

# *BIM Level 2 Benefits Measurement Methodology*

*Final*

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# Introduction

This document sets out our proposed methodology for measuring the overall benefits that potentially result from the application of Building Information Modelling (BIM) Level 2. Our methodology is focused only on the benefits; it excludes the costs to government construction clients and their supply chains associated with implementing BIM Level 2.

BIM Level 2 is “a process of modelling building information in separate discipline models and sharing and verifying this information with attached data in a controlled manner in a collaborative Common Data Environment”.<sup>1</sup>

Below, we briefly explain:

- How our benefits measurement methodology has been developed.
- The structure and content of the methodology.
- How the methodology can be used by officials in government construction clients to measure benefits.

For further details of the development of the methodology please see the introductory note accompanying this methodology document<sup>2</sup>.

## How we have developed our methodology

Our benefit framework has been developed in consultation with stakeholders, drawing on the relevant literature, to identify the benefits that could potentially arise from the use of BIM Level 2 during asset delivery, asset operation and service delivery. Our framework contains 117 separate impact pathways<sup>3</sup> which detail:

- The asset lifecycle stage in which the benefit originates and the stages at which it accrues.
- The activity being undertaken.
- The ‘BIM Level 2 enabler’ – the element or capability provided by BIM Level 2 that enables the benefit.
- The intermediate benefit.
- The end benefit.

For measurement purposes, we have collated these impact pathways into 22 high level benefit areas and then further grouped the benefit areas into eight measurement categories as shown in Table 1.

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<sup>1</sup> Our definition of BIM Level 2 is based on PAS 1192-2:2013 and interpretation of its clauses.

<sup>2</sup> This note details the approach to developing the benefits framework and the approach to the measurement process. It is recommended pre-reading to this methodology document.

<sup>3</sup> 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. Impact pathway = Activity>BIM Enabler>Intermediate Benefit>End Benefit. For further explanation see section 3.2 of the *Introductory Note*.

**Table 1: Benefit measurement categories, corresponding benefits, and link to detailed benefits framework**

Measurement category	Benefit area	# of individual impact pathways in benefits framework
Time savings	Time savings in Stage 0: 'Strategy' – Stage 3: 'Definition'	3
	Time savings in 'Design'	15
	Time savings in 'Build and Commission'	12
	Time savings from answering requests for information (RFIs) (during 'Build and Commission')	2
	Time savings in 'Handover'	4
	Time savings in incident response	1
Materials savings	Materials savings in 'Build and Commission'	5
	Environmental benefit from fewer materials used	20
Cost savings (time and materials)	Cost savings from better clash detection	6
	Cost savings from fewer changes	5
	Cost savings in operations – facilities management	4
	Cost savings in asset maintenance	4
	Cost savings in refurbishment	4
	Cost savings in asset disposal	3
	Cost savings in litigation	4
Improved health & safety (H&S)	Improved health and safety in construction	3
	Improved health and safety in maintenance / demolition	3
Reduced risk	Reduced project risk contingency in capital delivery phase	5
	Increased certainty in operating expenditure estimates	1
Improved asset utilisation <sup>4</sup>	Improved asset utilisation	5
Improved asset quality for end-user	Improved asset quality	3
Other intangible benefits	Improved reputation	5
<b>Total</b>		<b>117</b>

Our methodology describes how each measurement category of benefit can be both quantified and monetised. Where a benefit cannot be quantified, it provides a description of its value for use in assessing the benefits of BIM Level 2.

Our methodology is consistent with both HM Treasury's Green Book guidance and the Infrastructure & Projects Authority's guidance for the assurance of benefits from major projects. As such it is founded on five key principles (which are discussed in more detail in the **Introductory Note**):

- 1 It is holistic and seeks to cover all potential economic benefits – direct and indirect, and intended and unintended.
- 2 It is based on the development of impact pathways which helps to avoid double counting.

<sup>4</sup> Excludes any benefits that result from lower cost (time and / or materials) and lower risk.  
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- 3 It involves assessing the benefits against an appropriate counterfactual (in which BIM Level 2 is not used).
- 4 It considers impacts over the project lifecycle and suitably discounted so that they are expressed in constant price, present value terms.
- 5 It takes account of risk and uncertainty (including optimism bias).

## ***The structure and content of this methodology document***

Our benefits measurement methodology explains how, when and to whom the benefits from application of BIM Level 2 accrue and provides a suggested method for quantification and, then, monetisation of the benefits. We consider each of the following measurement categories separately:

- 1 Time savings.
- 2 Material savings.
- 3 Cost savings (time and materials).
- 4 Improvements in health & safety
- 5 Reduction in risk.
- 6 Improved asset utilisation.
- 7 Improvement in asset quality for the end user.
- 8 Other intangible benefits.

For each of the eight measurement categories, we describe:

- The types of benefits covered by the respective category.
- How the benefits arise.
- The potential significance of the benefits during asset delivery and service delivery.
- How to quantify the impact and, then, how to value it (with example calculations).
- The data required.
- Any assumptions that need to be made as part of the assessment.

For each measurement category we also provide a case study box to illustrate the application of our approach with a worked example. Data for the example case studies have been obtained from external sources such as the BIM Level 2 Working Group, other government organisations, supply chain partners and online sources. In some cases, we have created them for illustration purposes as in the example case study for “Improved Health & Safety”. Links to data sources have been included where they exist.

PricewaterhouseCoopers LLP does not have visibility over the accuracy or reliability of the claims made in these case studies, or the data contained within them.

## ***How to use the methodology***

Our benefits measurement methodology is primarily intended for use by government construction clients and asset owners seeking to appraise and/or evaluate the project level benefits from using BIM Level 2. The principles behind this methodology apply broadly to **ALL** construction clients and asset owners, including the private sector. I.e. each of the benefit categories that may accrue to a government construction client may also accrue to a private sector construction client. However, there are important differences to note if applying this measurement methodology as a private sector client. How the benefits accrue may be different, and even if they

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accrue in the same way, they may be valued differently. For example, Green Book valuation principles and procedures are followed throughout the methodology. These are appropriate when appraising projects from the point of view of UK society, rather than from the point of view of a private business, which will have different opportunity cost of capital, methods for treating contingency and risk, et cetera.

Examples (not exhaustive) of areas of the methodology which would be different for private sector clients include:

- Calculating the cost of capital would no longer be guided by the Green Book's social discount rate of 3.5%.
- The opportunity cost of holding contingency would not be calculated at the 3.5% rate, and optimism bias treatment may vary.
- The health and safety impact to a private sector client directly would only include the cost to the employer, and not to additional cost to society.
- The value of improved asset utilisation could be the value of additional profits from using that asset, rather than the social value lost from public services not being provided.

In practice, we believe that measurement efforts should be focused on those benefits that are likely to be most significant and where reliable data are most easily available or can be readily collected. To this end, we explain which factors government construction clients should consider when determining whether and how to focus their use of the methodology (see Chapter 6 of the Introductory Note for further discussion of these issues).

The following sections detail the measurement methodology for each of the measurement categories.

# 1. Time savings

The use of BIM has the potential to result in time savings in a number of different ways, both in asset delivery throughout each stage of the asset lifecycle, and in service delivery (or business as usual) for a government organisation. For example, use of a Common Data Environment (CDE) enables easier ways of working and quicker information exchange. In some cases time savings will accrue in the first instance directly to the supply chain, and in others to the government construction client or the asset owner.

## Significance of the benefit:

- **Asset delivery:** time savings during asset delivery have the potential to be significant for all government construction clients. Academic literature provides evidence of time savings accruing throughout the asset lifecycle as a result of BIM; for example BIM has been suggested to save up to 64% of time taken to complete cost and quantity estimation processes<sup>5</sup>, and up to 70% of time taken to finding and sharing asset information.<sup>6</sup> Time savings will accrue directly both to the parties undertaking design and construction (supply chain contractors) and to government construction clients who will save time on activities such as review of design details, coordination of construction from the client side, and stakeholder consultation.
- **Service delivery:** time savings from use of BIM asset information in service delivery also have the potential to be significant for government asset owners. Time savings will be significant where BIM can help organisations to save time in collecting information to fulfil information requests (from both internal and external stakeholders), or to undertake business/services more quickly (for example incident response on a rail network where an unexpected incident has occurred and services are delayed). Time savings accrue directly to asset owners in service delivery, and may also result in time savings to third parties such as customers and members of the public.

**Monetising the benefit:** Time savings provide monetary savings based on three possible effects:

- 1 Through a **reduction in direct labour cost** – every person hour saved because of BIM Level 2 will result in a labour cost saving on the project. The reduction in full time equivalent labour costs should include overheads in the form of pensions, national insurance and allowances, as well as basic salaries (as per Green Book guidance).
- 2 Through a **reduction in time-dependent recurring preliminary costs** – this saving will result if there is an overall reduction in the duration of the project which results in a reduced need to incur ‘prelim’ costs, and may be a fixed or semi-variable cost reduction per day/week. This reduction in cost will include reduction in labour, and reduction in other time-variant costs such as general site administration, services and security.
- 3 Through **an acceleration of asset delivery**, and hence acceleration of the corresponding project benefits. By reducing the overall time of the asset delivery lifecycle (from *stage 0: strategy* to *stage 6: handover and close out*), this accelerates the timing of the project’s cash flows – both costs and benefits. This changes the net present value (NPV) of the project.

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<sup>5</sup> See for example Taboada, J., and Garrido-Lecca A. (2014), *Case study on the use of BIM at the bidding stage of a building project*, Industry Papers who suggest estimation of quantities with BIM takes 64% of the time taken for estimation without BIM; and Leite, F. *et al.* (2011), *Analysis of Modelling Effort and Impact of Different Levels of Detail in Building Information Models*. Automation in Construction, 20(5), p. 601–609, who suggest cost estimation is 44% faster with BIM.

<sup>6</sup> See for example Lin, Y.C *et al* (2014) *Developing Mobile BIM/2D Barcode-Based Automated Facility Management System*, who suggest using traditional methods of finding information took between 12-23 seconds, whilst with BIM it took only 7-13 seconds, showing up to a 70% reduction in time required when BIM is used to find basic information on a facility for reference; and Migilinskas, D *et al.* (2013) *The Benefits, Obstacles and Problems of Practical BIM Implementation*, Procedia Engineering 57 pp. 767 – 774 who suggest as a result of BIM, approximately 10% of time spent looking for problems is saved as a result of early and easily accessible design information.

### 1) Calculating the reduction in direct labour costs:

- a. Quantify impact:** Determine the change in person hours attributable to BIM Level 2. As described in the **Introductory Note Section 5.3** there are a number of possible ways to do this against an appropriate counterfactual. It is important to understand whose time is saved and how much time is saved.

*For example:* Walk through the process or activity with relevant stakeholders and determine the amount of time required to undertake activities with and without BIM.

- b. Monetise:** Apply labour costs to determine total benefit.

$$\begin{aligned} & \text{Value of time savings (£)} \\ & = (\text{Change in time resulting from BIM (sum of days for all stakeholders with time saving)}) \\ & \times \text{Average daily wage including overheads (£)} \end{aligned}$$

**Data required:** Time savings (days) from BIM for each person who saves time; daily wages (£) including overheads of the people who save time.

### 2) Calculating the reduction in time-dependent recurring preliminary costs :

- a. Quantify impact:** Determine if the duration of a project was shortened because of application of BIM Level 2. As described in the **Introductory Note Section 5.3** there are a number of possible ways to do this against an appropriate counterfactual.

*For example:* Was it possible to reduce the duration of the build and commission phase by using BIM to optimise site planning? Would this reduction have been possible without using BIM? It may be possible to compare the project schedule of a BIM Level 2 project with a similar project that did not use BIM Level 2, taking out differences that occurred for other reasons, to determine the schedule reduction attributable to BIM Level 2.

- b. Monetise:** Apply 'prelim' costs to determine the total benefit.

$$\begin{aligned} & \text{Value of time savings (£)} \\ & = \text{Reduction in project schedule (days)} \times (\text{Project 'prelim' cost per day}) \end{aligned}$$

**Data required:** Project schedules for two similar projects with and without BIM Level 2 (days); an understanding of any project delays due to events that BIM Level 2 could not influence (e.g. delays due to poor weather); an understanding of schedule reduction that can be attributed to BIM Level 2; average daily project 'prelim' costs.

**Note:** It is important to avoid double-counting of benefits from time savings. There will be direct labour costs included in project prelim costs, so these should not be valued separately unless they occur over and above savings from a reduction in project duration. Please see Section 5.1 on double-counting for further explanation.

#### Assumptions:

- **Average wage rate:** In order to value the time saved, it is important to understand whose time is saved, their skills / skill level and sector they work in. This allows an appropriate wage rate to be applied. We assume here that it will be possible to gain insight into the breakdown of whose time is saved from stakeholder knowledge. ASHE provides data<sup>7</sup> on the gross hourly wage rate broken down by industry or by occupation; for example 'construction of railways and underground railways' as an industry or 'bricklayers and masons' as an occupation (see Table 2 below). This data can be used to estimate the average wage rate for employees. (As mentioned above, wage rate is not equivalent to the total labour

<sup>7</sup><https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/bulletins/annualsurveyofhoursandearnings/2016provisionalresults>

cost. Labour cost = wage + overheads. As per guidance from the Better Regulation Executive (2005), the overhead rate of 30% can be used<sup>8</sup>, if actual costs are not available.

**Table 2: Median gross weekly pay for full time workers in the construction industry taken from ASHE data**

Description	Median Gross Weekly Pay (£ in 2016 prices*)
<b>All construction</b>	544.6
Construction of buildings	571.3
Development of building projects	610.0
Development of building projects	610.0
Construction of residential and non-residential buildings	563.9
Construction of residential and non-residential buildings	563.9
Civil engineering	585.0
Construction of roads and railways	575.0
Construction of roads and motorways	572.0
Construction of railways and underground railways	-
Construction of bridges and tunnels	-
Construction of utility projects	535.9
Construction of utility projects for fluids	539.8
Construction of utility projects for electricity and telecommunications	520.0
Construction of other civil engineering projects	600.0
Construction of water projects	-
Construction of other civil engineering projects	600.2
Specialised construction activities	518.2
Demolition and site preparation	560.0
Demolition	557.0
Site preparation	559.5
Test drilling and boring	-
Electrical, plumbing and other construction installation activities	550.0
Electrical installation	568.5
Plumbing, heat and air-conditioning installation	532.0
Other construction installation	480.7
Building completion and finishing	460.1
Plastering	497.4
Joinery installation	458.7
Floor and wall covering	490.4
Painting and glazing	431.0
Other building completion and finishing	474.8
Other specialised construction activities	518.5

<sup>8</sup> The guidance to the application of the Standard Cost Model suggests using an overhead rate of 30% unless specific circumstances suggest otherwise. Available here: <http://regulatoryreform.com/wp-content/uploads/2015/02/UK-Standard-Cost-Model-handbook.pdf>.

Description	Median Gross Weekly Pay (£ in 2016 prices*)
Roofing activities	448.9
Other specialised construction activities	559.6

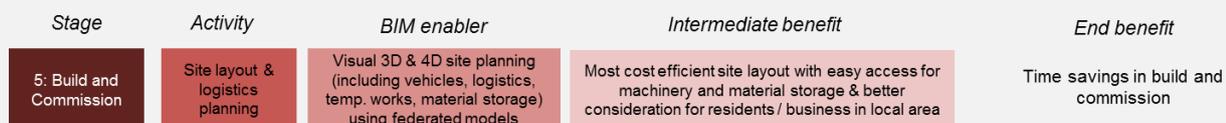
Source: Annual Survey of Hours and Earnings 2016 Data, Table 16.1a.9

- **‘Prelim’ rate:** The rate will be defined within the project’s cost plan and/or bill of quantities.

**Highways England Case Study: A11 Highway – Use of a BIM model to identify opportunities to access areas of site early.**

**Benefit measured:** Time savings in build and commission

**Impact pathway** (from detailed benefits framework):



**Source:** Highways England Lean Tracker<sup>10</sup>

**How use of BIM resulted in time savings:** A BIM model was used during site layout and logistics planning to digitally review conditions on the construction site. During the model review, issues such as poor site access were identified. Changes to the construction schedule were made to improve the efficiency of the plant working pattern and logistical layout. Without the use of BIM Level 2, these changes would not have been identified and the contractor would have proceeded with works as originally planned, resulting in traffic switch works being pushed later in the programme and causing more disruption. Use of BIM Level 2 resulted in a one week reduction in the duration of the project schedule.

A virtual review of the BIM Level 2 model also meant that physical site visits were no longer required, resulting in further time savings with a direct labour impact.

**Result:** The project was delivered in 21 weeks instead of 22 weeks as originally planned, resulting in one week overall programme saving. Additional labour time savings were also realised: better planning of site works resulted in 176 person-hours saved and avoidance of site visits resulted in 110 person-hours saved. The total value of saving was **£62,010** which constituted **0.06%** from the total CAPITAL cost.

**Benefit calculation:**

$$\begin{aligned}
 & \text{Value of time savings from reduced project duration (£)} \\
 & = \text{Total time saved on project schedule in build and commission phase (weeks)} \\
 & \times \text{(prelim rate)} \\
 & = 1 \text{ week} \times \text{£51,000 per week} \\
 & = \text{£51,000}
 \end{aligned}$$

$$\begin{aligned}
 & \text{Value of time savings from labour involved in operating plant and site inspections (£)} \\
 & = \text{(Change in time resulting from BIM (sum of hours for all stakeholders with time saving)} \\
 & \times \text{Average hourly wage including overheads)} \\
 & = (4 \text{ people} \times 2 \text{ hrs} \times 22 \text{ times} + 4 \text{ people} \times 2.5 \text{ hours} \times 11 \text{ times}) \times \frac{\text{£35} \times 1.205}{\text{hour}} = \text{£12,062}
 \end{aligned}$$

$$\text{Total saving} = \text{£51,000} + \text{£12,062} = \text{£63,062}$$

<sup>9</sup><https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/bulletins/annualsurveyofhoursandearnings/2016provisionalresults#main-points>. Hourly gross pay available in table 16.5a.

<sup>10</sup>[https://kol.withbc.com/pub/english.cgi/0/211772599?op=rdb\\_view\\_database&ctp=18&rtp=22&htp=20&modifier\\_1=contains&a\\_view1=-All-Fields--&page=1&search\\_items](https://kol.withbc.com/pub/english.cgi/0/211772599?op=rdb_view_database&ctp=18&rtp=22&htp=20&modifier_1=contains&a_view1=-All-Fields--&page=1&search_items)

**Assumptions:**

Average wage = £35/hour

Overhead rate = 30%

Total cost of project per week = £51,000

**How the benefit is realised:** This methodology for measuring time savings can be applied to the following benefits identified in our benefits framework (high level grouping derived from detailed framework):

- Time savings in Stage 0 'Strategy' to Stage 3: 'Definition'
- Time savings in design
- Time savings in build and commission
- Time savings from answering requests for information (RFIs) (during 'Build and Commission')
- Time savings in handover
- Time savings in incident response

In the following pages, we provide a description of how the methodology described above can be applied to each of these benefits, and the associated calculations required.

## 1.1 Time savings in Stage 0: ‘Strategy’ to Stage 3: ‘Definition’

The use of BIM Level 2 may result in time savings in Stages 0 to 3 of the asset lifecycle for both government construction clients and the supply chain. BIM Level 2 requirements require a more standardised approach to strategic project definition and procurement, bringing time savings through improved definition of information requirements, rules for information exchange, and a faster, more streamlined procurement process. The detailed impact pathways are shown in Figure 1.

**Figure 1: Impact pathways for time savings in stages 0-3** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	BIM L2 compliance enables clients to develop detailed information requirements (EIR*, AIR*, OIR*) at early project stages	Improved definition of the information (data / documents) required by client; this information received at the right times in the right format; stage gate reviews passed without delay	Time savings in Stage 0: ‘Strategy’ to Stage 3: ‘Definition’
1-3: Brief-Concept-Definition	Supply chain procurement, contract award and mobilisation	Standardised tender documentation production process by the client (i.e. standard EIR template)	Faster, more streamlined procurement process for client and suppliers	
1-3: Brief-Concept-Definition	Supply chain procurement, contract award and mobilisation	Standardised supply chain tender response review process	Faster, more streamlined procurement process for client and suppliers	

\*Note: May not occur at project level

Source: PwC.

### Quantification of reduction in direct labour cost:

*Value of time savings (£)*  
 = Change in time resulting from using each BIM enabler above  
 (sum of days for all stakeholders with time saving)  
 × Weighted average daily wage including overheads (£)

**Data required:** Time savings (days); average daily wage (£) including overheads.

### Quantification of savings from reduction in duration of project schedule:

*Value of time savings (£)*  
 = Reduction in project schedule in stages 0 – 3 (days) × Average daily ‘prelim’ cost (£)

**Data required:** Project schedules for two similar projects with and without BIM (days); an understanding of any project delays due to events that BIM could not influence (e.g. delays due to poor weather); an understanding of schedule reduction that can be attributed to BIM Level 2; average daily project ‘prelim’ costs.

## 1.2 Time savings in design

The use of BIM Level 2 potentially results in time savings in the design phase for both government construction clients and the supply chain. BIM brings time savings by improving the access to, and exchange of information through the use of Common Data Environment, shortening the duration of information retrieval and its review, and reducing the time for obtaining design cost estimates. The detailed impact pathways are shown in Figure 2.

**Figure 2: Impact pathways for time savings in design** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	BIM L2 compliance enables clients to develop detailed information requirements (EIR*, AIR*, OIR*) at early project stages	Improved definition of the information (data / documents) required by client; this information received at the right times in the right format; stage gate reviews passed without delay	Time savings in design
1-3: Brief-Concept-Definition	Supply chain procurement, contract award and mobilisation	CDE system set up & testing	Improved collaboration through use of CDE by client and the supply chain	
1-3: Brief-Concept-Definition	Supply chain procurement, contract award and mobilisation	BIM L2 compliance sets out the requirements for information exchange and collaborative working using CDE	Better quality of data and quicker exchange e.g. systemised data collection and storage for future learning/ knowledge sharing	
4: Design	Design authoring	BIM modelling improves accuracy of asset information and its flexibility for design changes	3D modelling & automated rule checking reduces design time	
4: Design	Design authoring	BIM modelling improves accuracy of asset information and its flexibility for design changes	Quick implementation of design changes by the supply chain	
4: Design	Design authoring	Creation of object and design libraries	Standard design solutions that can be used on any project	
4: Design	Design coordination and management	Use of common data environment as defined by PAS1192	Design and construction are easier to coordinate and take less time	
4: Design	Design coordination and management	Use of common data environment as defined by PAS1192	Reduced number of project co-ordinators from client's team	
4: Design	Design coordination and management	Use of common data environment as defined by PAS1192	Easier change control by the client	
4: Design	Design coordination and management	Use of common data environment as defined by PAS1192	Transparent audit trail in information delivery timeline	
4: Design	Design coordination and management	Use of BIM based file naming conventions	Fast access to documented information	
4: Design	Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Quicker access to valuable asset data (area/volume/material)	
4: Design	Design reviews	Visualisations aid in design reviews	Quicker review against client's EIRs, design standards, H&S	
4: Design	Cost estimation	Increased automation in material quantity take-off	Faster cost estimation	
4: Design	Client review & stakeholder consultation	3D & 4D virtual design simulations	Easier and faster to obtain approvals (e.g. planning)	

\*Note: May not occur at project level

Source: PwC.

### Quantification of reduction in direct labour cost:

$$\begin{aligned}
 & \text{Value of time savings (£)} \\
 & = \text{Change in time resulting from using each BIM enabler above} \\
 & \quad (\text{sum of days for all stakeholders with time saving}) \\
 & \quad \times \text{Average daily wage including overheads (£)}
 \end{aligned}$$

**Data required:** Time savings (days) from BIM; average daily wage (£) including overheads.

### Quantification of savings from reduction in duration of project schedule:

$$\begin{aligned}
 & \text{Value of time savings (£)} \\
 & = \text{Total time saved on project schedule in design (days)} \times \text{Average daily 'prelim' cost (£)}
 \end{aligned}$$

**Data required:** Project schedules for two similar projects with and without BIM (days); an understanding of any project delays due to events that BIM could not influence (e.g. a change in regulation mid-design); an understanding of schedule reduction that can be attributed to BIM Level 2; average daily project 'prelim' costs for the Design phase.

### 1.3 Time savings in build and commission

Use of BIM Level 2 potentially results in time savings in the ‘build and commission’ phase of the asset lifecycle for both government construction clients and the supply chain. Time savings are enabled by a number of different elements of BIM that improve information coordination and construction sequencing; enable stakeholders to access, review and exchange information faster using a Common Data Environment; allow faster control of construction quality; and enable easier production of Health & Safety documentation. The detailed impact pathways are shown in Figure 3. There are a number of BIM enablers listed that show the elements of BIM necessary to enable realisation of the benefit. Each of these impact pathways need to be taken into account using both calculation methods above.

**Figure 3: Benefits pathways for time savings in build and commission** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
1-3: Brief-Concept-Definition	Supply chain procurement, contract award and mobilisation	BIM L2 compliance sets out the requirements for information exchange and collaborative working using CDE	Better quality of data and quicker exchange e.g. systemised data collection and storage for future learning/ knowledge sharing	Time savings in build and commission
4: Design	Design coordination and management	Federated model enables checks	Virtual construction reduces error	
4: Design	Design coordination and management	Use of Common Data Environment as defined by PAS1192	Design and construction are easier to coordinate and take less time	
4: Design	Design coordination and management	Use of BIM based file naming conventions	Fast access to documented information	
4: Design	Design coordination and management	Engineering rules enforced by BIM	Design optimised for lean construction based on specified rules	
4: Design	Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Design can be optimised to reduce material waste and prevent unnecessary works	
4: Design	Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Early involvement of builder improves constructability (e.g. improving possibility of offsite fabrication)	
5: Build & Commission (B&C)	Site layout & logistics planning	Visual 3D & 4D site planning (including vehicles, logistics, temp. works, material storage) using federated models	Most cost efficient site layout with easy access for machinery and material storage & better consideration for residents / business in local area	
5: B&C	Construction schedule planning	Use of combined 3D federated models and project schedules for sequence planning, 4D management of lean construction	Easier understanding of construction sequence by supply chain	
5: B&C	Health & Safety management	Data and functionality of the model allows for extraction of H&S data points	Faster production of H&S document requirements	
5: B&C	Site inductions	Use of 3D models & walk-throughs for site inductions	Better understanding of site arrangement during the induction	
5: B&C	Construction quality control	Use of hand-held devices for site inspections with 3D model visualisation and automatic info upload to CDE; Point cloud design model clash detection	Easier to inspect construction works and spot defects	

Source: PwC.

#### Quantification of reduction in direct labour cost:

$$\begin{aligned}
 & \text{Value of time savings (£)} \\
 & = \text{Change in time resulting from using each BIM enabler above} \\
 & \quad (\text{sum of days for all stakeholders with time saving}) \\
 & \quad \times \text{Average daily wage including overheads (£)}
 \end{aligned}$$

**Data required:** Time savings (days) from BIM; average daily wage (£) including overheads.

#### Quantification of savings from reduction in duration of project schedule:

$$\begin{aligned}
 & \text{Value of time savings (£)} \\
 & = \text{Total time saved on project schedule in build and commission (days)} \\
 & \quad \times \text{Average daily 'prelim' cost (£)}
 \end{aligned}$$

**Data required:** Project schedules for two similar projects with and without BIM (days); an understanding of any project delays due to events that BIM could not influence (e.g. delays due to poor weather); an understanding of schedule reduction that can be attributed to BIM Level 2; average daily project ‘prelim’ costs during construction.

## 1.4 Time savings from fulfilling RFIs (during build and commission)

Use of a Common Data Environment (CDE) potentially allows time to be saved in the process of responding to RFIs. The CDE enables quick and transparent data exchange between the stakeholders involved in construction including the client, main contractor, lead designer and lower tier suppliers. Firstly, CDE ensures that the tasks of responding to RFIs are allocated to the correct team members thus preventing delay. Secondly, access to the latest design information enables faster response to RFIs. Finally, the use of modelling and availability of digital information on a CDE results in a reduction in number of RFIs issued by contractors to understand the design intent. The detailed impact pathway is shown in Figure 4.

**Figure 4: Impact pathways for time savings from fulfilling RFIs (during build and commission)** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
4: Design	Design authoring	BIM modelling improves accuracy of asset information and its flexibility for design changes	Fewer requests for additional information during construction	Time savings from fulfilling the RFIs (during build and commission)
5: Build & Commission	Construction information management	Use of CDE for RFIs, Non-conformances, drawing exchange	Faster information exchange and access between the construction team	

Source: PwC.

There are two possible impacts on RFIs from BIM Level 2:

- 1 A reduction in the number of RFIs issued
- 2 A reduction in the time required to respond to each RFI

It is unlikely that these impacts alone would reduce the total duration of a project, but more likely that they could lead to direct labour cost savings.

In order to estimate the change in the number of RFIs due to BIM Level 2, project documentation should be interrogated, such as RFI logs, associated workflow systems or similar for a BIM-enabled project, comparing this RFI count in a similar pre-BIM case.

An estimate for the average time required to respond to an RFI could be derived in one of several ways depending on the project systems and records available. An RFI workflow system or log may indicate typical RFI processing times, with project staff timesheets being a potential source of data relating to RFI processing times. This data, combined with the 'Walkthrough' approach of project staff involved in the RFI process can provide the necessary insight to derive an estimate.

### Quantification of reduction in labour costs:

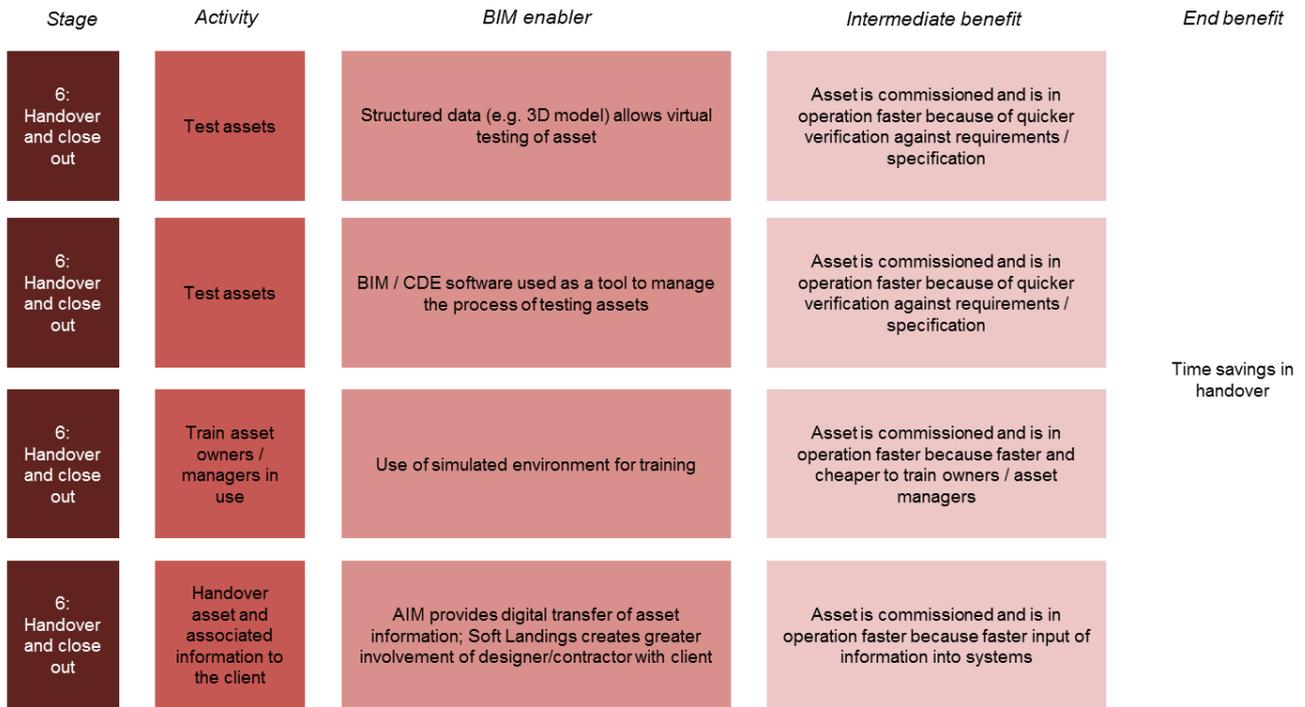
$$\begin{aligned}
 & \text{Value of time savings (£)} \\
 & = \text{Change in time amount of time required to respond to RFIs resulting from using BIM (hours)} \\
 & \times \text{Average daily wage including overheads (£)}
 \end{aligned}$$

**Data required:** RFI logs; an understanding of any changes in RFIs (both in terms of quantity issued, and time taken to respond) attributable to BIM Level 2; average daily wage including overheads.

## 1.5 Time savings in handover

Use of BIM Level 2 in the handover and close-out stage of the asset lifecycle potentially results in time savings has the potential to reduce the time required to handover the asset to the owner/operator. Most of these time savings are enabled through digital transfer of accurate as-built asset information to the client and by using the Asset Information Model (AIM) for testing and staff training. The detailed impact pathways are shown in Figure 5.

**Figure 5: Impact pathways for time savings in handover** (extracted from detailed benefits framework)



Source: PwC.

### Quantification of reduction in direct labour cost:

$$\begin{aligned}
 & \text{Value of time savings (£)} \\
 & = \text{Change in time resulting from using each BIM enabler above} \\
 & \quad (\text{sum of days for all stakeholders with time saving}) \\
 & \quad \times \text{Average daily wage including overheads (£)}
 \end{aligned}$$

**Data required:** Time savings (days) from BIM; average daily wage (£) including overheads.

### Quantification of savings from reduction in duration of project schedule:

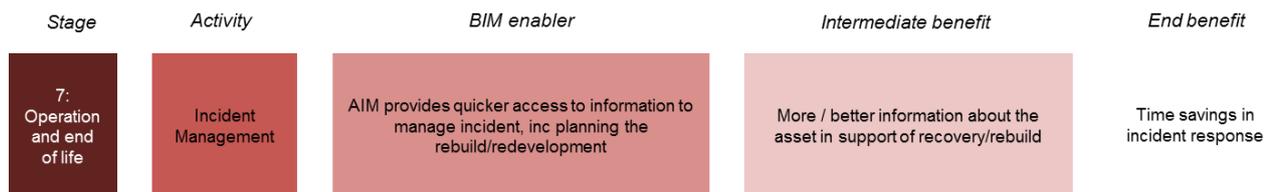
$$\begin{aligned}
 & \text{Value of time savings (£)} \\
 & = \text{Reduction in duration of project schedule in handover and closeout phase (days)} \\
 & \quad \times \text{Average daily 'prelim' cost (£)}
 \end{aligned}$$

**Data required:** Project schedules for two similar projects with and without BIM (days); an understanding of any project delays due to events that BIM could not influence (e.g. delays due to staff availability); an understanding of schedule reduction that can be attributed to BIM Level 2; average daily project 'prelim' costs during Handover.

## 1.6 Time savings in incident response

Use of BIM Level 2 may provide time savings to the asset owner in undertaking incident response. This is enabled by quicker access to accurate asset information through the use of AIM to manage the incident. Access to this information through an up-to-date AIM could reduce the time required for reporting and coordinating incident response. This could be useful in cases such as accidents on the road or rail network, or when fire is reported in a building.

**Figure 6: Impact pathways for time savings in incident response** (extracted from detailed benefits framework)



Source: PwC.

Time savings from incident response can be quantified as direct labour cost savings.

### Quantification of reduction in labour costs:

*Value of time savings (£)*

*= Change in time amount of time required to respond to incidents resulting from using BIM (hours)*

*× Average daily wage including overheads (£)*

**Data required:** Incident logs; an understanding of any changes in incidents (time taken to respond) that can be attributed to BIM; average daily wage including overheads.

## 2. Materials savings

Use of BIM Level 2 has the potential to result in materials savings during asset delivery and also in asset operation (maintenance, refurbishment, etc.) by reducing the volume of materials required, including reducing wasted materials by ensuring that the volume ordered to site is correct. This results in lower costs that will accrue in the first instance to the supply chain. Government construction clients may benefit indirectly if the materials savings are passed on to them by their suppliers as lower costs.

There may also be corresponding environmental benefits from using less materials. Any environmental benefits are positive externalities; we are primarily interested in those which accrue to UK society. Environmental benefits resulting from BIM Level 2 will assist the UK construction sector in meeting government targets to reduce greenhouse gas emissions in the built environment by 50%<sup>11</sup>.

In some cases, application of BIM Level 2 may increase materials costs in asset delivery but reduce them over the whole life of the asset. For example, BIM Level 2 may enable better decisions about the type of material to be used so that the whole-of-life asset cost is reduced (through reduced need for maintenance or replacement for example), but initial materials costs may be greater. Over the course of the asset lifecycle, we would expect changes in the materials used in construction to reduce costs in asset operation. (e.g. because the materials used are of higher quality, need replacing less often or because they insulate the building better thereby lowering energy costs in operations).

**Significance of the benefit:** Materials savings have the potential to be significant for all types of government construction client regardless of the asset type. In general, materials savings accrue due to design accuracy (e.g. from BIM enabled accuracy in material measurement and procurement) and through an ability to model and simulate the construction process (resulting in reduced construction waste). Broadly speaking, the academic literature we have reviewed suggests that BIM has significant effects on the accuracy of procurement<sup>12</sup> with one study suggesting that up to 20% of materials waste can be prevented using BIM Level 2 tools.<sup>13</sup>

**Monetising the benefit:** Three impacts relating to material savings can be monetised:

- 1 **A reduction in the amount of materials** needed during asset delivery or asset operation brings an associated cost reduction –e.g. because of improvements in the accuracy of materials procurement reducing the volume of materials which is purchased in excess of the amount needed.
- 2 **A change in the type of materials used**, if the newly used materials are cheaper, will bring a cost reduction or vice versa.
- 3 When fewer materials are used or there is less waste or where the type of materials used changes such that higher quality materials are used and need replacing less often/ are more energy efficient; there may be an associated **environmental benefit**.

**Calculating the change in the amount or type of materials used** (in terms of quantity and type i.e. impacts 1) and 2) above):

---

<sup>11</sup> The Construction 2025 strategy targets a 50% reduction in greenhouse gas emissions in the built environment

<sup>12</sup> See for example Migilinskas, D et al. (2013) *The Benefits, Obstacles and Problems of Practical BIM Implementation*, Procedia Engineering 57 pp. 767 – 774 who suggest that reduced human error in materials procurement has led to the generation of an accurate bill of quantities which has saved ten times the increase in extra management costs of using of BIM.

<sup>13</sup> See for example Holness, G. (2008), *BIM Gaining Momentum*, who suggests that in the construction of automotive plants it is possible to eliminate 20% of metal waste, with waste reduction alongside shop fabrication of materials expected to produce a cost saving of 7.5% to 10%.

- a. Quantify impact:** Determine the change in materials required attributable to BIM Level 2<sup>14</sup>. There are several possible ways to do this against an appropriate counterfactual. It is important to distinguish between the change in the volume of materials used and a change in the type (and, hence, cost) of materials used.

*For example:* Did parametric modelling using BIM Level 2 in the design review identify areas where materials ordered could be reduced? Or a change in the material type? Would these changes have been identified if BIM Level 2 was not being used?

- b. Monetise:** Apply the cost of each type of material to the reduction in quantity and sum the values to determine the total benefit.

$$\begin{aligned} & \text{Value of materials savings (£)} \\ &= \text{SUM OF: Estimated reduction in use of each type of material (units)} \\ & \times \text{Cost of that material } \left( \frac{\text{£}}{\text{unit}} \right) \end{aligned}$$

- c. Data required:** Project cost plan detailing material usage (physical – e.g. in kilograms, or IT – e.g. in terms of the number of pieces of software bought); bill of quantities (the amount of materials ordered); and a value for the cost of materials (£/unit); as well as an understanding of any change in materials required attributable to BIM Level 2.

**Calculating the environmental benefit:** To assess the environmental benefit that arises as a result of materials savings a weighting for the environmental impact of materials must be applied. In line with HM Treasury Green Book guidance, we use embodied carbon values as a proxy for total environmental impact. This embodied carbon value<sup>15</sup> is specific to the material type and is taken from the Inventory of Carbon and Energy (ICE) table.<sup>16</sup> Please see Section 2.2 for an example of the calculation required.

**Assumptions:**

- Usage of different types of material:** In order to derive the value of materials savings, the associated cost of those materials must be known (the full cost will include direct and indirect costs and attributable overheads). Additionally, the breakdown in terms of the types of materials used must be known. The calculations above depend on the stakeholders/ project schedules providing this information.

**Arup - Ice Arena Wales – Using BIM to reduce waste – blockwork case study**

Benefit measured: Material savings in build and commission

**Impact pathway:**

```

    graph LR
      A[4: Design] --> B[Design reviews]
      B --> C[Parametric modelling provides more information about the asset compared to non-object based design]
      C --> D[Design can be optimised to reduce material waste and prevent unnecessary works]
      D --> E[Materials savings in build and commission]
    
```

**Source:**  
[http://www.cewales.org.uk/files/4814/5346/0967/Constructing\\_Excellence\\_in\\_Wales\\_Building\\_Information\\_Modelling\\_Enabling\\_Zero\\_Waste\\_Ice\\_Arena\\_Wales\\_reducing\\_waste\\_blockwork\\_case\\_study.pdf](http://www.cewales.org.uk/files/4814/5346/0967/Constructing_Excellence_in_Wales_Building_Information_Modelling_Enabling_Zero_Waste_Ice_Arena_Wales_reducing_waste_blockwork_case_study.pdf)

**Description:** Arup constructed ‘Ice Arena Wales’ (IAW) in Cardiff Bay, a 3,000 seat Ice rink, separate training rink and support rooms and become home of the Devils Ice Hockey Team. During the design phase BIM Level 2 was used to change the design / configuration of the internal blockwork partitions to reduce the

<sup>14</sup> The change in transport, delivery and other associated costs should be considered when relevant.

<sup>15</sup> Embodied carbon is the amount of carbon emitted to produce a material from extraction through refining, processing, transporting and fabricating.

<sup>16</sup> Summary table of Embodied Energy and Carbon Coefficients per material, Embodied Carbon ‘kgCO<sub>2</sub>e/kg’ value. Available at: <http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html#.WW4g9oTyupo>.

material waste from cutting the blocks. Engineers used the parametric data from the BIM model to determine the optimal design.

Due to the shape of the building, some waste would occur regardless of the length of the partition walls (due to slanting wall geometry). Where rooms could not be reduced in size due to architectural requirements, the blockwork walls were slightly increased in size to avoid waste. In other cases, the blockwork walls were reduced in length.

**Result:** Across a sample area of the stadium containing 20 blockwork walls, the length of wasted block was reduced from 26.193 m to 25.591 m (a saving of 0.602 m of block). This represents a **2.3%** reduction in waste. Assuming you can apply the same level of waste reduction to the rest of the blockwork walls, the reduction in total waste is 2.3% times 773 m (total length of blockwork used) = 17.779 m. This results in 17.779 m / 450 mm (length of one block) = **39.5** full blocks saved.

**Benefit calculation:**

$$\begin{aligned}
 & \text{Value of materials savings (£)} \\
 & = \text{SUM OF: Estimated reduction in waste materials (by type)(blocks)} \\
 & \times \text{Cost of material (by type)} \left( \frac{\text{£}}{\text{block}} \right) \\
 & = 39.5 \text{ blocks} \times \text{£}1.07 = \text{£}42.36
 \end{aligned}$$

**Note:** The material saving generated in this case is small due to the slanted design of the walls. However, in the case of a larger or different building design, the material savings due to reduced waste in blockwork could be much larger. BIM-enabled design techniques can reduce material waste to near zero in some cases. For example, the brickwork façade designed using BIM in the Tate Modern Blavatnik building had almost no brickwork waste due to the design of the façade matching the brick modules.

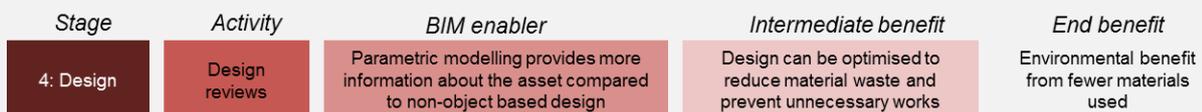
**Assumptions:**

- Uniform waste reduction of 2.3% for all blockwork walls in the project.
- Cost of a single block (440mm x 215mm) = £1.07 (excluding VAT).  
<http://www.buildbase.co.uk/glendinning-440-x-100-x-215mm-10400-2800639>
- Cost of mortar is not calculated but will result in further materials and cost savings.

**Highways England Case Study: M25 widening project – 3D control of drainage**

**Benefit measured:** Material savings in build and commission and environmental benefits from fewer materials used.

**Impact pathway** (from detailed benefits framework):



**Source:** Highways England Lean Tracker<sup>17</sup>

<sup>17</sup> Lean tracker, unique ID 71:  
[https://kol.withbc.com/pub/english.cgi/o/211772599?op=rdb\\_view\\_database&ctp=18&rtp=22&htp=20&modifier\\_1=contains&a\\_view1=-All-Fields--&page=1&search\\_items=](https://kol.withbc.com/pub/english.cgi/o/211772599?op=rdb_view_database&ctp=18&rtp=22&htp=20&modifier_1=contains&a_view1=-All-Fields--&page=1&search_items=)  
 March 2018

**How use of BIM resulted in materials savings:** 3D GPS equipment was installed on site excavators used to widen the M25 (between junction 16 and 23). The equipment was used to continuously survey the level of the drain being installed by the excavator. The 'as built' information was captured and fed back into the BIM model of the drain design. This improved the accuracy of the design and enabled a reduction in the quantity of '503 pipe bedding' material required.

The use of BIM Level 2 resulted in a reduction in 503 pipe bedding waste from an average of 37% (achieved without BIM) to only 10% waste on this project.

**Result:** The estimated reduction in wasted material as a result of BIM Level 2 was 6766 tonnes.

**Benefit calculation:**

**Financial benefit:**

*Value of materials savings (£) = SUM OF: Estimated reduction in materials (by type)(kg) × Cost of material (by type) ( $\frac{£}{kg}$ )*

$$= 6,766,000 \text{ kg} \times £0.01515/\text{kg} = £102,507$$

**Environmental benefit:** The material saved was 503 pipe bedding, and this can be measured as an environmental saving of aggregate material.

$$\begin{aligned} & \text{Environmental Carbon Value of Materials} \left( \frac{£}{\text{kg material}} \right) \\ &= \text{Carbon dioxide equivalent per material} \left( \frac{\text{kgCO}_2\text{e}}{\text{kg material}} \right) \\ & \times \text{Cost of carbon dioxide} \left( \frac{£}{\text{kgCO}_2\text{e}} \right) \\ &= 0.0052 \frac{\text{kgCO}_2\text{e}}{\text{kg}} \times \frac{£0.01198}{\text{kgCO}_2\text{e}} \\ &= £0.000062296/\text{kg} \end{aligned}$$

$$\begin{aligned} & \text{Environmental value of savings from fewer materials used (£)} \\ &= \text{SUM OF: Estimated change in materials (kg)} \\ & \times \text{Environmental Carbon Value of Materials} \left( \frac{£}{\text{kg}} \right) \\ &= 6766000\text{kg} \times \frac{£0.000062296}{\text{kg}} \\ &= £421.50 \end{aligned}$$

**Assumptions:**

- Cost of material (reported by Highways England) = £0.015/kg
- Carbon dioxide equivalent of aggregate which is the material closest to 503 pipe bedding material (see ICE table<sup>18</sup>) = 0.0052 kgCO<sub>2</sub>e/kg
- Cost of carbon dioxide (from government carbon valuation table 3<sup>19</sup>) in 2011 (time of project) = £11.98/tonneCO<sub>2</sub>e =£0.01198/kgCO<sub>2</sub>e

<sup>18</sup> Summary table of Embodied Energy and Carbon Coefficients per material, Embodied Carbon 'kgCO<sub>2</sub>e/kg' value. Available at: <http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html#.WW4g9oTyupo>.

<sup>19</sup> IAG spreadsheet toolkit for valuing changes in greenhouse gas emissions and supporting data tables accessible at: <https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal> March 2018

**How the benefit is realised:** This methodology for measuring materials savings can be applied to the following benefits in our benefits framework (high level grouping derived from detailed framework):

- Materials savings in build and commission
- Environmental benefit from less materials wastage

In the following pages, we provide a description of how the methodology described above can be applied to each of these benefits, and the associated calculations required.

## 2.1 Materials savings in build and commission

The use of BIM Level 2 potentially results in materials savings for the supply chain in the ‘build and commission’ phase of the asset lifecycle. Materials savings can be achieved by using the parametric BIM models to provide transparency on the aspects of asset design that can be improved to reduce material waste; to improve constructability through pre-fabrication; and to obtain more accurate material quantities reducing the amount of over-ordered material. The supply chain can also use BIM models to reduce material waste through 3D space planning and 4D material delivery planning. This leads to both reduced material usage in asset delivery and reduced material waste. The detailed impact pathways are shown in Figure 7.

**Figure 7: Impact pathways for material savings in build and commission** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
4: Design	Design coordination and management	Engineering rules enforced by BIM	Reduced chance of human error	Materials savings in build and commission
4: Design	Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Design can be optimised to reduce material waste and prevent unnecessary works	
4: Design	Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Early involvement of builder improves constructability (e.g. improving possibility of offsite fabrication)	
5: Build and Commission	Site layout & logistics planning	Visual 3D & 4D site planning (including vehicles, logistics, temp. works, material storage) using federated models	Better planned logistics leads to reduce wastage	
5: Build and Commission	Procurement of materials for construction	Automated component and material schedule production	Improved accuracy in materials procurement	

Source: PwC.

### Quantification method:

$$\begin{aligned}
 & \text{Value of materials savings (£)} \\
 & = \text{SUM OF: Estimated reduction in materials (by type)(kg)} \\
 & \times \text{Cost of material (by type)} \left( \frac{\text{£}}{\text{kg}} \right)
 \end{aligned}$$

**Data required:** Project cost plan detailing material usage (physical – e.g. in kilograms, m<sup>2</sup>, m<sup>3</sup>); design stage bill of quantities (the amount of materials ordered) and the actual final bill of quantities required to deliver the asset; and a value for the cost of materials (£/unit); as well as an understanding of any change in materials required attributable to BIM Level 2.

## 2.2 Environmental benefit from fewer materials used

The use of BIM potentially results in environmental benefits through a reduction in materials used and wasted due to efficient design, improved project constructability, and increased accuracy in materials procurement (as detailed above). Environmental benefits such as reduced embodied carbon dioxide are a positive externality of material savings and accrue to wider UK society. Other environmental benefits that are associated with material use may accrue more locally. For example, improvements in air quality, landscape, water quality, and biodiversity; or reduction in noise levels can correspond to fewer materials being used in a project. These local impacts should be estimated using Green Book guidance when they are likely to be significant. The detailed impact pathways are shown in Figure 8.

**Figure 8: Impact pathway for environmental benefit from less materials wastage** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	BIM L2 compliance enables clients to develop detailed information requirements (EIR*, AIR*, OIR*) at early project stages	Improved definition of the information (data / documents) required by client; this information received at the right times in the right format; stage gate reviews passed without delay	Environmental benefit from fewer materials used
0: Strategy	Develop project business case & information requirements	Soft Landings requires definition of business and operational performance outcomes at the outset, project stakeholders are engaged from the outset. Soft Landings is a common theme throughout the asset lifecycle	Performance feedback is used to better inform client requirements and design briefs; supply chain has incentive to improve design for operations and maintenance requirements	
0: Strategy	Develop project business case & information requirements	Soft Landings requires definition of business and operational performance outcomes at the outset, project stakeholders are engaged from the outset. Soft Landings is a common theme throughout the asset lifecycle	Reduced physical rework to meet end-user requirements	
0: Strategy	Develop project business case & information requirements	Soft Landings requires definition of business and operational performance outcomes at the outset, project stakeholders are engaged from the outset. Soft Landings is a common theme throughout the asset lifecycle	Better understanding of asset use & operation and agile approach to future change in use	
4: Design	Design authoring	GSL bring supply chain together to focus on operational outcomes	More accurate asset performance analysis based on design information e.g. Energy consumption over whole of life	
4: Design	Design coordination and management	Federated model enables checks	Automated clash detection reduces rework during construction	
4: Design	Design coordination and management	Engineering rules enforced by BIM	Reduced chance of human error	
4: Design	Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Design can be optimised to reduce material waste and prevent unnecessary works	
4: Design	Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Early involvement of builder improves constructability (e.g. improving possibility of offsite fabrication)	
4: Design	Client review & stakeholder consultation	3D & 4D virtual design simulations	Fewer changes needed during construction	
5: Build & Commission (B&C)	Site layout & logistics planning	Visual 3D & 4D site planning (including vehicles, logistics, temp. works, material storage) using federated models	Better planned logistics leads to reduce wastage	
5: B&C	Construction schedule planning	Use of combined 3D federated models and project schedules for sequence planning, 4D management of lean construction	Reduced need for rework	
5: B&C	Construction quality control	Use of hand-held devices for site inspections with 3D model visualisation and automatic info upload to CDE; Point cloud design model clash detection	Easier to spot clashes between different works contractors	
5: B&C	Procurement of materials for construction	Automated component and material scheduled production	Improved accuracy in materials procurement	
6: Handover	Handover asset and associated information to the client	AIM provides digital transfer of asset information; Soft Landings creates greater involvement of designer/contractor with client	Client / operator is better informed and educated about how to operate the building, client gets what they want	
7: Operation and close-out	Asset / building operation	3D model enables virtual simulation processes (less prone to error); Soft Landings supports continued client education	Reduced time taken to execute space changes, better decisions made about asset operation	
7: Operation and close-out	Maintenance	AIM provides better info. to inform strategic maintenance planning	Maintenance is carried out more efficiently (with greater potential for preventative maintenance)	
7: Operation and close-out	Refurbishments and upgrades	AIM provides quicker access to accurate asset information	Reduced need and cost for re-survey to support refurbishment design	
7: Operation and close-out	Refurbishments and upgrades	AIM provides quicker access to accurate asset information	Greater accuracy in materials needed, first time right procurement	
7: Operation and close-out	Disposal of asset	AIM provides quicker access to information and enables simulation of demolition using 4D BIM	More / better information about the demolition sequence	

Source: PwC.

### Quantification method

**Step 1: Estimate the environmental carbon value per unit of material saved:** For each individual material type, the associated environmental benefit will vary as the carbon dioxide equivalent generated by each material type differs. The Inventory of Carbon and Energy (ICE)<sup>20</sup> table provides a carbon dioxide equivalent

<sup>20</sup> <http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html#.WW4g9oTyupo>

per material; this can be substituted in to the calculation below and multiplied by the traded cost of carbon dioxide provided by the Green Book.<sup>21</sup>

$$\begin{aligned} & \textit{Environmental Carbon Value of Materials} \left( \frac{\pounds}{\textit{kg material}} \right) \\ & = \textit{Carbon dioxide equivalent per material} \left( \frac{\textit{kgCO}_2\textit{e}}{\textit{kg material}} \right) \times \textit{Cost of carbon dioxide} \left( \frac{\pounds}{\textit{kgCO}_2\textit{e}} \right) \end{aligned}$$

**Data required:** Project cost plan detailing material usage (in terms of both quantities and types of materials used in the relevant units – e.g. kilograms); ICE values of carbon dioxide equivalent per material; Green Book values for the traded cost of carbon dioxide.

**Step 2: Estimate the environmental value of materials savings:** The estimated reduction in materials is calculated as below.

$$\begin{aligned} & \textit{Environmental value of environmental savings from fewer materials used} (\pounds) \\ & = \textit{SUM OF: Estimated change in materials} (\textit{kg}) \\ & \quad \times \textit{Environmental Carbon Value of Materials} \left( \frac{\pounds}{\textit{kg}} \right) \end{aligned}$$

**Data required:** Project cost plan detailing material usage (in terms of both quantities and types of materials used in the relevant units – e.g. kilograms); above calculation of estimated carbon value.

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<sup>21</sup> Department for Business, Energy & Industrial Strategy Carbon Valuation: <https://www.gov.uk/government/collections/carbon-valuation--2>  
March 2018

## 3. Cost savings

Application of BIM Level 2 has the potential to result in other, broader cost savings for government construction clients and their supply chains across the asset lifecycle where it is difficult to distinguish the time and materials elements. As with potential time and materials savings, they may accrue directly to either the supply chain or the asset owner / government construction client. For example:

- During asset delivery, cost savings may be realised in the ‘build and commission’ Stage because fewer changes are made to the design and clashes are prevented if a federated BIM model is used.
- Cost savings in asset operation may be achieved from the use of the AIM, which can lead to more efficient maintenance, cheaper refurbishment and facilities management and quicker disposal.
- At the ‘Strategy’ stage of the asset lifecycle, better definition of the project scope and information processes through an Employer’s Information Requirement (EIR) and Asset Information Requirement (AIR) may reduce the likelihood of future claims by the supply chains.

### Significance of the benefit:

- **Asset delivery:** cost savings during asset delivery are likely to be significant for both government construction clients and supply chain members. The supply chain derives cost savings from the reduction in rework by better collaboration and clash detection. Academic literature suggests that savings from clash detection can reach up to 10% of the contract value<sup>22</sup>, with a majority of industry professionals reporting reduction in conflict and changes as a top benefit of BIM.<sup>23</sup>
- **Operations:** cost savings during asset operation have the potential to be more significant than those in the asset delivery phase due to the long asset service life of up to 120 years or more. According to some sources, cost savings of up to 25% can be achieved in the operations phase through BIM tools which increase the ease of access to accurate data<sup>24</sup>, primarily using a comprehensive AIM developed during asset delivery. Cost savings may accrue directly to asset owners through smaller utility costs, more agile maintenance regimes, and more efficient space refurbishments. Asset owners may also benefit from reduced cost of asset disposal by receiving a higher return on salvaged materials or decommissioning the asset faster.

**Monetising the benefit:** To monetise the cost savings outlined above, we need to consider two possible effects from application of BIM:

- 1 **A change in the number of instances of a particular event.** The event in question may be a clash, a change, a litigation claim, or the requirement to change a light bulb. For every instance of ‘event’ that occurs, there will be an associated cost (or associated avoided cost). A reduction (or increase) in the number of times that event occurs due to application of BIM Level 2 will therefore result in a cost saving. For example: if clash detection is an event, an increase in the number of clashes detected will result in a cost saving. If litigation is an event, a reduction in the number of litigation claims will result in a cost saving. The cost saving is made up of savings in labour and materials that are no longer required due to the reduced occurrence of the event in question.

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<sup>22</sup> Azhar, S., (2011). *Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry*. Leadership and Management in Engineering, 11(3), pp. 241-252, a review of 32 case studies

<sup>23</sup> Bernstein, H. M. et al., (2012). *The Business Value of BIM for Infrastructure: Addressing America’s Infrastructure Challenges with Collaboration and Technology SmartMarket Report*, Bedford, MA: McGraw-Hill.

<sup>24</sup> Kang, T.W., Choi, H.S. (2015) *BIM perspective definition metadata for interworking facility management data*, Advanced Engineering Informatics March 2018

- 2 **A reduction in the cost associated with one instance of an event** – this saving will occur because a particular event is faster to carry out and thus requires less labour input (or fewer materials) due to the availability of digital information through BIM Level 2. For example, BIM Level 2 provides faster access to asset information, which means dealing with litigation claims can be faster/easier. This reduces the cost per claim. Similarly, carrying out a particular instance of maintenance is faster using the easily accessible information in the AIM. The cost per maintenance task is therefore reduced.

It is important to identify which of these effects are occurring. It may be only one or both of the above.

**Estimating the cost saving from application of BIM Level 2:** We must consider any possible change in each of the two effects described above:

- **Quantify impact:**
  - Determine the change in the number of instances of a particular event attributable to BIM Level 2. As described in the **Introductory Note Section 5.3** there are a number of ways to do this against an appropriate counterfactual.
  - For example: By using BIM Level 2, was it possible to detect certain clashes that were not noticeable using other means?
  - Determine the change in cost associated with one instance of an event attributable to BIM Level 2. As described in the **Introductory Note Section 5.3** there are a number of ways to do this against an appropriate counterfactual. For example: For each clash that was detected, was it easier and hence quicker / less costly to resolve, given use of BIM Level 2 software?
- **Monetise:** Apply the average cost of each instance to the number of instances to determine the total cost saving. Alternatively, depending on data and comparison data available, calculate the total cost of an activity (and all events that comprise that activity) with-BIM Level 2 and subtract from the total cost of the same activity without-BIM Level 2.
  - $$\text{Cost saving (£)} = \text{Reduction in number of instances of an event (number)} \times \text{Change in average cost (time and materials) of an instance (£)}$$
  - $$\text{Cost saving (£)} = \text{Total cost of all events 'without BIM L2' (£)} - \text{Total cost of all events 'with BIM L2' (£)}$$
- **Data required:** Records/logs identifying the number of instances and average costs or costs of each instance based on cost data from similar projects or expert opinion.

**Assumptions: Average cost of an instance of a particular event:** the average cost of an instance occurring should be identified by suitably qualified stakeholders based on their experience of project performance. This value will depend on many factors such as project type, significance and maturity of supply chain and client organisation.

**How the benefit is realised:** This methodology for measuring cost savings can be applied to the following benefits in our benefits framework (high level grouping derived from detailed framework):

- Cost savings from better clash detection
- Cost savings from fewer changes
- Cost savings in operations – facilities management
- Cost savings in asset maintenance
- Cost savings in refurbishment
- Cost savings in asset disposal
- Cost savings in litigation

In the following pages, we describe how the methodology can be applied to each benefit and the calculations required.

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### 3.1 Cost savings from better clash detection

Improved collaboration between various design disciplines enabled by the use of BIM Level 2 may lead to cost savings from better clash detection during construction of an asset. If architects, engineers and other stakeholders are able to combine their respective digital information into a single federated model during the design stage, clash detection checks can be undertaken either visually in 3D or automatically using appropriate software (e.g. Autodesk Navisworks). This may result in the detection of clashes that would have gone undetected until construction without the use of BIM Level 2. During the build and commission stage, the use of hand-held devices during site visits can enable the supply chain to view design models and identify clashes between different works contractors on site. This can lead to cost savings due to early identification of clashes, and resolution prior to any abortive construction work starting on site.

**Figure 9: Impact pathway for cost savings from better clash detection** (extracted from benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
4: Design	Design coordination and management	Federated model enables checks	Automated clash detection reduces rework during construction (leading to material savings)	Cost savings from better clash detection
4: Design	Design coordination and management	Federated model enables checks	Automated clash detection reduces rework during construction (leading to time savings)	
5: Build and Commission	Construction schedule planning	Use of combined 3D federated models and project schedules for sequence planning; 4D management of lean construction	Reduced need for rework (leading to time savings)	
5: Build and Commission	Construction schedule planning	Use of combined 3D federated models and project schedules for sequence planning; 4D management of lean construction	Reduced need for rework (leading to material savings)	
5: Build and Commission	Construction quality control	Use of hand-held devices for site inspections with 3D model visualisation and automatic info upload to CDE; Viewing design models on site can aid clash detection	Easier to spot clashes between different works contractors (leading to material savings)	
5: Build and Commission	Construction quality control	Use of hand-held devices for site inspections with 3D model visualisation and automatic info upload to CDE; Viewing design models on site can aid clash detection	Easier to spot clashes between different works contractors (leading to time savings)	

Source: PwC.

#### Estimation of cost savings from reduction in number of clashes

$$\text{Cost savings (£)} = \text{Reduction in number of clashes on site (number)} \times (\text{Average cost (time and materials) of fixing one clash on site (£)} - \text{Average cost (time and materials) of fixing one clash in design})$$

**Data required:** Clash logs or other records containing the number of identified clashes for a project using BIM Level 2, and a suitable counterfactual project or knowledge of which clashes would not have been detected without BIM Level 2. Assumptions have to be made regarding the average cost of clash based on time and material cost estimates derived from clashes occurring on other projects of similar type, complexity, duration and value. Counterfactual project should provide an actual number of site clashes or the estimate of proportion of the clashes that would have been missed despite the clash detection checks. The assumption is that with BIM Level 2, clashes will be resolved in design rather than on site, therefore we quantify this benefit taking into account the relative cost of fixing a clash on site compared to in design. There is a design cost associated with clash checks. This includes the time it takes to federate models, run the checks, interpret clashes, report to

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senior engineers, and communicate with other members of supply chain. This time can be valued as a direct labour cost including overheads (see Chapter 1 Time Savings).

**Quantification of cost savings based on total costs of clashes on two comparison projects:**

*Cost savings (£)*

$$= \text{Total cost of clashes on 'without BIM L2' project (£)} \\ - \text{Total cost of clashes on 'with BIM L2' project (£)}$$

**Data required:** Total cost of rectifying clashes on a project delivered using BIM Level2 approach and appropriate counterfactual project delivered without BIM Level 2.

**Note:** Judgement of the project team has to be used to estimate how many clashes would have been missed without a thorough clash detection process.

**Highways England case study – A1L2B BIM Clash Detection**

Benefit measured: Cost savings from better clash detection

**Impact pathway:**

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
4: Design	Design coordination and management	Federated model enables checks	Automated clash detection reduces rework during construction	Time and material savings in build and commission

Source: Highways England Lean Tracker available at: <https://kol.withbc.com/pub/english.cgi/d348465486/A1L2B%20BRCF%20Clash%20Detection.pdf>

**Example:** Highways England was undertaking works to upgrade the A1 Leeming to Barton (A1L2B) by replacing the existing dual carriageway with a new 3 lane motorway. The design team used a federated model of the A1L2B, which included drainage, concrete step barriers, sign bases, communication ducting and other variables, to perform 3D static clash detection & 4D simulation to identify clashes in the construction sequence. 1,800 clashes have been identified to date (clash detection is ongoing as the project progresses). Based on the project manager’s experience of previous schemes of similar scope and value, it was estimated that without the use of BIM Level 2, about **20%** of the 1,800 clashes would have been left unnoticed and caused issues on site.

**Result:** 1,800 clashes have been identified to date of which 360 would have remained an issue if BIM Level 2 was not employed. Assuming the cost of time and materials to rectify one clash is on average £2,500, the total cost of clashes would have amounted to **£900,000** of extra cost. This represents **0.24%** of the total capital cost saved due to better clash detection provided by BIM Level 2.

**Benefit calculation:**

$$\text{Cost saving (£)} = \text{Reduction in number of potential clashes (number)} \times \text{Average cost (time and materials) of clash (£)} \\ = 360 \text{ clashes} \times \text{£}2500 = \text{£}900,000$$

**Assumptions:**

- No change in the cost per clash detected due to BIM Level 2
- Cost per clash £2,500 – value identified as industry standard in the case study by Highways England
- Total capital cost of £380.3 million – obtained from <http://roads.highways.gov.uk/projects/a1-leeming-to-barton-improvement/>

### 3.2 Cost savings from fewer changes

The use of BIM Level 2 may also lead to cost savings if fewer changes to the design are required during asset delivery. In the context of capital projects, change can be defined as any modification to the final asset during design or construction that results in a deviation from the original scope approved by the client.

During strategic definition, the use of BIM Level 2 can enable government construction clients to develop detailed requirements for information delivery (in the form of the EIR and AIR). Implementation of Government Soft Landings can help clients and asset users to explain their requirements for the asset to the supply chain in a clearer way. This means that clients might be able to produce a more detailed project scope, covering, for example, the level of information required from the supply chain at every 'Stage Gate'. More detailed scope definition and review of relevant information may reduce the number of both client-initiated changes, and changes during construction to meet the end-user requirements.

In the design stage, digital models and virtual design simulations can assist stakeholder consultations and reduce the amount of changes required by clients and their stakeholders during construction. By reviewing the visual information during design as a part of Government Soft Landings process, it can be easier for all stakeholders (clients, supply chain, specialists) to identify instances where design would not satisfy their criteria prior to asset construction.

#### **MYOI Cookham & Wood prison project<sup>25</sup>.**

An example where BIM Level 2 was used for client review and stakeholder consultation is the *HMYOI Cookham & Wood* prison project. The project design team proposed to use secure glazing between the central core and the wings of the houseblock, instead of traditional metal bars (commonly used in prisons) to increase the level of illumination inside the building.

The design concept to replace the metal bars with glazing was accepted in principle by the representatives of the Prison Governor at an early stage of design, prior to the creation of 3D BIM model. As design progressed, a 3D BIM model was developed and was used during the design review with the prison operation team, including the Prison Governor.

The BIM model enabled the Prison Governor and her team to visualise and understand the proposed design of the building. Visualising the internal space allowed the team to verify how it would be managed by the prison staff. The team found that the use of the secure glazing between the houseblock central core and wings was not acceptable, because it would block the sound transmission between these areas. The ability for prison staff to hear what is happening in both areas is essential for the operation of these areas. It allows them to maintain the welfare and well-being of both the prison staff and the young adults who are incarcerated.

The secure glazing was thus replaced with metal bars. Without use of the BIM model, the problem of the secure glazing is unlikely to have been identified until after construction was completed. This would have resulted in higher costs to replace the glazing with the metal bars on site. In this situation, the use of BIM Level 2 for client review resulted in a cost saving due to avoidance of remedial works during construction. A further cost saving was made because metal bars are cheaper than secure glazing.

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<sup>25</sup> Description of the "HMYOI Cookham Wood Use of Anti-Ballistic Rated Glazing" case study has been provided by Innovate UK. March 2018

**Figure 10: Impact pathways for cost savings (time and materials) from fewer changes** (extracted from benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	BIM L2 compliance enables clients to develop detailed information requirements (EIR*, AIR*, OIR*) at early project stages	Improved definition of the information (data / documents) required by client; this information received at the right times in the right format; stage gate reviews passed without delay	Cost savings from fewer changes
0: Strategy	Develop project business case & information requirements	Soft Landings requires definition of business and operational performance outcomes at the outset, project stakeholders are engaged from the outset. Soft Landings is a common theme throughout the asset lifecycle	Reduced physical rework to meet end-user requirements (leading to time savings)	
0: Strategy	Develop project business case & information requirements	Soft Landings requires definition of business and operational performance outcomes at the outset, project stakeholders are engaged from the outset. Soft Landings is a common theme throughout the asset lifecycle	Reduced physical rework to meet end-user requirements (leading to material savings)	
4: Design	Client review & stakeholder consultation	3D & 4D virtual design simulations	Fewer changes needed during construction (leading to time savings)	
4: Design	Client review & stakeholder consultation	3D & 4D virtual design simulations	Fewer changes needed during construction (leading to material savings)	

Source: PwC.

There are two potential approaches to estimating the cost savings.

**Estimation of reduction in cost of changes – Method 1:**

$$Cost\ savings\ (£) = Reduction\ in\ number\ of\ changes\ required\ (number) \times Average\ cost\ (time\ and\ materials)\ of\ change\ (£)$$

**Data required:** Change logs or other records containing the number of approved change requests for a BIM Level 2 project and a suitable counterfactual project. Assumptions have to be made regarding the average cost of change including time and materials cost estimates derived from changes occurring on other projects of similar type, complexity, duration and value.

**Estimation of reduction in cost of changes – Method 2:**

$$Cost\ savings\ (£) = Total\ cost\ of\ changes\ on\ 'without\ BIM\ L2'\ project\ (£) - Total\ cost\ of\ changes\ on\ 'with\ BIM\ L2'\ project\ (£)$$

**Data required:** Change logs or other records containing the number of approved change requests for BIM L2 project and a suitable counterfactual project with costs of each change. The total aggregate cost of all approved changes should be calculated for both projects. Please see notes below when calculating benefits using this method.

**Notes:** Change requests can have a positive and a negative value. For the purpose of this methodology, we assume that:

- Changes with a positive value add cost to the project.
- Changes with a negative value reduce the cost of the project (i.e. value engineering).

### 3.3 Cost savings in operations – facilities management

Cost savings in asset operations, (and potentially environmental benefits related to a reduction in time and materials costs in operations), may be achieved through implementation of Government Soft Landings (GSL), and by incorporating Asset Information Models (AIM) into computer-aided facilities management (CAFM) and related systems. Costs savings arise through more efficient use of existing and historic asset information. They may include reduced utility bills, building systems costs, and labour costs. GSL encourages clients and facilities managers to be present during the design stage of a project to communicate their specific requirements for asset operation and service delivery. For example, specific areas of a prison may need to be accessible via certain routes or sufficient clearances in the corridors may be required for machinery. Facilities managers can also agree with the capital delivery team the best format (e.g. COBie) to smoothly import the AIM into their systems. Construction clients can also identify target operational costs for assets which the design team needs to deliver using standard ratings such as BREEAM<sup>26</sup> or LEED<sup>27</sup>. GSL states that operational performance should be monitored by asset owners during the post-occupancy evaluation period for three years. This helps to ensure that there is no deviation from the intended operational targets. For example, the annual cost of utilities can be continuously monitored and changes implemented if performance is below target. Due to long asset life spans of up to 120 years, cost savings in facilities management can be significant when considered over the asset’s useful life.

If building/asset operations are more energy efficient, there is also potential for a corresponding environmental benefit due to reduction in energy use.

**Figure 11: Impact pathways for cost savings in operations** (extracted from benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	Soft Landings requires definition of business and operational performance outcomes at the outset, project stakeholders are engaged from the outset. Soft Landings is a common theme throughout the asset lifecycle	Performance feedback is used to better inform client requirements and design briefs; supply chain has incentive to improve design for operations and maintenance requirements	Cost savings in operations – facilities management
4: Design	Design authoring	GSL bring supply chain together to focus on operational outcomes	More accurate asset performance analysis based on design information e.g. Energy consumption over whole of life	
6: Handover and close-out	Handover asset and associated information to the client	AIM provides digital transfer of asset information; Soft Landings creates greater involvement of designer/contractor with client	Client / operator is better informed and educated about how to operate the building, client gets what they want	
7: Operation and end of use	Asset/ building operation	3D model enables virtual simulation processes (less prone to error); Soft Landings supports continued client education	Reduced time taken to execute space changes, better decisions made about asset operation	

Source: PwC.

#### Estimation of cost savings in operations (FM):

$$\text{Cost saving (£)} = \text{Cost of FM operations per annum 'without BIM L2'} (£) - \text{Cost of FM operations per annum 'with BIM L2'}$$

<sup>26</sup> BREEAM is a method of assessing, rating, and certifying the sustainability of buildings. See <http://www.breeam.com>

<sup>27</sup> LEED is a green building certification system. See <https://www.usgbc.org/leed>

**Data required:** FM costs (likely to comprise staff costs, cost of CAFM systems, utility bills) delivered using BIM Level 2 approach and appropriate counterfactual ‘without BIM L2’ project. This could be estimated using contract costs or actual costs.

**Estimation of environmental benefits in operations:**

We calculate the environmental cost of energy usage based on HM Treasury Green Book supplementary guidance on ‘valuation of energy use and greenhouse gas’.<sup>28</sup> This benefit can be calculated through two steps.

**Step 1: Assess the extent to which BIM Level 2 has resulted in a reduction in annual asset energy usage, and quantify the associated reduction in greenhouse gas emissions**<sup>29</sup> due to BIM (measured in tonnes of carbon dioxide equivalent). This can be calculated using the equation below.

$$\begin{aligned} & \text{Reduction in greenhouse gas emissions (tCO}_2\text{e)} \\ & = \text{Change in energy use as a result of BIM (GWh of electricity)} \\ & \times \text{Environmental cost of energy useage } \left( \frac{\text{tCO}_2\text{e}}{\text{GWh}} \right) \end{aligned}$$

**Step 2: Apply an environmental value to this reduction in energy** – i.e. the traded cost of carbon<sup>30</sup>:

$$\text{Value of environmental benefit (£)} = \text{Reduction of tCO}_2\text{e} \times \text{Cost of carbon dioxide } \left( \frac{\text{£}}{\text{tCO}_2\text{e}} \right)$$

**Data required:** An estimate for the reduction in greenhouse gas emissions attributable to BIM Level 2, estimated for example by using estimates of the increased energy efficiency due to BIM.

**Assumptions:** The emissions level per unit of energy saved depends on the source of energy. We assume that this can be identified so the relevant value can be applied. For example, to calculate changes in emissions resulting from changes in grid electricity usage, one would need to identify the appropriate environmental value (the long-run marginal emissions factor) that can be found in Data Table 1<sup>31</sup> (used for measuring small changes in consumption by an asset). To then monetise the change in carbon emissions identified, the BEIS short-term traded sector carbon values can be used (these give the £/tCO<sub>2</sub>e).

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<sup>28</sup>[https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/615374/1.\\_Valuation\\_of\\_energy\\_use\\_and\\_greenhouse\\_gas\\_emissions\\_for\\_appraisal\\_2016.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/615374/1._Valuation_of_energy_use_and_greenhouse_gas_emissions_for_appraisal_2016.pdf)

<sup>29</sup> IAG spreadsheet toolkit for valuing changes in greenhouse gas emissions and supporting data tables accessible at: <https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal>

<sup>30</sup> Department for Business, Energy & Industrial Strategy Carbon Valuation: <https://www.gov.uk/government/collections/carbon-valuation--2>

<sup>31</sup> IAG spreadsheet toolkit for valuing changes in greenhouse gas emissions and supporting data tables accessible at: <https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal>

### 3.4 Cost savings in asset maintenance

The use of BIM Level 2 has the potential to result in cost savings in asset maintenance in several ways:

- Maintenance may be carried out faster if there is quicker access to asset information through the AIM and this will result in time savings. AIM can assist in better planning of maintenance works by better understanding of the nature of works and specific components required to carry out the works. This approach can increase the chance of successful maintenance completion during the first visit by involving the right maintenance professionals and using the correct replacement components. This links to improved reputation benefits and increased asset availability (set out separately in this document).
- Maintenance may be carried out more efficiently if better asset information in the AIM enables a higher proportion of preventative maintenance (rather than reactive maintenance); this may reduce maintenance, repair and replacement spend. It may also allow the timing of maintenance to be less disruptive.
- Less inventory would be need due to improved visibility and predictability of future materials / inventory required provided by the BIM model.
- The cost of training staff in maintenance may be reduce if it can be carried out virtually using a 3D model. Training can be costly and create health and safety risks. BIM models in virtual reality or augmented reality provide realistic, risk-free environment for maintenance training compared to the traditional site-based training. This reduces costs such as transport, fuel and overall training time.

Each effect needs to be considered when calculating cost savings in asset maintenance. It is important to avoid double counting of cost savings. For example, if estimating the total saving from an increase in the proportion of preventative versus reactive maintenance, it is important to consider whether savings from better management of warranties or reduction in inventory holding costs are also included in the estimate. If so, they should not be counted separately as well.

**Figure 12: Impact pathways for cost savings in asset maintenance** (extracted from benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
7: Operation and end of use	Maintenance	AIM provides quicker access to info. needed to carry out maintenance	Maintenance is carried out faster	Cost savings in asset maintenance
7: Operation and end of use	Maintenance	AIM provides better info. to inform strategic maintenance planning	Maintenance is carried out more efficiently (with greater potential for preventative maintenance (leading to time savings in maintenance))	
7: Operation and end of use	Maintenance	AIM provides better info. to inform strategic maintenance planning	Maintenance is carried out more efficiently (with greater potential for preventative maintenance (leading to reduced inventory costs))	
7: Operation and end of use	Maintenance	3D model enables virtual maintenance training	Training in maintenance is carried out faster, earlier, and more safely	

Source: PwC.

#### Estimation of time savings in maintenance

$$\begin{aligned}
 & \text{Value of time savings (£)} \\
 & = \text{Change in time resulting from using AIM for maintenance compared to conventional methods} \\
 & \quad (\text{sum of days for all stakeholders with time saving}) \\
 & \quad \times \text{Average daily wage including overheads (£)}
 \end{aligned}$$

**Data required:** Time required for maintenance planning and execution using AIM and time required for maintenance planning and execution using conventional documentation. Time estimates for maintenance using AIM could be obtained by performing time and motion studies. Time estimates for maintenance using paper documents could be obtained from historic maintenance records. Average daily wage for the maintenance personnel including overheads (refer to direct labour cost savings in Chapter 1 for further explanation).

#### **Estimation of reduction in total annual cost of maintenance**

$$\text{Cost saving (£)} = \text{Annual cost of maintenance without AIM model (£)} \\ - \text{Annual cost of maintenance using AIM model (£)}$$

**Data required:** Total annual cost of maintenance on a project using AIM for maintenance and a project without the AIM, an understanding of factors influencing maintenance costs that are independent of / not related to BIM Level 2. Maintenance cost components will include personnel labour cost, cost of purchased service contracts, cost of hardware purchase or upgrades, cost of hardware maintenance, cost of software license purchase or upgrades, cost of software maintenance, cost of travel and cost of utilities for maintenance.

#### **Estimation of reduction in inventory cost**

$$\text{Cost saving (£)} = \text{Total cost of inventory without AIM model (£)} \\ - \text{Total cost of inventory using AIM model (£)}$$

**Data required:** Total annual cost of holding inventory for an asset using AIM for maintenance and an asset without the AIM. Total annual cost of holding inventory will include the money tied up in inventory, such as the cost of capital or opportunity cost of the money spent (For government construction clients, the opportunity cost of holding can be approximated as the social rate of time preference expressed in the Green Book; 3.5% per annum), the cost of the physical space occupied by the inventory including rent depreciation, utility costs, insurance; the cost of handling the items; and costs associated with deterioration and obsolescence.

#### **Estimation of cost savings from maintenance training:**

$$\text{Cost saving (£)} = \text{Cost of training using traditional methods (£)} \\ - \text{Cost of training using methods involving BIM outputs (£)}$$

**Data required:** Total cost of training using traditional methods (e.g. site visits) and training using BIM models. This could include training fees and the time required for training (it is important to understand whose time is saved) which can be quantified as a direct labour cost saving (see Chapter 1 Time Savings).

**Additional impacts:** The application of BIM Level 2 may alter when spending on asset maintenance happens. For example, applying a GSL approach may provide an asset owner with a better understanding of asset use and operation making it easier to reduce the volume of reactive maintenance by increasing the amount and frequency of predictive maintenance. These effects will be taken account by assessing the change in costs in NPV terms.

### 3.5 Cost savings in refurbishment

BIM Level 2 has the potential to generating cost savings for asset owners in undertaking refurbishment. At the strategic stage, GSL can enable a government construction client to use the lessons learnt from similar projects to understand and predict the actual use of the asset better. This can help to minimise the cost of asset refurbishment for a future change in use. The main source of cost saving comes from possessing accurate as-built data about the asset, which allows the refurbishment team to proceed with design development and subsequent construction work quickly and easily, avoiding re-surveying costs. Use of BIM Level 2 can reduce the time required for refurbishment, and also possibly the materials used, through more accurate information available through the AIM. In some cases, a refurbishment could be delayed, or might not be required at all.

**Figure 13: Impact pathways for cost savings in refurbishment (extracted from benefits framework)**

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	Soft Landings requires definition of business and operational performance outcomes at the outset, project stakeholders are engaged from the outset. Soft Landings is a common theme throughout the asset lifecycle	Better understanding of asset use & operation and agile approach to future change in use	
7: Operation and end of use	Refurbishments and upgrades	AIM provides quicker access to accurate asset information	Reduced time taken to execute refurbishments	Cost savings in refurbishment
7: Operation and end of use	Refurbishments and upgrades	AIM provides quicker access to accurate asset information	Greater accuracy in materials needed, first time right procurement	
7: Operation and end of use	Refurbishments and upgrades	AIM provides quicker access to accurate asset information	Reduced need and cost for re-survey to support refurbishment design	

Source: PwC.

#### Estimation of reduced survey costs:

$$Cost\ saving\ (£) = Cost\ of\ surveying\ without\ BIM\ data\ (£) - Cost\ of\ surveying\ with\ BIM\ data\ (£)$$

**Data required:** Cost estimates/quotes for surveying works from external consultants and internal cost (time and software cost) of using the existing BIM data to establish the as-built condition of the asset.

#### Estimation of cost savings in refurbishment:

$$Cost\ saving\ (£) = Estimated\ cost\ of\ refurbishment\ 'without\ BIM\ L2'\ (£) - Cost\ of\ refurbishment\ 'with\ BIM\ L2'\ (£)$$

**Data required:** Cost estimates (time and materials) for refurbishment projects undertaken without BIM Level 2 and undertaken with BIM Level 2.

**Additional cost impacts (change in timing of cash flows):** The application of BIM Level 2 may result in a change in the timing of the cash flows associated with refurbishment of a particular project or asset. GSL may provide an asset owner with a better understanding of asset use and operation; resulting in an agile approach to future change in use. BIM Level 2 may also help to optimise replacement/refurbishment regimes. For example, by considering whole of life impacts at the outset using BIM Level 2 and Government Soft Landings, it may be possible to change the planned replacement / refurbishment schedule so that the timing of cash flows relating to refurbishment costs changes over the lifetime of the asset. For example, refurbishment of a certain element of a building may only be required every 7 years rather than every 4 years. This will change the timing of the associated cash flows relating to refurbishment costs over the lifetime of the asset.

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In the case where BIM Level 2 results in a change to the timing of refurbishment cash flows, the effect of this change on a project's NPV needs to be assessed. One practical way of assessing the change in costs (in NPV terms), is to use the cost benefit analysis model that has been prepared for the project (for example, as part of the project business case), amend the cash flows to reflect the change in timing due to BIM Level 2, and calculate the new NPV.

### 3.6 Cost savings in asset disposal

Possession of a comprehensive AIM has the potential to enable asset owners to demolish or sell assets more cheaply and quicker.

Using 4D BIM for demolition simulation can result in a more efficient demolition sequence by reducing its overall time, using the right equipment and thinking through the best transport logistics. BIM Level 2 can help with planning demolition operations to reduce damage to materials which could be re-used on another project or sold. The AIM will provide a clear view of what the asset is, where it is located and which components it contains so it is quicker / easier to determine disposal plans, disposal value, or decommissioning method; and undertake sale or disposal.

The cost of asset disposal (sale) is predominantly the labour cost required to sell the asset (e.g. cost of agents/auctioneers /internal organisation labour costs). BIM Level 2 can help to reduce the time-variant labour cost associated with this.

**Figure 14: Impact pathways for cost savings in asset disposal** (extracted from benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
7: Operation and end of use	Disposal of asset	AIM provides quicker access to information and enables simulation of demolition using 4D BIM	More / better information about the demolition sequence (leading to time savings in demolition)	Cost savings in asset disposal
7: Operation and end of use	Disposal of asset	AIM provides quicker access to information and enables simulation of demolition using 4D BIM	More / better information about the demolition sequence (leading to material savings from increases in the value of salvaged materials)	
7: Operation and end of use	Disposal of asset	AIM provides quicker access to information needed for sale	Easier to sell asset, with faster disposal and decommissioning decision-making	

Source: PwC.

#### Estimation of reduced cost of demolition:

$$\text{Cost saving (£)} = \text{Total cost of demolition planned using BIM model (£)} - \text{Total cost of demolition without BIM (£)}$$

**Data required:** The total cost of demolition will include labour costs to plan demolition, labour cost to execute demolition, overhead cost for demolition, labour and material costs to landfill the construction waste and value of salvaged materials.

#### Estimation of time savings in sale:

$$\text{Value of time savings (£)} = \text{Change in sale time resulting from the use of AIM} \times \text{Average daily wage including overheads (£)}$$

**Data required:** Time required to sell an asset enabled with information available from a comprehensive AIM and time required to sell an asset using conventional methods of information management. The average wage/professional rate should include overheads (see chapter 1 Time savings). It is important to consider whose time is saved and use an appropriate corresponding wage(s).

### 3.7 Cost savings in litigation

BIM Level 2 may result in cost savings in litigation due to two main effects:

- Improved scope understanding by the supply chain may lead to a reduction in the number of claims initiated due to lack of information.<sup>32</sup> This could result in cost savings for both construction clients and the supply chain through avoided litigation fees and a reduction in the amount of time and thus labour required to deal with litigation.
- Improved availability of information to address claims that are initiated, may lead to a reduction in the cost per claim for the construction client. More accurate, easily accessible information should expedite the process of case resolution, by providing greater clarity on the construction client’s legal position. This should result in direct labour cost savings.

The two effects may not be independent of each other: to the extent that any reduction in the potential cost of litigation encourages players in the supply chain to litigate, it may increase the volume of litigation.

**Figure 15: Benefits pathways for cost savings from litigation** (extracted from benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
1-3: Brief-Concept	Supply chain procurement, contract award and mobilisation	Supply chain submits Master Information Delivery Plan (MIDP) and pre-contract BEP to the client	Improved scope understanding by the supply chain (leading to reduced cost of supply chain claims)	Cost savings in litigation
1-3: Brief-Concept	Supply chain procurement, contract award and mobilisation	BIM L2 compliance sets out the requirements for information exchange and collaborative working using CDE	Better quality of data and quicker exchange e.g. systemised data collection and storage for future learning/ knowledge sharing	
4: Design	Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Quicker access to valuable asset data (area /volume /material etc.)	
7: Operation and end of use	Incident Management	3D model-based data supports incident investigation	More/better information to support legal position	

Source: PwC.

#### Quantification of cost saving from reduction in number of claims:

$$\text{Cost saving (£)} = \text{Reduction in number of claims attributable to BIM Level 2 (number)} \times \text{Average cost of each claim (£)}$$

**Data required:** Total number of claims calculated on BIM Level 2 project and appropriate counterfactual project delivered without BIM Level 2. Assumptions have to be made regarding the average cost of a claim including time and materials based on cost estimates derived from similar changes occurring on other projects of similar type, complexity, duration and value. The average cost of a claim should be based on a sample of

<sup>32</sup> Claims due to lack of information usually arise due to uncertainty between the information required to deliver the asset and information available. For instance, in traditional procurement, a contractor wins a project on a lump sum fee basis based on available tender documentation produced at the end of design. However, once the construction starts, the original tender documentation is revised to incorporate client initiated changes. The new documentation is not provided to the contractor in a timely manner. Lack of information required to construct the asset results in construction delays, changes to construction methods, and an increase in the amount of material required to build the asset. Each of these issues can provide the basis for the contractor to make a claim against the client, if the client refuses to acknowledge the changes as a variation of the original scope. BIM Level 2 aims to improve collaboration and prevent such issues from occurring.

claims of a similar type and include the legal fees, labour and materials required to execute work, and labour to review the claims by the internal team.

**Quantification of cost saving per claim from reduced effort required to resolve:**

$$\begin{aligned} \text{Cost saving (£)} &= \text{Cost of resolving a claim using documents (£)} \\ &\quad - \text{Cost of resolving a claim using BIM simulations (£)} \end{aligned}$$

**Data required:** Historic cost/time estimates/quotes for claims investigation works from external consultants based on two different methods – one based on methods without application of BIM and one using BIM. The cost/time/quotes for claims investigation works should include all costs including labour cost, materials cost and overheads.

## 4. Improved health and safety

The use of BIM Level 2 has the potential to reduce, improve information about, and control health and safety risks in the construction and operations stages of the asset lifecycle; and enable project stakeholders to satisfy their duties under CDM 2015 regulations<sup>33</sup>. Currently, the PAS 1992-6 “*Specification for collaborative sharing and use of structured Health and Safety information using BIM*”<sup>34</sup> standard is being developed to summarise how BIM can be used to share information to review the risks and improve the project Health & Safety performance. For example, a 3D model can provide the visual basis for improved staff briefing and training, with further potential to use 4D simulations (including construction and demolition activities) to optimise sequencing from a safety perspective.

**Significance of the benefit:** The benefits from health and safety improvements (in terms of improved welfare) are likely to primarily accrue to those working on the construction site / operating the asset. There will also be associated welfare benefits accruing to the friends / relatives of workers; and indirect monetary savings such as the avoided associated cost faced by the NHS, and loss of GDP. Academic literature suggests that the potential scale of health and safety benefits from BIM is significant. For example, one study found that when BIM was used during asset delivery, there was an 87.5% reduction in the number recordable injuries compared with the national average.<sup>35</sup> Improved health and safety outcomes form part of many government construction clients’ strategic objectives. For example, one of the key values detailed in HS2’s corporate plan is to create a safe and secure working environment. Improved health and safety through BIM could help government departments and agencies meet objectives such as these.

**Monetising the benefit:** In line with Green Book<sup>36</sup> and HSE guidance<sup>37</sup>, we suggest that the reduced cost to society accrued from health and safety improvements can be divided into two main component costs:

- 1 *Financial costs:* Costs including productivity costs (accounting for the lost income and output resulting from absence from work, and production costs i.e. cost of recruitment and reorganisation for employers); the cost of employer’s liability compulsory insurance (less compensation payouts to individuals); health and rehabilitation costs (e.g. those faced by the NHS); and administrative and legal costs (e.g. those resulting from the administering of claims).
- 2 *Human costs:* Cost representing the monetary value associated with loss of quality of life / loss of life in the case of fatalities.

**Quantifying the benefit:** The approach we recommend to value health and safety improvements from BIM Level 2 involves estimating the reduction in the number of accidents (or reduction in the number of incidents of work-related illness) that are attributable to BIM Level 2 and applying a parameter that reflects the social cost of that accident or work-related illness, taken from Green Book and HSE guidance.

- a. **Quantify impact:** Determine the difference in the number of fatal and non-fatal injuries, and amount of work-related illness, attributable to BIM Level 2. As described in the **Introductory Note 5.3** there are a number of possible ways to do this against an appropriate counterfactual.

<sup>33</sup> See Health and Safety Executive, *Managing health and safety in construction*, Construction (Design and Management) Regulations 2015.

<sup>34</sup> See <http://bim-level2.org/en/standards>

<sup>35</sup> See Khanzode, A. et al. (2008) *Benefits and Lessons Learned of Implementing Building Virtual Design and Construction (VDC) Technologies for Coordination of Mechanical, Electrical, and Plumbing Systems on a Large Healthcare Project*, Itcon 13 who find that for 203,448 work hours during MEP coordination there was only 1 recordable injury, and compare this to the national average of approximately 8 recordable injuries for the same number of work hours.

<sup>36</sup> See *The Green Book*, Annex 2: Valuing Non-market Impacts, pp. 61-62.

<sup>37</sup> See Health and Safety Executive, *Appraisal values or ‘unit costs’*, <http://www.hse.gov.uk/economics/eauappraisal.htm> March 2018

*For example:* Compare the H&S logs and related site records on a BIM Level 2 project to a very similar project with the same type and length of construction involved. Remove from the analysis any accidents or work related illness that BIM Level 2 would not influence.

- b. Monetise:** Apply the cost to society per accident or incident of work related illness ((see Table 3 for these values, note that the value attached to a fatal accident differs from that attached to a non-fatal injury) to the reduction in number of accidents (or incidents of work-related illness) attributable to BIM Level 2 to determine the total benefit:

*Value of reduction in accidents*

$$= \text{Reduction in \# of accidents due to BIM Level 2} \times \text{Cost to society per accident (\pounds)}$$

*Value of reduction in work related illness (\pounds)*

$$= \text{Reduction in \# of incidents of work related illness due to BIM Level 2} \\ \times \text{Cost to society per work related illness (\pounds)}$$

**Data required:** The number of fatal and non-fatal accidents per project; the number of incidents of work-related ill health per project; details about those accidents/ work-related ill health incidents to determine whether BIM Level 2 could have affected them; and the cost to society per accident/ work-related ill health incident (taken from HSE guidance).

**Assumptions:**

- Cost to society per accident:** In line with HSE guidance<sup>38</sup>, we assume a cost of £1,570,000 (2014 prices) per fatal accident, £7,400 (2014 prices) per non-fatal injury and £17,600 (2014 prices) per incident of work-related illness (see Table 3).

**Table 3: Estimated cost of accidents**

<b>Cost to society per case (sum of cost to individual, employer; and government per case)</b>			
	<b>Non-financial human cost (\pounds in 2014 prices*)</b>	<b>Financial cost (\pounds in 2014 prices*)</b>	<b>Total cost (\pounds in 2014 prices*)</b>
<b>Fatal injuries</b>	1,149,000	421,600	<b>1,570,000</b>
<b>Non-fatal injuries</b>	4,500	2,900	<b>7,400</b>
7 or more days absence	18,200	10,300	28,484
Up to 6 days of absence	320	550	880
<b>Ill health</b>	9,400	8,200	<b>17,600</b>
7 or more days absence	19,600	16,800	36,400
Up to 6 days of absence	270	570	840

Source: HSE Cost to Britain model<sup>39</sup>

**Example – Comparison of the number of site accidents on two capital projects**

**Benefit measured:** Improved H&S

**Impact pathway:**

<sup>38</sup> See Health and Safety Executive, *Appraisal values or ‘unit costs’*, <http://www.hse.gov.uk/economics/eauappraisal.htm>

<sup>39</sup> <http://www.hse.gov.uk/economics/eauappraisal.htm>

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
5: Build and Commission	Health & Safety management	Improved information including 3D/4D models used to address health & safety hazards (supporting good CDM)	Better understanding of construction operations and better visibility of safety & health risks, including residual risks	Improved H&S (construction)

**Source:** Due to absence of comparable data or a case study, an arbitrary example has been used to illustrate the calculation approach.

**Description:** Two projects were analysed for the number of accidents on site. The first project was BIM Level 2 mature (*Project A*) with construction complete 2017. The second project was a ‘without-BIM’ project (*Project B*), completed at the end of 2010. Projects had similar scope of works to construct two new buildings, refurbishment of one of the existing buildings and associated the landscaping works.

Both projects had a total capital cost of approximately £200 million. *Project A* was delivered in 22 months and *project B* in 24 months. Based on site reports, the average daily worker headcount on site was roughly similar: *project A* had an average number of 43 workers on site per day and project B had 47 workers. Average person-hours per worker per day spent on site were also similar: on *project A* workers spent on average 7.9 hours and on project B – 8.2 hours. The main contractor was the same on both projects. Site reports were analysed and number and types of accidents were extracted. On *project A*, the data on accidents was only available for the 9-month part of the construction period. On *project B*, the data was available for a period of 18 months. Therefore, to compare the two datasets it was necessary to normalise the site accidents over a 9-month period. For simplicity, we divided by 2. Other criteria, such as project cost, schedule, scope, average daily number of workers and average daily man-hours appear comparable.

The site team on *project B* used paper drawings and health and safety manuals for hazard reviews. Toolbox talks were delivered verbally without any visual aids.

On *project A*, the site team used a federated Revit model to include the latest temporary works and simulate the construction sequence. Toolbox talks included the review of site progress in 3D with on-going hazard identification due to changes site configuration.

**Normalisation criteria:** based on availability of data and the differences in projects, it is necessary to consider other factors that could influence the number of site accidents, not related to use of BIM Level 2:

1. Project schedule – project A – 22 months & project B – 24 months; – similar in schedule, period for comparison between projects set to 9 months to reflect data available. Seasonality taken into account, data used for comparison between projects contains same number of winter / summer months. No noted adverse weather conditions on site during either construction period.
2. Project scope/complexity - similar scope – not likely that differences in scope would affect the number of accidents.
3. Project cost – both project costs are £200 million – no difference
4. Headcount on site – project A – 43 workers on average per day & project B – 47 workers on average per day; 8.5% difference – not significant enough to influence number of accidents.
5. Total person-hours – project A – 7.9 person-hours/day & project B – 8.2 man-hours/day; 4% difference – not significant enough to influence number of accidents.

**Result:** Records for *project A* identified 5 minor accidents, 3 near misses and 0 non-fatal RIDDOR accidents over the period of 9 months. *Project B* records identified 23 minor accidents, 3 near misses and 3 non-fatal RIDDOR accidents over the period of 18 months.

Over the 9-month period analysed, the number of accidents on a BIM mature project was significantly less: 0 fatal accidents have happened on both projects.

$(3-0)/2 = 1.5$  non-fatal accidents requiring 7 or more days’ absence

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$(23-5)/2 = 9$  non-fatal accidents requiring up to 6 days absence

Value of reduction in near misses is not taken into account as no accident has happened.

**Assumptions:**

- The ‘without-BIM Level 2’ project used for comparison represents a suitable and appropriate counterfactual. It is possible that there were other unforeseen circumstances that led to accidents occurring. However, we have analysed all data available on accidents, and based on the expertise of construction workers, it is possible that for the additional accidents that occurred on project B, they could have been prevented with use of BIM Level 2.
- See Table 3 in “Detailed Assumptions” for the cost values of accidents.

**Benefit calculation:**

*Value of reduction in accidents*

$$\begin{aligned} &= \text{Reduction in \# of fatal accidents} \times \text{Total cost of fatal accident} + \text{Reduction in \# of non} \\ &\quad - \text{fatal accidents (up to 6 days absence)} \times \text{Total cost of non} \\ &\quad - \text{fatal accident (up to 6 days absence)} + \text{Reduction in \# of non} \\ &\quad - \text{fatal accidents (7 or more days absence)} \times \text{Total cost of non} \\ &\quad - \text{fatal accident (7 or more days absence)} = 0 \times \text{£1,570,000} + 9 \times \text{£880} + 1.5 \times \text{£28,484} \\ &= \text{£50,646} \end{aligned}$$

**How the benefit is realised:** This methodology for measuring time savings can be applied to the following benefits identified in our benefits framework (high level grouping derived from detailed framework):

- Improved health and safety in construction
- Improved health and safety in maintenance/demolition

In the following pages, we provide a description of how the methodology described above can be applied to each of these benefits, and the associated calculations required.

## 4.1 Improved health and safety in construction

The information and project planning requirements enforced by BIM Level 2 can potentially bring health and safety improvements to the construction process by reducing the risk of error, and improving understanding of the construction process and associated health and safety risks and requirements. Figure 16 below, provides the detailed impact pathways.

**Figure 16: Impact pathways for improved health and safety in construction** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
4: Design	Design coordination and management	Engineering rules enforced by BIM	Reduced chance of human error	Improved H&S in construction
4: Design	Design reviews	Visualisations aid in design reviews	Quicker review against client's EIRs, design standards, H&S	
5: Build and Commission	Health & Safety management	Improved information including 3D/4D models used to address health & safety hazards (supporting good CDM)	Better understanding of construction operations and better visibility of safety & health risks, including residual risks	

Source: PwC.

**Quantification method** (as described above in Section 1.4):

*Value of reduction in accidents*

$$\begin{aligned}
 &= \text{Reduction in \# of fatal accidents} \times \text{£1,570,000 (2014 prices)} \\
 &+ \text{Reduction in \# of nonfatal accidents} \times \text{£7,400 (2014 prices)} \\
 &+ \text{Reduction in \#work related illnesses} \times \text{£17,600 (2014 prices)}
 \end{aligned}$$

**Data required:** The number of fatal and non-fatal accidents, and incidents of work-related illness per project, or reduction in number of accidents/work-related illness on one project that could be attributed to BIM Level 2.

## 4.2 Improved health and safety in maintenance / demolition

BIM Level 2 provides the basis for 3D and 4D visualisation capabilities which can potentially enable better understanding of residual risks in asset operation, a safer virtual training process, and result in better information about the demolition sequence. This reduces the chance of accidents occurring during maintenance and demolition. The detailed framework that demonstrates the pathway from BIM to the end benefit of improved health and safety is detailed below in Figure 17 .

**Figure 17: Impact pathways for improved health and safety in maintenance/demolition** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
4: Design	Health & Safety management	Improved information including 3D/4D models used to address health & safety hazards (supporting good CDM)	Better understanding of construction operations and better visibility of safety & health risks, including residual risks	Improved H&S in operation
7: Operation and End of Use	Maintenance	3D model enables virtual maintenance training	Training in maintenance is carried out faster, earlier, and more safely	
7: Operation and End of Use	Disposal of asset	AIM provides quicker access to information and enables simulation of demolition using 4D BIM	More / better information about the demolition sequence	

Source: PwC.

**Quantification method** (as described above in Section 1.4):

*Value of reduction in accidents*

$$= \text{Reduction in \# of fatal accidents} \times \text{£1,570,000 (2014 prices)}$$

$$+ \text{Reduction in \# of nonfatal accidents} \times \text{£7,400 (2014 prices)}$$

**Data required:** The number of fatal and non-fatal accidents per project.

## 5. *Reduced risk*

The use of BIM Level 2 has the potential to improve the accuracy of information about a project or asset, and improve visibility about associated costs, delivery timeline, and risks. Because of this increased certainty provided by BIM Level 2, there is a potential for a reduction in the variability of costs and time required for asset delivery and operation. This may result in the ability to reduce the contingency required against capital expenditure and/or operating expenditure, thus resulting in a reduction in costs associated with that contingency.

Contingency is the sum of money which needs to be held as a precaution to account for project risks being realised on a project. BIM Level 2 provides the potential for risks to be mitigated earlier in the project lifecycle. For example, improved design accuracy, the use of federated, object-based models and 4D construction simulation can all be used to identify, reduce or eliminate potential risks which typically could incur time and cost impacts during construction. Therefore, BIM level 2 may reduce the amount of contingency required, and therefore the associated cost of holding this contingency.

The cost of holding contingency can be thought of as the opportunity cost of what else could be done with that money (i.e. the costs associated with not being able to invest the money elsewhere – lost interest).

BIM Level 2 may result in a downward adjustments for optimism bias (a systematic tendency for stakeholders involved in appraising the costs and benefits of a project to be overly optimistic – overestimating the benefits and underestimating the costs).<sup>40</sup> In line with Green Book guidance, over time when more reliable estimates of relevant costs are built up, adjustments to project risk contingencies accounting for optimism bias may be reduced. This means that in practice, reduction in contingency due to BIM Level 2 may increase over time.

This benefit from reduced risk is likely to accrue to the government construction client or asset owner. It is likely that larger effects would be seen in the long term compared to the short run, given that over time the reduction in risk and optimism bias are likely to be increasingly recognised.

**Significance of the benefit:** The effect of reduced risk both in the capital and operating phases is potentially highly significant for all government construction clients and asset owners. The Green Book recommends upper and lower levels of optimism bias adjustment rates which vary by project type and are different for ‘works duration’ and ‘capital expenditure’. For example, a bias of between 2% and 24% should be applied to capital expenditure estimates for standard buildings (see

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<sup>40</sup> See the supplementary Green Book guidance on Optimism Bias.  
[https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/191507/Optimism\\_bias.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/191507/Optimism_bias.pdf)  
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Table 4).

In addition, the academic literature suggests the effect of reduce risk brings potentially significant benefits - one study suggests BIM enabled cost estimations to improve in accuracy to within 3% of estimates.<sup>41</sup> Reduction in contingency is likely to become more significant over time as it will take time for the effects of the increased accuracy of cost forecasts to be translated to industry practice in accounting for risk.

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<sup>41</sup> Azhar, S. (2011) *Building Information Modelling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry*, ASCE 11(3) March 2018

**Table 4: Green Book recommended adjustment ranges for optimism bias**

Project Type	Optimism Bias (%)			
	Works Duration		Capital Expenditure	
	Upper	Lower	Upper	Lower
Standard Buildings	4	1	24	2
Non-standard Buildings	39	2	51	4
Standard Civil Engineering	20	1	44	3
Non-standard Civil Engineering	25	3	66	6
Equipment/Development	54	10	200	10
Outsourcing	N/A	N/A	41	0

Source: Supplementary Green Book Guidance – Optimism Bias, page 2<sup>42</sup>

**Monetising the benefit:** Reduced risk provides monetary savings based on a **reduction in the amount of contingency** built in to appraisals, and an associated cost of this. For government construction clients, the opportunity cost of holding contingency is the social rate of time preference defined in the Green Book (3.5% per annum).

**Calculating the reduction in risk contingency costs:** *Has BIM Level 2 led to reduced project risk contingencies?*

- Quantify impact:** Determine the reduction in contingency attributable to use of BIM Level 2 for the relevant time period. As described in the **Introductory Note Section 5.3** there are a number of possible ways to do this against an appropriate counterfactual. The supply chain could advise if contingency has been decreased due to BIM Level 2, and it may be possible to compare contingency employed on a similar project (with a similar risk profile), that did not use BIM Level 2.
- Monetise:** Apply the opportunity cost (the social rate of time preference in the case of government construction clients) to the change in the value of the contingency.

$$\begin{aligned}
 & \text{Value of reduced risk per annum (£)} \\
 & = \text{Reduction in contingency held per annum (£)} \\
 & \times \text{Opportunity cost (3.5\% per annum currently)}
 \end{aligned}$$

- Data required:** Project contingency detail for the relevant stage (capital/operating) for two similar projects with and without BIM (£) if using a comparison approach; an understanding of any factors affecting project contingency due to events that BIM could not influence; the current social rate of time preference.

#### Assumptions:

- The value associated with opportunity cost:** Currently the Green Book suggests this value is 3.5%, the social rate of time preference (i.e. the value society attaches to present, rather than future, consumption, and is developed using comparisons of utility across time).<sup>43</sup>

<sup>42</sup> [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/191507/Optimism\\_bias.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/191507/Optimism_bias.pdf)

<sup>43</sup> Note that for the 'very long term' (beyond 30 years) the Green Book recommends a lower discount rate, which can be found in Annex 6 of the Green Book.

**Great Portland Estates – 240 Blackfriars Road office delivery**

Benefit measured: Reduced capital expenditure contingency

**Impact pathway:**

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	BIM L2 compliance enables clients to develop detailed information requirements (EIR*, AIR*, OIR) at early project stages	Improved definition of the information (data / documents) required by client, this information received at the right times in the right format	Reduced project risk contingency in CAPEX phase
1-3: Brief-Concept	Supply chain procurement, contract award and mobilisation	Supply chain submits Master Information Delivery Plan (MDP) and pre-contract BEP to the client	Improved scope understanding by the supply chain	

**Source:**  
[http://www.bimtaskgroup.org/wp-content/uploads/2013/07/BIMsupplement2013\\_download\\_v2.pdf](http://www.bimtaskgroup.org/wp-content/uploads/2013/07/BIMsupplement2013_download_v2.pdf)

**Description:** Great Portland Estates (“client”) required their supply chain to use BIM Level 2 on the delivery of a **£61 million** of office space at 24 Blackfriars Road in London. This helped to improve supply chain collaboration and minimise coordination issues. Mace, the main contractor, used the BIM model to demonstrate the validity of the proposed construction sequence through a series of 4D simulations. Overall, use of BIM Level 2 allowed Mace to provide more certainty to the client that the project would be delivered as planned. This allowed capital expenditure contingency to be reduced.

**Result:** The Client reduced the amount of contingency from **£2.1 million (3.44% of capital cost)** to **£0.6 million (0.98% of capital cost)** after the second stage tender - a total reduction in contingency held of **£1.5 million** over the period of one year.

**Benefit calculation:**

*Value of reduced risk (£)*  
 = Reduction in contingency held per annum (£)  
 × Opportunity cost (3.5% per annum ) = £1,500,000 x 3.5% = £52,500

**How the benefit is realised:** This methodology for measuring reduced risk contingency savings can be applied to the following benefits identified in our benefits framework (high level grouping derived from detailed framework):

- Reduced project risk contingency in capital delivery phase
- Increased certainty in operating expenditure estimates

In the following pages, we provide a description of how the methodology described above can be applied to each of these benefits, and the associated calculations required.

## 5.1 Reduced project risk contingency in capital delivery phase

The use of BIM Level 2 may result in reduced project risk contingency during the capital delivery phase for the government construction client. This benefit is enabled by the elements of BIM Level 2 which increase the client's assurance of project success: through improved scope definition and understanding by the supply chain, accuracy in design cost estimates and better cost control during asset delivery. The detailed impact pathways are shown in Figure 18.

**Figure 18: Impact pathways for reduced project risk contingency in capital delivery phase** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	BIM L2 compliance enables clients to develop detailed information requirements (EIR*, AIR*, OIR*) at early project stages	Improved definition of the information (data / documents) required by client; this information received at the right times in the right format; stage gate reviews passed without delay	Reduced project risk contingency in capital delivery phase
1-3: Brief-Concept	Supply chain procurement, contract award and mobilisation	Supply chain submits Master Information Delivery Plan (MIDP) and pre-contract BEP to the client	Improved scope understanding by the supply chain	
4: Design	Cost estimation	Increased automation in material quantity take-off	Increased accuracy of estimates - reduced risk of human error	
4: Design	Cost estimation	Soft Landings require review of design CAPEX & OPEX cost against targets	Better visibility of project costs upfront	
5: Build and Commission	Use of combined 3D Construction schedule planning	Use of combined 3D federated models and project schedules for sequence planning; 4D management of lean construction	Better cost control	

Source: PwC

### Quantification of reduction in capital contingency:

*Value of reduced risk per annum (£)*

$$= \text{Reduction in contingency held per annum} \times \text{Opportunity cost per annum (3.5\% currently)}$$

*Where: reduction in contingency held per annum (£) =*

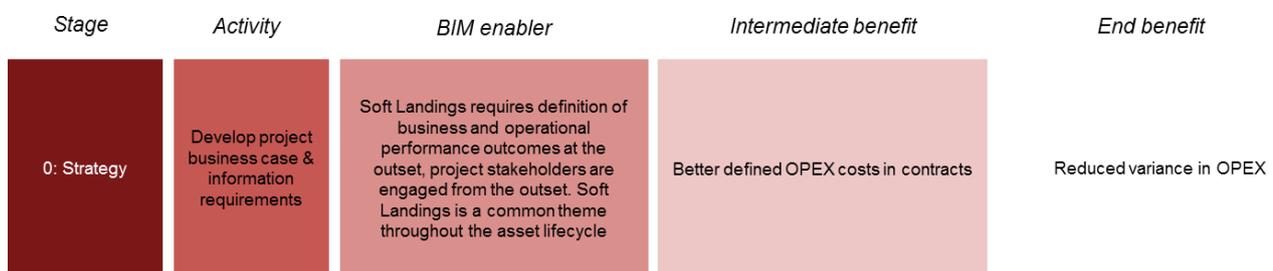
$$\% \text{ reduction in contingency per annum} \times \text{total CAPEX (£)}$$

**Data required:** Project contingency savings in capital expenditure (£) from BIM; social rate of time preference (currently 3.5% per annum).

## 5.2 Increased certainty in operating expenditure estimates

The use of BIM Level 2 may result in reduced ‘contingency’ for the government asset owner during operations, through increased certainty in running costs. When preparing cost estimates for a project / asset on a whole of life basis, optimism bias should be accounted for when estimating operating costs as well as capital costs. This benefit is enabled by Government Soft Landings which leads to continual focus on the operational performance of an asset from initial stages and throughout the lifecycle resulting in the generation of better defined operating costs in contracts. Additionally, GSL approaches should allow greater opportunity for asset owners to claim compensation for asset performance shortfalls which result in higher running costs. The detailed impact pathway is shown in Figure 19.

**Figure 19: Impact pathway for reduced project risk contingency in operating phase** (extracted from detailed benefits framework)



Source: PwC.

### Quantification of reduction in risk contingency costs:

*Value of reduced risk per annum (£) = Reduction in contingency held × Opportunity cost (3.5% currently)*

*Where: reduction in contingency held (£) =  
% reduction in contingency × annual OPEX (£)*

**Data required:** Project contingency savings in operating expenditure (£) from BIM; social rate of time preference (currently 3.5%).

**Note:** As indicated by several impact pathways of the framework, there is the potential for the application of BIM Level 2 to result in a reduction in the variability of operating expenditure. Operations phase ‘contingency’ may not be a usual term or approach used in the industry. However, annual operating expenditure is estimated for a project at the business case stage – if the cost range can be tightened, it may be easier to create a business case for that project; more and better projects may be selected; and less money put aside for future operating expenditure in forward looking budgets - this can be allocated to other projects or investments (which is why we value this benefit at the government construction client’s opportunity cost of capital – 3.5%).

## 6. Improved asset utilisation

The use of BIM Level 2 has the potential to improve the availability of an asset once it has been constructed: this means that it can potentially be used more productively over its lifetime to provide public services. This may occur in a number of different ways:

- Through the use of standard design solutions that can improve the internal space utilisation. For example, by being able to fit more rooms of a standard design from an object library into the internal space, compared to using bespoke room designs.
- Through GSL and greater involvement of the government construction client in the early stages of asset delivery, including the handover process, the client may be better informed about how to operate the asset most productively: for example, the planned use of space within an asset can be determined through modelling resulting in better configuration and the time required to reconfigure assets can be reduced.
- Through the use of an AIM in operations, maintenance and refurbishment can be carried out faster.
- The time required to respond to incidents can be reduced.

All three effects reduce the ‘downtime’ of an asset. The detailed impact pathways for improved asset utilisation are shown in Figure 20.

**Figure 20: Impact pathways for increased asset utilisation** (extracted from benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
4: Design	Design authoring	Creation of object and design libraries	Standard design solutions that can be used on any project	
7: Operation and end of use	Asset / building operation	3D model enables virtual simulation processes (less prone to error); Soft Landings supports continued client education	Reduced time taken to execute space changes, better decisions made about asset operation	
7: Operation and end of use	Maintenance	AIM provides quicker access to info. needed to carry out maintenance	Maintenance is carried out faster	Improved asset utilisation
7: Operation and end of use	Refurbishments and upgrades	AIM provides quicker access to accurate asset information	Reduced time taken to execute refurbishments	
7: Operation and end of use	Incident Management	AIM provides quicker access to information to manage incident, inc planning the rebuild/redevelopment	More / better information about the asset in support of recovery/rebuild	

Source: PwC.

**Significance of the benefit:** This benefit could potentially be significant across asset types, but is likely to be most significant for assets where downtime has the largest negative effect on the provision of the intended services. For example, train operators are fined if their services fail to meet their punctuality targets. Fines can be set at a level to reflect the economic costs to customers and the rest of society of service delay. In 2014 Network Rail was ordered to pay a £2 million financial penalty because “*Network Rail’s performance in respect*

*of passenger services on Southern, GTR, and in Scotland were below expectations and missed punctuality targets in 2014-15*".<sup>44</sup>

The use of BIM Level 2 could potentially reduce the downtime of assets, including rail networks. Other asset types, particularly buildings, may be more resilient to downtime as maintenance can be performed incrementally through spaces within the asset; however, benefit still exists in the ability to optimise maintenance cycles and limit downtime of critical spaces or functions.

**Monetising the benefit:** Estimating the benefit of improved asset utilisation involves two steps.

First, an estimate is needed of how much more productive an asset would be if the 'downtime' was reduced as a result of the application BIM Level 2. For example:

- In the case of a rail network, data on network outages could be used. If the length and reason for outages are recorded, it could be possible to estimate the proportion (or the percentage of outage time) that would not have occurred if BIM Level 2 was used.
- In the case of a hospital, data on bed availability and occupancy are collected from NHS organisations. Analysis of these data could be used to estimate the impact of improved utilisation due to BIM Level 2. The improved utilisation can then be valued either in terms of the avoided financial cost to the NHS or in terms of the welfare benefit to the patient from having access to earlier treatment.
- In the case of a road network, reduced downtime due to improved maintenance could enable better road utilisation. This could be measured in terms of the increase in average vehicle flow over a set period of time and/or the reduction in journey time.
- For some types of asset (e.g. office buildings) a portfolio approach can be taken, in which a consolidated AIM across a portfolio can be used to maximise the use of space designed for a common function. Benefit measures can be estimated by considering the number of times a solution to a space restriction can be found within the portfolio using a common AIM, as compared to hiring external space where a portfolio view is unavailable. See the 'avoided cost' method below.

Second, an estimate is needed of the value that would be foregone if the asset was unavailable. This could be estimated in two ways:

- **The economic/social benefit lost:** For example, in the case of a hospital, loss of productive time may lead to (health) dis-benefits for patients. Various techniques exist, including stated preference and revealed preference, which can be used to assign a monetary value to the loss in utility.
- **The avoided cost method:** An alternative approach is to estimate the cost of preventing a loss, for example by providing additional capacity to enable the system to cope with the disruption arising. The cost of providing the additional capacity can be used as a proxy for the cost of an asset's downtime.

**Estimating the benefit from improved asset utilisation:**

- **Quantify impact:** Determine the increase in productivity or reduction in downtime attributable to BIM Level 2. As described above, the way in which productivity or downtime is measured/ the form it takes will differ across asset types. Each asset owner must determine the most appropriate productivity metric for their asset type and a means of attributing productivity increases to BIM Level 2.
- **Monetise:** Apply the relevant value for that productivity increase to the change in downtime – avoided cost or social benefit lost:

Generally:

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<sup>44</sup> For further detail see the press release produced by the ORR on 10<sup>th</sup> August 2015, *ORR investigation finds Network Rail in breach of licence in 2014-15*, available at <http://www.orr.gov.uk/news-and-media/press-releases/2015/orr-investigation-finds-network-rail-in-breach-of-licence-in-2014-15>

$$\begin{aligned} & \text{Value of improved asset utilisation (£)} \\ & = \text{Reduction in the asset's downtime (hours or days)} \\ & \times \text{Value of the service the asset provides (£ / hour or day)} \end{aligned}$$

OR

$$\begin{aligned} & = \text{Improvement in productivity due to BIM Level 2 (\%)} \\ & \times \text{value attributed to a 1\% improvement in productivity of the asset (£)} \end{aligned}$$

For example: if improvements to the efficiency of refurbishments of a school due to BIM Level 2 mean that refurbishments take place 10 days faster, the school would need to rent an alternative premises for 10 days less. Therefore the value of the improved asset utilisations:

$$\text{Value of reduction in downtime (£)} = 10 \text{ days} \times \text{Rental costs of temporary premises}$$

- **Data required:** Change in asset's downtime or improvement in asset's productivity due to BIM Level 2; value of the service the asset provides/ rental costs of alternative premises.

For example: the improved spatial efficiency of a prison due to smarter operations may mean it can accommodate an additional 5 prisoners into the same space.

$$\begin{aligned} & \text{Value of improved asset utilisation (£)} \\ & = \text{Change in average \# of prisoners accommodated per square kilometre per annum} \\ & \times \text{Annual cost of accommodating each prisoner elsewhere (£)} \end{aligned}$$

## 7. Improved asset quality

Use of BIM Level 2 has the potential to improve service delivery if it enhances the design quality of the asset and this benefits the end-user of the public services which are delivered using it. For example, BIM's 3D and 4D visualisation capabilities may result in a building being better laid out, or more pleasant to be in (the building may be angled to get more sunlight for example). The processes defined by BIM Level 2, and the engagement with project stakeholders it encourages, enable clearly defined operational performance and design objectives from the outset. BIM Level 2 brings improved visibility over the process of design and construction, thus enabling the quality of the asset for the end-user to be improved.

**Significance of the benefit:** Benefits from improved asset quality will accrue during service delivery. There is some evidence that this benefit could be significant – the literature shows that asset quality has measurable impacts on end-user outcomes. However, it is difficult to quantify and attribute to the use of BIM Level 2. BIM Level 2 can improve design quality of assets in a number of ways. Academic literature suggests that the benefits of improved design quality can manifest themselves in diverse ways depending on the asset type/use. For example, within the healthcare sector, studies have found that improved building quality improves healthcare outcomes for patients – one study found that patients in new-build hospitals had 21% faster rates of discharge compared to older buildings, resulting in cost savings from reduced hospital stays.<sup>45</sup>

Literature on asset quality highlights that there are specific and measurable improvements derived as a result of improved quality in areas including, but not limited to, hospital stays, staff morale and public housing where the specific impacts that occur will depend upon asset type. Furthermore, there is a broader impact of BIM Level 2 on improved design quality through early stakeholder involvement and increased focus on the end user during design. The benefits displayed can only be partially attributable to BIM Level 2, given that BIM is only one element of many that influences asset quality.

**Table 5: Summary of literature review on improved asset quality**

Author	Outcome
<b>Hospital stays</b>	
University of Sheffield, School of Architecture (1999) <sup>46</sup>	Patients in a new-build compared to older buildings had 21% faster rates of discharge. Additionally psychiatric patients had 14% shorter stays and displayed reductions in verbal outbursts (24%) and threatening behaviour (42%).
Ulrich, R. (1984) <sup>47</sup>	Patients in rooms with open views had 9% shorter post-operative stays compared to those with views onto brick walls. They also required less medication and had lower rates of post-surgical complications.
Leather, P (2000) <sup>48</sup>	Patients staying in wards with improved interior design (lighting, external views) had lower pulse rates, blood pressure readings and 27% shorter post-operative stays.
<b>Staff morale</b>	
Coote, A. (Ed) (2002) <sup>49</sup>	Staff morale increased by 56% following the re-design of the hospital.

<sup>45</sup> University of Sheffield, School of Architecture (1999), *The architectural healthcare environment and its effects on patient health outcomes: a report at the end of the first year of study*. University of Sheffield, School of Architecture in association with NHS Estates, Poole Hospital NHS Trust and South Downs Mental Health Trust.

<sup>46</sup> University of Sheffield, School of Architecture (1999) *The architectural healthcare environment and its effects on patient health outcomes: a report at the end of the first year of study*. University of Sheffield, School of Architecture in association with NHS Estates, Poole Hospital NHS Trust and South Downs Mental Health Trust.

<sup>47</sup> Ulrich, R., (1985) *View through a window may influence recovery* from surgery Science 224 (7)

<sup>48</sup> Leather, P. (2000) *Hospital design, health and well-being*. Nottingham: Institute of Work Health and Organisations

<sup>49</sup> Coote, A. (Ed) (2002) *Claiming the health dividend: unlocking the benefits of NHS spending*. London. In CABI () *The value of good design*

Author	Outcome
<b>Public housing</b>	
Urban Land Institute	Study of over 10,000 housing transactions in four pairs of housing developments showed an average sales premium of \$20,000 (11%) on schemes upholding basic urban design principles. <sup>50</sup>

**How the benefit is realised:** The processes through which this benefit is realised is show in Figure 21 below.

**Figure 21: Impact pathways for improved asset quality** (extracted from benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
0: Strategy	Develop project business case & information requirements	Soft Landings requires definition of business and operational performance outcomes at the outset, project stakeholders are engaged from the outset. Soft Landings is a common theme throughout the asset lifecycle	Performance feedback is used to better inform client requirements and design briefs; supply chain has incentive to improve design for operations and maintenance requirements	Improved asset quality
1-3: Brief-Concept	Supply chain procurement, contract award and mobilisation	Supply chain submits Master Information Delivery Plan (MIDP) and pre-contract BEP to the client	Improved visibility of supply chain BIM L2 maturity by the client	
4: Design	Client review & stakeholder consultation	3D & 4D virtual design simulations	Higher quality of asset for end user	

Source: PwC.

Ultimately the impact of improved asset quality depends on asset type:

- Some impacts will have monetary benefits to the asset owner (e.g. a reduction in staff turnover will directly affect the owner’s costs – through reduced recruitment/training costs – and therefore will have monetary benefits);
- Other benefits will be purely welfare improving (e.g. an improvement in staff morale has welfare benefits accruing to staff members).

How far the benefits are realised by asset owners (rather than end users) will depend upon the type of asset, the service being provided with the asset and how quality benefits manifest themselves.

**Monetising the benefit:** the benefits of improved asset quality fall into two categories:

- 1 Those that directly accrue to the asset owner because asset quality directly affects the owner’s costs, such as reduced staff turnover or reduction in hospital stays required by each patient (which reduce costs faced by the hospital).
- 2 Those that indirectly affect the asset owner if the end-user directly benefits (e.g. improved educational outcomes<sup>51</sup>, reduced road accidents and improved user experience).

Care is needed to avoid double counting.

<sup>50</sup> See <http://www.designcouncil.org.uk/sites/default/files/asset/document/the-value-of-good-design.pdf>

<sup>51</sup> See Higgins, S. et al. (2005), *The Impact of School Environments: A literature review*, The Design Council. for a discussion of the potential effects of improved building quality on educational outcomes  
March 2018

**Estimating the value of improved quality for the end user:** Asset owners need to consider the way that improved quality might directly affect user outcomes and the associated benefits. Following guidance in HM Treasury’s Green Book, how to value improved asset quality depends on whether or not the improvement in quality has a direct economic impact on the asset owner. Direct economic impacts on the asset owner can be monetised (such as in the example described above about staff turnover) as can indirect benefits for the end user - however this may be more difficult in practice.

There are a diverse range of benefits that could occur. Drawing on the available academic literature, we provide examples of direct benefits and the associated calculations that could be used to capture these in Table 6. These are categorised by the type of asset from which they arise.

**Table 6: Examples of benefit calculations for improved asset quality**

Asset type	Effect of quality improvement	Calculation to capture benefit
All	Reduction in staff turnover as a consequence of raised staff morale/satisfaction with working environment	$\text{Cost saving} = \text{Reduction in costs training new staff} + \text{reduction in recruitment costs}$ <p>Where:</p> $\begin{aligned} \text{Reduction in training costs} &= \text{Reduction in no. of new staff trained} \\ &\times \text{average training cost (£)} \end{aligned}$ <p>Where:</p> $\begin{aligned} \text{Reduction in recruitment cost} &= \text{Time savings of staff (hours)} \\ &\times \text{Average daily wage including overheads (£)} \end{aligned}$
Health	Reduction in the length of hospital stays	$\begin{aligned} \text{Cost saving from reduction in duration of stays} &= \text{Reduction in stay (days)} \times \text{Cost of stay (£ per day)} \end{aligned}$

## 8. *Improved reputation*

The application of BIM Level 2 could potentially improve the reputation of government construction clients (and asset owners, if they are different) together with the supply chains involved in asset delivery by improving the experience of those associated with asset delivery and service delivery. For example, in asset delivery, use of BIM Level 2 may result in better site layout and improved logistics. This could reduce (or avoid) negative impacts on residents, businesses and customers who reside near the construction site. In service delivery, use of BIM Level 2 could enhance reputation if customer service is enhanced or incident management is better. In case of incident management, AIM models can reduce the costs associated with employing experts to retrieve relevant documentation and carry out surveys to gain understanding of the state of the asset prior to an incident. This can lead to a much quicker incident response and resolution which might have a positive impact on the reputation of a government asset owner.

### **Significance of the benefit:**

- **Asset delivery:** BIM Level 2 can improve the reputation of both the government construction client and the supply chain during the build and commission phase where efficient site layouts, consideration for the public and improved health and safety can improve public perceptions of the project and the parties involved. For example, if during the construction of a road, BIM resulted in more efficient site layout, such that the construction process was smoother and faster, with fewer temporary road works, this might result in reputational gains for the asset owner. The benefits of this are likely to be most significant for government construction clients/ asset owners whose assets have a large public profile, or where the construction process of assets is likely to affect the public.
- **Service delivery:** During service delivery the reputation of the asset owner or operator and associated parties can be improved if perceptions of service delivery improve. Notable improvement in the service provided by rail service providers, road service providers, et cetera could have a significant impact on the organisation's reputation.

**How the benefit is realised:** The detailed impact pathways for this improvement in reputation are shown in Figure 22.

**Figure 22: Impact pathways for improved reputation** (extracted from detailed benefits framework)

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
1-3: Brief-Concept	Supply chain procurement, contract award and mobilisation	Supply chain submits Master Information Delivery Plan (MIDP) and pre-contract BEP to the client	Improved visibility of supply chain BIM L2 maturity by the client	Improved reputation
5: Build and commission	Site layout & logistics planning	Visual 3D & 4D site planning (including vehicles, logistics, temp. works, material storage) using federated models	Most cost efficient site layout with easy access for machinery and material storage & better consideration for residents / business in local area	
5: Build and commission	Health & Safety management	Improved information including 3D/4D models used to address health & safety hazards (supporting good CDM)	Better understanding of construction operations and better visibility of safety & health risks, including residual risks	
7: Operation and End of Use	Maintenance	AIM provides quicker access to info. needed to carry out maintenance	Maintenance is carried out faster	
7: Operation and End of Use	Incident Management	3D model-based data supports incident investigation	More/better information to support legal position	

Source: PwC.

**Monetising the benefit:** Difficulty arises in attributing reputational improvements to BIM because many factors contribute to reputation and it will be difficult to isolate the extent to which each is responsible. For example, a government department may experience reputation improvement because of the construction of a new asset, and a smoother construction process, but equally that reputational gain could be the result of a policy change, or changes in staffing etc. It may be possible to assess the extent to which reputational gains are occurring through surveys, but attributing this to BIM Level 2 would still be difficult. Furthermore, it will be important to ensure that any reputation gain is over and above the benefits captured elsewhere in the benefits measurement methodology.

**The Business Value of BIM for Construction in Major Global Markets. How Contractors Around the World are Driving Innovation with BIM. SmartMarket Report. 2014.**

**Benefit measured:** Improved reputation

**Impact pathway:**

Stage	Activity	BIM enabler	Intermediate benefit	End benefit
1-3: Brief-Concept	Supply chain procurement, contract award and mobilisation	Supply chain submits Master Information Delivery Plan (MIDP) and pre-contract BEP to the client	Improved visibility of supply chain BIM L2 maturity by the client	Improved reputation
5: Build and commission	Site layout & logistics planning	Visual 3D & 4D site planning (including vehicles, logistics, temp. works, material storage) using federated models	Most cost efficient site layout with easy access for machinery and material storage & better consideration for residents / business in local area	
5: Build and commission	Health & Safety management	Improved information including 3D/4D models used to address health & safety hazards (supporting good CDM)	Better understanding of construction operations and better visibility of safety & health risks, including residual risks	
7: Operation and End of Use	Maintenance	AIM provides quicker access to info. needed to carry out maintenance	Maintenance is carried out faster	
7: Operation and End of Use	Incident Management	3D model-based data supports incident investigation	More/better information to support legal position	

**Source:** [https://www.icn-solutions.nl/pdf/bim\\_construction.pdf](https://www.icn-solutions.nl/pdf/bim_construction.pdf)

**Result:** According to the SmartMarket<sup>52</sup> report, page 19, **32%** of surveyed contractors cited “*Enhanced Organisational Image*” as one of top three benefits for their organisation related to BIM. As a result of the improved image, **19%** of contractors also claimed “*Marketing New Business*” and **13%** claimed that they were able to “*Maintain repeat business*”. These survey results show that BIM maturity can contribute to improved reputation which in turn may translate into more successful business for supply chain members.

<sup>52</sup> SmartMarket Report, ‘The Business Value of BIM for Owners’, McGraw Hill Construction. March 2018

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