Research

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Collaborative Building Information Modelling (BIM):

Insights from Behavioural Economics and Incentive Theory

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Insights from Behavioural Economics and Incentive Theory

Report for Royal Institution of Chartered Surveyors

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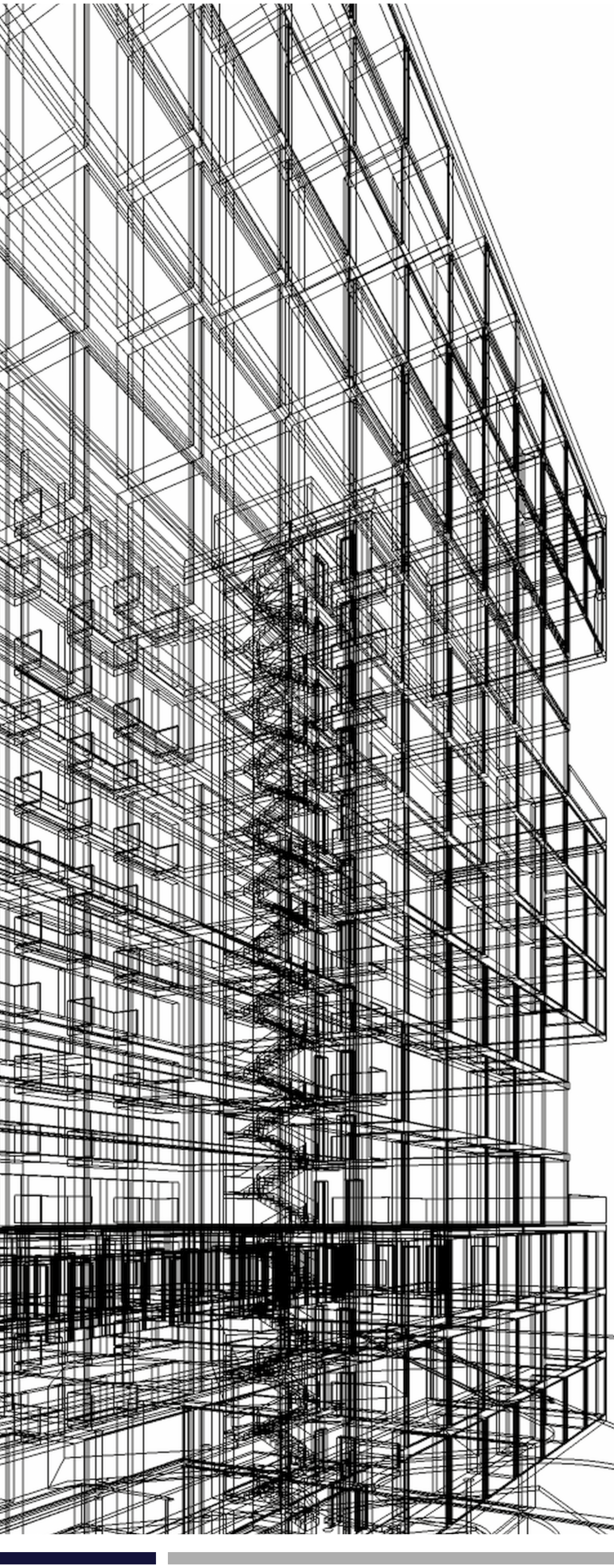


Executive Summary

Building Information Modelling (BIM) offers rich opportunities for using information technologies to manage and co-ordinate projects more effectively. BIM technologies have been developed primarily as a solution to information and co-ordination problems. Collaborative working has the potential to leverage social relationships and interactions, decreasing conflicts and opportunism within teams and throughout supply chains. Future versions of Collaborative BIM might be able to combine the advantages of both, significantly reducing project costs and improving supply chain efficiency.

This report outlines findings from a research project exploring the potential and pitfalls of collaboration and matching these with an analysis of BIM. Using interviews and online surveys, novel insights from behavioural economics and incentive theory are applied to investigations of collaborative working and the potential of BIM as toolkits, not only for improving information flows, but also for enabling collaborative working practices, particularly for lower tiers of supply chains where small and medium sized enterprises (SMEs) are strongly represented.

Research questions

This research focuses on blending insights from economics – in particular the interactions between economic incentives and constraints, and novel insights from behavioural economics applied to an analysis of BIM and collaborative working.

The benefits of BIM generally relate to information flows. Insights from economics show that there are two dimensions to this problem – the ease with which a supplier can conceal this information, and their desire to conceal this information. One solution to the first dimension of this problem is to improve the quality of information: as explored in this report, BIM has an important role to play in this. In addition, behavioural economists suggest that collaboration can reduce a supplier's incentives for concealing information by building trust and co-operation, and by encouraging contracting parties to take a longer-term view. If these additional benefits of collaboration, beyond improving information flows, can be embedded into BIM innovations, then the potential for significant reductions in construction transaction costs is increased.

In exploring these themes, the key research questions are:

- Do transaction costs, particularly at lower tiers of the supply chain – in which SMEs are strongly represented, impede efficient supply chain management?
- How and why can collaboration reduce transaction costs within supply chains?
- Are construction transaction costs inflated by constraints on the quick and easy flow of information and/or behavioural biases?
- What potential does BIM have to reduce these transaction costs, not only by increasing the transparency and comparability of building information data, but also by harnessing the benefits of collaboration?
- If BIM does have potential to ease the flow of information, do behavioural biases have an additional impact in constraining the uptake of BIM? For projects that have not implemented BIM, what are the implications?

Methods

These research questions are analysed using evidence from a range of qualitative and quantitative analyses. This evidence focuses on combining economic concepts with insights about project and supply chain management, and this approach is relatively novel because the academic literatures on economics and project management are not yet strongly connected.

To gather more evidence about the research questions, the qualitative analyses included a series of face-to-face interviews with suppliers and contractors, from across the construction industry including a range of suppliers and sub-contractors. The interviews were structured around economic insights, as outlined in more detail in Chapter 2. For the quantitative analyses, a series of online surveys were conducted – one set focussing on a single supply chain: the @one alliance (Anglian Water), and the other set focussing on project-based information, with respondents selected from the Glenigan project database. These surveys focussed on analysing the attitudes of businesses towards collaboration and BIM, with the overall goal being to collect some information to develop some insights about BIM's on-going potential, as well as its potential for embedding deeper forms of collaboration, beyond the simple exchange of information.

Another key issue is the uptake of BIM. What are the implications for projects that do not embed BIM within their project management processes? Chapter 4 focuses on a case study of Network Rail as an example of a non-BIM project. Another issue to consider is the constraints on uptake of BIM, particularly for smaller businesses with fewer resources to finance BIM uptake. To capture some of this, the empirical analysis also includes a survey of construction industry businesses' attitudes and opinions towards BIM.

Key findings

The key findings were centred around collaboration and BIM uptake, and include the following:

- For the case study of the @one alliance (Anglian Water) supply chain, the interviews and online suppliers' survey confirmed that suppliers value their long-term relationships with clients, and are unwilling to take lower cost short cuts for a number of reasons, including the business they would lose if their reputation for high standards was lost.
- The @one alliance study also showed that suppliers and subcontractors are aware that poor information and opportunistic use of information can inflate transaction costs and damage supply chain efficiency, particularly at lower tiers of the supply chain.
- These suppliers also offered some insights into how the process of innovation can be embedded into their practices – e.g. via social learning from other suppliers, opportunities for early engagement in project procurement stages.
- Overall, the interviews and survey results from the case study of the @one alliance (Anglian Water) showed that suppliers recognize the virtues of collaborative working not only in circulating information more efficiently, but also in building trust and cooperation, and reducing opportunism and short-termism throughout the supply chain.
- The surveys from businesses identified via the Glenigan project database indicate that building collaboration into BIM is perceived to be a key benefit, and respondents associated with high performing projects are more likely to view BIM-enabled collaboration as a positive feature.

Conclusions and recommendations

Collaboration can help to align the incentives of clients and suppliers, but – even with the best will in the world – communication and coordination can be difficult to achieve, particularly for complex projects. If properly designed, collaborative BIM can provide solutions: well-designed BIM toolkits can leverage the value of good information, enabling better co-ordination, synchronisation and sequencing of projects, by allowing all project participants to access and interrogate project information; and, at higher levels of BIM, by enabling better clash detection.[1] If BIM innovations can also be designed to enable inter-disciplinary learning and promote collaboration throughout a project supply chain, then the efficiency savings are likely to be large.

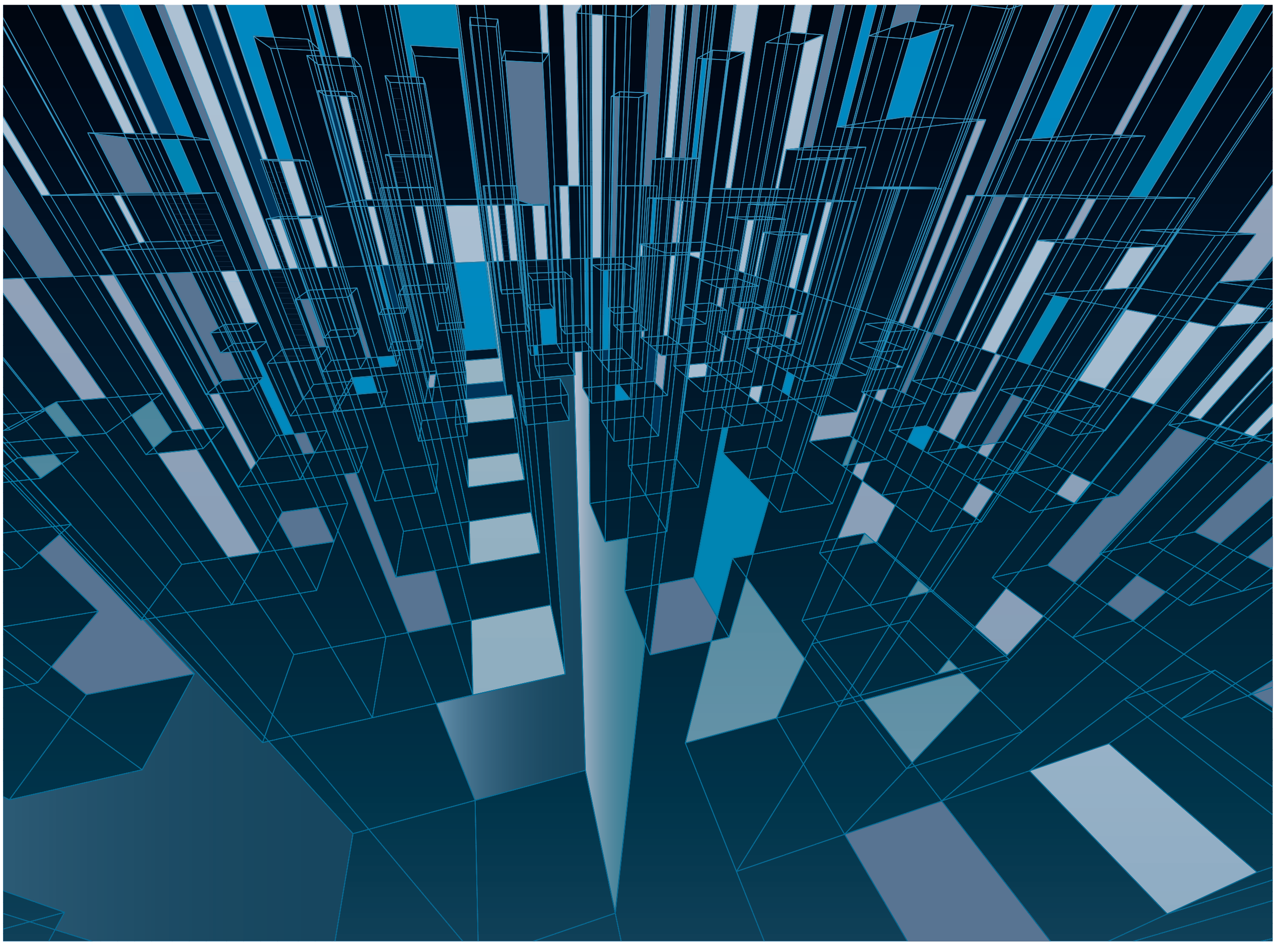
1 Detection of clashes between different project tasks – essentially clash detection enables better management of construction sequencing and effective and early clash detection has the potential to substantially lower construction costs.

There are pitfalls too however – for example, there maybe behavioural and financial constraints on BIM uptake, especially amongst SMEs. Incentivising BIM is therefore an important question. In devising ways to encourage uptake of innovative practices generally, the incentives and biases need to be thought through carefully.

Another crucial feature of effective innovation to improve supply chain efficiency, is the provision of educational opportunities to inform businesses, and also to promote interdisciplinary learning, so that the different construction industry players have a better understanding of the sort of information other disciplines can offer, and the real-world constraints that other disciplines face. BIM can play a key role in this – with better understanding from all players of what other players can do and need to have has the potential to significantly improve construction supply chain efficiency.

In terms of education and skills transfer, suppliers and sub-contractors at lower levels of the supply chain might well be open to innovative solutions to project co-ordination and management. The capacity for innovation demonstrated by some of the suppliers and sub-contractors in the @one alliance (Anglian water) suggests that they would not be resistant to embedding ICT solutions – the constraints would be direct financial costs, and indirect costs in terms of lost working time. These will be particularly significant for the smaller, more vulnerable businesses. Support, including financial support, is needed from construction organisations, clients, main contractors and government to enable smaller, more vulnerable businesses to access training and education opportunities, without disrupting their normal business. More generally, for novel technologies, processes and procedures, the construction industry organisations have a crucial role to play in informing construction businesses, particularly smaller businesses about the relative benefits of BIM and other ICT solutions.

The case study of Network Rail illustrated a collaborative project in which BIM was not used. There are ways in which BIM could have been used usefully to improve the performance of the project. However, another important point here is that there are alternatives to BIM, including models adopted by Network Rail and other infrastructure clients. The relative costs and benefits of BIM and its alternatives should be considered carefully by government and construction industry organisations.



1.0 Introduction

1.1 What is Collaborative BIM?

Building Information Modelling (BIM) is a set of digital tools used to capture the functional and design characteristics of a building. It is necessarily collaborative because it is about information sharing across the various businesses and within the inter-disciplinary teams on construction projects. The essence of the concept was outlined by van Nederveen and Tolman (1992), with a practical outline of BIM as a construction solution set out by Autodesk (2003). There is no absolute definition or version of BIM – BIM software is supplied by a range of organisations, but Autodesk is now, by a wide margin, the market leader. BIM is evolving rapidly all the time, and current practices are changing rapidly; with alternatives to the standard BIM approach in development too.[2]

BIM's origins lie in architectural design, and have evolved from Computer Aided Design (CAD) – devised in practice as a common record of plans and drawings for a building – initially in 2D form enabled by 2D CAD, later moving to 3D CAD versions. In comparison with old-fashioned methods of drawn plans, the technological innovations offered significant advantages in terms of digitised design and visualisation. More recently this has evolved into BIM models embedding protocols extending data and file sharing to higher "dimensions". Over time, BIM has been extended to Levels 2 and 3, with greater focus on dimensions of construction sequencing and asset management. Whilst BIM is now an industry standard, generally uptake has been concentrated on the lower levels of BIM. Neil Thompson, Principal BIM integrator at Balfour Beatty, conceptualises Level 1 BIM as file-based collaboration – essentially traditional practices, but on a computer. Level 2 involves more systematic ordering and standardisation of information, but the contractual information is still paper based. At Level 3, in theory the information systems can be integrated but level 2 is the maximum possible at this stage, given current legal and institutional constraints. At this time best practice in the construction industry is, at best, working with collaborative 3D BIM. More sophisticated versions are not in widespread use – though the technologies are increasing in sophistication and spreading more widely.

The ideal is to move towards models in which multi-faceted information about construction, including project and asset information, can be electronically stored, shared and interrogated. Potentially, further dimensions, including fourth "dimension" – capturing the temporal dimension potentially enabling the capture of a common archive about the entire history of a building, enabling more efficient lifetime management and control, with potential for considerable cost and efficiency savings over time. Higher levels of BIM have the potential to move information sharing beyond the procurement and construction phases towards enabling more efficient facilities management (FM) too, if BIM can evolve to capture of a common archive about the entire history of a building. This has potential to enable properly efficient lifetime management and control, with potential not only to generate considerable cost and efficiency savings over time, but also more reliable environmental information.

Current practice is captured in the latest BIM British Standard (BS 1192: 2007) and in the BIM Handbook (Eastman et al. 2011), but BIM is developing rapidly and understanding of what it entails is changing concomitantly, currently generating as much confusion as coherence. There is no universally accepted definition of BIM and in this report we will focus on the industry standards, specifically those outlined by the NBS – as summarized in Table 1. It is important to emphasise that level 3 BIM and beyond are speculative and have no clear, objective definition at this stage – they are more like visions of how BIM might evolve, but BIM at these levels is not used in practice at this time. Various regulatory and liability issues must be resolved before these levels of BIM can be adopted in practice.

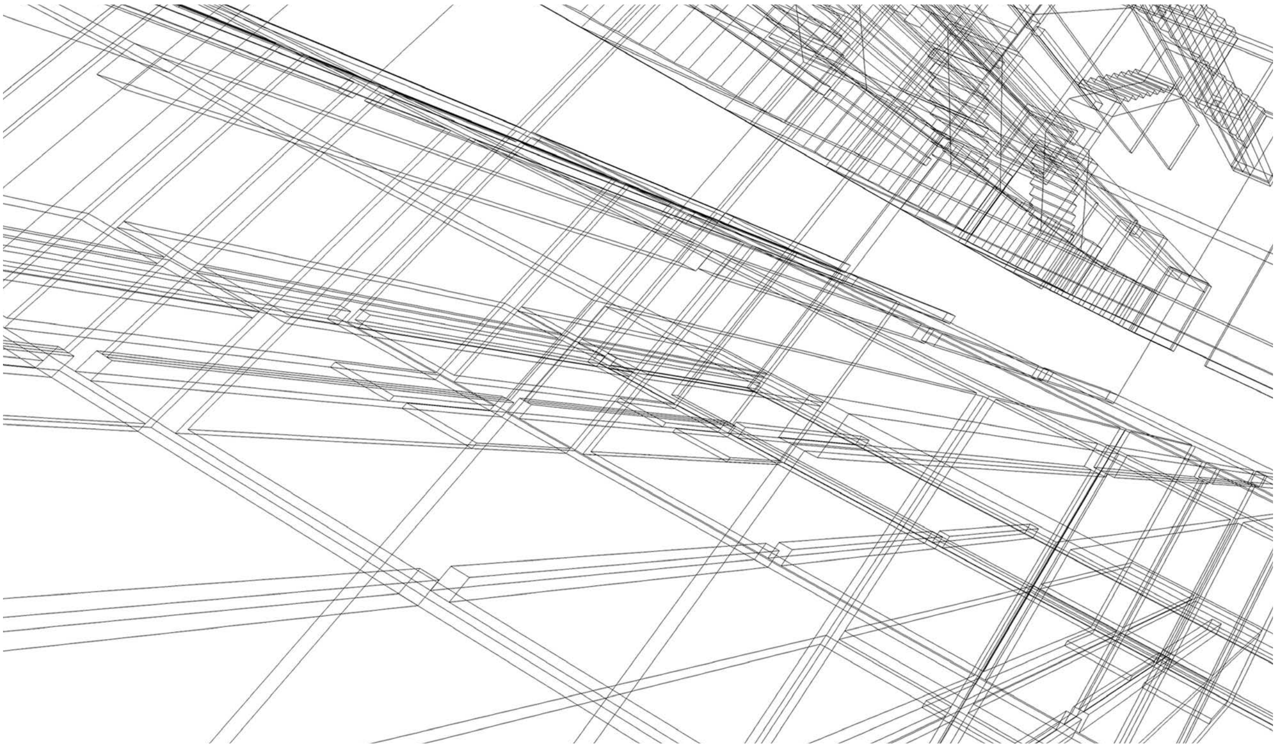
BIM is, in some senses necessarily collaborative because it involves the sharing of information. The analysis of collaboration in this report focuses on a broader definition – moving beyond the mere sharing of information and focussing also on collaboration defined more broadly. Can BIM be used not only to enable information sharing but also to encourage the various players in construction projects and supply chains to co-operate with each other? This research report will explore this broad question, linking the analysis to some insights from economics, including incentive theory, behavioural economics, information economics, and game theory.

2 For updates and analyses of current and recent practice, research and policy, see Fitzpatrick (2013), GCCG (2011), McGraw Hil Construction (2014), NBS (2014), Thompson (2014), and Whyte (2012). For latest news and views see www.thenbs.com/topics/BIM.

Table 1 **BIM Levels and Beyond**

BIM Level	Characteristics	Uptake
Level 0	**Technology:** 2D CAD drafting, mainly for product information **Outputs:** paper and electronic **Collaboration:** n/a **Management:** n/a	Generally, the construction industry has moved beyond Level 0
Level 1	**Technology:** 2D + 3D CAD to BS 1192:2007 **Outputs:** electronic sharing in a common data environment (CDE) **Collaboration:** No inter-disciplinary collaboration **Management:** by contractor	Commonly used, but each organization publishes and manages its own data
Level 2	**Technology:** 3D CAD + 4D construction sequencing and 5D cost information **Outputs:** electronic sharing **Collaboration:** collaborative working a distinctive feature, but is limited to information exchange using common file formats **Management:** federated BIM model but no single, shared model to manage	No yet very widely adopted, but will be a requirement for public sector work from 2016
Level 3	**Technology:** 3D CAD, 4D construction sequencing, 5D cost information, and 6D lifecycle management information **Outputs:** shared electronic model in central repository **Collaboration:** full collaboration via a single, shared model with universal editing rights	The next step in theory, but not yet ready to implement in practice because of regulatory and institutional constraints
Beyond BIM		Higher levels of BIM are in development, as are alternative models

Sources: http://www.thenbs.com/topics/BIM/articles/bim-levels-explained.asp, NBS (2014), GCCG (2011), and discussion with the Balfour Beatty's Principal BIM Integrators – Neil Thompson and Kevin Lloyd.



1.2 BIM in the UK

The UK is a path breaker in BIM adoption. BIM is now an industry standard in the UK, and government is supporting and encouraging the adoption of more sophisticated versions of BIM.

From the time of the Egan Report (1998) and the Wolstenholme Report (2009), there has been recognition of significant waste in the construction sector. Egan's key targets included "reductions of 10% in construction cost and construction time". In addition, the report focussed on replacing the adversarial approaches associated with competitive tendering with "long term relationships based on clear measurement of performance and sustained improvements in quality and efficiency" (Egan Report, 1998, p. 5). These concerns have persisted and government now sees BIM as part of the solution to these problems. "BIM has the potential to transform architecture, engineering and construction by providing accurate, timely and relevant information throughout a building's life cycle."

Government mandates are emerging: the UK government requires that Level 2 BIM be used on all its projects by 2016. Mirroring the Egan Report (1998), the target is to reduce waste in the construction sector by 20%. Also, poor quality work, stalled projects and over-runs are emphasized and information problems within construction supply chains are identified as major contributors to this waste. BIM has the potential quickly to circulate relevant and accurate information about construction projects, potentially throughout a building's life cycle too. In later versions, BIM-enabled collaborative working has the potential significantly to reduce these inefficiencies – ultimately, not just in the construction sector and for public sector projects, but also throughout the private sector and other industries.

1.3 Research objectives

Collaboration has the power significantly to improve supply chain performance, by lowering costs and more effectively aligning the incentives of different supply chain participants. Building Information Modelling (BIM) is promulgated as the solution to construction coordination problems, and there is particular potential for BIM to leverage the benefits of collaboration, assuming all tiers of contractors are properly incentivized to adopt BIM.

The research objectives in writing this report were to develop understanding of collaboration and BIM within construction projects and supply chains by applying concepts from economic theory and behavioural economics, to the analysis of construction supply chain. This research has two main aims:

1. To develop an understanding of some of the drivers, benefits, costs and constraints for collaboration within construction supply chains
2. To analyse the potential for BIM as a toolkit for enabling collaboration by developing these insights about collaboration more rigorously within an analysis of Building Information Modelling (BIM).

In practice, the analysis of supply chain performance has generally come from an engineering and/or management perspective, with the main insights from economists coming via analyses of transaction costs and contract theory. But economics and behavioural economics have more useful insights to add – particularly in terms of understanding different sources of incentives and motivation.

Economics in general is focussed strongly on the role of incentives in decision-making and in this sense economics and incentive theory are synonyms. But traditional economic approaches tend to focus on a very limited set of monetary incentives. Information economics and behavioural economics (BE) explore a wider range of incentives, and explore different aspects of motivation. BE has become one of the most prominent sub-disciplines of social science but it has not been well explored in the construction context. Unlike the mainstream principal-agent theory, which builds on relatively abstract theoretical models, new BE perspectives aim to reconcile the rigour of standard economic analysis with more intuitive insights into business behaviour, and especially the range of motivations affecting business performance. Motivations are defined broadly and can include a range of financial and non-financial inducements, each with varying effectiveness. One of the aims of this research is to examine the link between motivation and project performance from the perspective of behavioural economics (BE) and economic theories of incentives, broadly defined.

1.4 Theoretical insights

The main application of economic insights to construction has been in the area of transaction cost economics, for example as exemplified in Ive and Chang (2007a). As explained above, the research outlined in this report draws on a range of insights from information economics, behavioural economics and incentive theory. The main objectives are to explore these hypotheses using case studies and surveys, explored using the methods explained in section 1.6.

The main emphasis is on theoretical insights from economic literatures on

1. transaction costs, incentives and motivations;
2. information, risk and uncertainty;
3. behavioural bias and social influences.

These theoretical approaches will inform our understanding of the benefits, costs, drivers and constraints of collaboration within construction projects and supply chains – as analysed in chapters 2 and 3. It will also be used to capture some of the essential elements of BIM and constraints on the uptake of BIM – as analysed in chapters 4 and 5.

1.4.1 Transaction costs, incentives, motivations

The key theoretical ideas will be outlined in chapter 2 and will focus on the role of transaction costs in construction projects – construction procurement and supply chain efficiency can potentially be significantly increased with some robust insights about what contributes to transaction costs, how contracts can be designed to economise on these transaction costs, and how collaboration and/or BIM can play a role in reducing transaction costs.

A related set of insights from economic theory and behavioural economics concerns the role of different incentives and motivations. Traditionally economists have focussed on monetary and financial motivations, but this research confirms insights from behavioural economics about the important roles played by non-monetary incentives and motivations – for example pride in doing a job well, loyalty to a firm, and/or social influences.

1.4.2 Information, risk and uncertainty

A key set of influences identified in the interviews and surveys broadens the focus beyond transaction costs to information, risk and uncertainty. Economics explores the impact of risk and uncertainty on investment projects in general, not only construction projects. In the context of uncertainty, taking risks with investment projects is potentially more costly: uncertainty dampens incentives to invest in physical assets. Uncertainty is the problem of poor information, affecting all project participants. Another information constraint is asymmetric information: one party knows more than another party, and can exploit this informational advantage, e.g. a supplier can supply low quality and low cost products to customers who are not able to tell the difference. Better information flows, such as those enabled by BIM technologies, reduce opportunism because they increase chances of being caught. There are feedback effects as better information constrains opportunism, and also less opportunism encourages project participants to be more honest – by building trust, encouraging project participants to take the long-term view, and also by enabling social learning.

Applying the insights from information economics specifically to construction, if suppliers and sub-contractors have better information than a client about the quality of their products and services, then they may be able to exploit these informational advantages to boost their own profits at the expense of the client, thus inflating transaction costs and therefore project costs. Collaboration is one potential solution to this problem because people/businesses don't generally want to "cheat" people with whom they have long-term relationships - either for socio-psychological reasons and/or because they would lose business in the long-term.

1.4.3 Behavioural bias and social influence

Complementing these insights about incentives, motivations and information – behavioural economics explores the role of other socio-psychological influences on economic decision-making and, by extension, business practices. A key insight is that real-world decision-makers are not always able to make effective decisions – and their decisions are often driven by behavioural biases and social influences. Bias can lead to significant increases in construction project costs – for example optimism bias – e.g. for major infrastructure projects (Flyvbjerg 2008). Social influences are more nuanced and can have both positive and negative impacts. Collaboration is inherently about harnessing social influences – the inclination we have to co-operate with others. This report will outline some ways in which this instinct to co-operate can be harnessed, using collaborative working to promote construction supply chain efficiency.

1.5 Research hypotheses

Building on the theoretical insights outlined above, the main research hypotheses are;

H1: Significant transaction costs at lower tiers of the supply chain, including transactions costs between suppliers, impede efficient supply chain management.

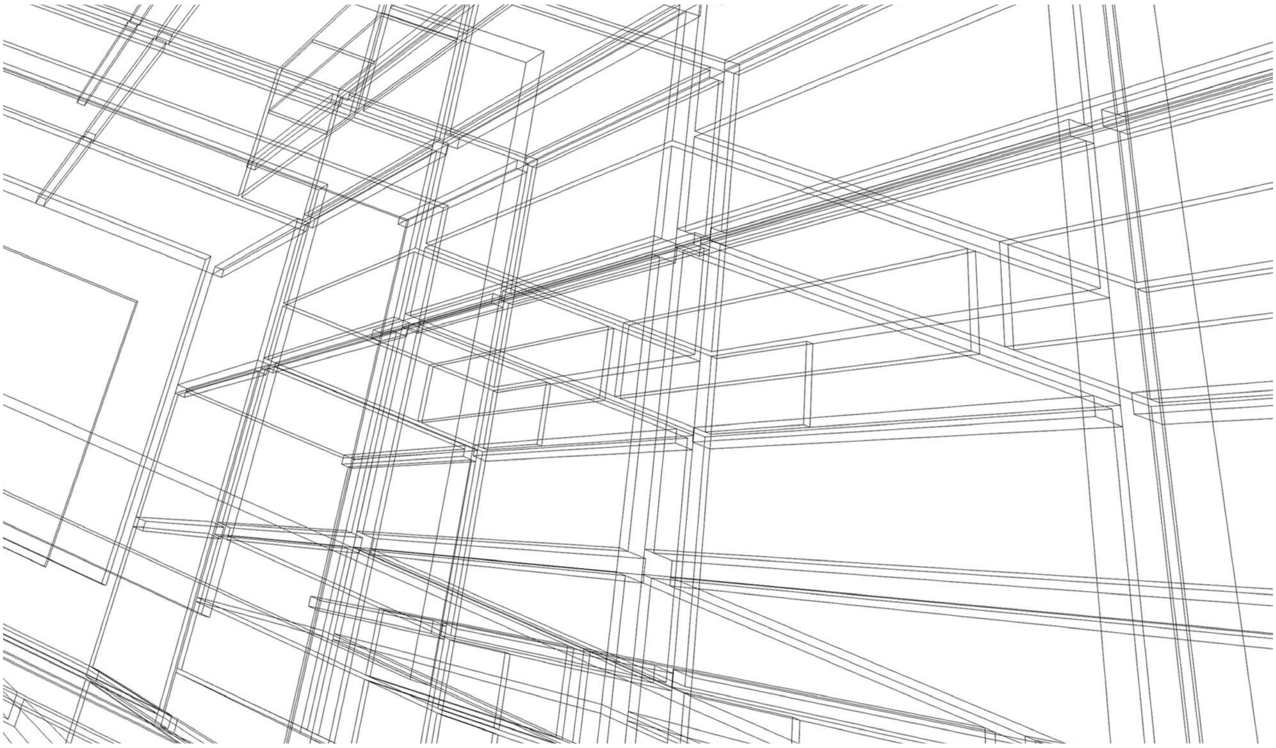
H2: Transaction costs are inflated by information constraints and behavioural biases, for example in the following ways:

- Information constraints lead to opportunistic behaviour by suppliers when suppliers can act inefficiently in ways that are not immediately observable by clients and other suppliers. For example, other businesses may not know when a supplier is making less effort and so the supplier is able to behave opportunistically e.g. by supplying lower quality products/services, and/or transferring burdens of risk down the supply chain.
- Information constraints are compounded by behavioural constraints for example over-optimism about deadlines and costs, misperceptions of risk and short-termism.

H3: BIM has the potential significantly to reduce these transaction costs by increasing the transparency and comparability of building information data, thus disciplining opportunistic behaviour and encouraging more efficient practices at lower tiers of the supply chain.

H4: Collaborative working has the potential to decrease the likelihood of opportunistic behaviour within supply chains because it improves information flows so suppliers do not have private information that is not available to other project participants. Information is shared more effectively and suppliers are more likely to cooperate and less likely to opportunistically exploit their information advantages when they know that a record of poor performance will tarnish their reputation and decrease the chance of future work. There are feedback effects between opportunism, collaboration and reputation: better information encourages and facilitates collaboration leading to less opportunism. Less opportunism is associated with more honest practices, thus facilitating collaboration. In the long-term, there are feedbacks between reputation and collaboration too: collaboration builds reputation; incentives to build reputation encourage more effective collaboration and therefore more collaborative attitudes – encouraging better information flows. Fear of reputational damage will increase collaboration and reduce opportunism, but similarly reduced opportunism will encourage more and better collaborations. Collaborative working will also enable social learning about best practice.

H5: Design of BIM-enabled collaborative working practices can combine the benefits of BIM and collaborative working by providing objective, systematic information about past projects.



1.6 Methods

The case studies and surveys identify the key constraints on supply chain efficiency and performance, focussing in particular on the potential for BIM to maximise the benefits of collaboration, and some of the constraints on BIM, including BIM uptake. The findings indicate how designing an effective incentive plan for BIM projects can be achieved by analysing the connections between project performance and choices of incentive plan and drawing on insights from incentive theory in economics.[3] In addition, the empirical studies will also explore attitudes and opinions of project businesses via a survey of participants in UK projects carried out in the period 2010-2013 – with the businesses identified from the Glenigan database. Case studies of Anglian Water and Network Rail qualitatively explore the themes outlined above using in-depth responses from interviews with a range of construction suppliers, contractors and sub-contractors.

A range of online surveys have been conducted to explore the following:

- levels of collaboration in Anglian Water's supply chain,
- perceptions of incentivising BIM, amongst small and medium sized enterprises (SMEs) in the construction sector
- the potential of BIM to harness the benefits of collaboration among project-based respondents selected from the Glenigan database.

In general the results will be presented graphically, but for the BIM attitudes and opinions survey in Chapter 5, simple statistical tests will be used to capture whether attitudes and opinions are significantly different for high performing versus low performing businesses.

The evidence presented in this report represents the outputs from a combination of qualitative and quantitative analyses.

Qualitative analyses

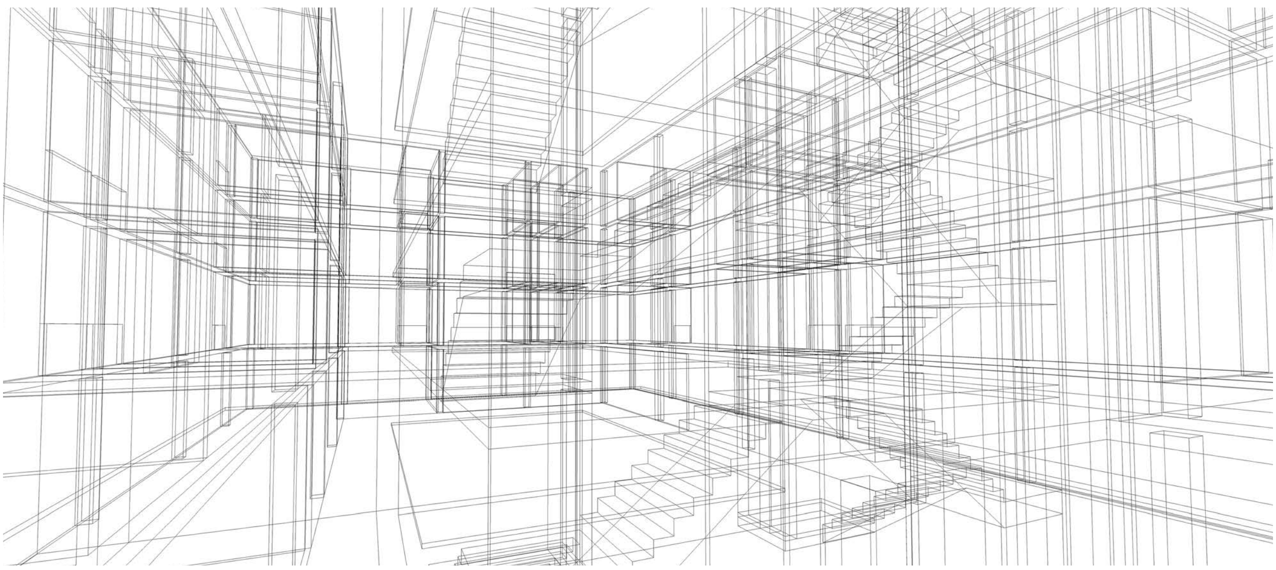
These included in depth face-to-face interviews with various players in the construction industry, focussing in particular on suppliers at tier 2 and below of construction supply chains. These structured interviews revealed the importance of a range of economic insights relating to construction supply efficiency generally and collaboration in construction specifically. Some of these insights are so far largely unexplored in construction, and are the focus of this report.

Quantitative analyses

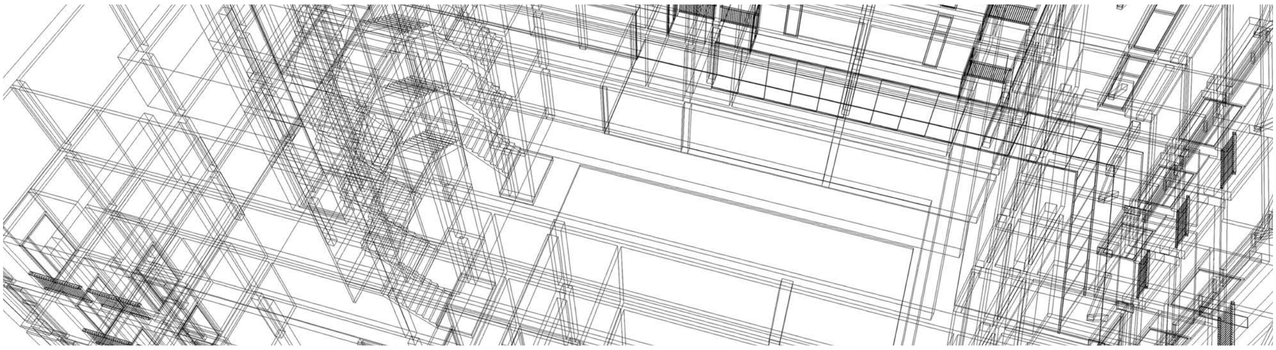
Using insights from economic theory and from the outputs of interviews conducted for the qualitative analyses, surveys were constructed, setting out a range of questions relating to collaboration and BIM – the aim being to use the answers from these surveys to develop some insights about Collaborative BIM's potential.

The surveys were conducted online using standard survey tools (UCL's Opinion survey tool and Survey Monkey). The results were analysed and reported using charts and tables, with tests of statistical significance being applied to test of the robustness of the findings. Four sets of online surveys are included in this report: a survey of a selected sample of Anglian Water Services @one alliance suppliers, a sample of small and medium-sized construction businesses identified from the FAME database; and two sets of surveys of companies sampled from the Glenigan project database.

In addition to the surveys, we have included some detailed case studies of Anglian Water and Network Rail including, preliminary findings from interviews of Anglian Water Services' lower tier suppliers at Tier 2 and below.



2.0 Collaboration: Economic Insights



2.1 An Overview

There are a range of insights from economics that have applicability to construction procurement and supply chains – some have had some attention already; others are relatively novel. The key applications are in the area of institutional economics, focussing on the theme of transaction costs – for example see Ive and Chang (2007a).[3] There are however large and relevant areas of economics that have not been applied extensively to construction, and this report suggests some areas that could be usefully applied to the analysis of construction projects and supply chains. The main economic drivers explored here can be divided into transaction costs; incentives and motivation; information, risk, uncertainty and information; and behavioural and social influences. These factors have complex implications for construction projects – their effects may be beneficial or detrimental, and the various influences will interact with each other.

2.2 Transaction costs

There is already a substantial literature on transaction costs and contract theory in construction economics. Arguably this is the main application of economic theory so far in the analysis of construction and construction transaction costs. As noted above, this has been analysed extensively by Chang and Ive (2007a, 2007b), drawing on seminal insights from Coase (1937) and Williamson (1979). For example, the decision to outsource production beyond the firm is determined by the relative costs, including transaction costs, of outsourcing to another business or individual. This is a powerful insight for construction projects and can be explained in terms of the transaction costs involved in forming economic institutions and writing contracts.

Transaction costs are a key issue because construction projects usually have a complex chain of diverse businesses throughout the supply chain. Understanding the role of transaction costs can enable us to understand why businesses outsource some activities to other businesses, and why other activities are conducted in house. In the context of construction – why some activities are done by the main contractor and others are contracted out to sub-contractors. Transaction costs are part of the explanation. For example – transaction costs will be lower if a client can outsource scaffolding to a sub-contractor because the transaction costs involved in the client organising its own scaffolding are relatively large. Transaction costs can also help us to understand the role of contracts in construction projects: if a business is outsourcing inputs into its activities beyond the firm, contracts are needed with external parties – and these contracts can add significantly to transaction costs. Contract design is also vulnerable to strategic, opportunistic behaviour – and this can lead to a significant magnification of transaction costs.

2.3 Incentives and motivation

Traditionally, economists focus on the role of monetary and financial incentives in motivating effort. Paying workers a higher wage should, all things being equal, encourage them to work harder. Their rising productivity will be associated with lower unit labour costs and higher profits. Contract theory is grounded in analysis of monetary incentives – taking into account the fact that economic agents will often behave strategically and opportunistically – to maximise benefits for themselves regardless of the costs these might impose on others. For example, contractors and sub-contractors incentives to save on project costs will be affected by whether they are on a cost-plus contract or a fixed price contract. In the process of tendering, contractors may have an incentive to underbid to get a job, but then make their profits out of contract variations. Understanding these factors and the potential they have to inflate the costs of construction projects has led to some interesting and innovative insights about how contracts can be designed to overcome these problems – for example, by changing the essential nature of the tendering process.

3 For a comprehensive survey of applications of economic theories and insights to construction, see Ive and Chang (2007b).

Another insight that connects with behavioural economics, is the idea that businesses and employees are not motivated solely by monetary and financial incentives. Some of the survey evidence below shows that monetary motivations, whilst important, are not necessarily the most important motivator in the construction industry – pride in doing a job well comes up as an important motivator for example.

This links into the distinction between extrinsic motivation and intrinsic motivation. Extrinsic motivations capture the incentives and rewards external to ourselves: sometimes these external rewards are monetary; other times they are non-monetary, including social rewards. Higher wages, good exam results, prizes and awards, and social approval are all external rewards. But we are also driven by intrinsic motivations – something within ourselves encourages us to make an effort. When we play a game of chess or cards, or a computer game – we enjoy the challenge – and that enjoyment is a response from within us, not from outside. It's not just about winning the game. Artisans and craftspeople take pride in doing a job well – quite apart from the money they are paid. Intrinsic motivations include pride in doing a job well, enjoying a task, personal ambition, moral principles, and loyalty to a firm or a cause. In motivating the various trades that contribute to construction projects, this is potentially a powerful motivating force, and one that can get lost in a heavily contractual context in which questions f quantity and money are more salient than quality.

2.4 Information, risk and uncertainty

In economic theory, subtle distinctions are made between risk, uncertainty and imperfect information. Risk and uncertainty are about the future and prospects that are, to a greater or lesser degree, unknowable for anyone. For example, if there is uncertainty about changes in government policy relating to renewable energy, then this will slow investment in both renewables and non-renewables because it becomes more difficult to assess the potential future benefits of investment in physical assets. In the context of BIM, if there is uncertainty about future government policy around BIM, then this may slow down businesses' investment in particular versions of BIM.

The clarity of information is a key issue – also the quality and speed of information transmission – Neil Thompson, the Principal BIM Integrator at Balfour Beatty, explains that it is not just about the information, it is also about the speed and quality of information is transmitted. "Heavy" information processes, and information lags inflate transaction costs.

Economists usually think of risk as quantifiable – if we can just figure out the chances that we'll get hit by a bus when crossing the road is – say 1 in 8,000 - then we can decide whether or not we want to take that risk, depending on how we value the consequences. If I buy a lottery ticket, my chance of winning £1 million is 1 in 14 million – I balance these low odds against the large prize, and decide according to my risk preference – Am I risk-loving? Risk-avoiding? Or risk neutral? If I prefer to avoid risk, I won't buy the ticket; if I like taking risks, I'll buy the ticket. For our risky choices, economists usually assume that we decide according to how much we like taking risks, or not. These risk preferences don't change just because our choice is presented and framed in a different way.

Whilst there is a strong focus on risk in construction projects, this risk can be very hard to quantify because construction projects are, by their inherent nature, idiosyncratic. Building even a relatively standard type of building is not like producing 1,000 identical cars on a car assembly line. For construction, uncertainty is a more meaningful concept – in an economist's terms – it is something unknowable and unquantifiable. As risk is difficult to quantify and define in the context of construction projects, it can be relatively easy to pass it down the supply chain – and this is a concern raised by some of the suppliers interviewed in this research. Collaboration has the potential to build trust, and reduce the risks that are within human control. BIM has the potential to bring together information effectively, thus increasing the ease of quantification of risk.

Information gaps are important in more subtle ways too, for example when information is there, but it is not being shared because parties to a contract have incentives to conceal it. Economists identify this problem as "asymmetric information": when one party to a contract has more information that the other party, and has an incentive to conceal or manipulate this information. One example is that supplier and sub-contractors can supply products and services, when the quality and value of that product/service is not immediately observable to the buyer. If the supplier is short-termist, then they will "cheat" their clients and customers by supplying lower quality products, reducing the suppliers' costs and increasing their profits. The information is there but it is not necessarily in the interests of one business to reveal this information to another business. A supplier or sub-contractor may have incentives to conceal concerns about the quality of their products or services and pass the costs onto the client or main contractor. Overall, poor information, endemic uncertainty and inherently unpredictable and uncontrollable risks all have a negative impact on entrepreneurship. The potential for opportunistic use of information, has a further negative impact. At the procurement stage, some clients may not have easy access to information about the quality of products and services supplied, and suppliers will have an incentive to exploit their superior information by using cheap but a lesser quality product – a cost saving for them but one which can significantly inflate the lifetime costs of a project.

Developing trust between different project participants has the potential to decrease the likelihood of opportunistic behaviour within supply chains. Suppliers are more likely to cooperate and less likely to opportunistically exploit their information advantages when they know that a record of poor performance will tarnish their reputation and decrease the chance of future work.

2.5 Behavioural bias and social influences

Economists are increasingly recognising that people respond to sociological and psychological influences in their economic decision-making. Psychological influences mean that business decision-makers find it difficult to identify optimal solutions – instead they make quick decisions, perhaps disregarding important information, and this leads them into various forms of bias. For example bias affects our perceptions of risks in different situations; for example Flyvbjerg (2008) analyses some insights from behavioural economics about misperceptions of risk in the context of major infrastructure projects. An every day example relates to the way we judge risks depending on how easily we remember information. Newspaper headlines about plane crashes are an example: we read about plane crashes regularly and these stories are often accompanied by very memorable, vivid and emotive images of wreckages and distraught relatives. This leads us into a misperception that airplane crashes are a lot more likely than pedestrian fatalities: we are more likely to be killed crossing the road, but pedestrian fatalities are rarely reported beyond the local newspapers. We may take a lot more care and worry when we're boarding a flight, when really we should be taking more care when we're crossing the road. One type of bias that affects construction projects is optimism bias – particularly for large, complex infrastructure projects, project participants underestimate costs and time-scales, and over-estimate benefits. Together with opportunistic behaviours in project procurement, this leads to significant inefficiencies in construction project procurement.

Another mistake identified by behavioural economists is that when making risky decisions we inflate the impact of losses relative to gains. Many behavioural experiments have shown that people suffer more from a loss than they enjoy from an equivalent gain: for example, we care a lot more about losing £10 than we do about winning £10. This phenomenon is called 'loss aversion' – and it has been applied to a wide range of people's decisions, and can be used to explain housing market instability. When property developers see house prices falling, they are reluctant to sell assets because, by selling, they would have to realise a loss from the lower house price. Similarly home-owners postpone their selling decisions, and housing markets are slow to respond to falling house prices – until, suddenly, many more home-owners are forced to sell simultaneously – perhaps because economic conditions have deteriorated or mortgage interest rates have risen. The housing market gets flooded with properties for sale, and ironically, home-owners' losses will be magnified, because loss aversion has delayed people's decisions to sell. This sort of behavioural bias contributes to significant housing market instability, with significant knock-on effects for the construction sector.

Similarly, behavioural economists have identified a status quo bias: people don't like change and so can be slow to shift business practices. This may have implications for the uptake of BIM.

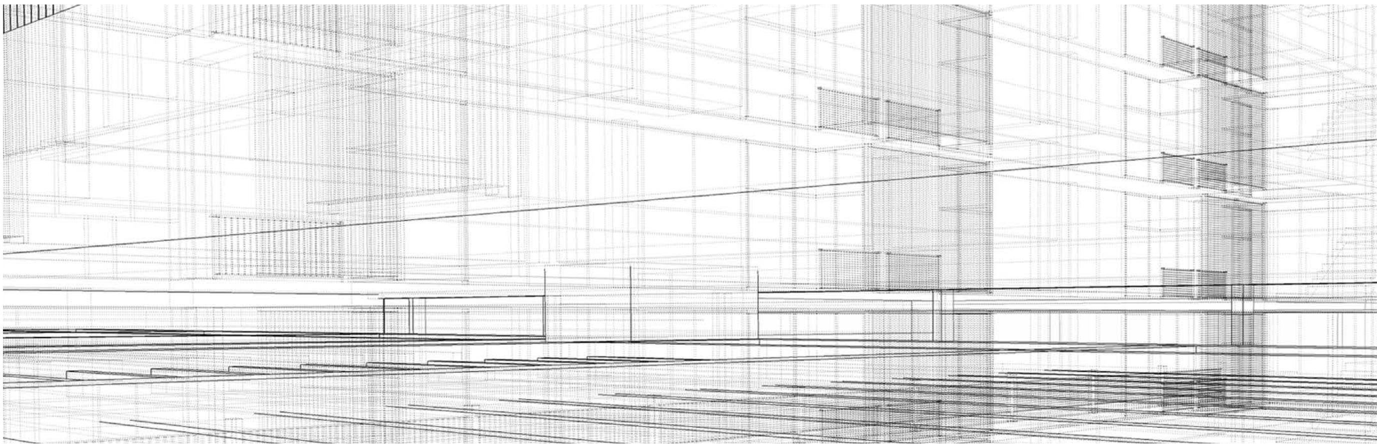
Another set of insights from behavioural economics that are particularly powerful for the analysis of collaborative BIM is the role of social influences. We respond to social influences in a number of ways: social learning means that we will copy others in order to improve performance, and this potentially has beneficial impacts for construction projects. We also respond to social pressures and tend to be swayed by group decisions – even if they conflict with our own individual judgements. This can have positive or negative consequences depending on whether or not the group is correct. Overall though it can contribute to significant inertia and conservatism, exacerbating problems of status quo bias, and this can contribute to slow adaptation in the construction sector to new innovations, including BIM and collaborative working.

2.6 Application of theoretical concepts to research objectives

To recap: the key objectives of this research focus on developing an understanding of drivers and constraints on collaboration within construction supply chains, and to analyse the potential of BIM as a toolkit to enable collaboration. The economic theoretical concepts are applied to the research objectives by exploring the role of the different economic and behavioural factors using interviews, case studies and online surveys. For example – businesses' responses to questions relating to transaction costs have helped us to untangle the role of transaction costs in the complex chain of diverse businesses that characterise construction supply chains. Similarly, the role of incentives and motivation is analysed using a combination of economic insights and survey findings – with the surveys designed to pick up the extent to which construction businesses are driven by monetary and financial incentives versus social and other non-monetary incentives.

A key overarching question for the report is what can economic theory tell us about the implications of collaboration and BIM on supply chain efficiency and project performance? For BIM, the answer is probably obvious: by effective sharing of life-cycle information about a project, duplication of time, effort and resources is less likely. For collaboration, when different people and businesses are engaged in a joint project, there is potential for opportunistic behaviour e.g. where a player does not devote the time and resources promised to a project the cost of detecting such behaviour leads to an increasing transaction costs. But if the different players have made a commitment to collaboration, perhaps on the basis that they are sustaining a long-term business relationship, then collaboration has the potential to lower transaction costs.

3.0 Collaboration in Construction



There is increasing interest in developing opportunities for collaboration within construction projects and this chapter presents some preliminary, largely qualitative evidence about economic lessons and the potential for collaboration to improve construction performance.

A British Standard has been developed covering collaborative working practices (BS11000) – and the chapter will start with some key insights about BS11000 – its advantages, disadvantages and potential gaps in terms of economic and behavioural insights.

Then a two-part case-study of Anglian Water Services supply chain will be analysed – focussing on key insights from a series of interviews, and from a large scale online survey. The overall aim of this case study was to identify some characteristics of collaboration in Anglian Water's supply chains, as well as ways in which collaboration could improve supply chain performance and efficiency. The case study analysis was conducted in two stages: first, an initial set of interviews were conducted in December 2013, and second, the insights from these interviews were used in a survey of Anglian Water Services' suppliers.

3.1 Collaborative delivery and collaborative business relationships

3.1.1 Collaborative delivery systems

First, in recent years, there has been an increasing awareness among practitioners that efforts should be made towards breaking the barriers to collaboration in the construction supply chain. The recent innovations in project delivery systems are encapsulated in two different ways of working: Integrated Project Delivery (IPD) and Construction Alliancing (Infrastructure UK, 2013).

IPD emphasizes the role of formal mechanisms (e.g., contracts). For instance, a formal risk-sharing arrangement is the key to differentiating Level 1 and Level 2 IPD (National Association of State Facilities Administrators, 2010) and a binding multi-party agreement is a prerequisite condition for Level 3 IPD. IPD has been heavily advocated by American construction professional bodies and deemed the most suitable vehicle for BIM-enabled projects (American Institute of Architects, 2007; Cohen, 2010; Lahdenperä, 2012; National Association of State Facilities Administrators, 2010; Thomsen et al., 2009).

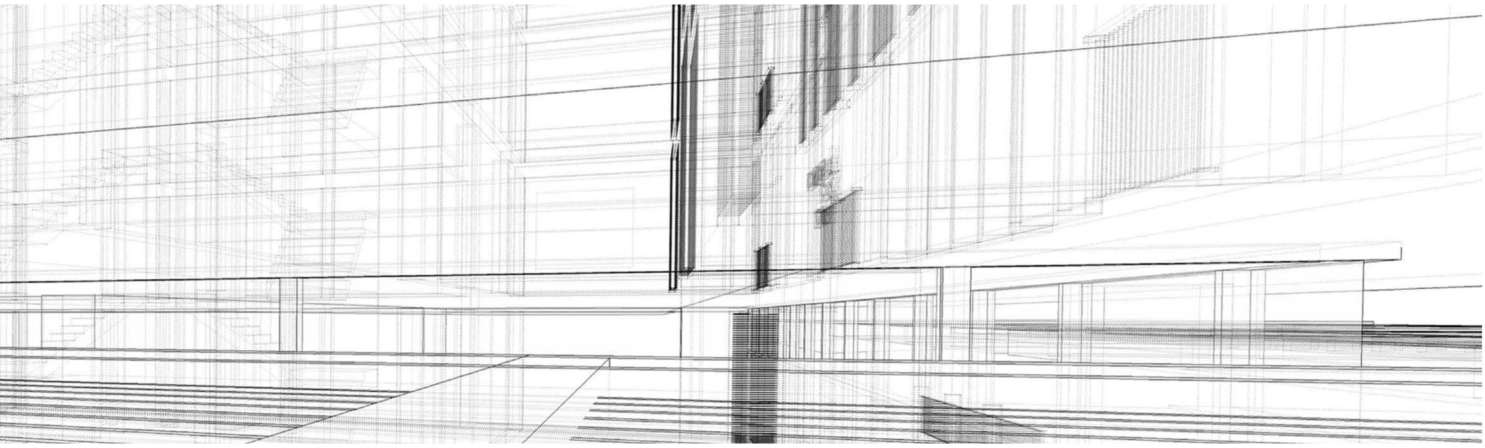
In contrast, construction alliancing is defined as a more flexible term (Infrastructure UK, 2013):

An alliance, in general terms, is an arrangement where a collaborative and integrated team is brought together from across the extended supply chain. The team shares a set of common goals that meet client requirements and work under common incentives. **(p.5).**

The importance of financial incentives is most prominent in the European Construction Institute's definition for alliancing:

Alliancing is a form of long term partnering on a project [or programme of works] in which a financial incentive scheme links the rewards of each of the alliance members to specific and agreed overall outcomes and in which all aspects of the arrangement are incorporated in legally binding contracts.

These authoritative definitions for integrated delivery systems indicate that interest alignment holds the key to the success of integration.



3.1.2 Collaborative business relationships

Whilst most respondents to the surveys explored below were familiar with BIM, respondents were less familiar with the current British Standard for Collaborative Business Relationships (BS11000). In this section, we set out some of the basic principles of BS11000, and assess the extent to which it effectively captures some of the potential benefits from collaboration.

What is BS11000?

The BS1100 standard focuses on explaining the benefits of collaboration for business, focussing on the advantages of better access to services and increased opportunities to win work and access resources. It also focuses strongly on the role collaboration can play in enabling better communication. It outlines some roles and responsibilities in collaborative partnerships, and ways in which businesses can support collaborative decision making, thus boosting the value of business partnerships. As well as the BS11000 documentation guide to implementing BS11000, training, certification and verification are also offered as extensions to the basic package.

Advantages

The advantages of BS11000 are that it sets out the benefits of collaboration, shifting businesses' attention towards the benefits of collaboration, moving the orientation away from a competitive, adversarial "zero sum game" approach. Economics – both game theory approaches and behavioural economics- show that collaboration can lead to benefits for all participants to a great or lesser extent, everyone's a winner with effective collaboration. In this sense BS11000 is backed up by economic theory and research. The BS11000-1 and BS11000-2 documents are guidelines outlining the key characteristics of effective collaboration, and how these can be leveraged using standardised practices. Given its emphasis on the benefits for SMEs, it affordability is a crucial element. The standard is also recognized by the Institute of Collaborative Working's (ICW) certification validation scheme – this increases the credibility and consistency of BS11000.

Disadvantages

The potential disadvantages are ensuring that the standards and approaches learned are applied in practice. The training and certification are relatively expensive, not only in terms of the financial cost but also in terms of the opportunity cost for businesses, particularly small businesses e.g. losing a member of staff's time whilst they attend training courses. Another potential disadvantage is that it is not strongly grounded in empirical evidence. More studies are needed to show that participating in the BS11000 has positive benefits, but collecting this evidence is difficult given that there is no clear, objective and measurable indicator that implementing BS11000 offers a concrete, measurable output.

3.2 @one Alliance (Anglian Water) case study: interviews with suppliers

The interviews were conducted in the Thorpe Wood Holiday Inn over one day in December 2013 with 8 suppliers selected from a range of businesses throughout the supply chain – including suppliers at Tier 2 and below. A selection of the firms were involved in collaborative working groups (CWGs), early contractor engagement (ECE), and/or other collaborative framework agreements.

Most of the suppliers were small and medium-sized enterprises (SMEs) though one was a branch of a business owned large multinational conglomerate. A large proportion of the businesses were relatively dependent on the @one alliance (@one-AW) and/or Anglian Water Services (AW).[6] The main characteristics of the suppliers, including the types of businesses, their market dominance and size (in terms of labour force and turnover), and their relationship with AW are summarised in Table 2.

Table 2 Supplier Self-Reported Characteristics

BIM Level	Type of business	Labour force	Location	Turnover	Relationship with @one-AW and/or AW
Supplier 1	**Production:** Pipe manufacturer and fitter	120 workers including 9 on shop floor, qualified truck drivers and technical engineers	International	N/A	• Framework agreement with @one-AW until 2015 • With AW since 2008 • £4m of £12m of their business with AW.
Supplier 2	**Civil engineering:** specialist formwork, and reinforced concrete	75 on site	Regional	Approx £25-30m	• AW is 3rd client; 15-20% of their business. More business with Trent Water, Welsh Water, HA etc. Gas industry business too, especially Shell. AW used to be their top client. 6 years ago had £12m of business with AW, now down to £5-6m
Supplier 3	**Production:** motor control centres	45	National	N/A	• AW 3rd biggest client after York (1st), 7 Trent (2nd), AW about 1/16th of turnover • With AW @one alliance framework: 8 years. Came in with AMP4, will be with AMP5 until about 2016 • Member of CWG, ECE.
Supplier 4	**M&E:** MEICA installation	63	Regional	Approx £3.5-4m	• AW 90% of their turnover, £3-3.5m and increasing • 30 years working with AW and on framework from AMP4 onwards, through Skanska • Member of a CWG, ECE
Supplier 5	**M&E:** pump fabrication	370 in the UK	International	Approx £10m in UK, Euro 70m total	• 25% of turnover via AW • Member of ECE
Supplier 6	**Process contractor:** hi-tech sewage and aeration	100	National	£7.5m	• £5m of turnover to AW • Member of ECE
Supplier 7	**Stockist, distributor, short-notice logistics**	Approx. 10 in their office	National but part of multinational conglomerate	£11b internationally, £120m in UK	• AW small part of their business
Supplier 8	**Aggregates**	75	Regional	£75m	• AW one of their top 20 customers

6 Some of these businesses were working with Anglian Water before the @one alliance was formed. To indicate the distinction @one-AW refers to a relationship with the alliance, and AW refers to a relationship just with Anglian Water Services.

The main insights gathered from the interviews were as follows:

i. Information gaps

For businesses supplying specialist equipment they may be able to opportunistically exploit their informational advantages – for example, different suppliers can offer different quality products – and the suppliers offering high quality products but at a higher price, may be undercut by other suppliers offering lower cost but poorer quality supplies. This is a problem of “adverse selection” and is identified by economists across a range of spheres as being a significant source of market failure. When the seller of a product knows more about its quality than the buyer, those selling lower quality versions of a product can still find buyers if the buyers can’t tell the difference. The problem is that the sellers of good quality products will find that their prices are pulled down. One of the solutions to this problem is trust and collaboration – if businesses have long-term relationships that they want to sustain then they are less likely to cheat each other in the short-run.

ii. Labour relations

The suppliers seemed, generally, to have excellent relationships with their workforce and labour turnover rates were low: economists have identified labour turnover costs (hiring, firing, recruitment and training costs) as a major source of labour costs and so retaining staff can have significant implications for profitability. In incentivising their workforce – pay was not the only determinant with most suppliers observing that their workers enjoyed good working conditions, often felt proud to work for the business and/or identified with the brand – some also identifying with the AW brand. This identification with the supplier and/or Anglian Water is facilitated via branded clothing etc. and can be a powerful motivator. It was also impressive how well some of the suppliers treated their workforce. One supplier allowed their workers time-off on full pay (not statutory sick pay) because of an injury whilst another supplier allowed a worker time off, again on full pay, because of a new baby. This consideration will be rewarded with the worker’s loyalty. This links to a phenomenon identified by economists: efficiency wages. If workers are treated well, they will value their jobs and will reciprocate by working harder. This can have significant impacts on labour productivity and therefore profitability.

iii. Planning, Early Engagement and Collaborative Working Groups

Planning and early engagement was the theme highlighted most strongly by almost all the suppliers. Many suppliers believed that they were brought into projects too late and that if they had been involved sooner, then they would have been able to help with design and other aspects of the planning process – with significant potential cost savings. A few contractors also observed that they were often asked to work on jobs at short notice. This meant that they had to pull workers off other jobs, inflating costs. Whilst with agreed prices this doesn’t have an immediate impact on AW’s costs, it is likely that these businesses will build in a safety margin in future contracts. Framework agreements were broadly welcomed and the suppliers who were parts of CWGs said that they worked well – enabling them to respond better to short-notice requests. There are potential downsides to early engagement however. One or two suppliers observed that they might spend time and money in a pre-contractual phase just for the contract to be awarded to another supplier – perhaps one who hadn’t had to expend resources beforehand and so was able to undercut others.

iv. Innovation

There were different attitudes and practices towards innovation – some of the suppliers were highly innovative, others not innovative at all. Some innovations had the potential to generate significant cost savings: e.g. a pipework supplier is using coloured wrapping on pipes instead of making different pipes out of different coloured polymers. This enabled them to manufacture all pipes with the same polymer resulting in considerable costs savings. Thus innovation has the potential to generate significant cost and efficiency savings. Some of the suppliers were however too small and insecure to be able to expend resources on innovation. Conservatism and risk aversion are likely to be stronger within businesses without spare capacity and resources. AW could potentially play a role in enabling the smaller, more vulnerable businesses to innovate – this is already happening to an extent and some suppliers appreciated AW’s and Tier 1 suppliers’ support with their innovative activities.

v. Relationships with AW and the Tier 1s (T1s)

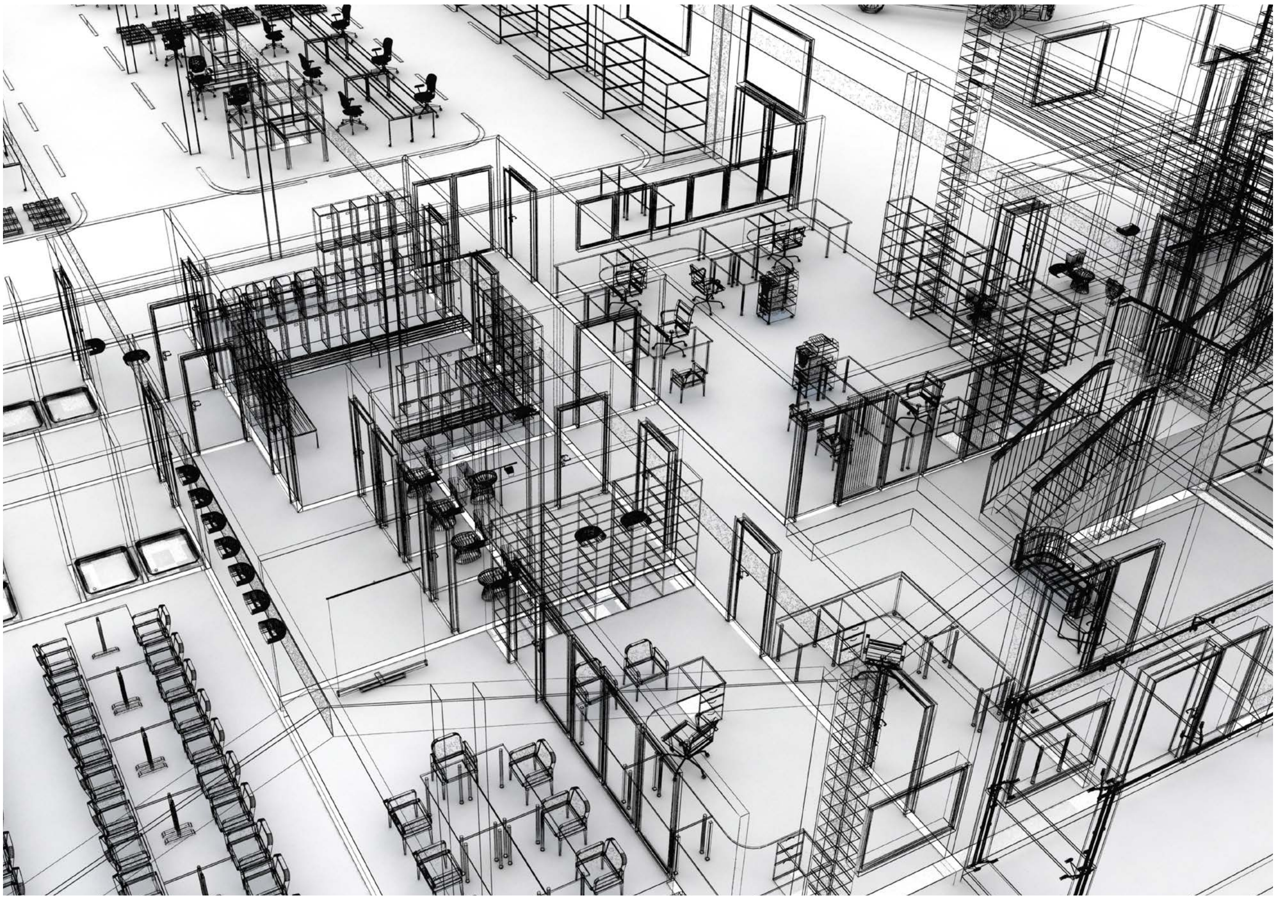
Many (not all) of the suppliers suggested that, whilst their relationships with AW were generally good, their relationships with the T1s were often uneasy. There were substantially lower levels of trust between the T1s and the businesses lower down the supply chain. More generally, some of the suppliers observed that trust was a one way street: they were expected to trust AW and the T1s but they were not trusted in return. One supplier observed that it is important that they were "treated like adults". Another issue that was raised in this context is the potential for exploitation: a few of the suppliers were small, local businesses – some of them almost entirely dependent on AW and its Tier 1 suppliers for their business. They probably have very little bargaining power in their negotiations with AW and the Tier 1s. One supplier observed that, whilst relations with AW were good there was nonetheless a "master-servant" tone to the relationship. This may have long-term implications if it discourages innovation and/or generates resentments that impede the otherwise smooth working of the supply chain.

vi. General impressions

All suppliers were asked the standard questions: "What does Anglian Water do well?" and "How could it improve?" Overall, most suppliers agreed that, whilst they all had some concerns, they still found Anglian Water to be superior to all other water companies in its commitment to collaborative working practices. Many of the suppliers also observed that they appreciated Anglian Water's open door policies, its relative transparency and its willingness to engage with them.

vii. Caveats

It is important to note that the interviews focussed only on the perceptions, subjective impressions and opinions from one side of the contracting relationships that make up Anglian Water's supply chain and therefore is not necessarily a balanced account. Given the partial impression conveyed via these pilot interviews, future research could focus on developing a better understanding of other perspectives including the Tier 1 suppliers and Anglian Water's own team's opinions on Anglian Water's relationships. Interviews do not lend themselves to objective analysis because they are by their nature anecdotal. Nonetheless some key insights were identified from these interviews that were used in the design of an online survey of a selection of Anglian Water's supplier, focussing on lower tier suppliers.

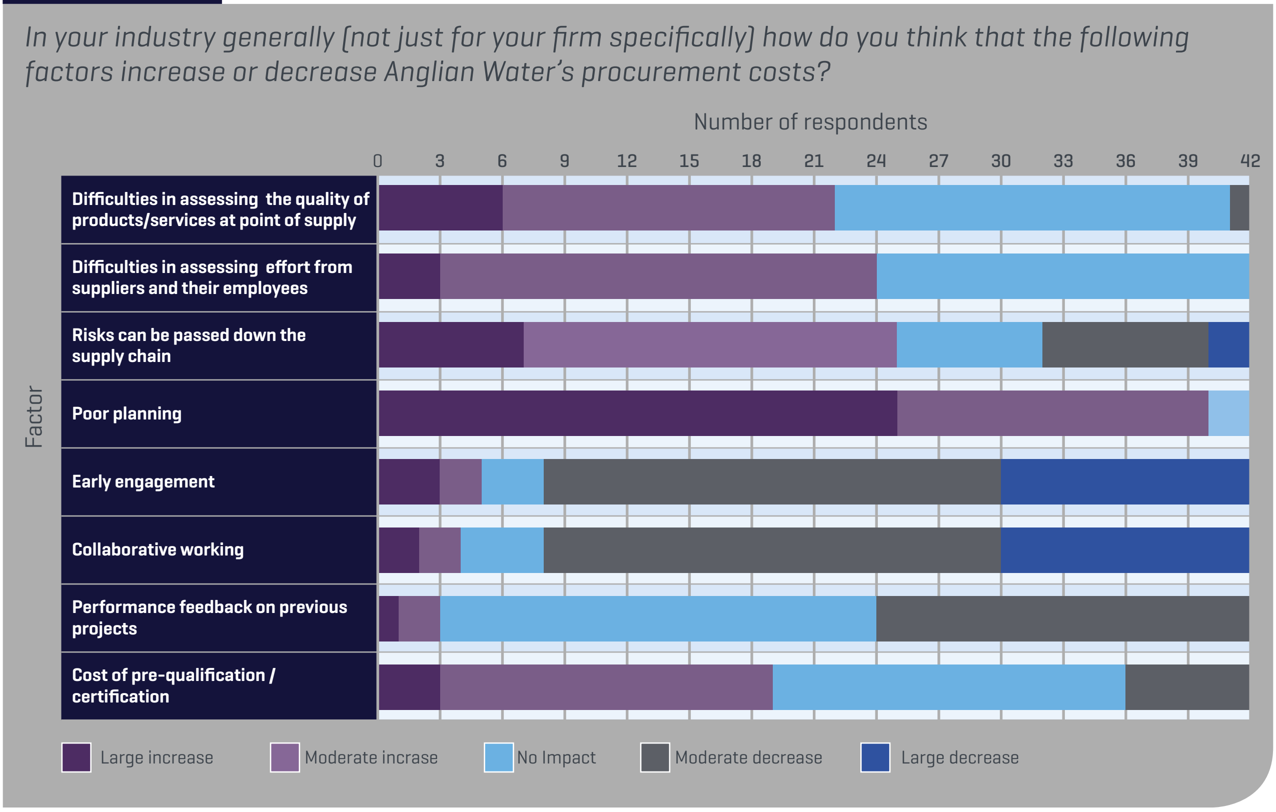


3.3 Anglian Water Services case study: online survey

The suppliers were selected to be representative of Anglian Water's suppliers overall – it was not a random sample as the suppliers were selected via Anglian Water – focussing in particular on their Tier 2 suppliers and below, including a large proportion of SMEs. Also, the sample size was relatively small, and so statistical testing is not appropriate in this context.[7]

Overall, 50 respondents participated in the survey which asked a range of questions about collaboration. Key findings were as follows:

Figure 1 **Online survey results – procurement costs**

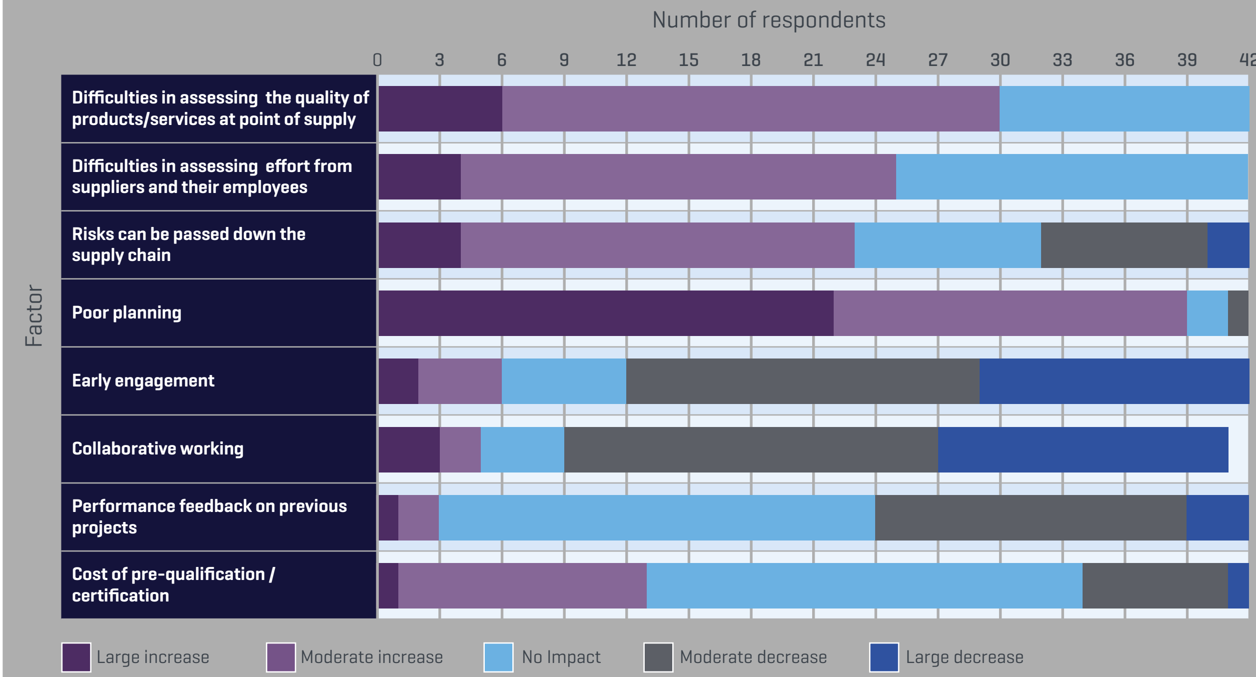


The key factors identified as increasing Anglian Water's procurement costs were difficulties in assessing product/service quality, and effort put in by suppliers, and poor planning. Early engagement was perceived as a way to achieve moderate to large decreases in procurement costs. (See figure 1).

7 Our aim is to find further funding so that the basic insights can be developed into a larger scale random sample survey of construction supply chains to be analysed statistically and econometrically, as part of on-going research at the UCL Bartlett School of Construction and Project Management

Figure 2 Online survey results – lifecycle costs

In your industry generally (not just for your firm specifically) how do you think that the following factors increase or decrease Anglian Water's long-term costs (lifecycle costs):



The findings for long-term costs are broadly similar to those for procurement costs. Again, information asymmetries, quality uncertainty, poor planning, lack of early engagement were all perceived as sources of higher long-term costs. (See figure 2).

This question again confirms some of the key insights from the interviews – with a relatively large proportion of suppliers judging that they were not kept so well informed about design/programming or pre-construction plans, but with better communication about changes in projects and programmes for on-site work. (See figure 3)

Figure 3 Online survey results – How well informed?

How well are you kept informed about changes in Anglian Water's projects / programmes? Rank from 1 - very well, to 5 - not at all.

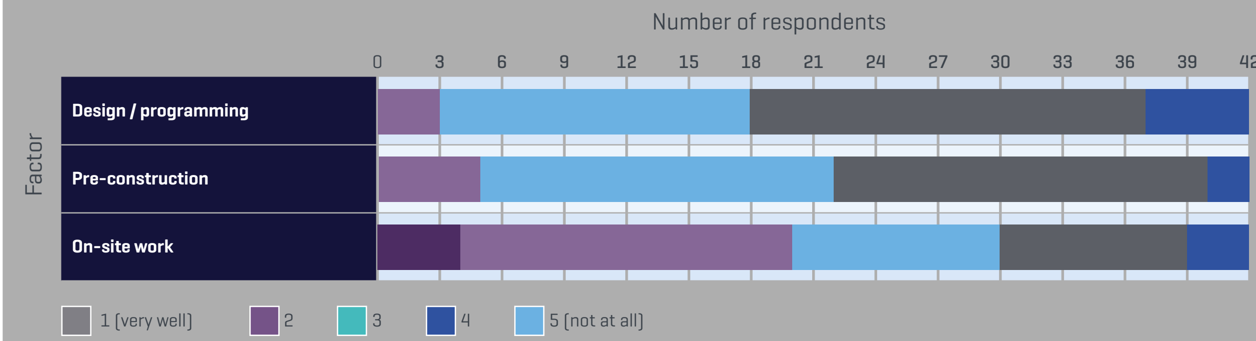
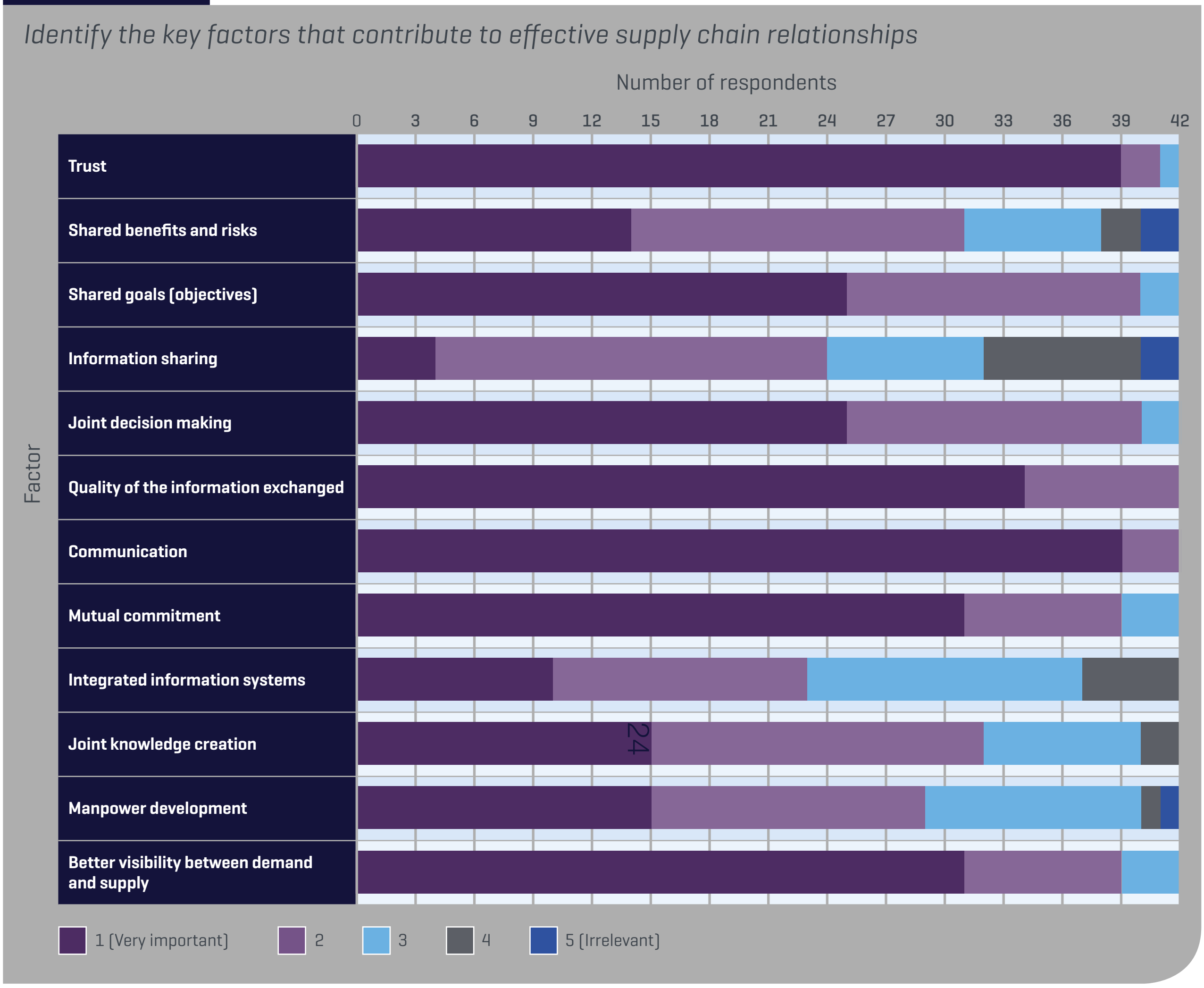


Figure 4 **Online survey results – supply chain relationships key factors**



Trust, shared goals, information sharing, joint decision-making, communication, mutual commitment and better visibility between supply and demand were all ranked as very important factors in creating effective supply chain relationships. (See figure 4).

Confirming the responses from interviews, most respondents agreed that collaborative working has value and most respondents agreed that collaborative working was somewhat to very effective in cutting costs and improving efficiency. (See figure 5).

Of the 50 respondents, 30 were involved with a collaborative working group – working with small groups of competitors in sharing and spreading the load of supply. These findings show that, for those suppliers with experiences actually working with a CWG, the main benefits came from social influence connected with social learning, reputation building, and building good relationships. Most were not excessively concerned about giving information to competitors, suggesting that an adversarial relationship is not a necessary feature of the construction industry. (See figure 6).

Figure 5 **Online survey results – cost cutting and efficiency**

Generally, how effective is collaborative working in cutting costs and improving efficiency?

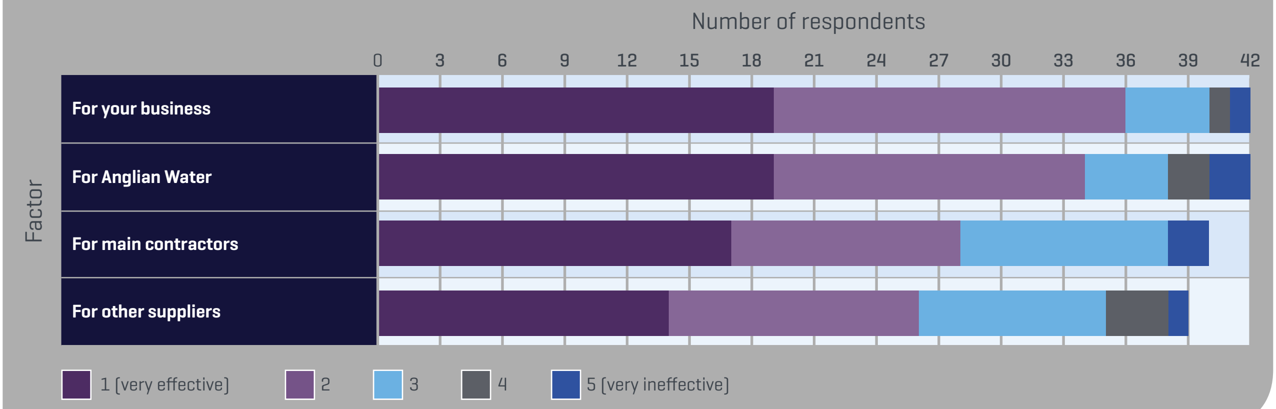
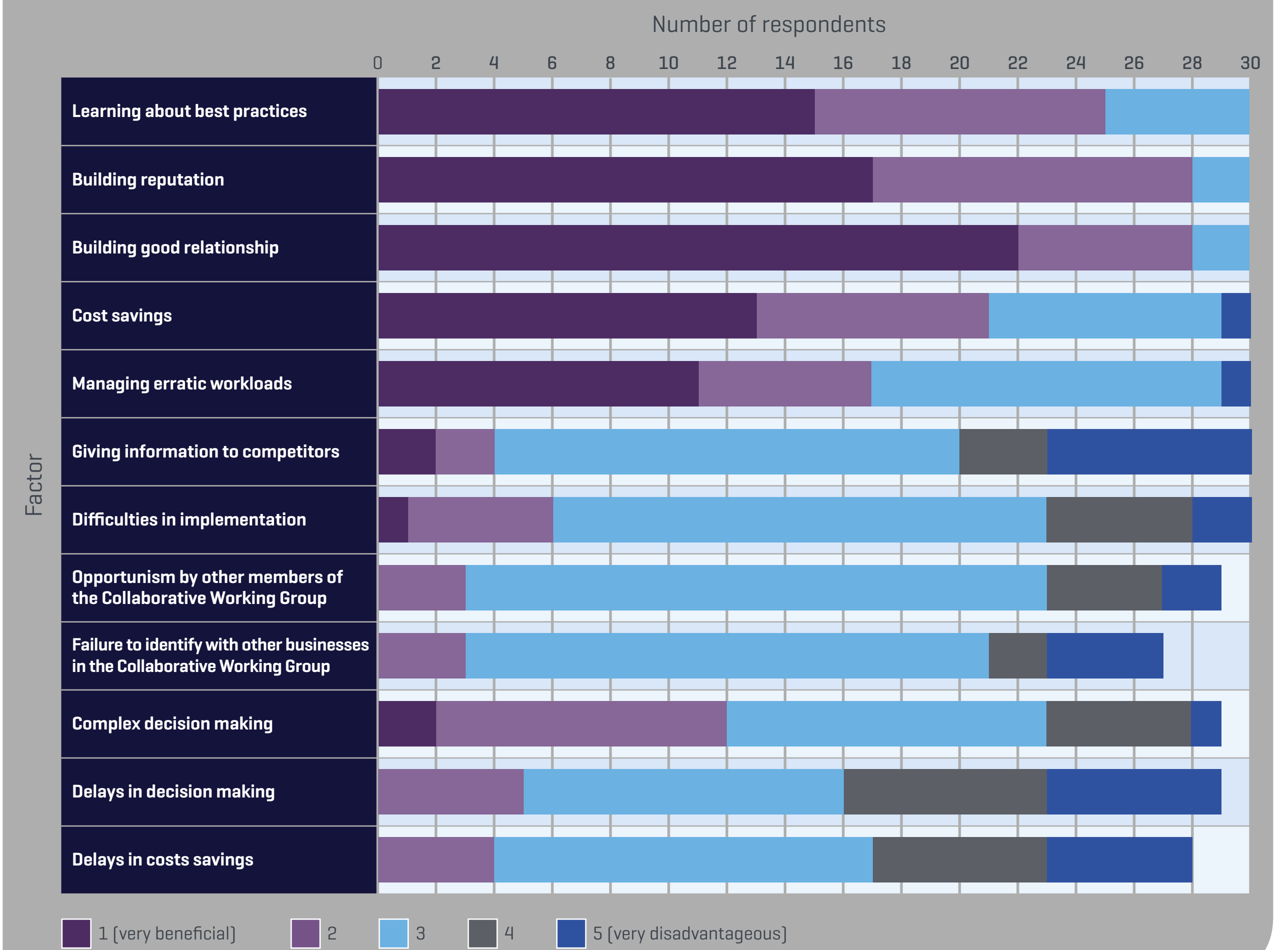


Figure 6 **Online survey results – how is business affected?**

When you are working within a Collaborative Working Group how do the following affect your business?

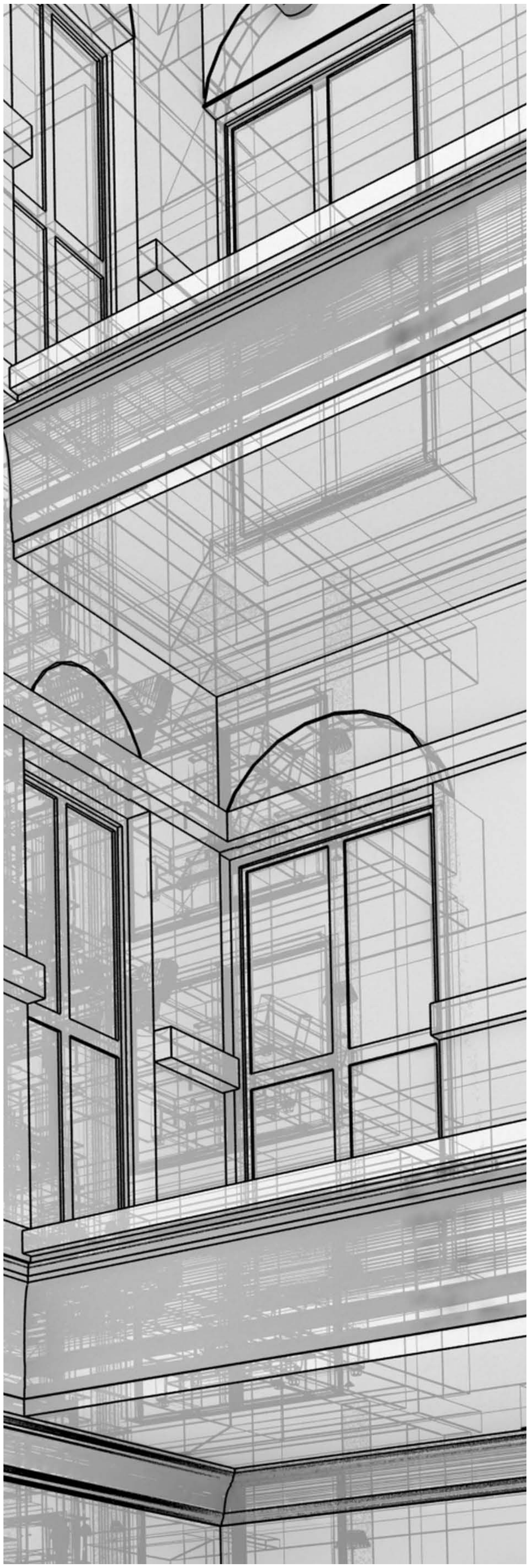


3.4 Key insights

The Anglian Water case study shows that suppliers perceive significant benefits can accrue from effective collaborative relationships – and these benefits go beyond the benefits that are associated with better information flows. The key benefits of better information flows include:

- More accurate information about products and services supplied enables better coordination and, in life-cycle terms enables better facilities management.
- Better information leads to better coordination and enables more effective planning for suppliers as well as clients and main contractors.
- Better information enables more effective construction sequencing, reducing the chance of clashes and enabling clash detection.
- Better information enables social learning so that different suppliers can learn from each other about best practice tools and techniques.
- Better information reduces opportunism by making it more difficult because information is more transparent and easier to retrieve.

How can the benefits of collaboration can be leveraged within a BIM framework. Many of the advantages of better information flows associated with collaboration, outlined above, are also potential advantages from the use of BIM. BIM can play a role in clarifying information, and also the scope of projects. Neil Thompson, the Principal BIM Integrator at Balfour Beatty, explains that clear information flows enable clients to articulate their needs more clearly, and – in turn – the tenderer can be more responsive to clients' questions. Clients can support supply chain innovation more effectively because they can implement computerised checks of tenders. Another key element identified in the interviews and survey outlined in this chapter is the issue of innovation and early engagement. A number of businesses strongly emphasised the contributions they could make via early engagement – improving overall project performance. If new generation BIM technology can be designed to enable better information flows, and to facilitate early contractor engagement, then the potential for improved project performance and innovation could increase significantly.



4.0 Building Information Modelling (BIM) Incentivisation

BIM has significant potential to harness productivity improvements by enabling collaboration. However, the first step in harnessing these productivity improvements is to encourage as much of the construction sector as possible to embed BIM within their standard practices. This chapter explores the problem of incentivisation: how willing are construction industry businesses, particularly those at lower levels of the supply chain, willing to adopt BIM? If they are not willing, what are some of the barriers to uptake, and how can they be incentivised to use BIM? The problem of designing effective incentives to encourage businesses' uptake of BIM is explored in this chapter. This incentivisation issue has been under-addressed by the UK government in the promotion of BIM. The government's current focus is mostly on "enablers", which ensure technical barriers are removed. However, equally important in promoting the uptake of BIM is the establishment of a well-conceived reward system to strengthen participants' motivation. This research can provide timely guidance on best practices in this regard for the government and practitioners alike.

Since the application of BIM involves collaboration from all parties on the supply chain, improving the effectiveness of this tool should be of central concern to RICS. Whilst the function of automatic quantity take-off provided by 5-D BIM might supplant the traditional role of quantity surveyor, the use of sophisticated BIM is bound to create a window of opportunity for business, particularly with respect to the design and monitoring of a BIM incentivisation system. A database of best practices for BIM incentivisation can bring this emerging business opportunity to the attention of RICS members.

4.1 Why does BIM need incentivisation?

The UK government has upheld BIM as a solution to age-old coordination problems experienced within the fragmented construction supply chain. In 2011, the Cabinet Office set out an ambitious plan for implementing Level 2 Building Information Modelling (BIM) on all centrally procured projects by 2016 in its Government Construction Strategy report (Cabinet Office, 2011). Yet, three years on, according to a survey by law firm Pinsent Masons, the majority of respondents from 70 major construction organisations (64%) predict that this goal is unachievable. An industry observer commented: *"the majority of construction contracts are not very collaborative. Risk tends to be allocated in a binary manner, with each party incentivised to look after its own interests – rather than the wider interests of a project. Because the parties' interests are rarely aligned, this tends not to create an environment where true collaboration is possible"* (Hallam 2014).

This view is echoed in the BIM Handbook (Eastman et al., 2011) – embedding BIM within a business's processes is not costless. The initial start-up costs associated with adopting BIM will be large, and may be prohibitive, particular for smaller construction sub-contractors. In addition to the software costs – training staff and embedding BIM into standard business practices will inflate construction costs in the short term. Embedding Level 2 BIM in traditional procurement systems (design-bid-build) represents a significant barrier to the acceptance of BIM, and the benefits of BIM cannot be fully realized without modifying the delivery vehicle and the incentive structure.

4.2 A Framework for the Analysis of BIM Incentivisation

To address BIM incentivisation problems more systematically, it is beneficial to set out a framework as the basis for discussion. Problems experienced in incentivising BIM are due to a lack of knowledge regarding how to harness the existing incentive measures in the organisational architecture of a delivery system. In this research, "incentivisation" refers to the act of employing any measures that help align the divergent interests of BIM participants. Through five case studies and an extensive review of incentives literature, Chang's work sets out seven critical questions to guide the design of a BIM incentive system (Chang, 2014b,c):

(1) how to manage the coevolution of design and target cost, (2) how to fund the incentive pools (e.g., fees, contingency fund), (3) on what basis to award the compensation (group-based vs. individual), (4) what weightings to assign to objective and subjective evaluation, (5) how to allocate risk through the choice of risk-sharing ratio, (6) how to choose the right compensation form between linear and non-linear plans, (7) how to set the threshold value for each incentive award band. In response to the incentive plan, BIM participants choose a course of action in order to optimize their own interest and this dynamic together with project risks, determines the project performance.

The implications of this BIM incentive system for building collaboration into BIM is that having robust systems for awarding group-based compensation is essential if collaboration is to work. If different participants are sharing rewards then there is an incentive for free-riding behaviour, and BIM incentivisation schemes need to take this into account.

Table 3 Perception of the importance of key elements of an incentive system (1–5 scale)

Answer options	1 strongly disagree	2 disagree	3 neither agree nor disagree	4 agree	5 strongly disagree
Monetary rewards can improve the effectiveness of BIM considerably better than non-monetary rewards	3.17%	8.47%	22.75%	49.21%	16.40%
Group based rewards will work considerably better than individual rewards in incentivizing contractor participation in BIM systems	2.12%	7.41%	30.69%	42.86%	16.93%
Objective metrics are considerably better than subjective ones as the basis for determining incentive rewards for BIM participants	2.12%	4.23%	31.22%	48.15%	14.29%
It is absolutely necessary to assign different weightings to performance metrics in the determination of incentive rewards for BIM participants	1.06%	7.45%	35.11%	42.02%	14.36%
A simple linear reward sharing rule (e.g., reward linked to a fixed percentage of cost savings) will work considerably better than a more complicated non-linear reward sharing rule in incentivizing contractors to contribute to BIM	4.76%9	15.87%	31.22%	40.74%	7.41%
There is a minimum amount of incentive reward that can motivate contractors' full participation in BIM	2.65%	20.63%	29.63%	33.86%	13.23%

Sources: Chang and Howard (2014)

4.3 Incentivising BIM: some survey evidence

The aim of this section is to identify key ways in which suppliers and contractors can be incentivised to adopt BIM, and there are implications for the adoption of more sophisticated versions of BIM, including those that more effectively embed collaboration. Awareness remains low of the significance of BIM incentivisation. The value creators of a BIM system are likely not to be the primary recipients of its benefits, which could impede BIM parties from exerting their best effort. Generally, the main beneficiaries of potential savings are owners and designers (architect/engineer), but project production involves parties from the entire supply chain. However, a large portion of the savings from early clash detection and innovation are a result of the contributions of lower-tier suppliers and trade contractors (Chang and Howard, 2014).

Evidence in support of the view that lower-tier suppliers play a crucial role, Chang and Howard (2014) conducted a survey of 368 BIM experts from major countries including the US, UK, the EU, China, Japan and Australia (Chang and Howard, 2014). The respondents were asked to rate their agreement on a scale of 1 to 5 with given statements on BIM incentivisation, outlined in Table 3.

The first set of questions investigated the key decisions involved in the design of incentives. Table 3 illustrates the overall averages and statistical tests for the six questions, where on a scale of 1-5, 1 indicates that respondents strongly agree with the statement and 5 indicates that they strongly disagree. These results indicate that:

- financial rewards were perceived to be of benefit in incentivising BIM collaboration;
- the provision of incentives should be based on group performance instead of individual contribution;
- objective performance indicators are expected to work more effectively than subjective ones;

Building upon this framework and results, the current research takes one step further towards exploring to what extent the components of this incentive system have affected project performance.

4.4 A Case study: a collaborative project without BIM

To illustrate the value of BIM via a counter-example, this section analyses a collaborative project conducted without BIM – focussing on various features of the project and its performance and concluding with an assessment of the role BIM could have played in the project.

i. Project Information

Network Rail (NR) has led the way as a forerunner in the UK in the application of alliancing. Alliancing was employed by NR for the first time in 2011 to improve the punctuality of trains on a section of the East Coast Main Line (ECML) where the Cambridge line crosses the ECML on the flat crossing. During this 3-year £23m project (see Table 4), NR adopted BS 11000 Collaborative Business Relationships as guidelines in the formulation of procurement strategy.

In procuring for this project, NR followed an eight-grip process[8]: output definition, feasibility, option selection, single option development, detailed design, construction test and commissioning, scheme hand back, and close out. Atkins completed the detail at Grip 4, then the project was bid out under the NR9 traditional Network Rail contract. In forming the team, behavioural workshops were held with potential bidders. Apart from traditional financial criteria, the bidder's performance in the workshops accounts for 15% of the score in the assessment of bids. The contract was ultimately awarded to Hochtief with work then subcontracted to Tony Gee and Partners-TGP (Civils) and VolkerRail (Rail) to design, build and commission the Hitchin project. The project was delivered through an alliance contract. Alliancing involves bringing different businesses together into a larger entity in which all participant businesses are collectively responsible for the project. Alliancing is a form of collaboration used increasingly in the construction industry.

The key features of construction alliancing are outlined in Table 5

In this case, the form of alliancing was allowed to evolve through the procurement process. The final alliance contract only came into existence 18 months into the project delivery. There were eight principles guiding the formation of the alliance (Table 5). Principle 4 & 5 aside, the other six principles are all associated with the incentivisation issues identified in table 5.

Table 4 Key facts of the Hitchin Grade Separation project

Client:	Network Rail
Contractors Designers:	TGP (Civils) Volker Rail (Rail)
Form of Contract:	NR12 Alliance
Dates work carried out:	2011–2014
Value:	£23,000,000

Sources: Hochtief Construction (2014)

Table 5 Principles of alliancing

1	Joint management structure with collective responsibility for performance with an equitable sharing of risk and opportunity
2	Risk and opportunity sharing – joint development of solution, target cost and risks
3	Target cost with pain/gain (capped pain, uncapped gain)
4	Commitment to 'no disputes' – avoidance of a 'blame culture'
5	Best for Project unanimous decision-making processes
6	Fully reimbursable – all costs incurred will be recoverable
7	Majority of risks will be owned & managed by the Alliance
8	Open book documentation and reporting

Sources: Hochtief Construction (2014)

8 GRIP –Guide to Rail Investment Process is the Network Rail project management process, and each GRIP refers to different stages of a project. For more information see Network Rail (2014).

ii. Assessment

In order to evaluate the extent to which alliancing has improved upon collaboration, the research team interviewed one representative from each of the two companies that formed the Hitchin alliance with the aim of learning about their experiences and exploring their views on the effectiveness of the alliancing arrangement. The assessment is based on the interviews of the scheme project managers of Network Rail and Hochtief.

Target cost setting

Fact: In this project, the design did not coevolve with the target cost as the alliance was not formed from the onset and the contractor joined after grip 4. Discussions with the construction teams revealed that TGP was employed by Hochtief (UK) to undertake grip 5, detailed design, and challenged elements of the design that they thought could be delivered at a lower cost. Since the tendering process took a traditional competitive form, the contractor priced the project in a typical way by submitting a "lean" price that was trimmed down to reflect the "opportunities" and "loopholes" identified within the tender documents which could enable them to gain higher profits. Yet, once the alliance agreement was established, such "opportunities" were shared openly with the client and the target cost was revised upward reasonably. From the client's point of view, the revised target cost was still below the Network Rail's authorised budget for the project.

Reflection: The contractor believed that the alliance would have worked more efficiently if it was formed at either grip 2 or 3. On the one hand, early engagement of the supply chain can secure continuity with the same designer and thus reduce the amount of duplicated work. On the other, at the time when Hochtief was retained as a design and build contractor, the design was already fixed, leaving the contractor with little room to implement radical solutions.

Discussions with the project team highlighted the interplay between the target cost and project scope, with one member of the team emphasising that the "realistic-ness" of the target cost plays a crucial role. He highlighted that one should be careful not to over-encourage de-scoping. In his view, the best time to engage the alliance is when design criteria needed for the final output can all be identified by the client. It is desirable to allow the alliance to undertake the basic design so as to maximize cost savings. Other members of the project team took a similar view regarding the best timing for setting the target cost.

He noted that, had the alliance been introduced from the outset, a target cost that captured the input of all alliance parties including the designer would have been jointly built as part of the process through grips 2 up to 4, hence developing a joint alliance fund. He further stated that in the correct operation of the alliance, had they started two years earlier and built the target cost, the same result in terms of cost would have been achievable as openness and transparency could ensure that the contractor's tendency to inflate cost was muted, making for a more robust target cost with a more reasonable risk profile.

iii. Risk-sharing

Fact: There was a gain/pain share mechanism in the project using open book accounting practices.

Reflection: One participant considered that having such a mechanism in operation contributed to the reduction in claims, which was in stark contrast to the behaviours of non-alliance rail subcontractors who were still claim-prone when it came to financial losses. Arguably, TGP and VolkerRail were the most crucial members of the supply chain. Yet, they were contracted under the traditional sub-contract and design agreement and had no voting rights on the alliance board. From the participant's point of view, inclusion of the rail subcontractor in the alliance could give them a stronger sense of cost certainty as the pains would be shared by the alliance members. In light of this, Powell emphasised the significance of including major players, who can affect programme and cost, in the alliancing agreement to achieving success and what is "best for project". The contractor's representative had similar views regarding the inclusion of VolkerRail in the alliance agreement as he described the difficulties faced throughout the lifespan of the alliance when a contract was not in place while having to revert to traditional contracts with their supply chain; he mentions that VolkerRail behaved strictly by the contract and that as the client faced problems, such as not being able to provide access to the railway, the subcontractor felt the effects and rightly had a claim under their subcontract against Hochtief. The contractor's representative stated that on site, the designer would not have added massively to the alliance but VolkerRail would definitely have (and should have) been a full alliance member as the value of their delivery was nearly 50% of the direct works and they had a substantial influence on the project's success. Furthermore, the client's representative considered fairness to be a key element to encourage "best for project" behaviour. The sharing rules of pains/gains should be perceived to be fair instead of being equitable.

iv. Funding of the incentive pool

Fact: In the Hitchin project, risks were categorised into project and client risks. For instance, the latter encompasses changes in scope as well as the costs incurred as a result of the delay in granting the contractor access to the lines where this is Network Rail's responsibility. The risk allowance for client risks is not part of the incentive pool.

Reflection: Setting aside a separate fund for the client risks outside the gain/pain share incentive pool led to a problem: parties were incentivized to test every risk against the client's risks. For example, the contractor may try to bring in contractor mentality to the whole project team, i.e., "the contractor will make a claim anyway and see whether it works". Generally, project team members that are part of both the alliance and the client team have an incentive not to have any money coming out of the shared risk fund. In spite of this drawback, the client still preferred having funds separated for two reasons: first, it can keep the contractor "on their toes"; second, having one fund may prompt the contractor's adversarial behaviour as they know there is just a certain fixed amount of money and once this amount is dangerously approached, further loss will start eating into what they see as their perceived level of profit. As such, separate funds can serve as a buffer for the contractor as it signals that not everything that goes wrong will affect their profit. However, there is a strong case to impose a risk cap to limit the contractor's maximum loss/liability to avoid contractor default.

v. Performance evaluation

Fact: In the Hitchin Project, compensation was only tied to cost savings/overruns.

Reflection: Although the client team formulated key result areas (KRA) as performance indicators, they are properly quantified or objectively measureable – they are subjective evaluations of performance, and these client-driven subjective performance goals are therefore prone to large margins of error and, at worst with opportunistic clients, a way in which clients can reduce their own liabilities. From the contractor's perspective these indicators are not fully reflective of their performance. Clients may have incentives to misreport their subjective evaluations of project performance – contractually, if a lower subjective evaluation of performance by a client is a form of "rent-seeking" – they can increase their chances of a lower overall construction cost if they can claim that the contractors did not do their job properly. However, the contractor did favour tying incentives to measureable performance goals and the client considers the measurability of the project goals to be significant.

Both sides agreed that, in circumstances where subjective performance goals were the focus, an independent evaluator should be called upon to ensure fair assessment. The client emphasised that in such a case, the evaluator needs to have sufficient knowledge of the project and keep involved along the way. Ideally, compensation should be tied to a mix of objective and subjective performance goals. However, subjective evaluation comes with a cost: measurement and enforcement procedures might be challenged and thus the procedures should be agreed upon beforehand. Regarding the flexibility of measurement procedures, particular performance goals need to be flexibly measured. Without doing so they may blunt the contractor's effort in other areas. For instance, provision of financial incentives for the safety target of zero accidents is not well thought out because the incidence of even a major accident will stop the incentive from working.

vi. Potential usefulness of BIM

Reflection: Although BIM was not used on this project, the interviewees' perspectives were explored. One project participant considered the incentive to use BIM as essentially a key client requirement and a client driven change. He felt that many clients were still not ready for BIM and its benefits would not be reaped after the project completion, as the actual operators were still incapable of fully utilising it. He considered the biggest challenge with BIM lying in data ownership and storage. Upon reflection, he stated that using BIM would have been advantageous in the Hitchin project, but viewed the requisite IT support as a blocker to making BIM work effectively in alliancing. The contractor's representative thought that BIM would have been beneficial from a design perspective and considered it to be a facilitator of collaboration in the alliance arrangement as it provided shared access of information. Most importantly, he argued that alliancing could promote the use of BIM because the different participants in an alliance would learn from each other about best practice and better, more efficient ways to manage and coordinate their projects. A combination of the alliancing model and its ability to leverage the benefits of collaboration is an illustration of how social learning can enable innovation to spread through projects and, ultimately, through the construction industry.

5.0 An Empirical Investigation of BIM Incentivisation Practices

5.1 Introduction

The purpose of this chapter is to report on the result of a survey designed to explore project participants' attitudes towards BIM. The survey had two goals: first, investigate the current practices on the use of incentives and Building Information Modelling (BIM), and second, their effects on the improvement of project performance in general and on the effectiveness of supply chain collaboration in particular. A key problem for BIM is incentivising early adoption, especially amongst smaller businesses, a problem underscored by the National Federation of Builders Early Adoption Programme (NFB 2012, 2013). This chapter aims to explore some of these constraints, and construction businesses' response to them.

5.2 Survey design

The contact emails of the respondent were obtained from Glenigan, a commercial vendor for construction data. At the early stage of BIM application, the clients of large projects are more likely to have attempted to apply BIM, so the researchers only chose projects with a contract value of over 10 million pounds that were carried out in the period 2011-2014. The dataset contained around 1800 projects of various types, about half of which were provided with a direct email address to the respondent. Eventually, 650 questionnaires were successfully sent out in early December 2014, 118 of which were returned by the end of 2014.

The questionnaire consisted of six sections:

- Control questions concerning the respondents' years of experience
- details regarding the project of interest such as contract value, duration, procurement system, level of BIM used and the stage(s) in which BIM was used
- questions concerned with collaborative features of the project
- questions concerning the incentive measures used
- questions concerning effects of behavioural biases
- question concerning effects of collaborative measures on the effectiveness of BIM, and project performance.

The respondents were asked to evaluate the extent to which they agree with a set of statements. (7: strongly agree; 1: strongly disagree).

5.3 Results

1. Procurement systems used

The types of procurement system used are summarised in Figure 7. Of the 118 questionnaires which were returned, the majority (53%) employed design-build (the main contractor is responsible for both the design and build elements; for example, the architects are hired by the main contractor, not the client) while approximately one fifth (20.4%) of the projects chose the traditional contracting (the architects and their design team are hired directly by the client). Partnering agreements, formal and informal, were not widely employed only accounting for 15%.

2. Where was BIM used?

Of the projects surveyed, BIM was most used in the assistance of detailed design development (60%). Nearly 40% of the projects used BIM in the construction stage. The third most common area of BIM application was to concept design development. By contrast, nearly 30% of the projects were not involved in the application of BIM. (See figure 8).

3. What level of BIM was used?

The respondents were asked to classify their projects into four levels. It is not surprising to find that BIM was mainly used as a platform for exchanging information among parties in digital formats (44.4%). Around one third (31.6%) of the clients tried to have more data attached to BIM models to assist the management of projects, particularly with respect to cost control and programme management. (See table 6).

4. Conditions for above-average project performance

A central question of this research was from the perspective of the client; what factors may make the outcome of the project more satisfactory. Project performance involves multiple dimensions, so the performance score considers five factors including: construction costs, schedule management, quality, innovativeness of the design solution, and innovativeness of the construction technology employed (see Table 7). Respondents were asked to score projects on a scale of 1 to 7, and respondents were sorted into two groups – those working on relatively poorly performing projects with project performance scores above or below the average score of 4.6. The projects are classified as above-average or below-average project performances respectively.

Figure 7 **Which type of procurement system was used in the project?**

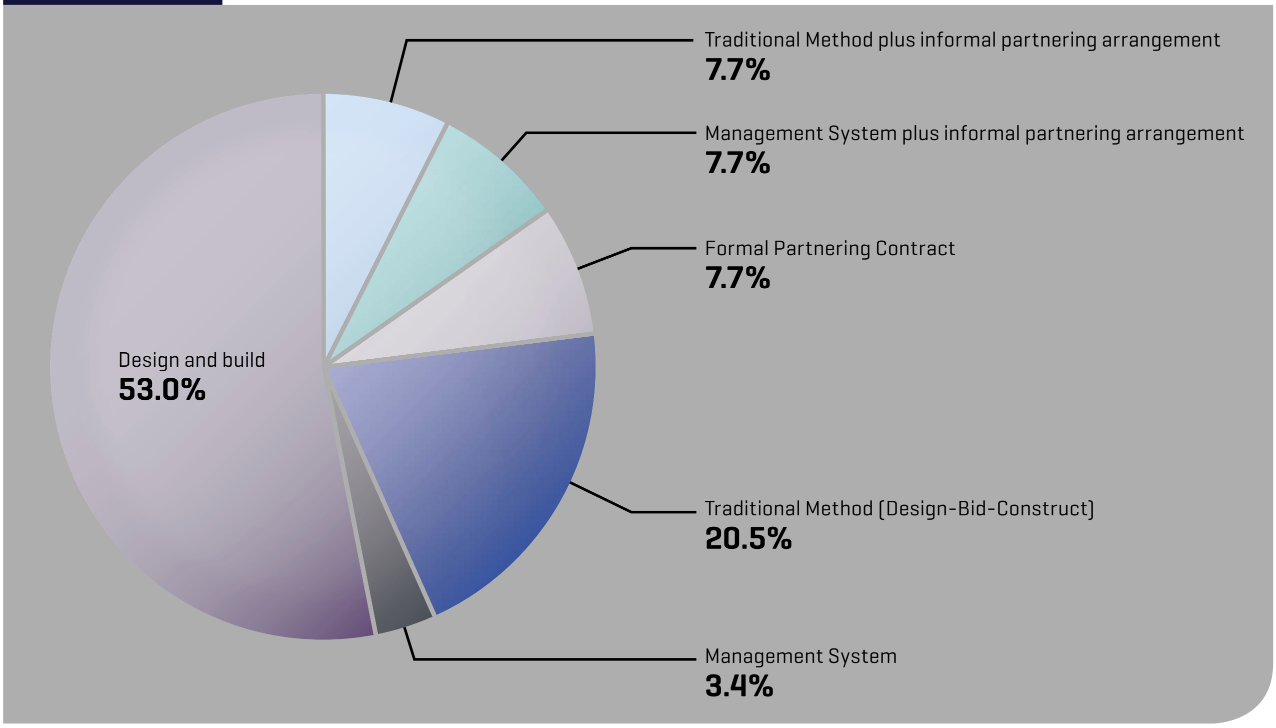


Figure 8 **Where has BIM been used?**

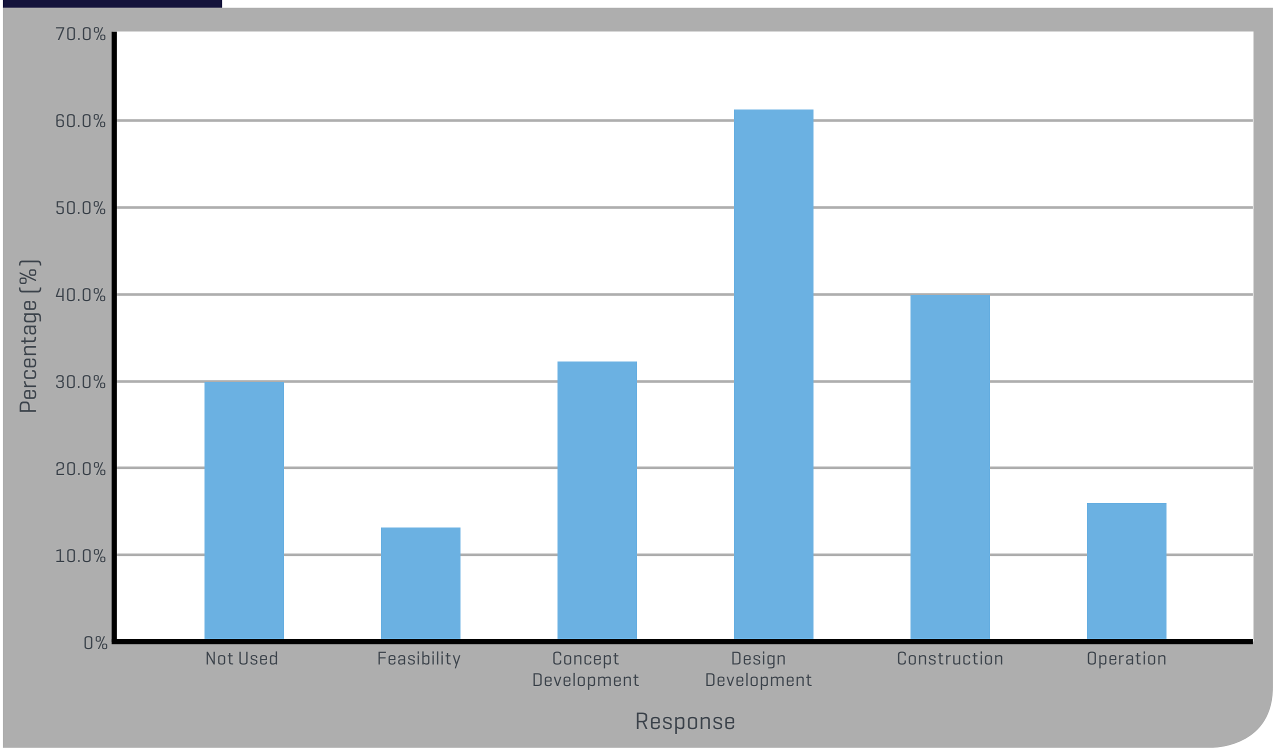
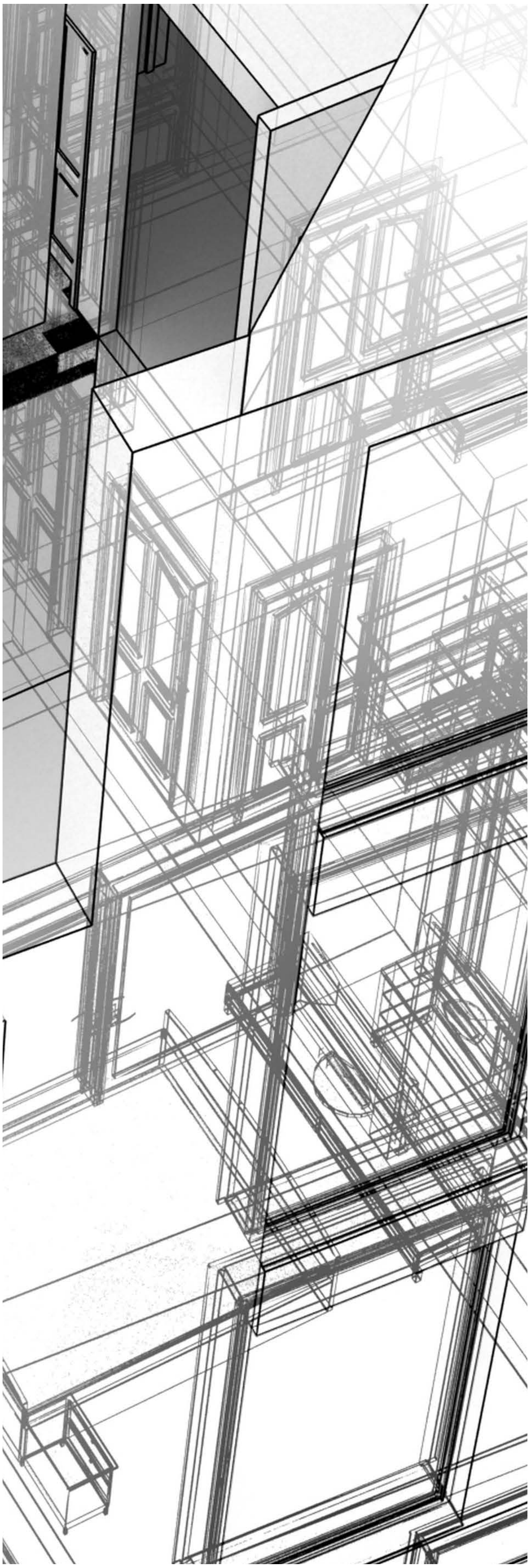


Table 6 Level of BIM Application

Level of BIM		Percentage
Level 0	[Unmanaged CAD, in 2D, with paper or electronic paper data exchanges.]	23.9%
Level 1	[Managed CAD in 2D or 3D format with a collaborative tool providing a common data environment and standardized approach to data structure and format. Commercial data managed by standalone finance and cost management packages with no integration.]	44.4%
Level 2	[A managed 3D environment held in separate discipline 'BIM' tools with data attached. Commercial data managed by enterprise resource planning software and integrated by proprietary interfaces or bespoke middle-ware. This level of BIM may utilise 4D construction sequencing and/or 5D cost information.]	31.6%
Level 3	[Characterized by a fully integrated and collaborative process enabled by web services, and incorporating 4D construction sequencing, 5D cost information and 6D project lifecycle management information]'	0.0%

Table 7 Measures of Project Performance

1	From the perspective of the client, you are highly satisfied with the performance of this project in terms of construction cost.
2	From the perspective of the client, you are highly satisfied with the performance of this project in terms of schedule management.
3	From the perspective of the client, you are highly satisfied with the performance of this project in terms of construction quality.
4	From the perspective of the client, you are highly satisfied with the innovativeness of the design scheme chosen in this project.
5	From the perspective of the client, you are highly satisfied with the innovativeness of the construction technology employed in this project



5.4 Effectiveness of Incentives

The main factors influencing the effectiveness of incentives to improve project performance are outlined in Table 8. Respondents were asked to score whether or not various collaborative features, as outlined in Table 8, affected project performance. The collaborative features they were asked to assess, and the average response, included:

a) The use of an explicit risk-sharing scheme in the project can lead to a better performance.

b) Group-based compensation tends to yield a more satisfactory outcome.

c) An explicit incentive for the contractor to improve buildability in the design stage seems helpful for the outcome.

d) It proves to be pivotal to incentivise trade contractors to participate in the improvement of buildability in the design.

For BIM-enabled projects, this research also explores the extent to which incentive measures have resulted in their intended effect.

a) The clients of above-average performing projects exhibit stronger endorsement for the positive effects of risk-sharing arrangements on the effectiveness of BIM over those of below-average performance projects. The difference in view is marked in statistical terms (within the 98% confidence interval).

b) The positive effect of group based compensation on the working of BIM is more highly valued by satisfactory clients than unsatisfactory clients.

c) The data shows 99.9% confidence that satisfactory clients think exceedingly highly of the positive impact of the contractor's early participation in BIM over unsatisfactory clients.

d) Similar to (c), the trade contractors' early participation is also more highly valued by satisfactory clients.

Table 8 Measures of collaborative features

		Above-average performance	below-average performance	Level of confidence
	Extent of collaborative measures used	4.77	3.71	99.9%***
Incentives related	Explicit risk-sharing arrangement	3.59	2.86	95%*
Incentives related	Group-based compensation	4.01	3.49	95%*
Incentives related	Subjective evaluation	3.58	3.54	45%
Incentives related	Incentives for the contractor to improve buildability	4.12	3.62	93%
Incentives related	Incentives for the trade contractor to improve buildability	3.83	2.97	99%**

The scores in the tables in this chapter refer to simple averages from a 1-7 scale. The final column conveys information from some statistical hypothesis tests to capture whether or not the responses from above average performing firms are significantly different from the responses from below average performing firms – to capture whether attitudes to BIM uptake correlate with performance. The statistical significance is based on a Student's t test on the following null and alternative hypotheses:

H_0: $b_H = b_L$, and H1: $b_H \neq b_L$

where is b_H is the average score for score for above average performing firms and b_L is the score for below average performing firms. The statistical confidence with which the null hypothesis can be rejected is indicated in the final column of each table. This translates to statistical significance as marked, with *** indicating that, at a 1% significance level, there is a statistically significant difference between the scores for high versus low performing firms. Similarly, ** indicates a statistically significant difference at 5%, and * indicates a statistically significant difference at 10%.

5.5 Impacts of behavioural bias on the effectiveness of incentives

Behavioural biases have gained prominence as pivotal factors for decision making. The impact of behavioural biases can be examined by contrasting the cases where incentives are used differentially. In terms of how explicitly risk-sharing mechanisms are set out in the contract (1: silent; 7: explicit formula), the projects are categorized as heavily incentivized (the score > the mean (3.28)) and lightly incentivized (the score $\leq$ 3.28). As explained above, a 1 to 7 scale as used and respondents were asked to judge how the following biases affected contractors' responses to incentives for collaboration.

This links to behavioural economics, and Kahneman and Tversky's theory of risk – known as "prospect theory" (Kahneman and Tversky, 1979). People may value the loss and gain from betting on a particular outcome asymmetrically by weighting the latter higher than the former. As a result, the tendency to avoid a large loss could blunt the effectiveness of risk-sharing mechanisms. It is intriguing to investigate whether the workload the contractor is under prior to entering the contract could negatively impact the contractor's responsiveness to incentives. The argument is that the contractor working at his or her full capacity would not be as keen to capture the opportunities offered by the incentive scheme, perhaps for fear that other project participants would gain disproportionately from his or her efforts. The response of the contractor to the incentives on offer could be affected by the contractor's prior experience in working under similar schemes as that experience allows him or her to better evaluate the upside and downside that the incentive scheme could bring. The result demonstrates that the difference for this factor between two groups of clients is strikingly large with a level of confidence close to 100%.

By contrast, the current financial conditions of the contractor at the start of a contract was not perceived as a significant bias.

Table 9 The effect of status quo biases

Sources of status quo bias	Heavily incentivized project	Lightly incentivized project	Level of confidence
Avoid large risk losses (-)	4.60	3.75	96%*
Contractor's current workload (-)	4.15	3.35	94%
Contractor's prior experience in working under risk-sharing arrangements (+)	4.85	3.20	99.9%***
Contractor's financial conditions (-)	3.7	3.35	2%[9]

9 This very low level of confidence indicates that the null hypothesis that contractors' financial conditions have no significant impact is not rejected; in other words, this is not a statistically significant factor.

5.6 Role of collaboration

In explaining the perceived differential project performance, the questionnaire considered how strongly the delivery system encourages collaboration. Collaborative features are recognised in the guides issued by leading construction professional bodies, including American Institute of Architects (2007), Cohen (2010), and Infrastructure UK (2013). Some of these features were incorporated into a series of questions abut the connections between project governance and collaboration, with 7 indicating perfectly collaborative and 1 totally uncollaborative.

The role of collaboration was measured by the average score of the responses to questions on eight collaborative features (see Table 10). Respondents were asked to indicate on a scale of 1-7 the extent to which 5 forms of collaboration were part of their project. These scores were averaged for each collaborative feature, following the same method as outlined in the tables above.

As reported in Table 8 collaborative features were more intensively employed by above-average performing projects (4.77) than below-average performing projects (3.71). This difference was significant for most features, at a 2% significance level (98% confidence interval) or less (more) , except for the question about subjective evaluation.

These results indicate that there are strongly significant differences between the high and low performing projects, with the largest difference emerging in answer to the question about early participation. The overall scores are higher for the above average performing projects – this could reflect the fact that the participants who are more aware of the benefits of collaboration, and the potential of BIM to harness these collaborative benefits, were more innovative and productive participants and therefore associated with more highly performing projects.

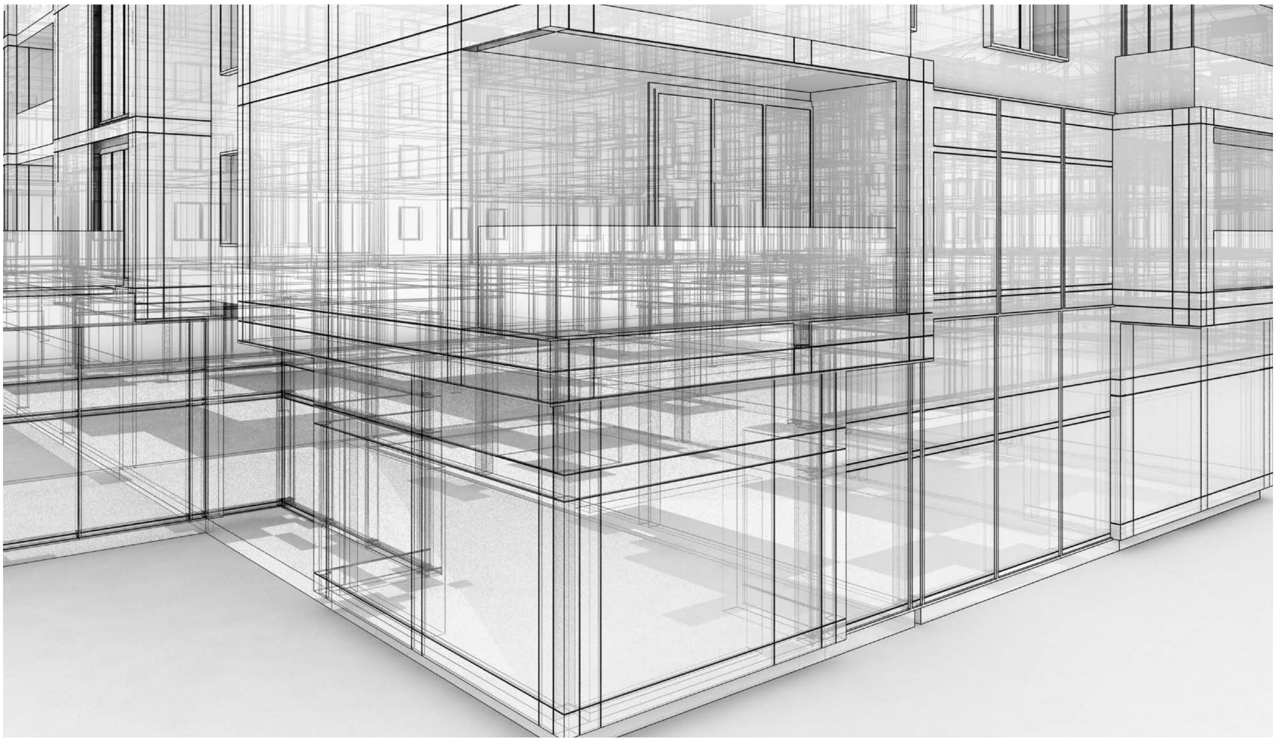
These results show that perceptions about collaboration and BIM are inter-related. The respondents are identifying collaboration as a key feature of BIM – in a range of different ways. Thus in incentivising BIM uptake, the benefits of collaboration could be emphasised in order to accelerate uptake.

Overall, these results show that project businesses believe that incentives relating to collaboration have a strong and significant impact on the effectiveness of BIM.

Table 10 **The effect of incentive measures on the effectiveness of BIM**

To what extent have the following incentive measures impacted upon the effectiveness of BIM?	Above-average performance	below-average performance	Level of confidence
The explicit risk-sharing arrangement has a positive effect on the effectiveness of BIM	4.25	3.52	98%**
Group based compensation has a positive effect on the effectiveness of BIM.	4.07	3.25	98%**
The contractor's compensation on the client's subjective evaluation can increase the effectiveness of BIM	3.75	3.33	84%
The early participation of main contractor in the design process has a positive effect on the effectiveness of BIM	5	3.6	99.9%***
The early participation of trade contractors in the design process has a positive effect on the effectiveness of BIM	4.79	3.6	99.7%***

6.0 Discussion and Conclusions



This report has brought together insights from economic theory, incentive theory and behavioural economics about the potential benefits and pitfalls from collaboration with an analysis of BIM. BIM necessarily involves a collaborative element because it is about sharing information. The aim of this report is to go further in analysing – firstly, how businesses can be encouraged to use BIM; and secondly, to understand how BIM can help improve project performance, not just by improving information flows but also by leveraging the wide range of benefits that can emerge from collaboration.

6.1 Key findings

In terms of the four hypotheses outlined in section 1.5, these are the key findings the introduction. The businesses surveyed here identified significant transaction costs at lower tiers of the supply chain, including transactions costs between suppliers and these impede efficient supply chain management (Hypothesis 1). The businesses surveyed also verified that information constraints and behavioural biases are likely to inflate transaction costs, for example by enabling opportunistic behaviour by other suppliers (Hypothesis 2). The survey findings support the hypothesis that BIM, particularly if it can facilitate collaboration can significantly improve project performance and supply chain efficiency (Hypotheses 3-5).

6.2 Implications for BIM as a multi-dimensional collaborative tool

The more detailed surveys identified a range of factors affecting incentives for the uptake of BIM – in the design of effective incentives for BIM uptake, emphasising the benefits of collaboration and group working are likely to be important, alongside more traditional economic and financial incentives.

The first step as the adoption of BIM grows is to understand how and why businesses can be encouraged to adopt BIM in the first place. Generally, the widening and deepening application of BIM to the construction supply chain could ultimately create enormous benefits. However, as seen in the diffusion of other technologies, BIM entails a high setup cost in both software investment and training, potentially hindering the initial rate of conversion. The nebulous benefit of BIM perceived by individual users also intensifies the resistance to this new technology. In the short run, a proper incentive system can help lift most of the barriers. In the long run, even greater challenges exist in how to rework the business model to enable BIM to reach its full potential.

Going forward, further research is needed to unravel other limits and constraints on collaborative BIM. As an ideal it has a lot to offer but there may be technical constraints in effectively embedding collaborative practices into BIM technologies. There will also be constraints in terms of skills – for example, training costs are likely to be large and potentially prohibitive for smaller businesses – adding to the costs they face, even in adoption of current BIM technologies. Indirect costs, including loss of working time whilst employees are on training programmes, is likely to be a further barrier for smaller businesses If the SMEs that tend to dominate the lower tiers of supply chains are excluded by an expensive technology then the benefits are likely to be limited, even if the technical hurdles can be overcome. Government and construction organisations need to focus on this constraint in devising subsidised training programmes.

Once BIM has been adopted by a given business, the next step is to better understand how BIM might interact with real-world behaviour and performance. The benefits of BIM in terms of information sharing are self-evident, but in developing BIM generally and collaborative BIM specifically, insights from information economics, behavioural economics and incentive theory have particular power in helping us to understand how and why collaboration can improve project efficiency and supply chain performance. In further developments of BIM, one potentially fruitful avenue for BIM is in leveraging the value of collaborative relationships. The survey explored in Chapter 3 shows that suppliers value relationships with other suppliers, as well as with clients and main contractors. Whilst they may have some suspicions of main contractors, sometimes more than their suspicions of the client, they are able to participate constructively in collaborative working groups, even if those groups are comprised of their own competitors.

To focus on the key areas in which insights from this paper can be developed within a BIM framework, social influences are key. Collaboration is not just about sharing information but it is also about social learning. The formation of collaborative working groups enables the various players in a project to learn from each other in a non-adversarial context. Information-sharing via BIM reduces the potential for opportunism and so necessarily reduces monitoring costs required to deter opportunism from other businesses within a supply chain. But an additional insight from economics is that BIM can make the benefits of co-operative behaviour more salient. If a supplier is willing to supply low quality products and services in the belief that they will not suffer consequences because their client/main contractor will have forgotten who might be responsible – this potential source of additional maintenance and replacement costs is less likely if the suppliers know that, within a BIM framework, there is a digital record not only of the fact that they supplied a part but also of exactly which part was supplied. Thus BIM has the potential to discipline opportunistic behaviour, and encourage suppliers and other players in a construction project to take a more long-term view.

This report has outlined some preliminary findings showing how economics theories about collaboration have the potential to usefully inform the evolution of BIM so that it becomes something more than just information-sharing. If it is well-designed to harness the socio-psychological factors that might affect the performance of main contractors, sub-contractors and suppliers on a project, then the potential benefits in terms of lowering life-cycle costs and improving efficiency through all stages of a project – from procurement, through to construction, and then throughout the life of a building, are likely to be large.

For future research the plan is to extend the online surveys and analyses to a larger number and wider range of construction businesses, to collect more detailed information about the role of collaboration and BIM in construction projects.

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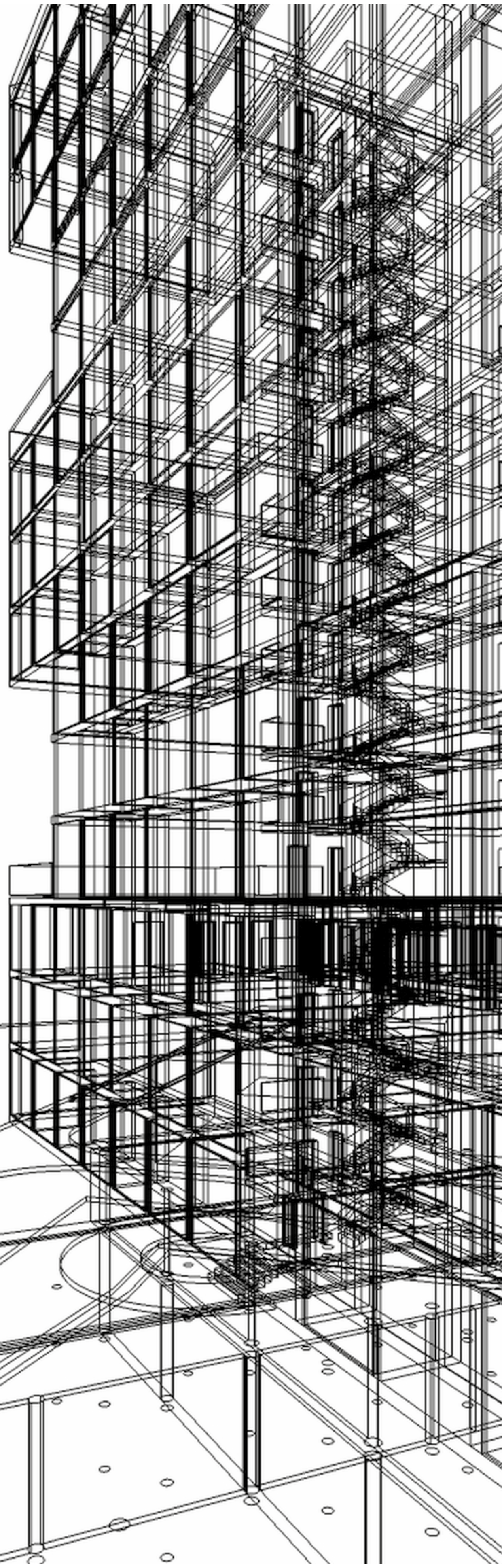

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