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BIM Level 2 Benefits Measurement

Introductory note: Approach and benefits framework

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Contents

1. Introduction

The purpose of this introductory note is to explain:

1. How we have developed our Building Information Modelling (BIM) Level 2 ***Benefits Measurement Methodology (BMM)*** and the ***benefits framework*** that underpins it.
2. The benefits framework that underpins our BMM.
3. The principles that underpin our BMM and how they should be taken into account when practically measuring benefits.

The rest of this note is structured as follows:

- Section 2 sets out the policy context for our work, including BIM Level 2's role in helping to achieve the objectives of the UK Government Construction Strategy, and how BIM Level 2 is defined.
- Section 3 explains our approach to developing the benefits framework and the BMM.
- Section 4 describes the benefits framework itself, the scope of the benefits we consider and the dimensions of the framework.
- Section 5 sets out the key principles that underpin our proposed approach to measurement of the benefits and the practical implications of these principles for measuring the benefits of BIM Level 2.
- Section 6 provides some final practical considerations for measuring benefits.

2. Context

This section briefly sets out the background and context to our work of developing a methodology for measuring the benefits of applying BIM Level 2. It describes the vision for BIM to address problems in the construction sector (as set out in the Government Construction Strategy), progress towards and challenges to BIM Level 2 implementation and how our work will help to address the challenges. It then provides a definition of BIM Level 2 and BIM maturity, and explains how this relates to our ***benefits framework***.

2.1 Government Construction Strategy

The construction sector is a significant sector for the UK economy, and central government is the industry's biggest customer – as stated in the Government Construction Strategy (GCS) published in 2011, the construction sector "*represents some 7% of GDP or £110bn per annum of expenditure - some 40% of this being in the public sector*".[1]

It has been widely acknowledged that government construction clients do not derive the full value of benefits from the public sector construction. As the 2011 GCS states *"…the UK does not get full value from public sector construction; and that it has failed to exploit the potential for public procurement of construction and infrastructure projects to drive growth."*[2]

As a consequence, there has been a push from Government to make the public sector a better, more intelligent client, which gains better value from construction. The 2011 GCS set out 13 integrated objectives seeking to encourage change in the relationship between public authorities and the construction industry – one of which focuses on the implementation of BIM. BIM Level 2 was mandated as a minimum requirement on all centrally-procured public projects from April 2016. The Cabinet Office is "*coordinating the Government's drive to the development of standards enabling all members of the supply chain to work collaboratively through Building Information Progress…"* and "*Government will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016."*[3]

The GCS 2016-2020 seeks to build on this progress to further improve central government's capability as a construction client. It states the aim to "*embed and increase the use of digital technology, including Building Information Modelling (BIM) Level 2*", and deploy collaborative procurement techniques. It also includes the objective to "*enable and drive whole-life approaches to cost and carbon reduction across the construction, operation and maintenance of public sector buildings and infrastructure*."[4] BIM Level 2 has been mandated by UK Government because information rich BIM technologies, processes, and collaborative behaviours have the potential to unlock new and more efficient ways of working, and produce better and more consistent outcomes at all stages of the asset lifecycle.

2.2 Progress and barriers to implementation

There has been positive progress towards BIM Level 2 implementation across government construction clients; departments and agencies have undertaken various action to scale up their use of BIM in asset construction

[1] Cabinet Office and Infrastructure Projects Authority, 'Government Construction Strategy' (2011), available at: https://www.gov.uk/government/publications/government-construction-strategy

[2] Ibid.

[3] Ibid.

[4] Cabinet Office and Infrastructure Projects Authority, 'Government Construction Strategy: 2016-2020', available at: https://www.gov.uk/government/publications/government-construction-strategy-2016-2020

(and in some cases operation), working with partners in the supply chain. However, each organisation is at a different stage of its BIM journey, with some organisations more BIM mature than others. A number of potential barriers to the implementation of BIM exist, including:

1. **The costs of implementation** – such as the training costs and software costs associated with BIM implementation.
2. **There can be misaligned incentives that lead to underinvestment in BIM –** the benefits realised as a result of BIM do not always accrue to those who pay the costs of implementation. For example, use of a BIM model may result in a reduction of whole of life costs energy costs for a building. A necessary condition for this may be a higher upfront cost of insulation. Because contracting arrangements may be that the government entity that operates the building is not the same as the government entity that constructs the building, this overall cost reduction may not be taken into account when deciding on use of BIM Level 2 in asset construction.
3. **There is a lack of 'hard' evidence of the benefits of BIM** – Some government construction clients perceive BIM as a net cost; given that the costs of implementing BIM can be easily quantified, while the less tangible and more complex benefits of BIM are more difficult to quantify.
4. **There is a lack of practical guidance that can be used to assess and measure the costs and benefits of BIM** – there is no clear or 'off the shelf' methodology for government construction clients to undertake benefit measurement and evaluation.

Our work aims to address the last two of these barriers by developing a methodology that can be used to assess the realised benefits of BIM. It may also enable an assessment of the extent to which these benefits are accrued by government construction clients and asset owners both directly, and indirectly through the supply chain.

2.3 BIM Level 2 and BIM maturity

Our definition of BIM Level 2 is based on PAS 1192-2:2013 and interpretation of its clauses. *'BIM Level 2 is a process of managing information throughout the lifecycle of a built asset, with key features including: the definition of information requirements by the client; the use of a collaborative Common Data Environment; and the use of 3D modelling in design, capturing both geometric and non-graphical data.'* At Level 2, BIM modelling is typically undertaken separately by design trades, with federation of models taking place subsequently to allow for applications such as Clash Detection. Within our definition, we have also included applications which are readily enabled by BIM Level 2, for example, the integration with the construction schedule in 4D BIM.

Different government construction clients have applied BIM in asset delivery and operation to varying extents – i.e. each organisation is at a different level of 'BIM maturity'. The BIM Maturity Assessment Tool (BMAT) has been developed to assess the level of adoption of BIM Level 2 by government construction clients and their supply chains.[5]

The BMAT breaks down the applications of BIM by '*competency areas*' such as BIM procurement/employer engagement, BIM delivery (by supply chain), data verification and validation, collaborative working, visualisation / stakeholder engagement, discipline based model authoring, construction, model based estimating, and change management. Each competency area is associated with particular activities carried out during each stage. For example, 'collaborative working' requires that federated models are checked for clashes and reviewed for other risks such as buildability. A percentage score reflecting the extent to which BIM has been

[5] Document developed by BIM Working Group members and shared with PwC for information.

applied is provided at each stage for each of the competency areas. This is then aggregated to provide BIM maturity scores for client's, the supply chain and overall for projects.

The general hypothesis is that the higher the BIM maturity score (of either a government construction client or supply chain partner), the higher the level of benefit that will be realised from use of BIM. We have not tested this hypothesis in our work to date. In developing our ***benefits framework*** we have defined individual elements of BIM, called '*BIM enablers*' that enable benefits to be realised. These 'BIM enablers' are similar in content and scope to the BMAT's *competency areas*, although they do not specifically match. Our framework is based on the principle that a 'BIM enabler' must be present in order for a benefit corresponding to that BIM enabler to be realised.

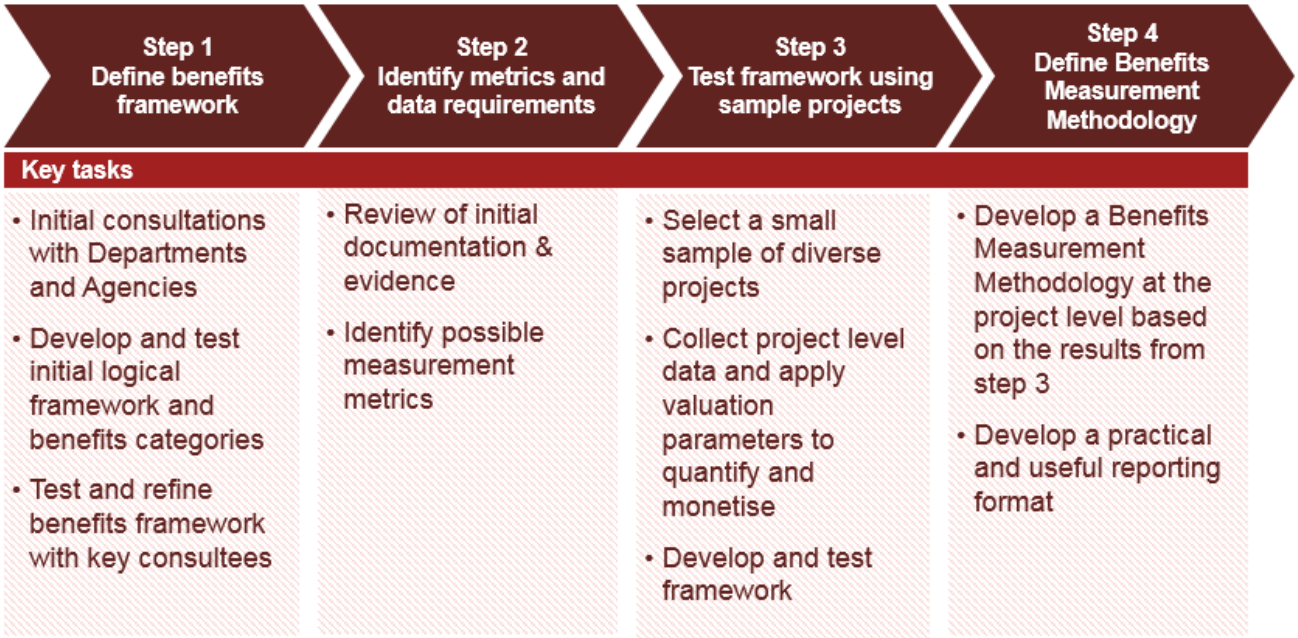
3. Our approach

In this Chapter we describe how we have developed our ***BMM*** for BIM Level 2, including the ***benefits framework*** that underpins it. We have focused on developing a methodology which can be used by government construction clients to identify, quantify and, monetise benefits of BIM Level 2. At this stage, we have concentrated on assessing the **project level** benefits of BIM Level 2 across the asset lifecycle; at a later stage, it will be important to look beyond individual projects, and consider how benefits accrue at departmental level, and potentially across government organisations.

3.1 Overall approach

As shown in Figure 1, our approach to developing a ***BMM*** involved four main steps.

Figure 1: Our approach to developing the BMM



Source: PwC.

As with any investment, adopting BIM Level 2 has associated costs. However, the focus of our work has been on the **benefits** of BIM Level 2; we have not considered any of the costs of implementing or applying BIM. This means that our **BMM** can provide important inputs for a cost-benefit analysis, but it is not alone sufficient to assess return on investment in BIM Level 2, since assessment of costs is out of scope.

Costs associated with BIM Level 2

Investment in BIM Level 2 has associated costs, which for appraisal or evaluation purposes should be calculated on an incremental basis against an appropriate counterfactual in a similar way to benefits. As in the case of benefits, costs may accrue to the government construction client and / or the supply chain, and may also include indirect effects on the wider economy. The 'total cost' of implementing BIM Level 2 therefore, will include all of these impacts, but must exclude costs that represent a transfer between parties, with no change in resources expended (to avoid double counting).

The types of costs incurred by construction clients and the supply chain to implement BIM Level 2 will include fixed costs occurring on a one-off basis (e.g. for transition over from legacy systems and processes to BIM Level 2), and recurring costs, such as training, which may occur repeatedly over time. Each of these costs should be estimated on an incremental basis – that is, if there are IT costs, training or upskilling costs, these should be included net of what the cost would have been if BIM was not in use (but the most appropriate alternative was). E.g. In the 'without-BIM Level 2' case, there would be software costs. What is the difference between these costs and costs in the 'with-BIM Level 2' case?

We have designed the methodology to be consistent with existing public sector guidance on benefit appraisal (HM Treasury's Green Book) and benefit realisation (Cabinet Office). As detailed in section 1.3 of the methodology on 'How to use the measurement methodology', this has implications for its use by construction clients and asset owners in the private sector. While the principles of the methodology apply to all construction clients, there are some important distinctions in its application. We have sought to develop a methodology which is capable of looking forward as well as backwards (i.e. to understand potential benefits as well as achieved benefits).

3.2 *Defining and developing the benefits framework (step 1 in figure 1)*

Our first step was to identify all of the potential areas of benefit from BIM Level 2 that might need to be measured. To do this, we considered each of the eight stages of the asset lifecycle (seeTable 1) and identified how BIM Level 2 is being (or could be) used at each stage.

Table 1: Asset lifecycle stages

	Stage name	Brief description
0	Strategy	Project business case and strategic objectives
1	Brief	Project brief and procurement strategy
2	Concept	Refined project brief and concept approval
3	Definition	Approval of co-ordinated developed design
4	Design	Integrated production information
5	Build & commission	Asset production
6	Handover & close-out	As-built information transfer to the client/asset operator
7	Operation & end of life	Asset in operation and disposed of in the end of life

Source: PAS1192-2:2013.

We then developed a set of '*impact pathways*' which described how application of BIM Level 2 could lead to benefits for government construction clients and/or parts of their supply chains. Figure 2 shows the elements incorporated into our impact pathway. These elements are based on Infrastructure and Projects Authority (IPA) Guidance on benefit maps.[6]

[6] Infrastructure and Projects Authority, 'Guidance for Departments and review teams. Assurance of Benefits Realisation in Major Projects. Supplementary Guidance v1, April 2016. Appendix B: Benefits Map, pg. 31, available at: https://www.gov.uk/government/publications/major-projects-authority-assurance-toolkit

Figure 2: Impact pathway used in benefits framework

We define each element in the impact pathway as follows:

- **Activity:** An activity that is undertaken at a particular stage of the asset lifecycle (with or without BIM)
- **BIM Enabler:** A technical capability provided by using BIM Level 2, that can lead to one or more measurable benefits (that may accrue at the same stage of the asset lifecycle and/or later stages).
- **Intermediate benefit:** A direct effect of the BIM enabler.
- **End benefit:** The ultimate impact of the intermediate benefit (which needs to be assessed and potentially measured).[7]

Our detailed ***benefits framework*** is provided in Section 4.2and contains 117 separate potential impact pathways in total.

Our approach to developing the ***benefits framework*** was informed by several key inputs including:

- **The BIM Working Group Benefits Realisation Map:** This set out the strategic drivers and key elements of BIM Level 2 that enable the benefits of BIM. It provided the foundation of our benefits framework.
- **Consultations with, and inputs from, government stakeholders**: We consulted government construction clients, including Highways England, HS2, the Ministry of Justice, the Ministry of Defence, the Education and Schools Funding Agency, the Environment Agency, and the Department of Health. We used these consultations to obtain feedback on our benefits framework, our proposed approach, and to gain case study information that could be used to test the approach.
- **A literature review:** We reviewed both academic literature and industry papers (120 items of literature in total) to understand both the range of benefits that could arise from BIM, and what the evidence indicated about which benefits would likely be most significant. We used this to inform both the benefits framework (making sure it captured the benefits identified) and to understand the measurement approaches that could be used to quantify and value the benefits.
- **Our own experience** both in economics and capital projects/BIM, we drew on our experience and construction industry expertise.

3.3 Developing the BMM (steps 2 to 4 in figure 1)

After developing and testing the benefits framework, we then developed our proposed approach to measuring each of the identified benefits. This approach required us to develop a methodology to both quantify and monetise each benefit. Quantification of the benefits involves identifying the form and scale of the actual or expected benefit. Monetising each benefit involves placing an economic value on each.

[7] The end benefit results directly from the impact pathway it is included in. There may be multiple impact pathways that result in similar or the same end benefit. For example there may be an end benefit 'time savings' that results from both quicker access to information, and 3D visualisation of a design. Time savings will therefore be included as an end benefit in multiple impact pathways.

So that we could capture all of the benefits - and their associated value - we constructed *driver trees* for each of the 117 benefit pathways.[8] We then assessed what measurement approaches could potentially be used to quantify and monetise each benefit identified in the framework (*step 2 in Figure 1 above*). We found there was commonality in the types of benefit and, thus, the data required to measure them. Reflecting this, according to the types of expected benefit, we consolidated the 117 pathways into 22 high level benefit areas which we grouped further into eight discrete 'measurement' categories. Table 2 in Section 4.2 of this note shows each of the eight measurement categories, the corresponding 22 benefits, and the number of unique benefit pathways corresponding to each.

We explain the key principles that underpin the BMM in Section 5.

In parallel with our benefit grouping and identification of measurement metrics and data requirements, we began collecting supporting data from government and supply chain stakeholders to test our measurement methodology. To date, we have used the data provided to develop some sample case studies of benefit measurement. These are included in our detailed ***BMM*.**

[8] This technique follows the Infrastructure and Projects Authority, 'Guidance for Departments and review teams. Assurance of Benefits Realisation in Major Projects. Supplementary Guidance v1, April 2016. Appendix C: Driver Trees, pg. 32, available at: https://www.gov.uk/government/publications/major-projects-authority-assurance-toolkit

4. The benefits framework

This section explains the ***benefits framework*** we have developed. We start by summarising the key dimensions of the framework. We then provide details of the impact pathways that underpin the framework: these are presented separately for each stage of the asset lifecycle. Finally, we explain how our benefits framework relates to the level of BIM maturity (BMAT).

4.1 Key dimensions

In developing the project level benefits framework for BIM Level 2, we considered the following questions:

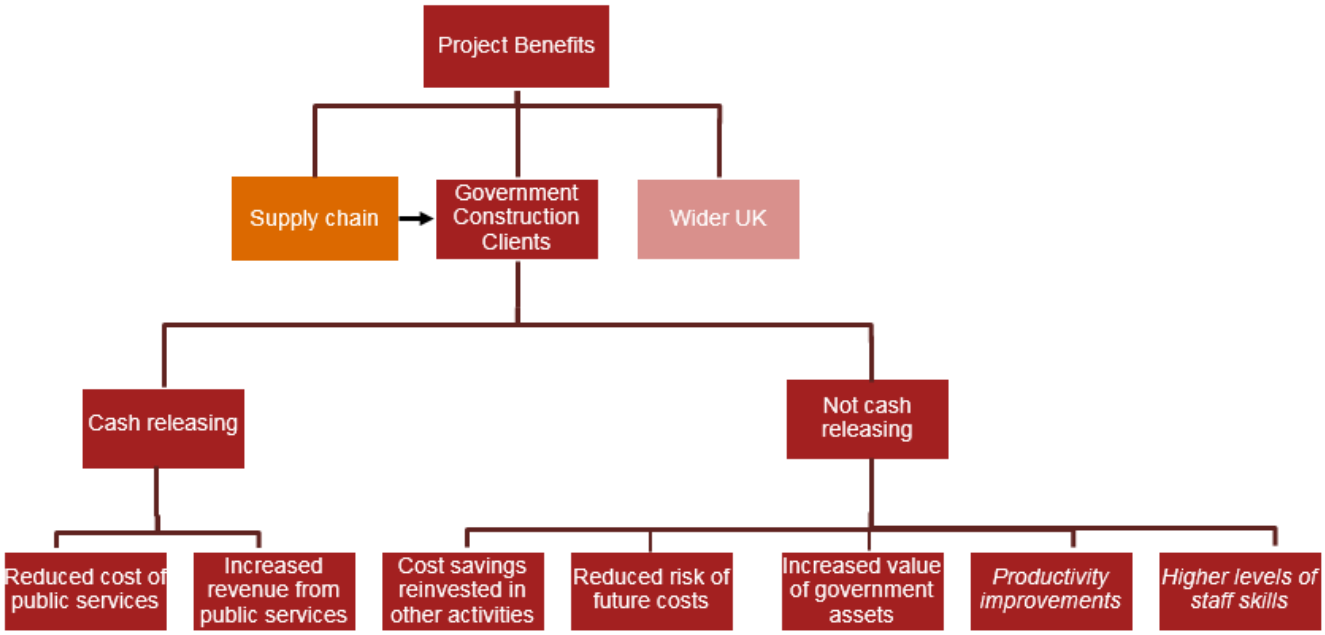
- **When are the potential benefits realised across the asset lifecycle?** The framework distinguishes between when benefits are enabled and when they are realised; for example, 3D modelling might enable a more energy efficient design to be embedded at the design stage, but the benefits will only be realised during the operations stage of the asset lifecycle. It is important not to forget to take into account benefits that occur in future time periods. If these are not fully accounted for, underinvestment in BIM Level 2 may occur. Our benefits framework is structured around each stage of the asset lifecycle and breaks down the activities undertaken within each stage to assess when the benefits of BIM were enabled. It then categorises the end benefits that accrue by when they are realised:
    1. **Benefits realised during asset delivery** (i.e. those realised between 'Stage 0: Strategy' and 'Stage 6: Handover and close out' of the asset lifecycle – see Table 1: Asset lifecycle stages). The capital phase of projects have significant cost, and therefore any benefits realised in the asset delivery phase will potentially be significant.
    2. **Benefits realised in the asset's operation** (Stage 7 of the asset lifecycle: Operation and end of life). BIM has the potential to reduce costs by improving the efficiency of asset operation. The operation phase (facilities management/maintenance) usually has a significantly larger cost associated with it than the capital phase, thus the potential for savings is even larger than in asset delivery. Principally, those benefits realised in operation of an asset are cost savings.[9]
    3. **Benefits realised through service delivery / business as usual** by the asset owner and its users (i.e. in services that are delivered through use of the BIM enabled asset). These benefits include improved service delivery from higher quality asset design, and benefits from more services delivered due to higher asset utilisation enabled through BIM.
- **Who do the potential benefits accrue to?** At the project level, the benefits of BIM may accrue to government construction clients directly (e.g. the government's costs are directly reduced) or indirectly (i.e. the benefit accrues to a third party, and some of this is passed on to government). The market dynamics and commercial arrangements between government construction clients and the supply chain will influence how far and how quickly the benefits are passed on when they accrue to the supply chain. Benefits may also accrue to wider UK society, for example through positive environmental externalities. We have included these benefits in our framework where they arise.
- **Are benefits to government cash-releasing or non-cash-releasing?** Our framework focuses on identifying the economic benefits of application of BIM Level 2 (see section 5.2) – considering benefits that accrue to the whole economy – that is government construction clients, the supply chain, and wider

[9] See for example Hughes, W., *et al.* (2004), *Exposing the myth of the 1:5:200 ratio relating initial cost, maintenance, and staffing costs of office buildings,* Proceedings of the 20th Annual ARCOM Conference pp. 373-381 who discuss the well-known ratio of costs of 1:5:200 (construction: maintenance: operation) and based on primary research suggest a ratio of 1:0.4:12

UK society. Where benefits accrue to government construction clients, they may be cash releasing or non-cash releasing. A cash releasing benefit is defined by the IPA as 'a reduction in the cost of, or increased revenue from, public services, as a result of successful delivery of a project' that 'contributes to reducing the UK budget deficit'.[10] A non-cash releasing benefit is one that is financially quantifiable but does not reduce the UK budget deficit – it may instead be re-invested into other organisational activities or contribute to reducing the risk of future expenditure, or increase the value of an asset. Benefits to government organisations from BIM Level 2 will therefore be cash releasing if they impact that organisation's revenue or cost lines in the financial statements. All of the benefits in our framework relating to time savings, materials savings, and cost savings have the potential to be cash-releasing for government organisations. For example, if BIM Level 2 results in time savings that can be monetised as direct labour cost savings – these labour cost savings will be cash releasing if it is possible to reduce the number of FTE headcount as a result of the reduction in direct labour required. If instead the direct labour saved through use of BIM Level 2 is reinvested in other activities, the benefit is not cash releasing. Cash releasing and non-cash releasing benefits are equally important in economic terms. Non-cash releasing benefits have the potential to become cash-releasing in the future, for example when an asset is sold for a higher price, or a combination of labour savings allows for a reduction in a whole FTE.

Figure 3 illustrates the structure of the benefits framework at the project level. It distinguishes those benefits which accrue within the supply chain from those which accrue directly to government construction clients. It also recognises that benefits to the supply chain may be passed onto government construction clients. It then shows that benefits to government may be cash releasing or non-cash releasing. Non cash releasing benefits include productivity improvements – while productivity improvements may result in lower costs in future time periods, they do not result in reduced cost of public services in the current time period.

Figure 3: Structure of BIM Level 2 benefits for government construction clients



In addition to the project level benefits outlined in our detailed framework, there is likely to be benefits to government organisations from application of BIM Level 2 at the Departmental or agency level, and potentially

[10] Infrastructure and Projects Authority, 'Guidance for Departments and review teams. Assurance of Benefits Realisation in Major Projects. Supplementary Guidance v1, April 2016. Appendix A: Benefits Categorisation, pg. 27, available at: https://www.gov.uk/government/publications/major-projects-authority-assurance-toolkit

across government. We have not considered these benefits in detail in our framework. The type of benefits that may arise at these higher levels are:

- **Benefits from the management and use of improved asset information to undertake organisational tasks quicker / more efficiently:** Similar to benefits that arise during asset delivery or operation, use of an AIM or object libraries for example, can reduce the time needed to find information. This could help to reduce the time taken for many activities undertaken by government organisations on a day-to-day basis such as fulfilling information requests (e.g. internal requests, ministerial requests for information, freedom of information (FOI) requests from the public).
- **Benefits from economies of scale in managing a portfolio of assets:** By using the information contained in BIM models to manage asset information across all assets in an organisation's portfolio, opportunities to take advantage of economies of scale may arise. Where it is possible to standardise specific components across different assets for example, an organisation may gain better buying power in procurement negotiations. Without BIM (object libraries, AIMS) it is difficult for many government organisations to have visibility of their asset portfolio and understand where opportunities for standardisation and related cost savings might arise. Going one step further and sharing asset information across government through use of BIM, could result in even greater economies of scale.

In assessing the total benefits of the BIM Level 2 programme, these 'higher order' benefits should be taken into account.

4.2 Detailed benefits framework

We present here our detailed project level benefits framework. It shows the 117 impact pathways resulting from BIM enablers employed during specific activities across each stage of the asset lifecycle. For each unique benefit pathway there is a chapter reference that matches the chapter and section in the ***BMM***, where we provide detailed guidance for measurement of that benefit. These chapter references are listed in Figure 4.

Following the framework, we provide a table that shows our benefit groupings for measurement purposes.

Figure 4: Benefit methodology chapter reference

Benefit	Chapter number	Benefit	Chapter number
Time savings in Stage 0 to Stage 3	1.1	Cost savings in asset maintenance	3.4
Time savings in design	1.2	Cost savings in refurbishment	3.5
Time savings in build & commission	1.3	Cost savings in asset disposal	3.6
Time savings from fulfilling RFIs (during build and commission)	1.4	Cost savings in litigation	3.7
Time savings in handover	1.5	Improved health and safety in construction	4.1
Time savings in incident response	1.6	Improved health and safety in maintenance/ demolition	4.2
Material savings in build and commission	2.1	Reduced project risk contingency in capital delivery phase	5.1
Environmental benefit from fewer materials used	2.2	Increased certainty in operating expenditure estimates	5.2
Cost savings from better clash detection	3.1	Improved asset utilisation	6
Cost savings from fewer changes	3.2	Improved asset quality	7
Cost savings in operations – facilities management	3.3	Improved reputation	8

Figure 5: Detailed benefits framework – Stage 0: Strategy

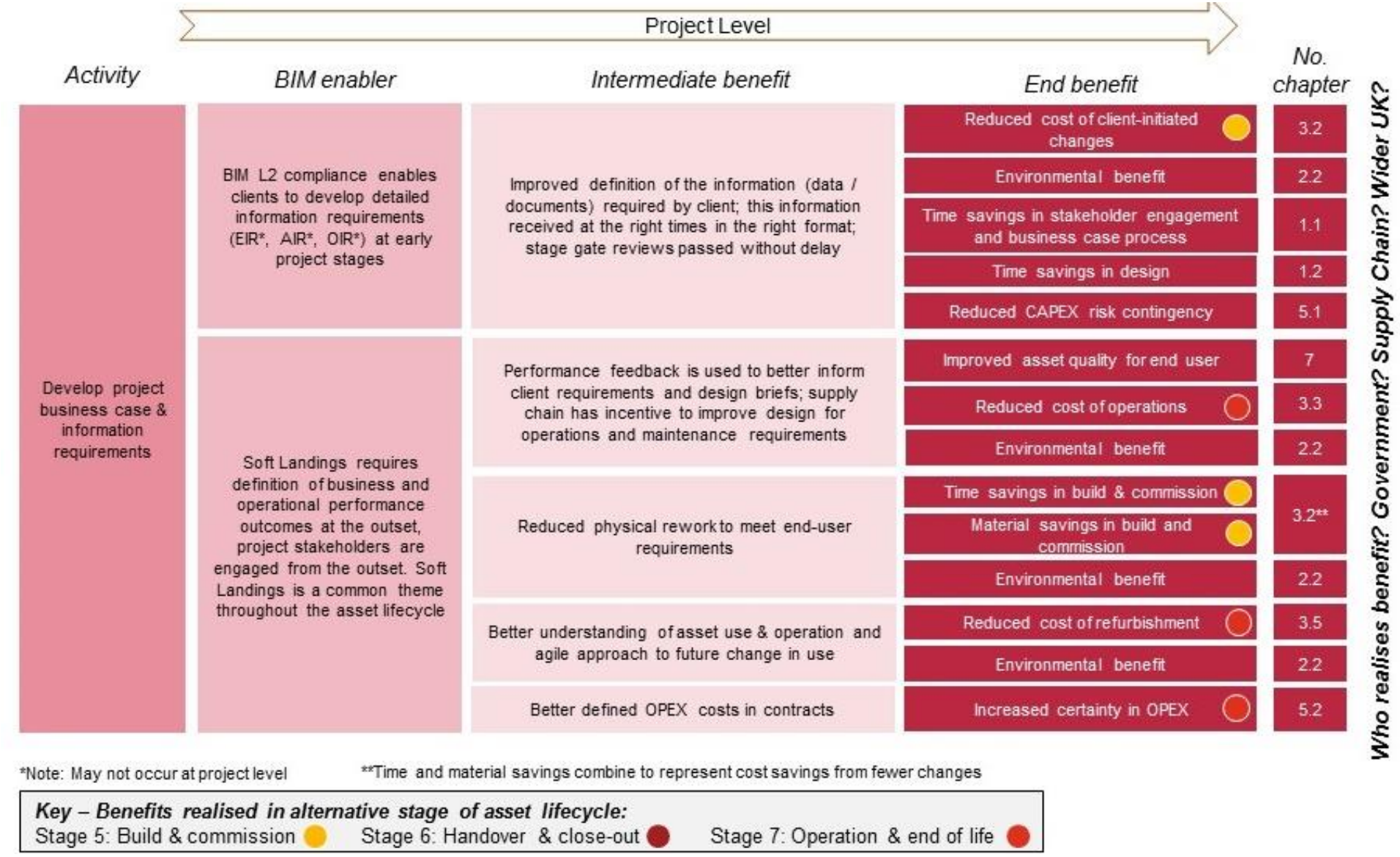


Figure 6: Detailed benefits framework – Stage 1-3: Brief-Concept-Definition

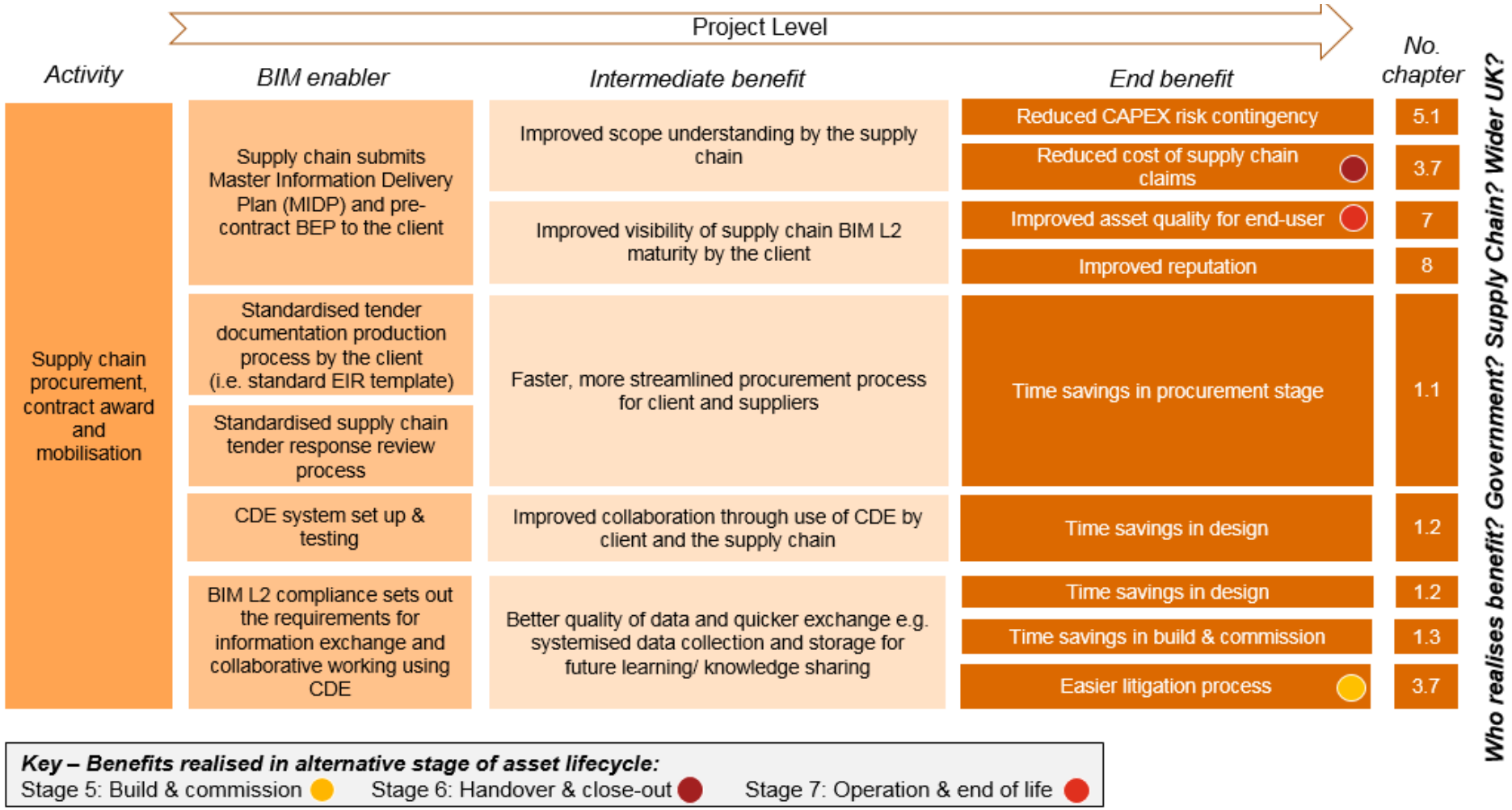
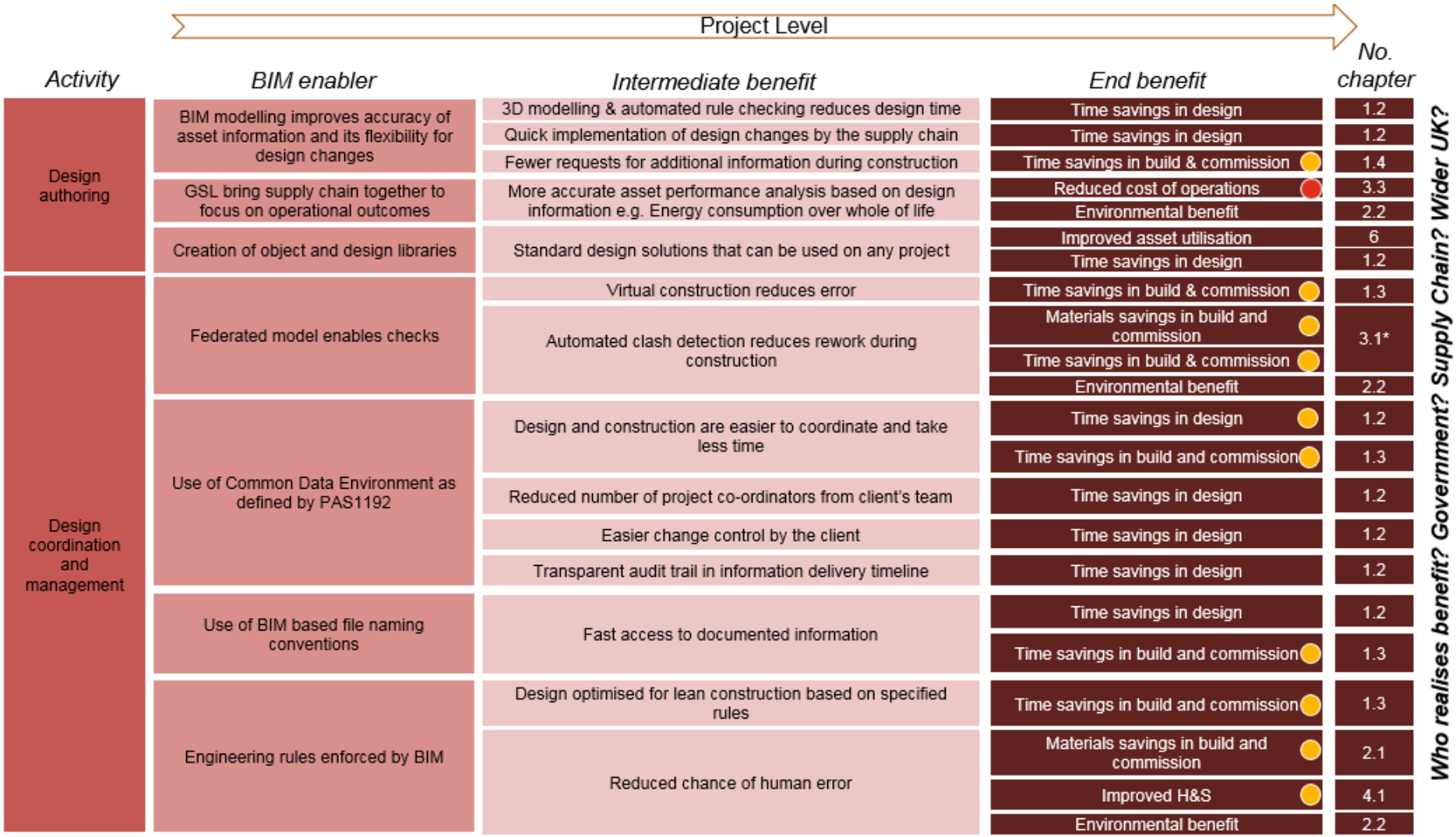


Figure 7: Detailed benefits framework – Stage 4: Design (1 of 2)



*Time and material savings combine to represent cost savings from better clash detection.

Key – Benefits realised in alternative stage of asset lifecycle:
Stage 5: Build & commission ● Stage 7: Operation & end of life ●

Figure 8: Detailed benefits framework – Stage 4: Design (2 of 2)

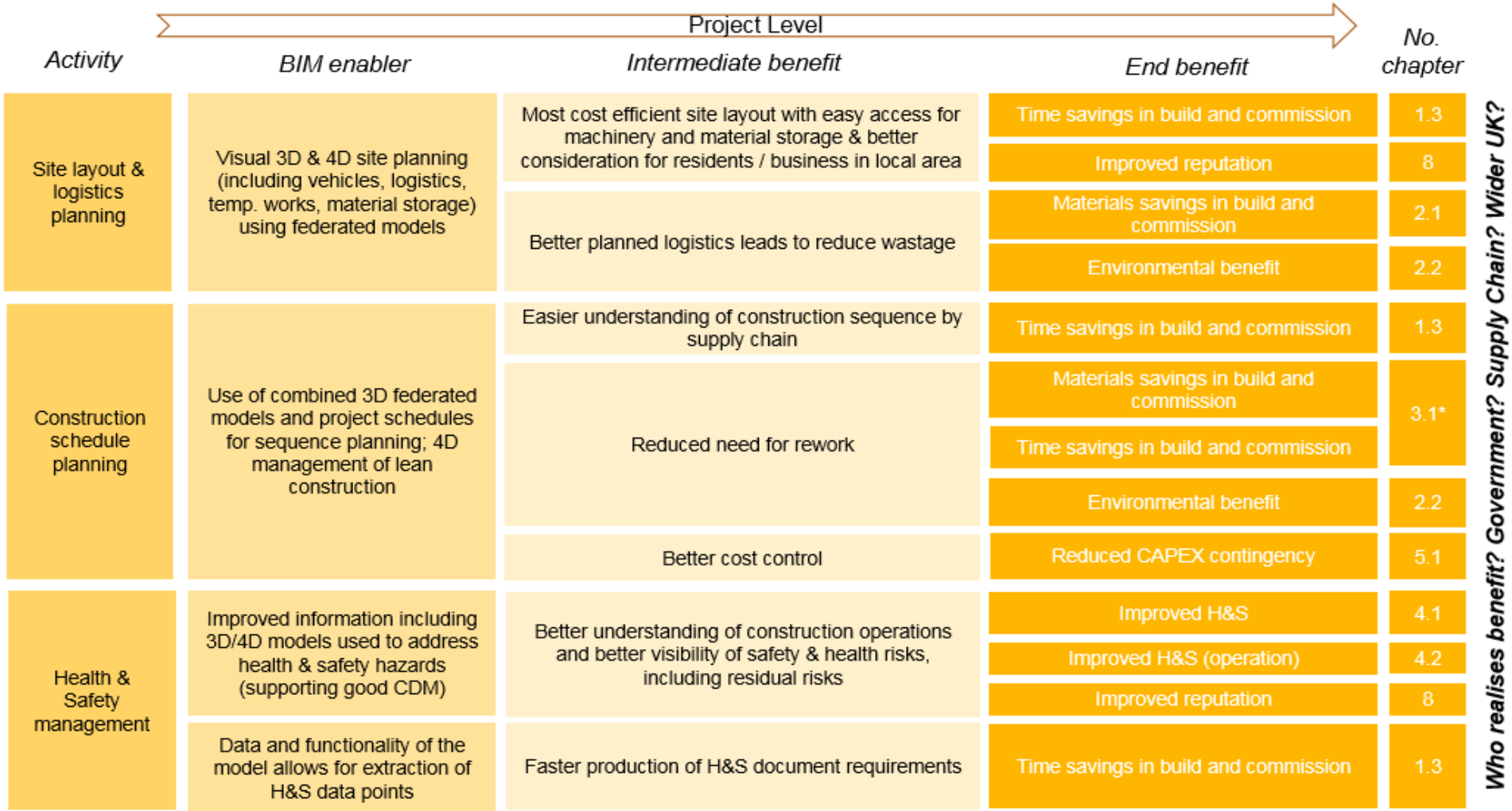
Activity	BIM enabler	Intermediate benefit	End benefit	No. chapter
Design reviews	Parametric modelling provides more information about the asset compared to non-object based design	Quicker access to valuable asset data (area /volume /material)	Time savings in design	1.2
			Reduced cost of supply chain claims	3.7
		Design can be optimised to reduce material waste and prevent unnecessary works	Materials savings in build and commission	2.1
			Environmental benefit	2.2
			Time savings in build and commission	1.3
		Early involvement of builder improves constructability (e.g. improving possibility of offsite fabrication)	Materials savings in build and commission	2.1
			Environmental benefit	2.2
			Time savings in build and commission	1.3
	Visualisations aid in design reviews	Quicker review against client's EIRs, design standards, H&S	Time savings in design	1.2
			Improved H&S	4.1
Cost estimation	Increased automation in material quantity take-off	Faster cost estimation	Time savings in design	1.2
		Increased accuracy of estimates - reduced risk of human error	Reduced CAPEX risk contingency	5.1
	Soft Landings require review of design CAPEX & OPEX cost against targets	Better visibility of project costs upfront	Reduced CAPEX risk contingency	5.1
Client review & stakeholder consultation	3D & 4D virtual design simulations	Easier and faster to obtain approvals (e.g. planning)	Time savings in design	1.2
		Higher quality of asset for end user	Improved asset quality for end-user 🔴	7
		Fewer changes needed during construction	Time savings in build and commission	3.2*
			Material savings in build and commission	
			Environmental benefit	2.2

Who realises benefit? Government? Supply Chain? Wider UK?

*Time and material savings combine to represent cost savings from fewer changes.

Key – Benefits realised in alternative stage of asset lifecycle:
Stage 5: Build & commission 🟡 Stage 7: Operation & end of life 🔴

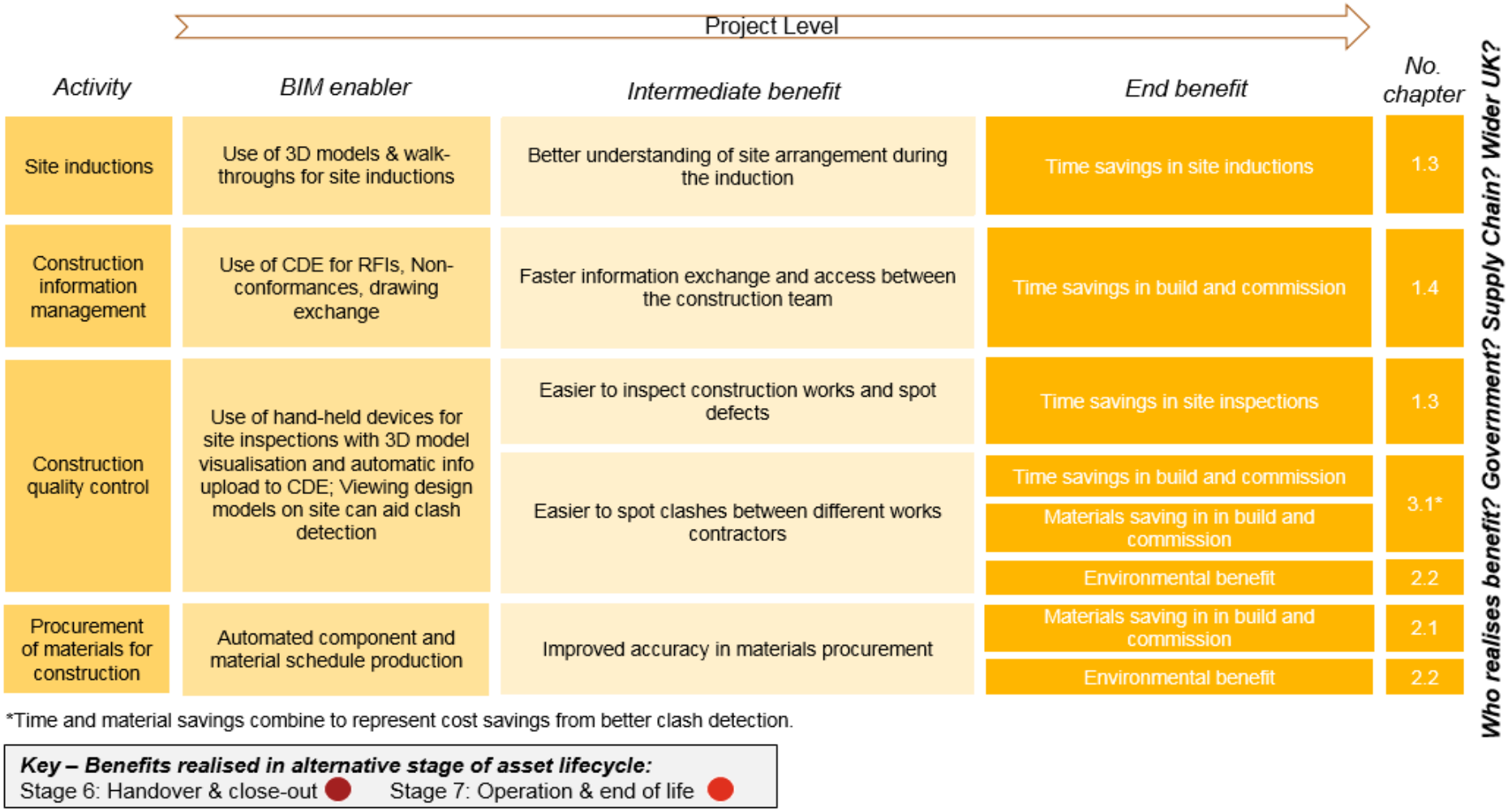
Figure 9: Detailed benefits framework – Stage 5: Build and Commission (1 of 2)



*Time and material savings combine to represent cost savings from better clash detection.

Key – Benefits realised in alternative stage of asset lifecycle:
Stage 6: Handover & close-out ● Stage 7: Operation & end of life ●

Figure 10: Detailed benefits framework – Stage 5: Build and Commission (2 of 2)



*Time and material savings combine to represent cost savings from better clash detection.

Key – Benefits realised in alternative stage of asset lifecycle:
Stage 6: Handover & close-out ● Stage 7: Operation & end of life ●

Figure 11: Detailed benefits framework – Stage 6: Handover and close out

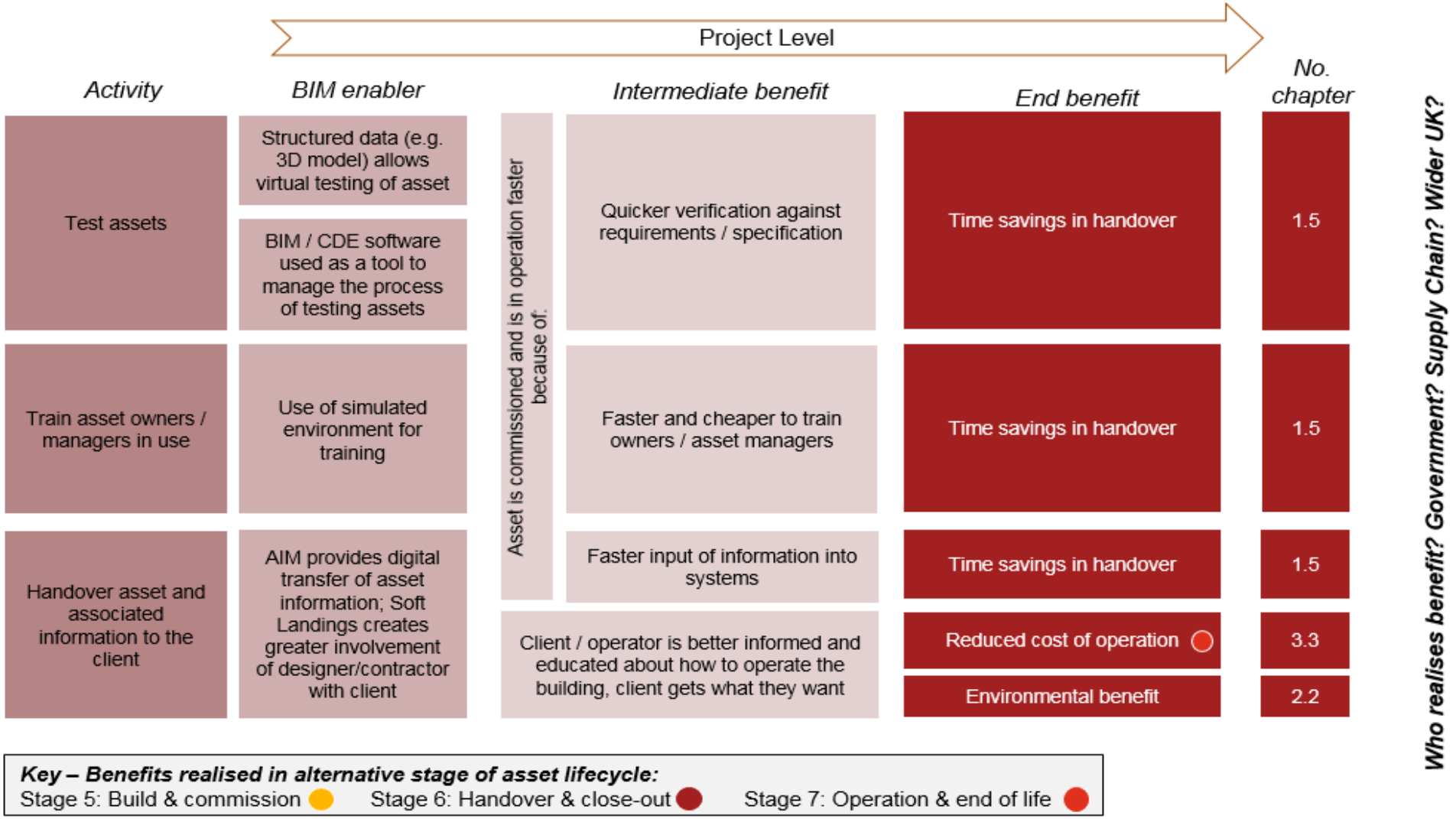
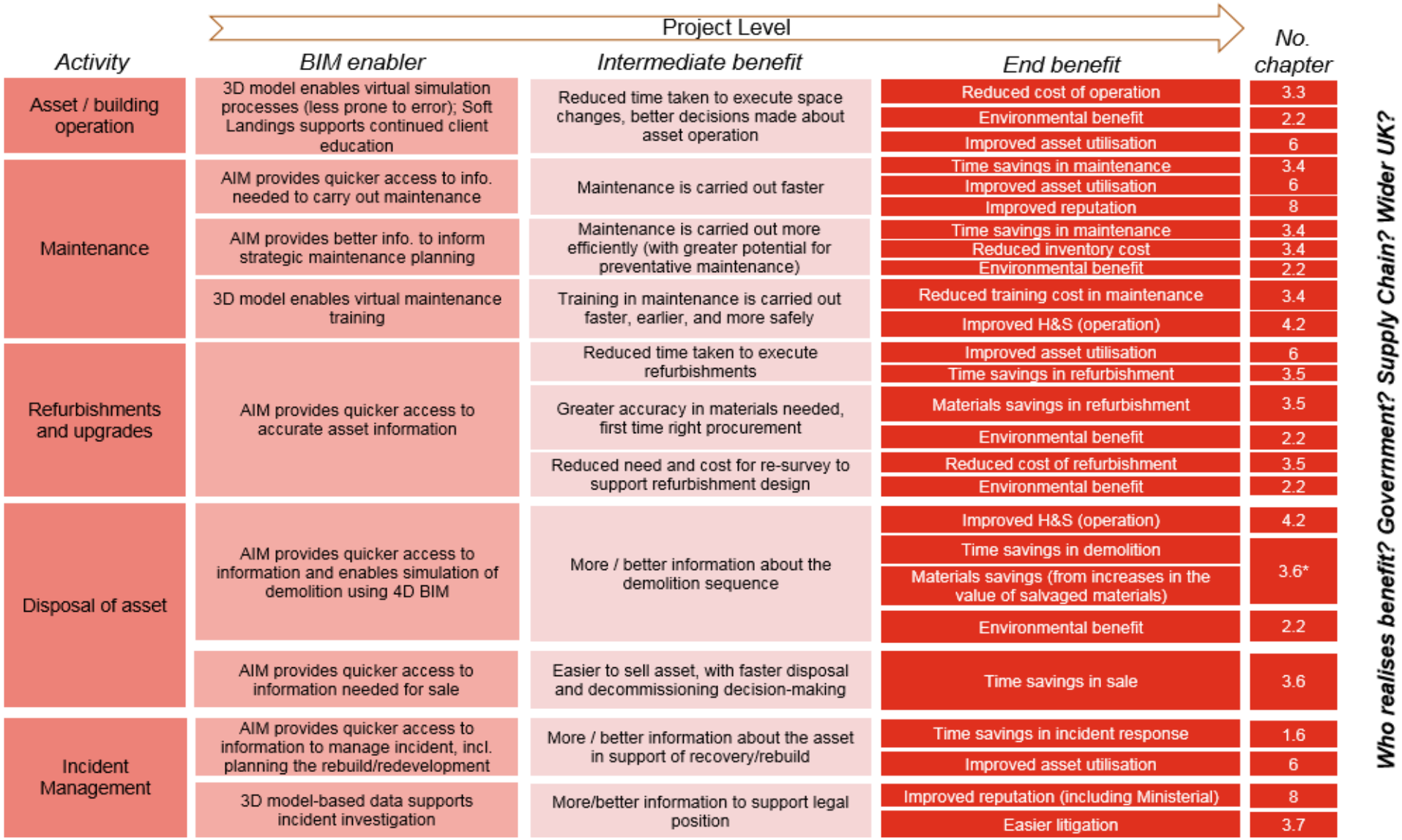


Figure 12: Detailed benefits framework – Stage 7: Operation and end of life



*Time and material savings combine to represent cost savings in asset disposal.

Table 2 shows how we have grouped each of our unique benefit pathways. We group each detailed pathway into a group of benefits that have the potential to be measured together 'benefit grouping'. These are then further grouped into a 'measurement category' of benefits that are measured in a similar way (and hence similar guidance is required). Benefits are also grouped into 3 high level activity categories through which they accrue, as explained in Section 4.1.

Table 2: Benefit groupings

High level activity through which benefit accrues	Measurement category	Benefit grouping	Number of corresponding pathways from detailed framework above
Asset delivery and Service delivery/ BAU	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
Asset delivery / Operations	Materials saving	Materials savings in 'Build and Commission'	5
		Environmental benefit from fewer materials used	20
Asset delivery / Operations	Cost saving (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
Asset delivery / Operations	Improved health & safety (H&S)	Improved health and safety in construction	3
		Improved health and safety in maintenance / demolition	3
Asset delivery	Reduced risk	Reduced project risk contingency in capital delivery phase	5
		Increased certainty in operating expenditure estimates	1
Service delivery/ BAU	Improved asset availability	Improved asset utilisation	5
Service delivery/ BAU	Improved asset quality	Improved asset quality	3
Service delivery/ BAU	Other intangible benefits	Improved reputation	5
Total			**117**

Source: PwC.

5. Benefits measurement methodology – key principles

This Chapter explains the key principles that underpin our BMM. The approach we propose for measuring benefits has been developed to be consistent with:

- The Infrastructure and Projects Authority (IPA) guidance on benefits realisation[11], which describes benefits categorisation (Appendix A), benefits maps (Appendix B), and driver trees (Appendix C).
- HM Treasury Green Book[12] which provides guidance on how to appraise and evaluate the costs and benefits of projects.

In practice, drawing on this guidance, there are five main principles which we have incorporated into the proposed BMM:

1. It is based on the development of impact pathways which helps to reduce the risk of double counting or omitting impacts. This corresponds to IPA guidance on benefits maps.
2. It is holistic and seeks to cover all potential economic benefits – direct and indirect, and intended and unintended.
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 or asset lifetime, which involves using an appropriate price basis and suitable discounting so that benefits are expressed as present values (PVs) at constant prices.
5. It takes account of risk and uncertainty (including optimism bias).

Below, we explain the significance of each of the principles in more detail.

5.1 Development of impact pathways

In measuring the potential benefits from application of BIM Level 2, there is a risk that benefits will be double counted (or overlooked). It is important to be aware of areas where this might happen so that this can be avoided. Otherwise, the benefit estimates may be overstated and incorrect.

Double counting may occur in two situations:

- **When the different effects of BIM overlap:** For example, BIM may result in time savings both in terms of a reduction in the number of person hours required; and in a reduction in the project's duration. It is possible that these effects may overlap: if there is a reduction in the project's duration, this will also usually mean a reduction in the number of person hours required. If this is the case, it is important to ensure this benefit is only counted once. If labour cost reduction is included in calculating the cost reduction from a shorter project duration, it should not be calculated again separately.
- **When the effects of BIM have been 'grouped' for measurement purposes:** For the purposes of developing a practical measurement methodology we have grouped benefits where they result in similar

[11] Infrastructure and Projects Authority, 'Guidance for Departments and review teams. Assurance of Benefits Realisation in Major Projects. Supplementary Guidance v1, April 2016, available at: https://www.gov.uk/government/publications/major-projects-authority-assurance-toolkit

[12] Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

impacts. For example, time savings in the build and commission phase may occur in a number of different activities (undertaken during design or build and commission) due to a number of different 'BIM enablers' as shown in Figure 13.

Figure 13: Benefit 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	
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)	Time savings in build and commission
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.

Practical implication: avoiding double counting

To prevent double-counting, it is important to understand how each benefit arises, and how it will be measured. For example, it might be possible to quantify time savings during build and commission in two ways:

1. Time savings from faster information exchange between the construction team may result in 5 person hours saved on the supplier side and 10 person hours on the client side.
2. Application of BIM Level 2 generally during build and commission, may result in a 3 week reduction in the entire duration of the build and commission phase of the project.

Both impacts are accurate. Both can be quantified and attributed to BIM Level 2. However, it is possible that time savings on the supplier side from faster information exchange have already been captured in the savings from reduction in duration of the project schedule. If they have been, this is double counting.

In order to avoid double counting in instances like this, it is necessary to be aware how benefits arise. For example, if the reduced schedule duration was not a result of faster information exchange, then it is possible to consider the person hour saving as an addition to this impact. If the reduced schedule occurred because of multiple (BIM Level 2 related) factors - possibly including faster information exchange – the person hour saving should not be counted separately.

5.2 A holistic approach

As noted above, the benefits of BIM Level 2 may accrue to government construction clients and asset owners in two ways:

1. **Directly** – a benefit such as time savings in design review from use of a virtual 3D walkthrough (as opposed to 2D drawings that are more difficult to understand) would accrue directly to a government construction client because the person(s) who saves time during the review is an employee (or employees) of the government client.

2. **Indirectly** – a benefit such as a time saving in undertaking construction from more efficient site layout and better logistics planning would accrue firstly to the contractor who is undertaking the construction of an asset. This saving could be passed through to the construction client in terms of reduced construction costs from a more efficient construction process.

In line with HM Treasury Green Book guidance, our proposed measurement methodology is based on the principle that the purpose of valuing benefits is to consider whether [an option's] benefits are worth its costs, and to allow alternative options to be systematically compared in terms of their net benefits or costs. Our methodology seeks to capture all benefits to the United Kingdom – not only those that directly accrue to government construction clients or asset owners, but also the indirect and wider effects that accrue to the rest of the economy.

Some of the benefits that arise as a result of BIM do not have readily available market values (for example, where BIM improves asset quality for the end user, there is no value that can easily be applied to monetise this effect). Additionally, where our framework captures effects which cannot be valued, these are not ignored but are described such that they too can be considered in appraisal, in qualitative terms.

Practically, the implication of this is that the stakeholder directly benefiting from BIM may not be a government construction client, and therefore the extent to which benefits are passed on needs to be accounted for.

Practical implication 1: establishing who accrues the benefit

In measuring the benefits from the application of BIM Level 2, it is important to consider:

- Who benefits directly in any particular case (e.g. in the case of time savings, whose time is saved?)
- How much of the benefit accruing in the first instance to the supply chain (or other party) is passed on (indirectly) to the construction client?

Where a government construction client / asset owner benefits directly, they will realise the full benefit. But if the benefit accrues in the supply chain, any benefit will only be indirectly realised. The extent to which the government client benefits will depend on two factors:

1. **Market dynamics:** This depends on the nature of competition in the market, and could change over time. In theory, if there is effective competition in construction markets, construction suppliers should compete with each other to drive down prices and any cost savings (including time and materials savings) should be passed on to the client. One of the practical issues is observing this in real life.
2. **Commercial arrangements:** The commercial arrangements between the clients and suppliers can impact which benefits get passed on to government construction clients. As a generalisation, clients and asset owners have greater potential to realise CAPEX benefits directly when procuring through collaborative contracting methods including gain-share, target cost and cost-plus models. Conversely, fixed price, lump sum and risk-transfer arrangements will limit a client's opportunity to realise benefits in the asset delivery phase, with greater opportunity for benefit capture within the supply chain.

When considering these two factors it is important to account for their interaction with time. If benefits are assessed in the short run, government construction clients may be locked in to commercial arrangements and procurement models such that benefits are not passed through. In the long run, we would expect market dynamics and contractual arrangements to adjust as the benefits of BIM Level 2 are recognised.

The implications of these two influences are important for measuring benefits. If benefits are measured at the point they directly accrue to the supply chain:

- **Data would need to be collected directly from the supply chain** to fully understand the extent of the benefits brought by BIM. In order to do this, government construction clients would need to communicate what these expected benefits are to the supply chain, and define the data needed to enable

the benefit to be measured and reported. This is an important consideration for the application of this methodology and we plan to investigate this further when we test the methodology. Benefits and supporting data required could be communicated through procurement documents such as the EIR.

- **Assumptions need to be made about how much of that benefit is 'passed through'** to the government construction client / asset owner, depending on market dynamics and the contracting model. This may be straightforward in some cases (for example, when there are target-cost arrangements, therefore a predefined proportion of CAPEX savings will be accrued by the client), but may be more difficult to determine in other cases (for example, when there are fixed-price arrangements therefore the client will generally only realise benefit through market price adjustment over time).

Practical implication 2: using appropriate evaluation metrics

Benefits are generally valued based on market prices, which reflect the opportunity cost of a good or service. However, non-market goods (including wider social and environmental impacts) that affect utility (or wellbeing) which cannot be valued using market prices, can be assigned a monetary value though looking at their impact on utility. We have aligned our approach to HM Treasury Green Book guidance, using the valuation approaches and values it prescribes. For example, when valuing the environmental benefit associated with the increased energy efficiency of an asset we derive the carbon dioxide equivalent and price of the cost of carbon, following Green Book guidance.

5.3 Assessment against an appropriate counterfactual

In order to be able to attribute benefits to the application of BIM Level 2, it is important to compare the impacts against those that would be expected to arise in an appropriate '*counterfactual*' situation. This involves comparing the **outcomes achieved** *with the application of BIM Level 2* and those that **would have been achieved** if *BIM Level 2 had not been used or available*. For example, use of BIM Level 2 may result in 15 clashes being detected on a project, but if 10 would have been found without using BIM Level 2, then the net impact of applying BIM Level 2 is to spot five additional clashes. So, to attribute benefits to BIM Level 2, we need a method for assessing the number of clashes that would have been detected without it. In this way, we can isolate changes in an outcome (e.g. risk, time, cost, quality) and attribute the change to the use of BIM Level 2. The key challenge in measuring the net benefits against an appropriate counterfactual is that the counterfactual cannot be directly observed and so the impact must be determined in some other way. [13]

As a part of assessing the counterfactual it is important to understand the relationship between BIM maturity and realised benefits. Many of the specific benefit pathways, identified within our framework, will only be achievable when clients have achieved a certain level of BIM maturity. The BMAT can be used to help assess both this, and the impact of BIM on project outcomes, as it tracks the use of BIM on projects. Therefore the BMAT could be a useful tool in future that can help to establish the counterfactual.

Practical implication: establishing the counterfactual

In practice, in the context of BIM, we have identified four possible ways that a counterfactual could be established. We discuss each below.

1. **Empirical observation:** Compare the outcomes between two otherwise similar projects where one uses BIM Level 2 and one does not. This involves:

[13] The 'Get It Right Initiative' Research Report (2016) details the most common sources of error in construction. This may be one source that can be used in developing an understanding of what would have happened in the 'without BIM' counterfactual case, and in determining if application of BIM Level 2 has brought benefits. Available at: https://getitright.uk.com/report/research-report/

- Selecting two projects that are as similar as possible across as many features as possible (e.g. asset type and size, cost, design required for use, location, proposed design and construction schedule, project management and construction team, etc.).
- Comparing the two projects in terms of the drivers of cost or benefit (for example, the duration of project schedules in asset delivery, the number or cost of changes undertaken in asset delivery, the annual facilities management cost for an asset) to determine the impact of using BIM Level 2.

For such a comparison to yield useful results, the effect of other factors that may cause differences to arise between the projects need to be stripped out. For example, if two road construction projects of similar dimensions, user needs, materials, and capital cost are compared (but they are not undertaken at the same time in the same location), unexpected adverse weather conditions may affect the duration of construction on one project but not the other. The effect of this difference needs to be stripped out so that it does not distort the impact attributed to the use of BIM Level 2.

Limitations: In practice, it may be difficult to find two projects that are similar enough that the sole factor that might change the benefits that arise is BIM Level 2.

2. **Expert Judgement:** Compare elements of a project or asset with-BIM Level 2 to one without-BIM Level 2 by drawing on expert opinion / experience to assess the scale of the impact on the key metrics which drive cost and /or benefits. This involves:

   - Asking the expert to consider and explain, or 'walking through' the process required to undertake certain activities in both cases (with-BIM Level 2 and without-BIM Level 2) across the relevant phases of the asset lifecycle.
   - Understanding the tasks that are undertaken in both scenarios, as the difference between them is the basis for estimating the impacts that can be attributed to BIM Level 2.

   For example, if BIM Level 2 is expected to result in faster cost estimation (e.g. because the process can be automated), an expert who has performed cost estimation *with-BIM Level 2* and *without-BIM Level 2* should be able to provide a view about the impact that application of BIM Level 2 has on the time required to estimate costs. This can then be used to estimate the benefit (time savings) of faster cost estimation attributed to BIM Level 2.

   Limitations: The robustness and credibility of this approach will depend on the expertise and objectivity of the expert(s) asked to assess the extent to which changes occur. While this method involves judgement, it can be effective when reliable data are not available for two similar projects for use in method 1).

3. **Combination of empirical observation and expert judgement:** Given the difficulties of obtaining data on similar projects, the most practical way of establishing an appropriate counterfactual when measuring benefits may be to combine elements of Methods 1 and 2.

   For example, in the case of analysing the impact of BIM Level 2 on the amount of rework required during construction, it might be possible to compare data from change logs on the cost of changes required for two similar projects (one *with-BIM level 2* and one *without-BIM Level 2*). However, there are likely to be other factors unrelated to BIM that affect the cost of changes on those projects. If these factors cannot be isolated through data analysis alone, it will be useful to discuss the changes undertaken on each project with the change controller (with reference to the change log data) and determine which changes are relevant to and affected by use of BIM Level 2. This allows for a more evidence-based estimation of BIM Level 2's impact on the cost of changes. We suggest using this method for most benefits detailed in our ***BMM***.

4. **Regression analysis:** If there was a large database of relevant data, consisting of many projects, across varying asset types, regression analysis could be used to estimate the effects of BIM Level 2 on project outcomes such as the duration of project schedules, and costs. Data would need to be collected on all the

parameters that might affect the project outcomes. This approach has the potential to control for the influence of confounding factors on project outcomes.

For example, a client might implement BIM Level 2 when the economy is booming (e.g. because as a result of good economic conditions the client had a larger budget and could afford the costs associated with BIM implementation). Additionally as a result of the booming economy, there is greater demand for construction projects. This high level of demand pushes the prices of inputs to the construction process up. BIM Level 2 saves a proportion of the construction costs of an asset as a result of increased efficiency in the construction process. Given that costs are higher, these cost savings from BIM Level 2 appear to be larger. If a regression was run excluding the effect of economic conditions, then the effects of BIM on costs might seem greater than they actually were. Therefore it is important for the regression to account for all factors that might affect both the use of BIM, and the benefits accrued from BIM.

Limitations: Regression analysis relies upon large data sets, therefore to estimate the impact of BIM Level 2 on project outcomes such as cost/ time/ risk et cetera, an extensive data collection process would need to be undertaken. The feasibility and cost associated with collecting this data are such that, when compared to the quality of the results from the other methods, may mean that this approach will not provide greatest value for money.

Throughout the ***BMM*** we explain the possible ways to go about measuring certain benefits, which involve one or a combination of Methods 1-3 above.

5.4 Considering impacts over the project or asset lifetime

All benefits should be measured in present value (PV) terms so that they can be compared. This is because through comparisons of utility across time it can be shown that society attaches a higher value to present, rather than future consumption; due to a preference to receive goods and services now rather than in the future.

Our measurement methodology for each benefit type explains how to measure the impact that can be attributed to BIM Level 2 at the time that it occurs (e.g. time savings, materials savings, reduction in risk). The impacts can then be expressed as a present value by discounting them at 3.5 per cent per annum[14] as specified in HM Treasury's Green Book as the social time preference rate.

The application of BIM Level 2 may result in a change in the timing of the cash flows associated with a particular project or asset. For example, Government Soft Landings may provide an asset owner with a better understanding of asset use and operation; resulting in an agile approach to future change in use and thus change the time that costs are incurred for refurbishment / upgrade. 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. The refurbishment of a certain element of a building, for example, 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.

Practical implication: using the present value

In any case where BIM Level 2 impacts the timing of project or asset cash flows, the effect of this on PV needs to be assessed. We have specified where this is likely to be the case throughout our methodology. The further that a cash flow takes place in the future, the less it will be worth in PV terms due to greater discounting. The

[14] Note that for the 'very long term' (beyond 30 years) the Green Book recommend lower discount rates, which can be found in Annex 6 of the Green Book.

examples below illustrate the effect on PV when costs are reduced (see Figure 14); and the effect of acceleration of project cash flows (see Figure 15).

Example: BIM Level 2 increases the efficiency of boiler use over the life of an asset. This may results in (a) a lower cost each year to service / replace boilers and / or (b) less frequent replacement of boilers – or the ability to delay costs of replacement/servicing further into the future.

Figure 14 shows how a reduction cost that occur in the future affects the PV. In non-discounted terms there is a difference of £20,000 between the 'with' and 'without' BIM Level 2 cases. In PV terms the difference is £19,329.39.

Figure 14: Present value in the case of reduced project costs

Period	1	2	3
Without BIM	£10,000	£20,000	£20,000
Present value	$= 10{,}000 + \left(\frac{20{,}000}{1.035}\right) + \left(\frac{20{,}000}{1.035^2}\right) = £47{,}993.89$		
With BIM	£5,000	£10,000	£15,000
Present value	$= 5{,}000 + \left(\frac{10{,}000}{1.035}\right) + \left(\frac{15{,}000}{1.035^2}\right) = £28{,}664.50$		

Source: PwC.

Figure 15 shows the effect of changing the timing of future costs on the PV. It may be possible with the better information provided by BIM Level 2, to delay costs of maintenance or refurbishment / replacement. In the example below, the undiscounted value of the costs is held constant, but the overall cost is reduced in PV terms, resulting in a £1,160.7 saving due to BIM Level 2.

Figure 15: Present value in the case of accelerated project cash flows

Period	1	2	3
Without BIM	£25,000	£25,000	-
Present value	$= 25{,}000 + \left(\frac{25{,}000}{1.035}\right) = £49{,}154.59$		
With BIM	£10,000	£20,000	£20,000
Present value	$= 10{,}000 + \left(\frac{20{,}000}{1.035}\right) + \left(\frac{20{,}000}{1.035^2}\right) = £47{,}993.89$		

Source: PwC.

5.5 Accounting for risk and uncertainty

For any ex-ante appraisal, risks and uncertainties about project costs, expected benefits, and timing; mean that estimated costs and benefits will almost always differ to ultimate outcomes achieved. Risks should be identified, monitored and appropriately attempted to be mitigated in accordance with the Green Book and Orange Book. Detailed guidance is provided on the level of risk premium that must be included in cost estimates to account

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).

Practical implication: the effect of BIM Level 2 on improving certainty

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 CAPEX and/or OPEX, 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. 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 is unlikely to occur all at once, and will more likely increase over time.

6. Final considerations for measurement

Our proposed ***BMM*** is intended to help government construction clients and asset owners measure the benefits realised from application of BIM Level 2 at a project level, in a systematic and structured way.

We believe that measurement efforts should be focused on those benefits that are expected to be most significant for an organisation, and those for which reliable data are available or can be collected. In practice, this implies that before attempting to measure any benefits from application of BIM Level 2, the following factors should be considered:

- **The potential size of the benefit:** This could be determined based on both consultation with relevant stakeholders around the benefits they have experienced and their relative sizes, and through a review of the academic literature seeking to measure the benefits of BIM. For example, the costs incurred in operating an asset over its useful life are often around five-fold larger than costs incurred in design and construction[15], therefore the potential for cost saving in the operations phase is also likely to be larger.
- **The types of asset being assessed:** Although many of the benefits of BIM Level 2 will apply to all asset types, we would expect some to be more significant for specific asset types. For example, BIM can potentially result in improvements in an asset's utilisation – this benefit is likely to be most significant for assets where downtime has the largest negative effect on operation of a public / customer service.
- **Who the benefit is likely to accrue to:** As discussed in Section 5.3, how far a benefit is passed on by the supply chain to the client will depend on market dynamics and commercial arrangements. If a benefit is unlikely to be passed on to a government construction client, it may or may not be useful to spend time measuring that benefit (depending on the desired objective of undertaking measurement in a particular case).
- **The ease of measurement:** This will partially depend on who the benefit initially accrues to, and the data /evidence available that can be used in the measurement process.

[15] See for example Hughes, W., *et al.* (2004), *Exposing the myth of the 1:5:200 ratio relating initial cost, maintenance, and staffing costs of office buildings,* Proceedings of the 20th Annual ARCOM Conference pp. 373-381 who discuss the well-known ratio of costs of 1:5:200 (construction: maintenance: operation) and based on primary research suggest a ratio of 1:0.4:12

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