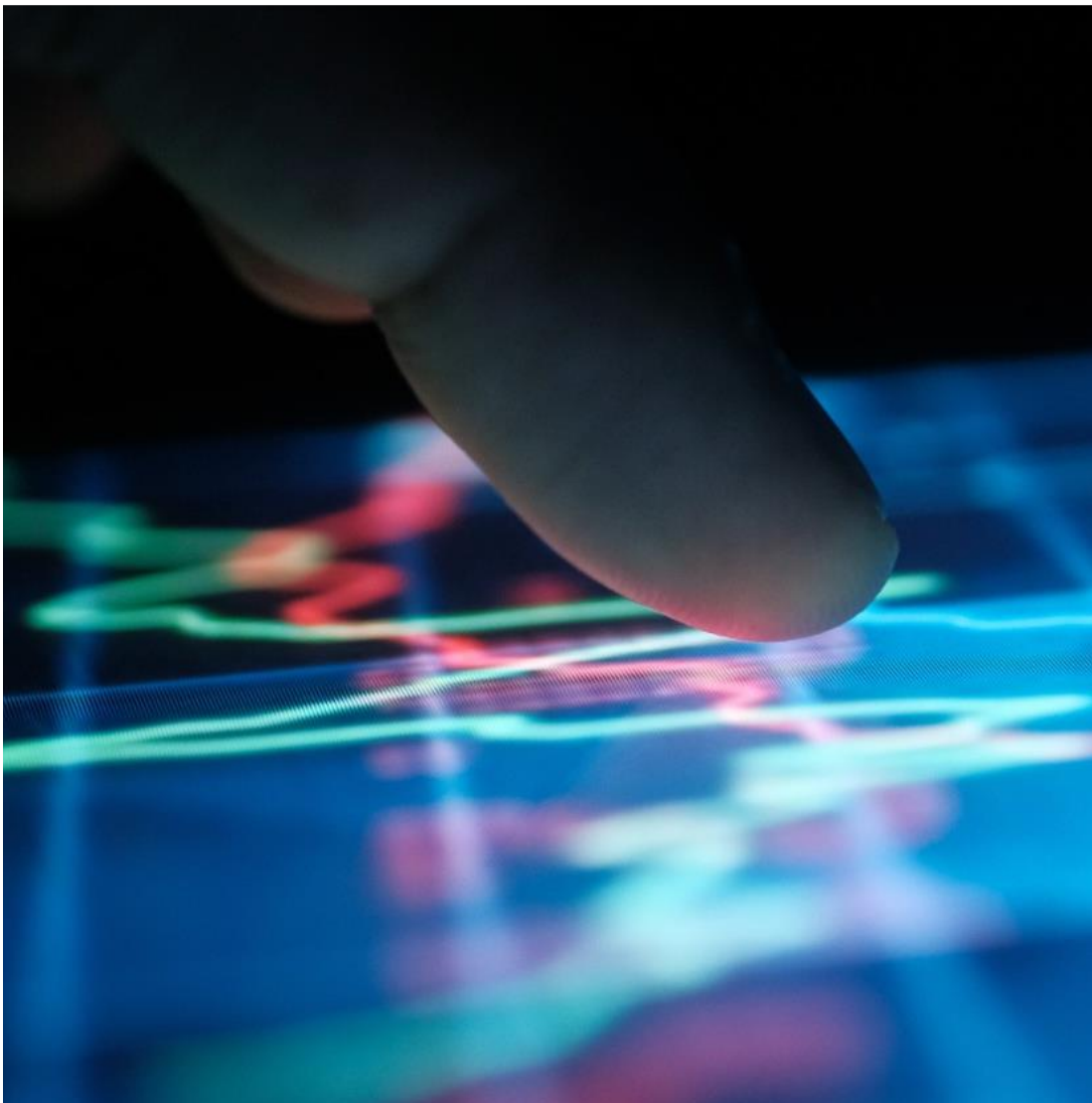
Assessment of the value of BIM

Part 1 - Context and Methodology

31 March 2020



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1 Introduction and context

1.1 Introduction

In 2016 the UK Government mandated the use of Building Information Modelling ('BIM') Level 2 on all centrally procured public construction projects. After three years of mandatory BIM adoption, senior figures across the construction industry and in government have called for greater clarity on 1) the benefits of BIM as it is currently used, and 2) the next phase of the digital transformation of asset management (i.e. extending the current uses of BIM) and the associated benefits.

In response, the Centre for Digital Built Britain (CDBB)[1] commissioned[2] PwC to develop two methodology[3] documents to outline an approach to provide clarity in the two respective areas introduced above. It is intended that in a subsequent phase of work, these methodologies will be applied to case study projects to collate the necessary evidence and report on any benefits, in order to provide the clarity that industry and government have called for.

This document provides the methodology for the first area above, i.e. assessing the benefits of BIM based on the current UK definitions of BIM. This document builds on the 2018 PwC BIM benefits work[4] commissioned by Innovate UK, that set out a methodology for measuring the benefits of BIM Level 2. This report extends the 2018 methodology to clarify the benefits of BIM as it is currently used. The previous PwC BIM benefits work is publicly available on the CDBB website[5].

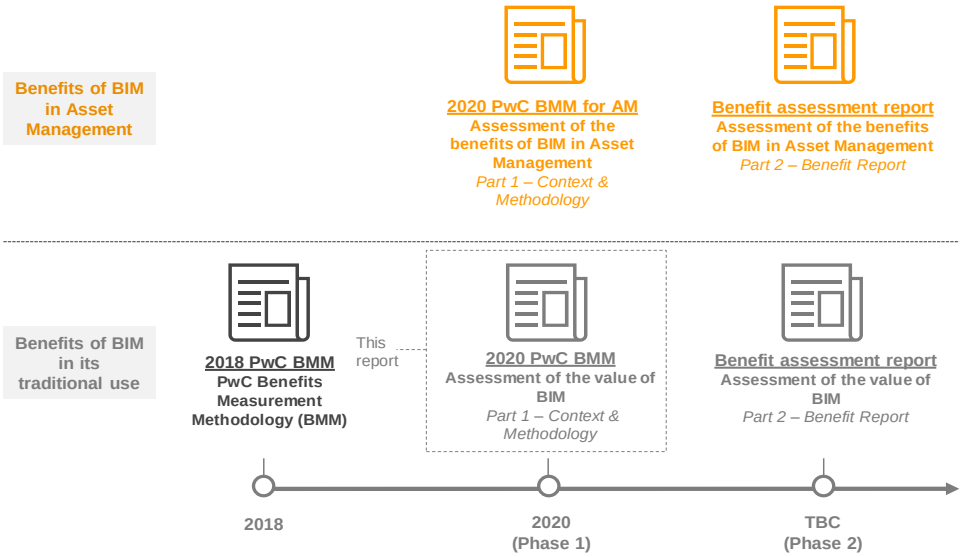


Figure 1. The timeline of the work carried out on the benefits of BIM.

1.2 Scope of this report

The scope of this report is to provide a preliminary view of a methodology, and the information required to evidence the benefits of BIM as it is currently used. This report also sets out an approach to respond to the following hypothesis, and corresponding high-level requirement:

[1] Centre of Digital Built Britain, 'About Us' available at https://www.cdbb.cam.ac.uk/AboutDBB
[2] The terms of engagement between CDBB and PwC are defined in the engagement letter 'CDBB 017-19 -Final PwC Agreement' 25/10/19.
[3] CDBB commissioned PwC to develop a separate methodology to define and assess the benefits for the next phase of the digital transformation of the asset management lifecycle, and how asset data (including BIM) enables this and generates associated benefits.
[4] The 2018 PwC BIM benefits work for Innovate UK comprised of four documents: 1) BIM Level 2 – summary guidance to BMM, 2) PwC Introductory note to BMM, 3) PwC Benefits Measurement Methodology, and 4) PwC BMM Application Report.
[5] https://www.cdbb.cam.ac.uk/news/2018JuneBIMBenefits

***Hypothesis** - There are measurable benefits to different parties in UK construction and asset management businesses from the greater use of BIM.*

***Requirement** - Clarify the benefits of current BIM processes to the different parties in the UK construction industry, including clients, contractors and consultants, in a briefing note.*

Central to the selected 2020 methodology is an extension of the 2018 PwC BMM[6]. The extension primarily consists of an updated definition of BIM and the applicable lifecycle stages of an asset, it also now clarifies the beneficiaries of BIM. This document also sets out the context for the methodology, the approach taken to develop the methodology, and the next steps to apply the methodology.

Guiding principles for the ultimate BIM benefit assessment report were established to inform the development of this methodology. They are as follows:

1. The final BIM benefit assessment report will be aimed at business decision makers, it will not be a technical report.

2. The final BIM benefit assessment report will set out where the benefits are and are not realised.

3. The final BIM benefit assessment report will be objective, be evidence-based and quantified, and be clear where the findings are not, or cannot be quantified. In this respect any quantified benefits are likely to be closer to lower bound estimates, rather than upper bound estimates.

4. The final BIM benefit assessment report will set out the limitations of the work.

The intent behind these principles is to demonstrate to consumers of the final BIM benefit assessment report (yet to be commissioned) that any reported benefits of BIM have been assessed based on facts and evidence. This methodology and any subsequent BIM benefit assessment report aim to provide transparency into the methods, data, calculations, assumptions and interpretations, so that the basis of any reported benefits is clear.

1.3 History of UK BIM development

The UK Government is aware that the construction sector is a significant economic driver, and that there is an opportunity to derive better value for money with increased benefits from public sector construction.

In 2011 the Government published its Government Construction Strategy (GCS)[7] framework in order to facilitate the transition of the UK's construction industry to a more efficient and digitally enabled sector, of which BIM was a key component. The aim of the GCS was to reduce the cost of government construction projects by 15-20% by 2015 compared to a 2009/2010 cost baseline. **Figure 2** summarises the key policy documents and milestones that played an important role in the development of UK BIM following the 2011 GCS.

[6] PwC, 'BIM Benefits Measurement and Report', March 2018, available at: https://www.cdbb.cam.ac.uk/BIM/BBM
[7] Cabinet Office and Infrastructure Projects Authority, 'Government Construction Strategy', 2011, available at: https://www.gov.uk/government/publications/government-construction-strategy

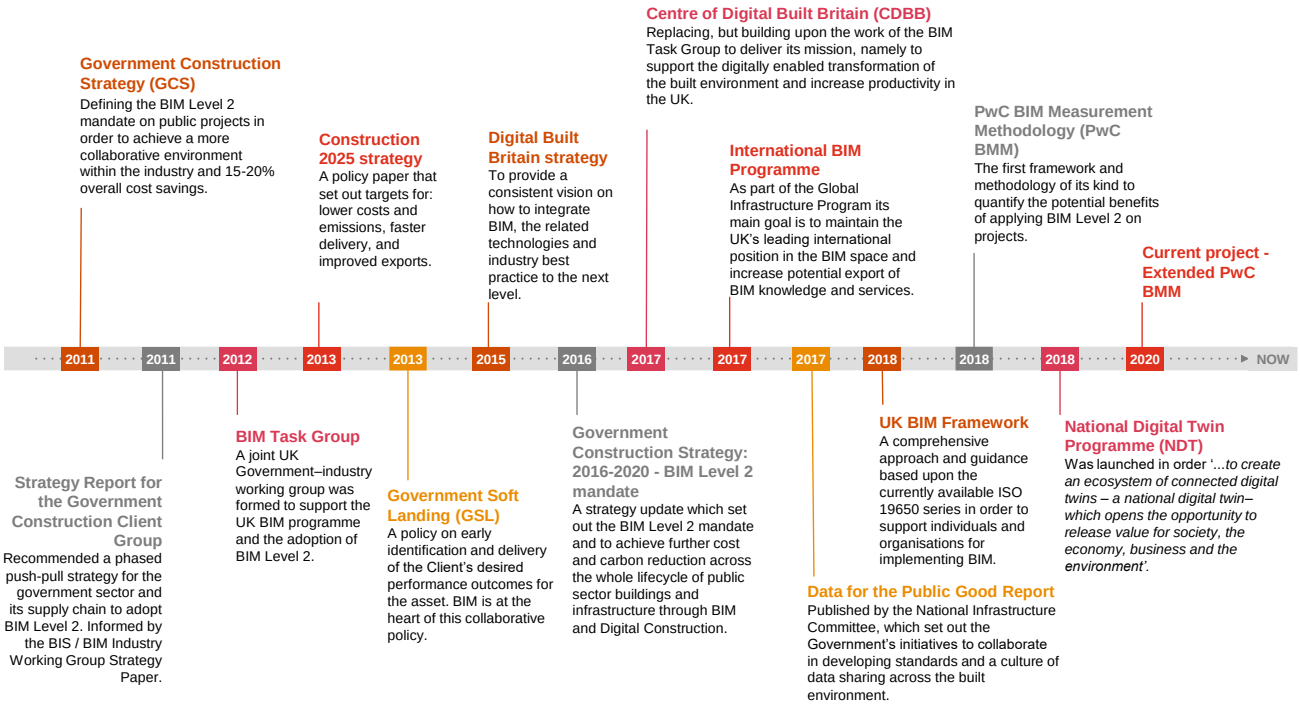


Figure 2. The timeline of BIM policies and initiatives in the UK.

This current work focusses on a methodology to capture and quantify the benefits of BIM across the whole lifecycle of an asset, for projects based on the BIM Level 2 mandate[8] or the UK BIM Framework[9]. The 2020 PwC methodology provides a retrospective benefits analysis focusing on the design, build and operate stages, which is detailed in **Section 2** of this document.

1.4 Current adoption of BIM in the UK

The adoption and awareness of BIM has increased in the UK since the GCS was published in 2011. According to the National Building Specification (NBS) survey data[10], there has been a year on year increase in the adoption of BIM across the construction industry. Between 2011 and 2018 the adoption rate increased from 31% to 71%. Notwithstanding the increase in adoption, challenges and impediments to the further uptake of BIM have been observed, based on the 2018 PwC BMM assessments and the NBS survey analysis. These are discussed in more detail in **Appendix A: Impediments to adoption of BIM**.

Approximately 1,000 industry professionals participated in the 2019 annual NBS survey, which was more than in previous surveys. Survey respondents were predominantly from the design community, with 28% being architects and 20% being architectural technologists, which along with the survey sector analysis that shows 13 out of 14 project types were buildings projects[11], indicates that the survey is heavily weighted towards the buildings sub-sector of the industry, with little representation from the infrastructure sub-sector.

The 2019 survey shows a 69% BIM adoption rate, which is a decrease of 2% compared to 2018. The reason for this small decrease is unclear from the survey data, but it may be due to the increase in respondents. The survey does not report any increase or decrease in BIM adoption in the infrastructure sub-sector. However, it may be inferred that BIM adoption in infrastructure has increased, because the 2016 BIM mandate applies to publicly funded infrastructure as well as buildings (where there has been an increase), however no evidence to support this inference has been identified.

[8] Cabinet Office and Infrastructure Projects Authority, 'Government Construction Strategy: 2016 - 2020', 2016 available at https://www.gov.uk/government/publications/government-construction-strategy-2016-2020
[9] UK BIM Framework, 'Standards & Guidance' 2018, available at https://ukbimframework.org/standards-guidance/
[10] National Building Specification, 'National BIM Report 2019 - The definitive industry update', 2019, available at https://www.thenbs.com/knowledge/national-bim-report-2019
[11] National Building Specification, 'National BIM Report 2019 - The definitive industry update', 2019, available at https://www.thenbs.com/knowledge/national-bim-report-2019 - page 26, project types chart

Although the rate of BIM adoption has decreased for the first time since 2015, there is a view[12] that digitisation, in which BIM has a key role, will transform the UK's construction industry. According to the NBS survey, industry professionals predict that more than 90% of small to large size practices will adopt BIM in the next five years[1310].

[12] National Building Specification, 'Construction Technology Report', 2019, available at https://www.thenbs.com/knowledge/nbs-construction-technology-report-2019

[13] National Building Specification, 'National BIM Report 2019 - The definitive industry update', 2019, available at https://www.thenbs.com/knowledge/national-bim-report-2019

2 The Extended PwC BIM Benefits Measurement Methodology

2.1 Summary of the Extended PwC BMM

The 2018 PwC BMM was designed and developed to be consistent with the principles that are set out in HM Treasury's Green Book and the Infrastructure and Projects Authority's (IPA) 'Guide for Effective Benefits Management in Major Projects'.

It was designed to identify, quantify and value the actual (and potential) benefits of applying BIM to capital projects compared to the alternative – where the same project would have been undertaken but without the use of BIM ('the counterfactual'). The 2018 PwC BMM was then tested using data and information collected from two projects. This provided limited evidence with which to understand and gain confidence about the scale of the benefits; this can only be achieved by applying the BMM to more projects, perhaps by using different data gathering and analytical techniques.

The focus of the Extended PwC BMM is to deliver three key enhancements to the 2018 PwC BMM[14], namely: 1) to apply the methodology to a larger sample of projects; 2) to increase confidence in the claimed benefits of BIM; and 3) to include analysis of the beneficiaries.

2.2 Benefit measurement options

The Extended PwC BMM is comprehensive in that it can accommodate multiple options for data gathering and analysis techniques, while remaining consistent with the Green Book principles and IPA guidance. This means that the methodology is flexible in terms of the techniques that can be used and therefore, specific techniques do not need to be discounted, before the extent of available information is known. Examples of the alternative techniques for 1) data gathering and 2) analysis were considered, and the basis for selecting or discounting each option is described in **Table 1**.

Benefit measurement techniques	Decision	Basis for decision
1) Data gathering (Case studies – extensive)	Selected – subject to data availability	Further evidence on the benefits of BIM could be acquired by undertaking similar additional case studies to those described in the 2018 PwC BMM work. Whilst such case studies have the potential to generate robust data, they are resource intensive to undertake, and require input from multiple parties. Experience from the 2018 PwC BMM suggests that it is also challenging to solicit the right information from the supply chain stakeholders, as they can find it difficult to conceive what they would have done in the absence of BIM.

[14] PwC, 'BIM Benefits Measurement and Report', March 2018, available at: https://www.cdbb.cam.ac.uk/BIM/BBM

1) Data gathering (Case studies – simplified)	Selected – subject to data availability	An alternative way of getting further evidence on BIM benefits would be to develop simplified case studies focused on gathering data in targeted areas e.g. on specific BIM enablers or pathways that are expected to be most material, rather than covering all elements in the Extended PwC BMM. Such case studies can generate valuable additional data that could supplement the existing data. A key challenge, however, would be to agree which parts of the process are most material as these might vary depending on the stakeholders. Experience from the 2018 PwC BMM suggests that it is challenging to solicit the right information from the supply chain stakeholders, as they can find it difficult to conceive what they would have done in the absence of BIM.
1) Data gathering (Expert interviews)	Selected – subject to access to experts	Another way of obtaining evidence on the benefits of BIM is to use a Delphi approach whereby experts are asked to provide their views on the impact of BIM. Such an approach could, for example, be used across the project life cycle and/or to fill gaps left by other data collection methods. The advantages of this approach are that it is easier to organise than multiple case studies, it allows multiple opinions to be considered in a non-adversarial manner, it weights all responses equally and allows experts to reconsider based on the opinions of other experts. The disadvantages are that it requires significant commitment from a few expert participants, there is no evidence of reliability (i.e. two different panels may not reach the same conclusions) and it is not certain that the consensus reached is factually correct.
1) Data gathering (Secondary sources)	Selected – subject to data availability	An alternative to primary data collection, is to identify secondary sources of project cost data which could be used to underpin econometric or another analysis to test the impact of using BIM. To be valuable, such data sets would also need to cover other project parameters that might be expected to drive differences in cost (timing, scale, location, complexity, commercial arrangements, etc.) as well as the role of BIM. Potential data sets of this nature have been identified, but not obtained.
2) Data analysis (Randomised Controlled Trials)	Discounted	If the data analysis could be conducted based on the evidence from a well-constructed, controlled experiment (e.g. randomised controlled trials), this would potentially provide a sound basis for assessing the benefits of BIM. Such a technique would require capital projects to be assigned randomly to one of two groups: those which use BIM and those that do not. A comparison of costs over time would give a basis for assessing the benefits of BIM. In practice, such an approach is unrealistic for several reasons: it would need to be applied to many projects, it would deny the potential benefits to those projects which do not use BIM, and it would take many years to obtain the results.
2) Data analysis (Econometric analysis)	Selected in support of the Extended PwC BMM - where data permits	If an adequate data set could be assembled covering multiple capital projects that used BIM (as well as those that did not), this could provide a basis for analysing the benefits of BIM using econometric analysis techniques. Data analysis is discussed further in **Section 2.5** Benefit estimation on historic data sets.

Table 1. Benefit measurement methodologies considered.

2.3 Extended impact pathway

The original impact pathways will be extended to include the “beneficiary”, with the other pathways remaining as per the 2018 PwC BMM. The revised pathway will only assess the direct beneficiaries and will not include the indirect beneficiaries. More detail on beneficiary definitions is provided in **Section 2.7 Key beneficiaries**. The applied steps in the extended impact pathway are described in **Figure 3.**

Figure 3. Extended benefit pathway.

- **Activity** - A technical capability provided by using BIM, that can lead to one or more measurable benefits, that may accrue at various stages of the asset lifecycle with various beneficiaries.
- **BIM enabler** - A BIM tool, process or application that results in a direct positive effect, which enables realisation of the benefit, at a specific stage of the asset lifecycle.
- **Intermediate benefit** - A direct measurable positive benefit resulting from application of the BIM enabler at a specific stage of the asset lifecycle.
- **End benefit** - The ultimate impact of the intermediate benefit, which is assessed and potentially measured/ quantified. The end benefit can be the result of multiple pathways, e.g. time, material or cost savings.
- **Beneficiary** - Depending on the impact pathway multiple stakeholders can realise the benefit. While multiple beneficiaries will be identified, only the direct beneficiaries will be considered as part of the Extended PwC BMM. The level of benefit realisation will also be considered e.g. project, programme, or organisation level.

The following steps show the journey for BIM and/or BIM enabled processes in providing benefits to a certain beneficiary. See an example below in **Figure 4.**

Figure 4. Detailed example of a benefit impact pathway[6].

- **Activity** - Creation of 2D design drawings, an activity that can be achieved through a manual process, or through an automated process of extracting 2D drawings from a 3D model, in a BIM-enabled environment.
- **BIM enabler** - An object-oriented 3D BIM model that enables quick and accurate generation of conventional 2D design drawings, by extracting the 2D drawings from the 3D object model.
- **Intermediate benefit** - BIM enables design changes to be reflected in the drawings faster, when compared to manually and individually updating all 2D drawings with each respective design change.
- **End benefit** - Time is saved due to the more efficient BIM-enabled process for updating design drawings.
- **Beneficiary** - Time savings as an end benefit are realised by the designer as the direct, immediate beneficiary, and these benefits are monetised. The direct, end beneficiary will also be considered and, in this case, is determined by the commercial arrangements between the designer and the client. For example, in a fixed fee contractual arrangement, the designer is the end beneficiary (they save time, but are paid the same), whereas in a time-based contractual arrangement, the client is the end beneficiary. Indirect beneficiaries will not be considered.

2.4 Benefit assessment process map

The benefit assessment process is based on a logical decision map which demonstrates how benefits will be assessed using a defined, repeatable process. This process will capture the findings and explain whether benefits and beneficiaries do, or do not exist, and whether they can be robustly proven through consultation, and within the constraints of available data. It is necessary to capture all findings during the application of this methodology to gain a better understanding of the benefit realisation process.

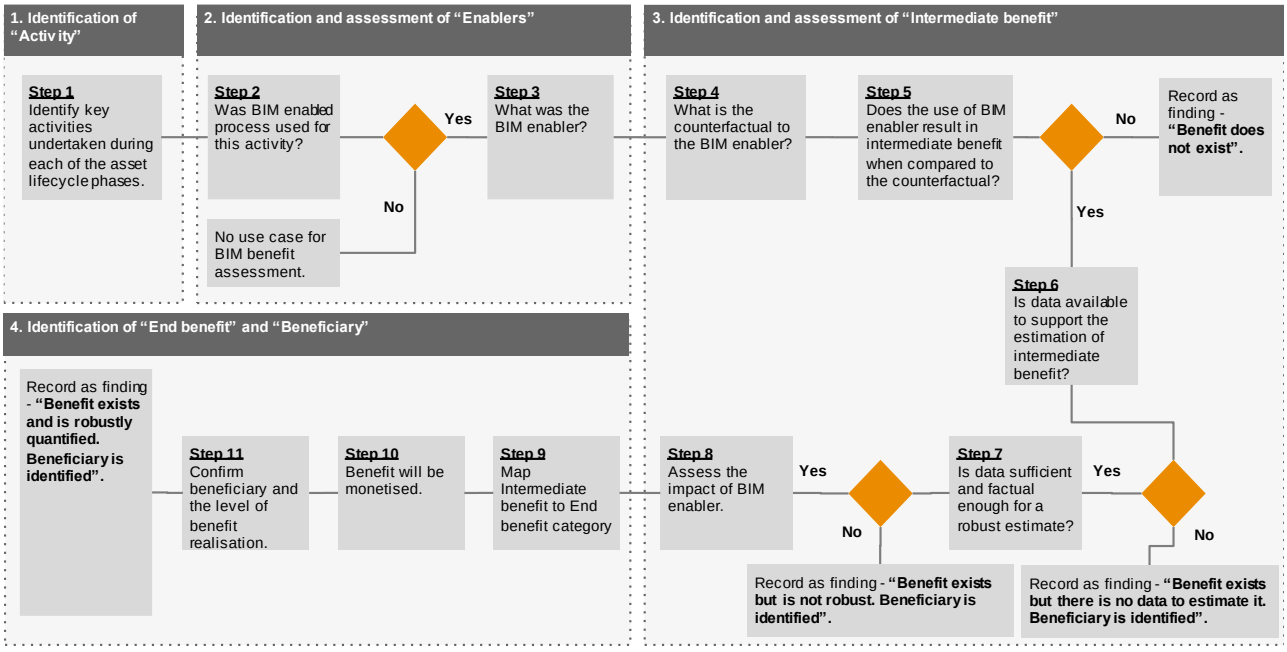


Figure 5. Process map for benefit assessment.

The benefit assessment process map is defined in more detail below in **Table 2. Detailed benefit assessment process.** This layout has been introduced to provide clarity on the process, such that it can be applied more consistently across multiple projects, using different resources, if necessary.

Process step	Description
1 Identification of "Activity"	**Inputs** – Project documentation, data and consultations. Extended PwC BMM and reference material. **Resources** – Construction project delivery teams including consultants and/or contractors. External BIM and capital project experts. **Process/ control** **Step 1** - Consultation through workshops with project teams to identify the key activities carried out in each of the asset lifecycle stages. These activities would be standard activities such as cost estimation, project planning, design coordination or information exchange that are carried out with or without BIM. The assessment of activities will be led by BIM and capital project experts. **Outputs** – A list of key activities by stage to inform further benefit investigation.
2 Identification and assessment of "Enablers"	**Inputs** – Evidence of BIM enablers used on the project. **Resources** - Construction project delivery teams including consultants and/or contractors. External BIM and capital project experts. **Process/ control** **Step 2** – Assess how BIM was enabled during the delivery of an activity. If a BIM process was not used to deliver an activity, then it will not be used for benefit assessment. If BIM was enabled, then the enabler will be identified in Step 3. **Step 3** – Identify the BIM enabler. For example, project cost estimation can be done in two ways: 1) A manual process of measuring quantities using drawings and spreadsheets for calculating quantities with corresponding rates; or, 2) An automatic process using software to extract material quantities from a digital BIM model. Using software to automate the measuring process saves time compared to the manual process. In the first case, there is no enabler for realisation of BIM benefit, whereas in

Process step	Description
	second, the enabler is the increased automation in material quantity take-off using software. The assessment of enablers will be led by BIM and capital project experts. **Outputs** - The key output for this phase is the list of BIM enablers for the key activities.
3 Identification and assessment of "Intermediate benefit"	**Inputs** – Specific project documentation and data relating to the identified BIM enabler from previous steps. **Resources** - Construction project delivery teams including consultants and/or contractors. External BIM and capital project experts and economists. **Process/ control** **Step 4** identifies the intermediate benefit or direct effect from the use of BIM enablers. To assess the effect, a counterfactual for the BIM enabler needs to be established. Using the cost estimation example in the previous section, the counterfactual for increased automation in material quantity take-off using quantity extraction software is using manual quantity measurement. The assessment of the counterfactual will be led by BIM and capital project experts and verified by the economists. **Step 5** – Discuss the impact of the BIM enabler with the project teams to understand if the impact is positive or negative, and what the impact is. This part of the process will be led by economists and supported by BIM and capital projects experts. If the impact is negative, the finding will be recorded as "Benefit does not exist." If the impact is deemed to be positive, then data will be requested from the project teams. **Step 6** - Data that supports the estimation of the benefit and identification of the beneficiary will be reviewed and assessed for sufficiency and robustness. Data gathering requests will be led by BIM and capital projects experts, with beneficiary analysis led by economists. If data does not exist, the finding will be recorded as "Benefit exists but there is no data to estimate it". Beneficiary analysis can still be carried out in the absence of data. **Step 7** - Data sufficiency testing will be led by economists. If data is proven to be insufficient or not robust enough, the finding will be recorded as "Benefit exists but it is not robust". Beneficiary analysis can still be carried out without robust data, provided it has not been done in the previous step. **Step 8** - The impact of the BIM enabler will be assessed. Assessment of the impact will be led by economists. **Outputs** – The key output of this phase is the list of identified intermediate benefits and their potential beneficiaries.
4 Identification and assessment of "End benefit" and "Beneficiary"	**Inputs** – BIM enabler and intermediate benefit data from previous steps. **Resources** – Economists, BIM and capital projects experts. **Process/ control** **Step 9** - The intermediate benefit will be mapped to the end benefit category based on the benefits framework. This will enable aggregation of the effects of benefits by category. **Step 10** - The benefit will be monetised to assess the financial value of the benefit. This step is defined in more detail in the 2018 PwC BMM. **Step 11** – The beneficiary and level of the benefit realisation will be confirmed (e.g. project, programme, organisation). Steps 9 to 11 will be led by economists and supported by BIM and capital projects experts.

Process step	Description
	Outputs – Once the analysis is completed, the output will be a record that a "Benefit exists, is robustly quantified and the beneficiary is identified." The output can be aggregated with other outputs to demonstrate multiple benefits identified.

Table 2. Detailed benefit assessment process.

Benefit assessment outcomes

The possible assessment outcomes using this method are:

- There is no use case for benefit assessment;
- The BIM benefit does not exist;
- The benefit exists but there is no data to prove it and the beneficiary is identified;
- The benefit exists but the data is not robust, and the beneficiary is identified; or
- The benefit exists, is robustly quantified and the beneficiary is identified.

2.5 Benefit estimation on historic data sets

The availability of the data required to inform benefit estimation is uncertain. In addition to any case study data, analysis will, where possible, be conducted on historic datasets and databases to identify whether there is a correlation[15] between the use of BIM and any resulting benefits.

In addition to obtaining detailed (actual) cost data, data will be required on other parameters that might be expected to drive differences in cost (timing, scale, location, complexity, commercial arrangements, etc.). If large, structured data sets covering multiple projects are available, it may be possible to use econometric analysis to identify the determinants of differences in cost performance that can be attributed to the application of BIM.

However, not all the benefits of BIM will necessarily be reflected in costs, and this approach will not necessarily identify how benefits are attributed across the supply chain. Despite these limitations, this approach may add to the body of evidence to support any conclusions from the Extended PwC BMM.

Data tools and data quality

Any analysis will use advanced business intelligence and analytics software to query, structure, analyse and visualise the available data. Any analysis is likely to be descriptive i.e. it will describe what has happened in the past. It is unlikely that available data will allow for predictive or prescriptive analysis.

These analyses cannot be defined in any meaningful way until the data has been acquired and the nature of the data understood in terms of the following factors:

- **Data content** – What does the data represent, what attributes exist and how much data is available.
- **Data source** – What is the origin of the data e.g. system download, manually created spreadsheet, survey data, etc.
- **Data quality** – How reliable is the data in terms of metrics such as completeness, validity and accuracy.
- **Data format** – Is the data machine readable, structured or unstructured, and in a consumable file format.

Any analysis of this type will be designed on a bespoke basis depending on the nature of any available data. As such, this part of the methodology is likely to take second priority to any Extended PwC BMM conclusions, and is likely to be used to support or query any such conclusions.

2.6 Data for benefit analysis

Obtaining data to inform the benefit analysis is a key activity in the application of the Extended PwC BMM. The benefit analysis will use historic data to assess the value of benefits. Data required to inform the benefit estimation is contained within the project documents and will require review and extraction in order to calculate the benefits.

The process of collection and extraction of data represents a key risk for benefit quantification as most projects do not collect and store data in a structured way. It is possible that collecting data and conducting consultations to verify its

[15] Any available data may indicate a correlation between BIM and benefits, but there is a low likelihood of identifying causation of benefits due to BIM using this technique.

validity might consume a significant amount of time and resource and that this process may need to extend over several months to provide reliable datasets for benefit assessment.

Using available data to prove that positive impacts have resulted from BIM, as opposed to any other project interventions, in a statistical manner is unlikely[16]. The Extended PwC BMM accommodates for this by using a structured methodology, use of a BIM counterfactual, applying expert judgement, and by taking a flexible data gathering approach that allows different data gathering techniques as described in **Table 1**.

Approach to data gathering

The data gathering approach will depend on the availability and willingness of stakeholders to share the data required for benefits analysis. A broad range of stakeholders including asset owners, engineering consultants and contractors will be approached for data. The outreach will be done using formal information requests through CDBB, BEIS, IPA and Construction Leadership Council. Stakeholders will be offered Non-Disclosure Agreements and data anonymisation to control how data is handled and ultimately presented in the report.

Benefit estimate robustness criteria

The robustness and the credibility of the benefit estimate will depend on a set of criteria, which have been developed based on economic, capital project, forensic accounting and data analysis expertise. The criteria in **Table 3** have been developed specifically for the Extended PwC BMM should be tested and refined during application. These criteria will be agreed and applied individually for the assessment of each benefit type.

Criteria	Low credibility	Medium credibility	High credibility
Quality of data source	An indicative estimate, or verbal account of an event	Evidence indirectly supported by project data	Evidence directly supported by a record of an historic event (a fact)
Frequency of benefit occurrence	Less than two occurrences on a project	Multiple occurrences on a project	Multiple occurrences on multiple projects
Robustness of counterfactual	No counterfactual	Counterfactual relies on expert opinion	Counterfactual can be quantified using reliable data
Expertise and objectivity of stakeholders	Indirectly involved, and/or impacted by the data	Directly involved, and/or impacted by the data	Experienced, directly involved, but not impacted
Sufficiency of data for analysis	No quantitative data available	Some data or qualitative metrics are available	Quantitative metrics available

Table 3. Benefit estimate robustness criteria.

Project data request

A list of document and data types necessary to inform the benefit assessment is included in **Appendix C**. This is not an exhaustive list and document names might differ from what has been specified, however, it assists in identifying key data points required for benefit assessment.

2.7 Key assumptions and definitions

Key assumptions for the development of the Extended PwC BMM are presented in the following section.

Asset lifecycle

Defining the asset lifecycle is important for benefits assessment. Within the Extended PwC BMM, the asset lifecycle stage has been used to define both: (1) when BIM enablers are implemented; and (2) when the enablers impact on efficiency. There may be cases where the benefits enabled in one lifecycle stage are realised in another stage (e.g. better coordination between multidisciplinary teams in the design phase of a project could lead to time savings in

[16] Proving the benefits of BIM in a statistical manner would require controlled trials of two projects, using a control project identical to the BIM-enabled project in every way, other than its use of BIM. The Extended PwC BMM is likely to demonstrate evidence of BIM benefits, however proving benefits in a statistically reliable way may not be possible.

construction phase). Therefore, a consistent asset lifecycle definition is required for consistent comparison between benefits across different projects.

The existing and the Extended PwC BMM use the same eight stage asset lifecycle, as defined in PAS 1192-2:2013[17] and BS 8536-1:2015. For the purposes of this Extended PwC BMM, this lifecycle has been mapped to National Digital Twin Programme ('NDT')[18] stages and to the UK BIM Framework[19].

Both BIM Level 2 and the UK BIM Framework outline the development of information models[20] across the whole asset lifecycle. In the design and build stages the Project Information Model ('PIM') is developed by the project teams. Once the build stage is finished, the 'as-constructed' PIM is handed-over to the client. Following handover this model becomes the Asset Information Model ('AIM') used for asset management in the operate stage.

These information models are mapped to the asset lifecycle stages to illustrate how information is progressively created and used. The use of the data and information contained within these models by project teams and businesses is one of the core benefit drivers, allowing them to improve business process efficiency and generate benefits. **Table 4** below maps the PAS 1192-2:2013 asset lifecycle stages to the UK BIM Framework BIM Process lifecycle stages.

Original stage name (PAS 1192-1:2013)	Description of stage	#	UK BIM Framework BIM Process (excluding 'Integrate')	Description of the stage	Information model development
0 Strategy	Project business case and strategic objectives	1	Design	This stage includes activities for strategic definition and brief development including business case, project definition, financing, outline procurement strategy and stakeholder engagement.	Development of project initiation information based on existing asset information about the asset, site etc. Asset risk identification and project selection/ optimisation. Information identified will be an input into the Project Information Model (PIM)[21].
1 Brief	Project brief and procurement strategy				
2 Concept	Refined project brief and concept approval				
3 Definition	Approval of co-ordinated developed design				
4 Design	Integrated production information			This stage includes activities for development of design information from conceptual into technical, "for construction" information.	Development of PIM based on contributions from the multidisciplinary team in preparation for build.
5 Build & Commission	Asset production	2	Build	This stage includes construction activities on site as well as commissioning and handover of the built asset from	Use of PIM for construction and development of it into the As Constructed PIM for handover to client.
6 Handover & Close-out	As-built information transfer to the client/asset operator				

[17] The standard has currently been withdrawn and superseded by ISO 19650-1:2018 and ISO 19650-2:2018.
[18] Centre of Digital Built Britain, 'National Digital Twin programme', 2018, available at https://www.cdbb.cam.ac.uk/national-digital-twin-programme
[19] UK BIM Framework, 'Standards & Guidance' 2018, available at https://ukbimframework.org/standards-guidance/
[20] 'Set of structured and unstructured information containers' as per ISO 19650-2:2018
[21] Information model relating to the delivery phase (as per ISO 19650:1-2018). Note: During the project, the project information model can be used to convey the design intent (sometimes called the design intent model) or the virtual representation of the asset to be constructed (sometimes called the virtual construction model).

Original stage name (PAS 1192-1:2013)	Description of stage	#	UK BIM Framework BIM Process (excluding 'Integrate')	Description of the stage	Information model development
				supply chain to the client.	
7 Operation & End of life	Asset in operation and disposed of in the end of life	3	Operate	This stage includes activities for operation and maintenance of the asset including planned and reactive maintenance and disposal of the asset.	Accepting 'As Constructed' PIM as Asset Information Model (AIM)[22] and using it for operation and maintenance. AIM is maintained to capture changes to the asset.

Table 4. Mapping of 2018 PwC BMM asset lifecycle stages to 2020 Extended PwC BMM stages.

Definition of a BIM-enabled project

The Extended PwC BMM will need to identify BIM enabled projects for the purposes of benefits assessment. For the purposes of this Extended PwC BMM, the definition used for a BIM enabled project will be "a project that implemented information management methods in accordance with BIM Level 2 and/or UK BIM Framework requirements".

When considering development of the Extended PwC BMM and potential data sources, the above definition allows for the inclusion of projects that utilised BIM and commenced following inception of the government BIM mandate in 2016 and the more recent release of ISO 19650 standards in 2018. A comparison of the standards and guidance documents underpinning the definitions of BIM Level 2 and UK BIM Framework[23] is provided in **Table 5** below. Together, these provide the definition for BIM-enabled projects for the purposes of the Extended PwC BMM.

BIM Level 2 Mandate	UK BIM Framework
PAS 1192-2:2013	Standards – ISO 19650 – Parts 1, 2
PAS 1192-5:2015	Same as BIM Level 2 Mandate
PAS 1192-3:2014	
Did not exist at the start of the mandate	PAS 1192-6:2018
BS 1192-4:2014	Same as BIM Level 2 Mandate
BS 8536-1:2015	
BS 8536-2:2015	
Did not exist as the start of the mandate however relevant guidance existed for PAS standards	Guidance Part 1: Concepts (Second Edition)
	Guidance Part 2: Processes for Project Delivery (Second Edition)
	PD 19650-0:2019 Transition guidance

[22] Information model relating to the operational phase (as per ISO 19650:1-2018)

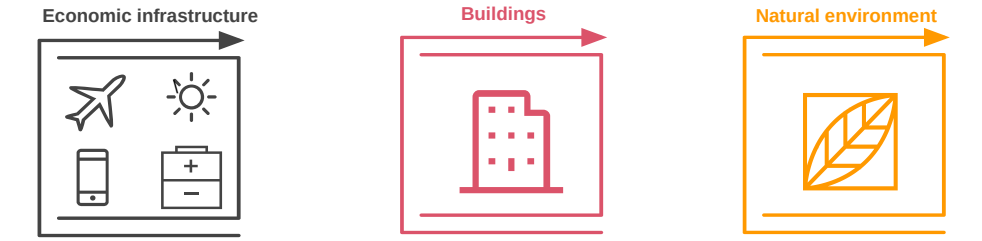
[23] The UK BIM Framework is largely based on ISO19650, which was released in 2018, and as such, the number of projects that have used this standard, and available for the Extended PwC BMM is likely to be low.

BIM Level 2 Mandate	UK BIM Framework
Government Soft Landings	Same as BIM Level 2 Mandate but tailored for PAS 1192 Parts 1 and 2

Table 5. Comparison of standards and guidance between BIM L2 and UK BIM Framework.

Key industry sectors

The key industry sectors were selected to align with the definition of the built environment as per the National Digital Twin Programme[24][18].



Economic infrastructure sub-sectors include:

1. Transport
2. Energy
3. Flood defence
4. Telecommunications
5. Utilities

Buildings sub-sectors include:

1. Residential buildings, housing development
2. Commercial and industrial buildings
3. Social infrastructure (e.g. hospitals, schools, defence, justice, etc)

Natural environment sub-sectors include:

1. Urban space
2. Landscape

Figure 6. Key industry sectors as per Gemini Principles document.

For the purposes of this Extended PwC BMM, the key industry sectors selected for use in the assessment and comparison of BIM benefits and beneficiaries are based on the Gemini Principles[25]: (1) Economic Infrastructure; (2) Buildings; and (3) Natural Environment[26].

Both Economic Infrastructure and Building industries have unique challenges and opportunities in relation to the application of BIM on projects. These challenges and opportunities will be explored in more detail through the application of the Extended PwC BMM.

As an example, Buildings typically follow the RIBA Plan of Work[27], often have a repeatable building sequence, more standardised construction methodologies, and use a common cost breakdown structure. Conversely, Economic Infrastructure are more likely to use bespoke plans of work across sub-sectors, construction methodologies and cost structures. Additionally, Economic Infrastructure schemes can span many years, which means project teams, scope, and delivery plans are more likely to change over the course of a project. These factors will likely have an impact on the application of the Extended PwC BMM.

[24] Centre of Digital Built Britain, 'National Digital Twin programme', 2018, available at https://www.cdbb.cam.ac.uk/national-digital-twin-programme

[25] Centre of Digital Built Britain, 'The Gemini Principles', 2018, available at https://www.cdbb.cam.ac.uk/system/files/documents/TheGeminiPrinciples.pdf

[26] Natural Environment features in the definition of "built environment", however, will be excluded for benefit assessment due to the expectation that access to stakeholders and available data will be very limited.

[27] Royal Institute of British Architects, 'RIBA Plan of Work' available at: https://www.architecture.com/knowledge-and-resources/resources-landing-page/riba-plan-of-work

Types of BIM benefits

The types of BIM benefits and the benefit pathways[28] used in the Extended PwC BMM are based on the 2018 PwC BMM[29]. In order to illustrate how 2018 PwC BMM pathways map to the UK BIM Framework BIM Process, the benefit pathways were aggregated by high level benefit categories and mapped to the lifecycle stage as shown in **Figure 7**.

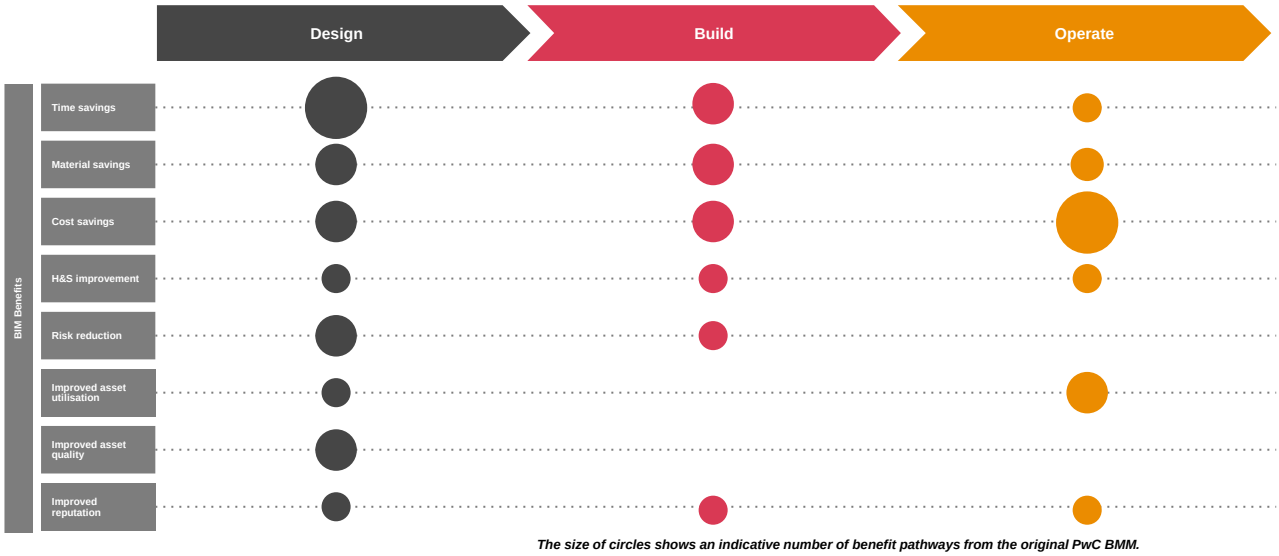


Figure 7. Number of benefit pathways from PwC BMM along the lifecycle of an asset.

The Extended PwC BMM sets out an approach to analyse project data using the PwC BMM pathways to establish the high-level benefits shown above. Only direct benefits[30] will be considered as part of the Extended PwC BMM. Indirect effects will not be considered.

Key beneficiaries

Assessment of the beneficiary organisations from the use of BIM is the key addition in the Extended PwC BMM. Key beneficiaries are defined based on the concepts and the assumptions outlined in the 2018 PwC BMM[31].

The definitions for beneficiaries are provided below:

- **Direct beneficiary** - A party who realises the direct effect of the benefit (e.g. in case of a time saving it is the party who directly saves time).

Direct beneficiaries are further divided into two sub-categories:

1. **Immediate beneficiary** - A party who delivers the BIM-enabled activity and directly realises the benefit (e.g. time saved in design is delivered and monetised as a cost saving by applying labour cost to time saving by designers).
2. **End beneficiary** - A party who does not necessarily deliver the BIM-enabled activity but still directly realises the benefit. (e.g. due to pain/gain share contractual arrangements, the benefit of a time saving in

[28] An impact pathway describes how application of BIM Level 2 can lead to benefits that can be measured. The pathway begins with an activity undertaken during the asset lifecycle, during which a 'BIM enabler' or technical capability of BIM is employed, resulting in intermediate and end benefits.
[29] PwC, 'BIM Benefits Measurement and Report', March 2018, available at: https://www.cdbb.cam.ac.uk/BIM/BBM
[30] Example: Direct and indirect benefits of BIM. The use of federated BIM models for design coordination and management can lead to reduction in construction errors on site and result in time savings in construction and earlier project completion. The indirect effect of time savings in construction is a potential earlier handover of the finished project to the client resulting in earlier use of the asset. The earlier use of the asset can result in improved asset utilisation (e.g. earlier handover of rental space to the tenants).
[31] PwC, 'Introductory note to BMM', Section 5.2, Practical implication 1: establishing who accrues the benefit, March 2018, available at: https://www.cdbb.cam.ac.uk/BIM/BBM

construction delivered by a contractor is shared between the contractor and the client where client is the end beneficiary and the contractor is the immediate beneficiary).

- **Indirect beneficiary** - A party who can potentially realise the benefit only if it is passed from direct beneficiaries. E.g. indirect beneficiaries of the early completion and opening of a highways project (due to BIM) could be those members of the public that use the highway.

In the Extended PwC BMM, only the direct beneficiaries, typically within the design, construction, or operational teams or businesses, will be considered.

Multiple stakeholders can realise the benefit depending on the impact pathway. **Figure 8** below summarises the potential beneficiaries from BIM in each of the stages based on analysis of the available case studies and workshops with CDBB working group. The figure also includes the potential beneficiaries for 'Extended PwC BMM in Asset Management' document[32]. Actual (direct) beneficiaries will be identified and confirmed during the Phase 2 of the project.

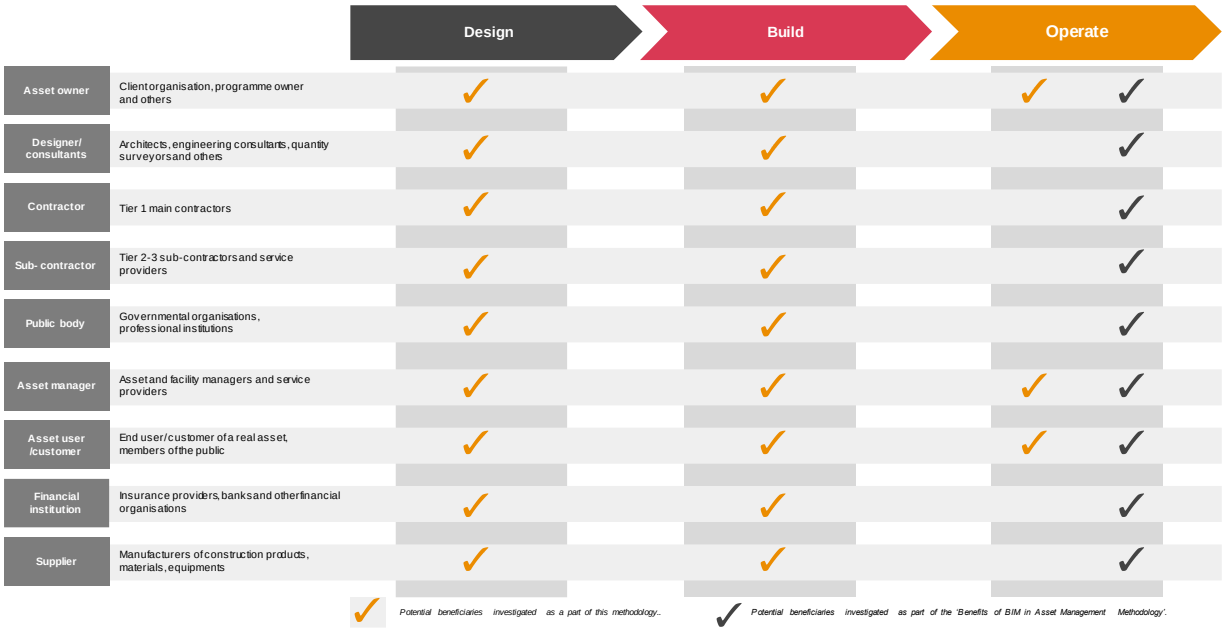


Figure 8. Potential beneficiaries at various lifecycle stages of an asset.

Beneficiaries will vary based on factors considered during the benefit measurement process. These factors include but are not limited to:

- The nature of the project or asset;
- The effect of contractual models;
- The maturity of BIM utilisation;
- The lifecycle stage of the asset; and
- The type of benefit.

The nature of the project or asset

The use of BIM on specific types of projects or assets will likely influence who the beneficiaries are. In the case of a newly built capital infrastructure project that required capital investment (e.g. through private finance), insurers and financial organisations may benefit from how BIM related processes can de-risk the project and increase confidence in delivery. However, this benefit may manifest differently and have different beneficiaries in the absence of private finance.

The effect of contractual models

Contractual models will influence the beneficiaries. Models that include a pain-gain share or incentive mechanisms make it easier for clients and their supply chain to share benefits compared to lump sum contracts.

For example, in a lump sum contract model, most construction risk (and therefore the associated reward) often resides with the contractor, and therefore the contractor is not incentivised to generate and share benefits with the client.

[32] PwC, 'Assessment of the Benefits of BIM in Asset Management, Part 2 – Context and methodology'.

However, in a target cost contract with a pain-gain incentive mechanism, both client and the contractor are incentivised to gain efficiencies. This can encourage both parties to use BIM to collaborate and find cost savings on the project.

The maturity of BIM utilisation

The level of maturity in utilising BIM is a key enabler for stakeholders to realise its benefits in different lifecycle stages. For example, if an asset owner intends to benefit from a quicker and data-rich asset handover, then a detailed Asset Information Requirement ('AIR')[33] should be developed and utilised. A well-defined and used AIR can save time, and unlock potential further benefits in the operate stage, however this requires a high level of BIM and digital maturity to exist across the design, construction and operate business functions of an asset owner.

The lifecycle stage of the asset

There are certain lifecycle stages where benefits are more likely to be realised by specific stakeholders as beneficiaries. For example, following handover at the end of the build stage there are reduced, or no benefits realised by contractors. Instead, asset owners, managers and the asset users are the potential beneficiaries in the operate stage, due to improved asset utilisation.

The type of benefit

There are certain types of benefit, which can be only realised by specific stakeholders using BIM. For example, improved quality benefits will mainly be realised by asset managers or asset users.

Cost of BIM implementation

The focus of this methodology is on the benefits of BIM and not the costs of implementing or applying BIM. This means that the Extended PwC BMM can provide important inputs for a cost-benefit analysis but using the Extended PwC BMM alone will not provide enough information to assess the return on investment in BIM.

2.8 Extended PwC BMM development approach

The approach adopted to extend the 2018 PwC BIM BMM, is shown in **Figure 9**.

Figure 9. Methodology development steps.

Step 1 - Workshops and consultations were undertaken with members of CDBB working group consisting of public and private sector representatives. For the list of representatives refer to **Appendix B: CDBB Steering Group and Working Group**

These sessions tested and agreed definitions for BIM-enabled projects and the asset lifecycle to be used for measuring BIM benefits against. The session also provided guidance on the definition for key industry sectors for analysis. Lessons learnt from the application of the 2018 PwC BMM on real projects were also discussed and considered in the extended methodology.

Step 2 - Focused on adapting the 2018 PwC BMM based on agreed assumptions and developing the revised benefits framework. This step utilised PwC's expertise in developing the 2018 PwC BMM, drawing upon capital project and economics expertise, as well as consulting with members of the CDBB working group.

Step 3 - The Extended PwC BMM was reviewed by economists and tested using example data.

Step 4 - The Extended PwC BMM was made available for review by the CDBB Steering Group and Working Group and finalised ready for testing on pilot projects.

2.9 Benefit measurement expertise

Application of the Extended PwC BMM requires a combination of BIM, capital project, and economic expertise. BIM and capital project expertise will be necessary to understand the use of BIM, identify relevant project documents and extract

[33] 'information requirements in relation to the operation of an asset' based on ISO 19650-1:2018

data points for benefit analysis. Economic expertise will be used to verify the counterfactual, to measure the impacts of BIM through changes in time or resource, and to monetise the value of those impacts.

3 Project planning

This section describes an indicative plan and key project management considerations for the application of the Extended PwC BIM benefits methodology on current or completed projects.

3.1 Project plan

After completion of this methodology phase 1, the project delivery plan consists of two phases: Phase 2a and Phase 2b. Phase 2a is a preparation phase for Phase 2b when the benefits will be measured.

Phase 2a – Preparation phase

Phase 2a will focus on three primary activities:

1. **Stakeholder outreach** – Engaging and confirming the stakeholders and projects for benefit assessment. Plan of methodology application will be refined based on confirmed access to stakeholders, projects and data, and BEIS and UoC will be updated accordingly.

2. **Data sourcing and collection** – Identifying, validating and confirming access to data and information for benefits measurement. This phase will include activities that provide access to data and information, for example, establishing non-disclosure agreements and commercial arrangements for data as required. Available data will be collected during this phase.

3. **Planning for data collation and processing** – Planning, structuring, collating, organising, manipulating, processing and storing available data and information. Template documents, processes and tools to manage the data and information for benefits analysis will be established.

Phase 2b – Benefits measurement phase

Phase 2b will be delivered in a series of Sprints. A Sprint is a two-week work period during which the engagement teams will proactively deliver the scope of work included in the sprint using the Extended PwC BMM. The scope of work, and application of the Extended PwC BMM will be based on the specific characteristics of the projects and consultation with stakeholders. The results of Sprints 1 to 3 will be provided to BEIS and UoC for review and comment. A draft report with benefit findings will be created during the final sprints. A final report will incorporate the comments and updates for final submission.

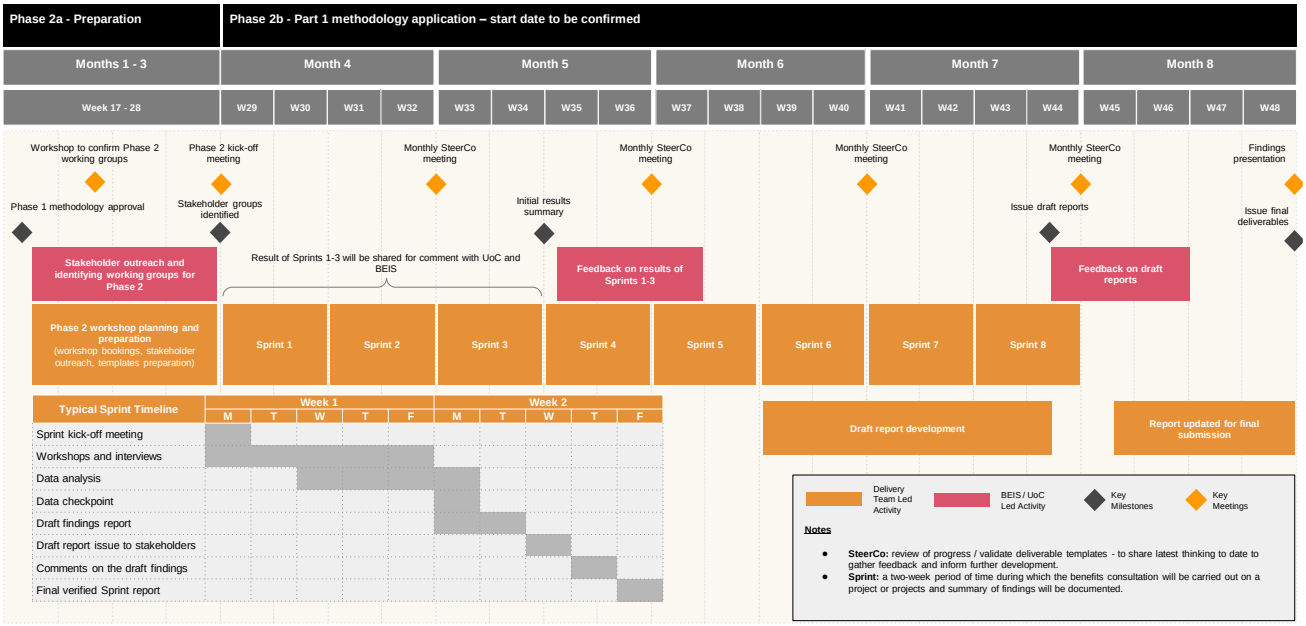


Figure 10. Phase 2 plan on a page.

Each Sprint will follow a similar and repeatable execution plan, which will typically comprise of the following activities:

- **Kick-off meeting** – To summarise the key information in relation to benefits about the project or a stakeholder and the approach to workshops and interviews;
- **Workshops and interviews** – To understand the project context, explain the Extended PwC BMM, and identify potential benefit pathways;
- **Data collection and processing** – Collected data will be validated by the workshop attendees to avoid misinterpretation or loss of data. The data points will be input into the benefits template documents or tools and analysed;
- **Benefits measurement** – Data and information will be measured for benefits using the 'Extended PwC BMM' and will be subject to challenge by economists and forensic experts to provide rigour to the process;
- **Reporting** – Results of the analysis will be summarised in draft findings reports and shared with the workshop stakeholders for validation. Reports will be updated and finalised based on comments and feedback from the stakeholders. These reports will form the basis for the final report which will incorporate findings from all Sprints.

3.2 Project risks, assumptions and dependencies

The section below outlines the key project risks, assumptions and dependencies.

Risks

Key risks in applying the benefit measurement methodology have been identified in **Table 6** below with mitigation measures.

Risk	Mitigation measures
A lack of access to stakeholders who are willing to participate in the benefit measurement project, will lead to fewer projects to review, which would reduce the confidence in any benefits identified.	Initial outreach to key industry stakeholders within Tier 1 contractors and consultants has already started, and support from senior and influential UK construction industry stakeholders has been gained.
Insufficient project data and information to measure benefits from will reduce the clarity and robustness of any benefit estimates.	• Pilot projects are identified to test the availability of data; • Project data will be reviewed prior to full-scale measurement and workshops; • Initial consultations with Tier 1 contractors and consultants have been held to confirm that project data is available; and, • Non-Disclosure Agreements have been prepared to allow controlled data sharing for benefit estimation.
A lack of an appropriate counterfactual to enable benefit assessment will reduce the number of benefit impact pathways that can be measured, which will reduce the confidence in any benefits measured.	In line with prior experience of identifying counterfactuals, an assumed counterfactual for benefit estimation will be applied, based on examples from industry, expert opinion, and benchmarks.
The principles for the methodology and the requirements for facts and evidence to quantify the benefits may mean that the reported benefits of BIM are more likely to be lower bound estimates as opposed to upper bound estimates.	Any final BIM assessment report will be transparent with regards to data, methodologies, assumptions and interpretations. The BIM benefit assessment outcomes defined in the Extended PwC BMM will identify where benefits are found and will clarify whether those benefits are supported by evidence.
The CDBB Working Group generally have vested interests in BIM-related initiatives, and therefore may apply subconscious bias when contributing to any work related to the Extended PwC BMM.	Refer to the guiding principles for the Extended PwC BMM and apply the methodology rigorously, with attention to elements such as the counterfactual and the estimate robustness criteria.

Table 6. Key risks and mitigation measures for benefit measurement.

Assumptions

Key assumptions that apply to the delivery of the Extended PwC BMM project are listed below:

- CDBB and BEIS stakeholders will continue to assist with identifying potential organisations and projects to measure the benefits, and help with initial stakeholder outreach (e.g. introductions); and,
- Workshops on the same projects will be carried out with a range of stakeholders to allow for rigorous identification of benefits and beneficiaries.

Dependencies

Key dependencies that may be required to deliver of the Extended PwC BMM project are listed below:

- The project team will have access to stakeholders to brief them on the purpose of the project, methodology and the required data and information types;
- Project stakeholders will be available for benefit workshops within the agreed period; and,
- Project stakeholders will share enough project data and expert opinions to assess the benefit and beneficiaries.

3.3 Target stakeholders

Target stakeholders to engage and apply the methodology in order to quantify the benefits of BIM were identified as:

- Designers and design consultants;
- Contractors;
- Asset owners and asset managers;
- Product suppliers and manufacturers; and,
- Insurers and financial institutions.

The list of target stakeholders is not exhaustive.

Appendix A: Impediments to adoption of BIM

Based on the 2018 PwC BMM[34] and the latest NBS BIM Report[35] this section reports the most common challenges and impediments to the implementation of BIM. These challenges will likely be expanded and validated during any subsequent application of the Extended PwC BMM.

1. The costs and time associated with the implementation – BIM requires changes in technology, tools and processes, and associated training. This means there are likely to be costs associated with implementation, which vary depending on the size and initial digital maturity of the organisation. However, in order to overcome some of the major obstacles identified by industry professionals[36] [37] , such as 'lack of in-house expertise' and 'time to get up to speed', initial investment may be required.

2. There is no joint whole life cycle cost approach to planning and procurement – The whole-life cost or total expenditure (TOTEX) of an asset may not be considered during the strategy or design phases. Also, the key operation and maintenance stakeholders may not be involved early enough to inform whole-life or TOTEX decisions.

3. The benefits of BIM are not always accrued to the those who bear the costs - Benefits realised as a result of BIM do not always accrue to the stakeholders making the initial investment on its implementation. This potential misalignment of incentives can be further compounded by the contractual arrangements[38] in place.

4. Historically, there is a low level of digitisation in the construction industry - Traditionally the construction industry is among the least digitised sectors and this potentially results in lower productivity when compared to other sectors[39]. Therefore, greater investment is likely to be needed to implement BIM and new digital technologies. Furthermore, as the level of digitisation has been historically low, there is a perceived resistance to adopt new technologies and procedures.

5. The Government has mandated BIM, but there is lack of enforcement - The Government's BIM Level 2 mandate has set the expectation that BIM adoption will increase, however, there is a lack of enforcement[40] which may result in limited adoption, or adoption that is not sustained if project decision makers do not see initial benefits .

6. There is a lack of evidence for the benefits of BIM – There is limited publicly available evidence to support, quantify and clarify the benefits of BIM. While the 2018 PwC BMM provides a framework to measure the benefits, it's use on projects is discretionary and there is no central management function to provide oversight to any benefit measurement.

[34] PwC, 'BIM Benefits Measurement and Report', March 2018, available at: https://www.cdbb.cam.ac.uk/BIM/BBM

[35] National Building Specification, 'National BIM Report 2019 - The definitive industry update', 2019, available at https://www.thenbs.com/knowledge/national-bim-report-2019

[36] National Building Specification, 'National BIM Report 2017', 2017, available at https://www.thenbs.com/knowledge/nbs-national-bim-report-2017

[37] National Building Specification, 'National BIM Report 2018', 2018, available at https://www.thenbs.com/knowledge/the-national-bim-report-2018

[38] National Building Specification, 'National BIM Report 2019 - The definitive industry update', 2019, available at https://www.thenbs.com/knowledge/national-bim-report-2019

[39] The Economist, 'The construction industry's productivity problem', 2017, available at https://www.economist.com/leaders/2017/08/17/the-construction-industrys-productivity-problem

[40] National Building Specification, 'National BIM Report 2019 - The definitive industry update', 2019, available at https://www.thenbs.com/knowledge/national-bim-report-2019

Appendix B: CDBB Steering Group and Working Group

The CDBB steering group and CDBB working group that was consulted during the development of the Extended PwC BMM comprised of the following individuals:

Steering Group	
Alexandra Bolton	CDBB
Barry Blackwell	CDBB and BEIS

Working Group	
Rachel Atcherson	Department for International Trade
Marcus Deeley	Department for International Trade
Amelia Burnett	Centre for Digital Built Britain
Mark Enzer	Mott Macdonald and National Digital Twin Programme
Alana Gluck	Centre for Digital Built Britain
Anne Kemp	Atkins and UK BIM Alliance
Alex Luck	Centre for Digital Built Britain
Adam Matthews	Centre for Digital Built Britain
Fiona Moore	Centre for Digital Built Britain
David Philp	Aecom
Terry Stocks	Faithful & Gould
Pauline Tzachrista	Centre for Digital Built Britain

CDBB Working Group Meetings were held on the following dates:

Working Group Meetings	
22nd January 2020	JJ Tompson Room, Maxwell Centre, JJ Tompson Avenue, CB3 0HE, Cambridge
14th February 2020	JJ Tompson Room, Maxwell Centre, JJ Tompson Avenue, CB3 0HE, Cambridge
16th March 2020	JJ Tompson Room, Maxwell Centre, JJ Tompson Avenue, CB3 0HE, Cambridge

Appendix C: Data for benefit assessment

No.	Document/data type	Content and aim	Potential location	Preferred format
1	**Project Management Plan/Project Execution Plan**	Content: Report that sets out the strategy for managing and delivering a project. Aim: To provide the necessary project context to understand the stakeholders involved, project governance, procurement route, contractual arrangements, high level summaries for cost, quality and time targets.	Client/Supply chain Common Data Environment	pdf doc
2	**BIM Documents** • OIR (Organisational Information Requirements) • EIR (Exchange Information Requirements) • AIR (Asset Information Requirements) • BEP (BIM Execution Plan) • Supply chain capability statements	Content: Information requirements laid out by the client for asset delivery and operation and supply chain's responses to those requirements. Aim: This will provide an insight into how BIM processes were implemented on the project and which BIM enablers have been deployed.	Client/Supply chain Common Data Environment	pdf doc xls
3	**Project progress reports**	Content: Report describing the progress of the project phase. Aim: This will provide the necessary context to understand the technical parameters of the project and understand other project related documentation.	Client/Supply chain Common Data Environment	pdf doc
4	**Project schedules** • Baseline project schedule • Actual final project schedule	Content: Information describing the planned and actual project programmes with breakdown of project stages. Aim: This will provide an insight into the duration of project phases.	Client/Supply chain Common Data Environment	msp p6 xls asta others

No.	Document/data type	Content and aim	Potential location	Preferred format
5	**Project Cost Plans/Project Financial Plans** • Cost data	Content: Information describing the planned and actual project costs including information cost breakdowns by stage or area and estimate for project CAPEX risk contingency. Aim: This will provide an insight into: • Planned project CAPEX cost (total and breakdown by areas – planning, design, construction, handover) • Actual project CAPEX cost (total and breakdown by areas – planning, design, construction, handover) • Initial project CAPEX risk contingency and its change during the project lifecycle • Whole-life asset cost estimates	Client/Supply chain Common Data Environment	pdf doc xls
6	**Project Bill of Quantities (BoQ)** • Baseline BoQ • Actual final BoQ • Material quantity data	Content: Information describing the planned and actual bill of quantities. Aim: This will provide an insight into: • Average total daily project 'prelim' costs • Planned quantity of materials (kg or m^3) • Actual quantity of materials (kg or m^3) • Material rates (£/kg or m^3) • Labour costs (£/hour) • Other relevant costs	Client/Supply chain Common Data Environment	pdf doc xls
7	**Tender Queries (TQ) Register** (during procurement) • Procurement process data	Content: Information describing the number of TQs queries issued on the project. Aim: This will provide an insight into: • Number of TQs on the project including descriptions of TQs to estimate which ones could have been prevented with BIM processes.	Client's systems	xls
8	**Request for Information (RFI) Register** (during construction)	Content: Information describing the number of RFIs issued on the project. Aim: This will provide an insight into the number of RFIs on the project, including descriptions of RFIs to	Client/Supply chain Common Data Environment	xls pdf

No.	Document/data type	Content and aim	Potential location	Preferred format
		estimate which ones could have been prevented with BIM processes.		
9	**Early warning log, Change management logs/Change request forms/Scope changes**	Content: Information describing the number of RFIs issued on the project. Aim: This will provide an insight into: • Number of project changes described by category – client/supply chain initiated, approved or discarded • Cost of each change (time and materials) • Average cost per change • Total cost of all changes	Client/Supply chain Common Data Environment	xls pdf
10	**Health & Safety records**	Content: Information describing the number of H&S accidents occurring on the project during construction or H&S accidents in asset operation. Aim: This will provide an insight into: • The number of fatal and non-fatal accidents per project • The number of incidents of work-related ill health per project.	Supply chain's Common Data Environment	xls pdf
11	**Project Risk Register, Hazard Log, CDM Register** • Risk data	Content: Information describing the number and type of risks associated with project. Aim: This will provide an insight into: • The number of risks • Type of risks • Cost of risks	Client/Supply chain Common Data Environment Risk management system	xls pdf
12	**Clash detection reports**	Content: Information describing the number of clashes that occurred on site. Aim: This will provide an insight into: • Number of clashes that occurred or would have occurred on site • Cost of each clash • Average cost of clashes	Client/Supply chain Common Data Environment	xls pdf

No.	Document/data type	Content and aim	Potential location	Preferred format
13	**Site inspection reports including information on defects**	Content: Information describing the number of defects occurring on site that require re-work. Defects require physical re-work to meet the end user requirements. Aim: This will provide an insight into: • Number of defects that require re-work • Cost of each defect (time and materials) • Average cost per defect • Total cost of all defects	Client/Supply chain Common Data Environment	pdf xls
14	**Legal claims records**	Content: Information describing the number of legal claims by supply chain against client. Aim: This will provide an insight into: • Number of supply chain claims • Total cost of each claim • Average cost of a claim • Legal fees • Labour and materials (including overheads) required to execute work • Labour to review the claims by the internal team	Client/Supply chain Common Data Environment Contract management system	pdf xls
15	**Supply chain timesheets or consultations with the supply chain to establish man/hours estimates (time and motion studies)**	Content: Time spent by supply chain staff on various project activities. Aim: The timesheet or consultation should provide an assessment into average duration of time required for a staff member to complete activities such as: • Author design by stage (concept to technical) • Coordinate design • Review design • Respond to RFI • Fixing a clash in design • Fixing a clash on site • Site induction • Surveying for refurbishment • Inspect an asset • Resolve a defect	Client/Supply chain Common Data Environment Financial management system	xls

No.	Document/data type	Content and aim	Potential location	Preferred format
		• Preparation of as-built information and handover to client		
16	**Client staff timesheets or consultations with the client to establish man/hours estimates (time and motion studies)**	Content: Time spent by client staff on various project activities. Aim: The timesheet or consultation should provide an assessment into average duration of time required for a staff member to complete activities such as: • Business case development • Supply chain procurement • Design review • Stakeholder consultation (e.g. obtaining planning permission) • Project cost estimation • Asset operation • Asset sale • Incident management • Maintenance training • Preparing for refurbishment • Asset operation training • Review of supply chain claims	Client/Supply chain Common Data Environment Financial management system	xls
17	**Contracts with design/construction supply chain**	Content: Legal agreement between client and designers. Aim: The contract could include the following information: • Average daily/hourly wage including overheads or professional rates including overheads • Procurement route • Original scope of works/services • Agreed project programme • Cost of delay • Extensions of original scope • Total cost of works/services	Client/Supply chain Common Data Environment Contract management system	pdf

No.	Document/data type	Content and aim	Potential location	Preferred format
19	**Contracts with maintenance supply chain**	Content: Contract describing arrangements with maintenance providers. Aim: This will provide the total annual cost of asset maintenance services: • Average daily/hourly wage including overheads or professional rates including overheads • Original scope of works/services • Penalties cost when asset is out of operation for longer than expected • Extensions of original scope • Total cost of works/services	Client/Supply chain Common Data Environment Contract management system	pdf
20	**Contracts with operations supply chain**	Content: contract with facilities management providers. Aim: This will provide the annual cost of facilities management operations on a project using AIM including: • Average daily/hourly wage including overheads or professional rates including overheads • Utility bills	Client/Supply chain Common Data Environment Contract management system	pdf
21	**Facilities management cost plan** • Cost data	Content: contract with facilities management providers. Aim: This will provide the annual cost of facilities management operations on a project using AIM including: • Average daily/hourly wage including overheads or professional rates including overheads • Cost of CAFM systems • Utility bills	Client/Supply chain Common Data Environment Cost management system	xls
22	**Asset maintenance cost plan** • Cost data	Content: Document that includes information about the breakdown of total asset maintenance costs per year. Aim: This will provide the following information: • Total annual maintenance cost	Client/Supply chain Common Data Environment Cost management system	xls

No.	Document/data type	Content and aim	Potential location	Preferred format
		• Total annual cost of holding inventory for an asset • Total maintenance training cost		
24	**Asset utilisation reports**	Content: Reports showing how utilised the asset is i.e. road is at 80% capacity based on the average traffic flow, or, the number of desks occupied in the office. Aim: to assess whether BIM processes improve the asset utilisation.	Client/Supply chain Common Data Environment Operational asset management system	pdf xls
25	**Maintenance log/reports**	Content: Reports showing the number of maintenance cases per asset Aim: to assess whether BIM processes reduces the number of maintenance operations required	Client/Supply chain Common Data Environment Client's asset management systems	xls pdf
26	**Post-Occupancy Evaluation Forms**	Content: Form comparing asset operating performance against the design targets. Aim: to assess whether there is increased certainty in asset operational performance.	Client/Supply chain Common Data Environment	pdf

Table 7. Examples of data and documents for benefit assessment.