Digitalisation in construction: Mixed blessing for collaboration in projects

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Abstract

The United Kingdom (UK) construction industry has seen the last years a proliferation of digital technologies used throughout the project lifecycle. Through this increasing demand for digitalisation, industry practitioners are subjected to an unprecedented exposure to visions and rhetoric for the 'Construction 4.0', a fully automated and smart industry, leveraging cyber-physical systems. Nevertheless, amidst this technological determinism, projects struggle to leverage these digital technologies.

Initially, the focus of the research was to identify the effect of a digital platform, namely Building Information Modelling (BIM), on collaboration in construction projects. More specifically, the study addresses the following research question: "*To what extent can digital technologies such as BIM facilitate collaboration within the construction industry*"? As part of the research, the primary data has been collected through eight 1.5 hours-long interviews carried out with leading industry professionals and policy-makers in the UK until the data reached saturation. Afterwards, the collected data was coded, using open and axial coding, analysed and discussed with academic literature.

The industry experts agreed that digital technologies such as BIM definitely have the potential to improve collaboration in the industry. To this end, they acknowledged that digitalisation can provide better utilisation of information, integrated working platforms, clear evaluation of project requirements, ensuring a lifetime approach and increasing overall efficiency.

Nevertheless, beyond these easy and obvious answers, the study revealed surprising new challenges related to the implementation of digitalisation and its relation to collaboration. To a certain extent, digitalisation was a mixed blessing for collaboration, because of cultural barriers within the construction industry, that restrict any form of collaboration. Therefore, the main focus for improving collaboration through digitalisation should be on changing the culture, making it more receptive to collaboration.

Because of the key findings mentioned above, the paper turned out to be covering the cultural aspects within the construction industry, in relation to acceptance of BIM. So, although the study set out to explore an operational topic (that of collaboration), it ended up discussing the high-level concept of culture among teams and industry. The phrase ‘adapt of die’ is more relevant to construction now than any time before, because if its culture remains non-collaborative, as it is now, digitalisation will continue facing the same barriers during implementation, despite all benefits it offers.

Furthermore, the study provides practical recommendations to the industry bodies. This includes paying attention to the importance of cultural aspects, introduced by Schein (2010). Moreover, there should be a proper leadership to “walk” people through the change, ideally performed by the government. Also, it is advised to encourage collaboration, through tackling the artefacts and norms, which is the “top” of the cultural iceberg to leverage digitalisation in construction.

Introduction

Different stakeholders have differing expectations, and in order for a project to be defined as successful, it should satisfy the needs of all parties (Artto et al., 2007). Collaboration lies at the very heart of efficient project delivery. With diversity of backgrounds, complexity of tasks and fluid environments, collaboration is key to achieving an optimal result. A lack of collaboration has been identified as one of the main concerns and points of discussion within the industry.

Project-based organisations, especially within the construction industry, tend to operate in a very dynamic environment. Referring to Hobday (2002), a project's structure is likely to change due to contingencies, such as size, complexity and duration. The management of project-based organisations involves high product complexity, fast-changing markets, customer-focused innovation, cross-functional business expertise and has a high degree of uncertainty. Furthermore, there is a combination of different backgrounds (Liu *et al.,* 2016), which are further separated by rigid departmentalisation, where division takes place according to function, task, process and geographic location (Robbins, 2008).

Considering all factors above, members of supply chains often forget the main aim, which is to efficiently deliver the project achieving the time, cost and quality targets whilst remaining within scope (CIOB, 2016). The lack of collaboration remains one of the main problems, faced by the construction industry (Rahman *et al*, 2014). There are multiple strategies and models relating to how best to improve collaboration. One of such suggestions is to promote collaboration through 'Building Information Modelling' (BIM). Current study considers BIM in a wider context, as a "Process" rather than a "Technology".

Nevertheless, BIM brings great opportunities as well as great challenges. This is a massive change driven by innovation, which can potentially impact the processes, that have been in place for decades. Despite all benefits, BIM adoption is taking longer than expected. What are the likely reasons for change restrictions? The paper is then addressing the following main research question: "*To what extent can BIM facilitate collaboration within the construction industry*"?

Literature Review

Defining Collaboration

Collaboration can be defined as a process through which individuals/groups work together towards a shared objective on a particular endeavor (Light, Bell & Halpern, 2011). Collaboration is needed, when individuals/groups reach the limits of abilities, resources, knowledge and experience, required to complete a task. In these situations, collaboration can help to complete the task in more quick and efficient ways (Zeng *et a*l.,2008). Collaborative work can help to succeed in larger and more complex tasks, allowing individuals/groups to gain a perspective on the common enterprise, which they couldn't have been able to gain separately, and finally to learn from their colleagues during work (Kalay, 2001). Collaboration can be seen beyond just the individuals/groups, instead it could be a collaboration within the project, company, community or even the business eco-system.

Successful collaboration cannot be achieved easily and require efforts. Light et al (2001) identified 4 supportive Points of Collaboration (*See Figure 1*):

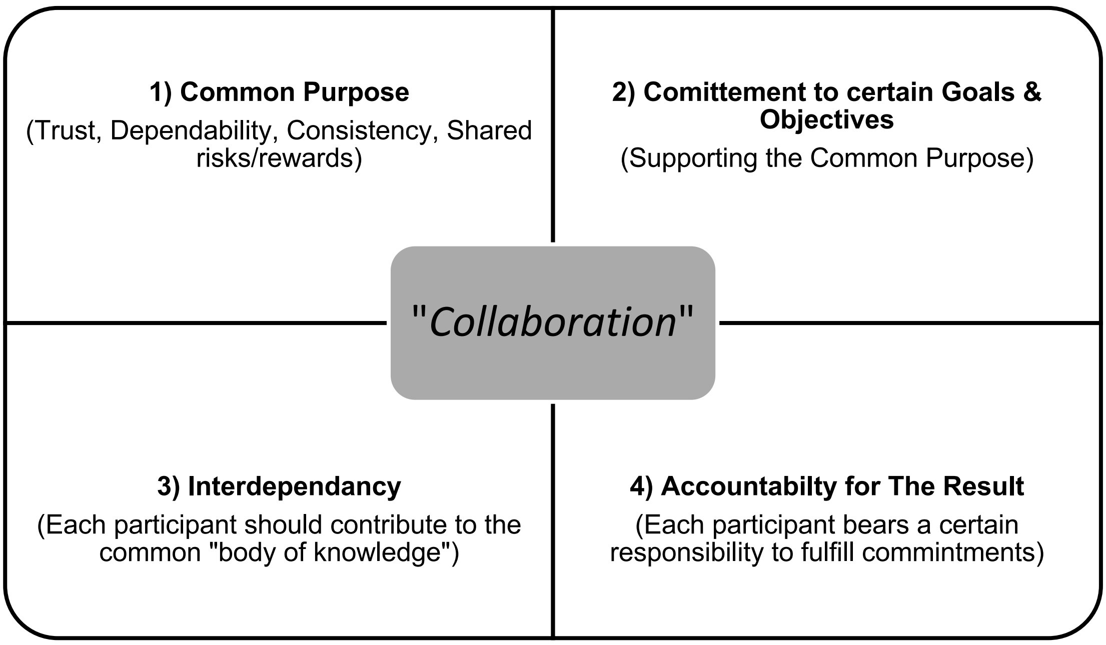

Figure 1: Four Supportive Points of Collaboration (Light et al, 2001)

Firstly, the participants must share a common purpose, supported by mutual and unambiguous trust. Secondly, even if each participant has different goals/objectives, these goals/objectives should still support the common purpose. In the third place, there must be an interdependency, where participants rely on each other's experience, knowledge and skills, therefore creating the collaborative Body of Knowledge. Finally, each participant must feel the responsibility for achieving the final result and based on that demonstrate reasonable efforts.

The paper focuses on collaboration in construction industry, which is primarily project-based. Therefore, the next step is to understand why and how the collaboration in project-based organisations differs from the permanent organisations and its impact.

Specificity of Collaboration in Construction Industry

Project itself is a temporary activity undertaken to create a unique product or service (PMBOK, 2008). Furthermore, project delivery assumes the presence of a temporary system (Grabher, 2002), where diversely skilled people, work together over specified period of time. The Project-Based Organisation (PBO) involves the creation of such temporary-systems, to achieve specific aims (DeFillippi, 2002). The following areas distinguish collaboration in project-based organisations from permanent organisations.

Innovation and Knowledge Transfer

There are many controverting opinions regarding PBOs and the output that they bring. Hobday (2002) believed that PBOs are effective in facilitating innovation and stated that in contrast to the matrix, functional and other organisational structures, the PBO use the project as the primary unit for innovation, production and competition. Moreover, Hobday (2002) saw the fact that projects are temporary activities, in a positive way. He believed that PBOs structure is flexible and reconfigurable comparing to anti-innovative hierarchical organisations.

However, according to DeFillippi (2001) and Grabher (2002) PBOs tend to face challenges in capturing, sharing and developing knowledge across the projects. For Grabher (2002) the limited duration of projects restricts learning. Grabher (2202) specified the importance of long-term relations and established trust between the parties. In the Grabher's (2002) opinion, most of the project-management literature is focusing on successful delivery of a "single-project". In other words, the project is being considered as a separate system, which have been designed and scheduled, and can be isolated from the external environment (Blomquist and Packendorff, 1988) and knowledge is lost after the project handover.

Overall the issue with knowledge-transferring, innovation and trust has been summarised by Bresnen *et al*., (2004), stating that in contrast to what presented in academic literature, most of the projects are negligently prioritizing short-term goals, over the long-term goals such as knowledge-transferring/innovation accumulation. Furthermore, projects are temporary, and most of the time parties are not maintaining long-term relationships, therefore losing the opportunity improve though partnership/collaboration.

Highly Uncertain Environment

Referring back to Hobday (2002), projects' structure is likely to change due to contingencies, such as size, complexity and duration, meaning that projects are highly-dynamic environments. The management of PBO's involves high product complexity, fast changing markets, customer focused innovation, cross-functional business expertise and high uncertainty.

If we compare the project with traditional organisations – projects should have a flatter and more flexible, organic structure (Child & McGrath, 2001; Child & Rodrigues, 2003). Similar to ideas of Burns and Stalker (1961), about the environmental uncertainty. If we separate the environments according to the level of uncertainty, projects should be characterised as "Highly Uncertain". Therefore, project-based organisations need to operate in a more organic way, to survive in continually-changing, industry **(***See Figure 2***)**.

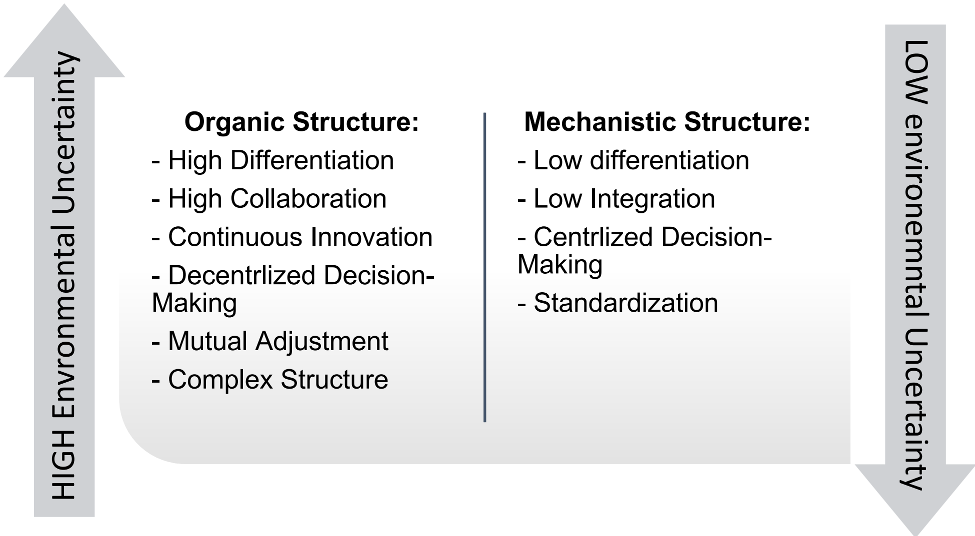

Figure 2: Relationship Between Organic & Mechanistic structures Burns & Stalker (1962)

Nevertheless, in Construction industry the risk imposed on contractors tends to be very high, which is unsuitable for the uncertain environment. As a result, contractors have to minimize risks and it restricts collaboration (Roberts et al., 2016).

Stakeholder Diversity

Lundin and Soderholm (1988) allocated projects into three different contexts, and one of them was "projects as standard organisation practice". In construction projects, there is a combination of people from different backgrounds, including engineers, architects, contractors, project managers and suppliers (Liu *et al.*, 2016). Hence knowledge boundaries can vary significantly from one person to another (Brown & Duguid, 2001), and members of the project can have differentiated thought worlds (Dougherty, 1992). This can result in an increased difficulty of knowledge transfer and mutual understanding.

High Departmentalisation, Specialisation and Geographic Dispersion

We need to consider that members of the project are not only coming from different backgrounds but are also divided into multiple departments. Division takes place by function, task, process and geographic-location (Robbins, 2008). The decentralized project-team work is normal for construction-companies (Bresnen and Marshall 2000a) as well as difference between project activities and strategies (Dubois and Gadde, 2002). The non-routine work, involving inter-professional, inter-organizational, contractual and working relationships as part of project-interaction (Bresnen, 1990), and require collaboration.

Furthermore, problems arise because of high specialization and segmentation within projects (Weber, 1947). Going back to organisation theories diverse and dynamic environments require high level of differentiation between departments (Lawrence and Lorsch, 1967). PBOs are very uncertain and different departments might have different structures. Thus, high departmentalisation is often used negligently, resulting in each participant focusing on personal benefits (Liu *et al*.,2016).

Next, in construction, projects are usually delivered by virtual teams, potentially in different geographic locations. To collaborate, there should be a communication, which as mentioned by Samset (2001) can be very complicated. The message created by “sender” can get distorted before reaching the “receiver”. Dispersed projects tend to be more expensive/challenging than local-based (Boh *et al*., 2007) and the technology is playing a key role. Communication takes place via email, phone, or other IT (Iskdag and Underwood, 2010). This can significantly slow down the project.

Introducing E-Collaboration

The positive impact could be brought by the rapidly emerging information technologies and the term 'E-Collaboration' is increasingly used nowadays (Mayrhofer & Back, 2003). During the last decade, industry adopted emails and online communication, while before that, innovation has been brought by Internet. Nowadays, technologies keep developing and in the 21st century collaboration can potentially be improved by BIM. As mentioned by Fong (2005) - a virtual organisation, is a network of individuals/groups that are geographically separated but share mutual aims/objectives. Moreover, Sanders (2007) purposed that Information Technology (IT) has a positive impact on intra/inter-organisational collaboration. Collaborative IT can be classified into four groups as seen in Figure 3:

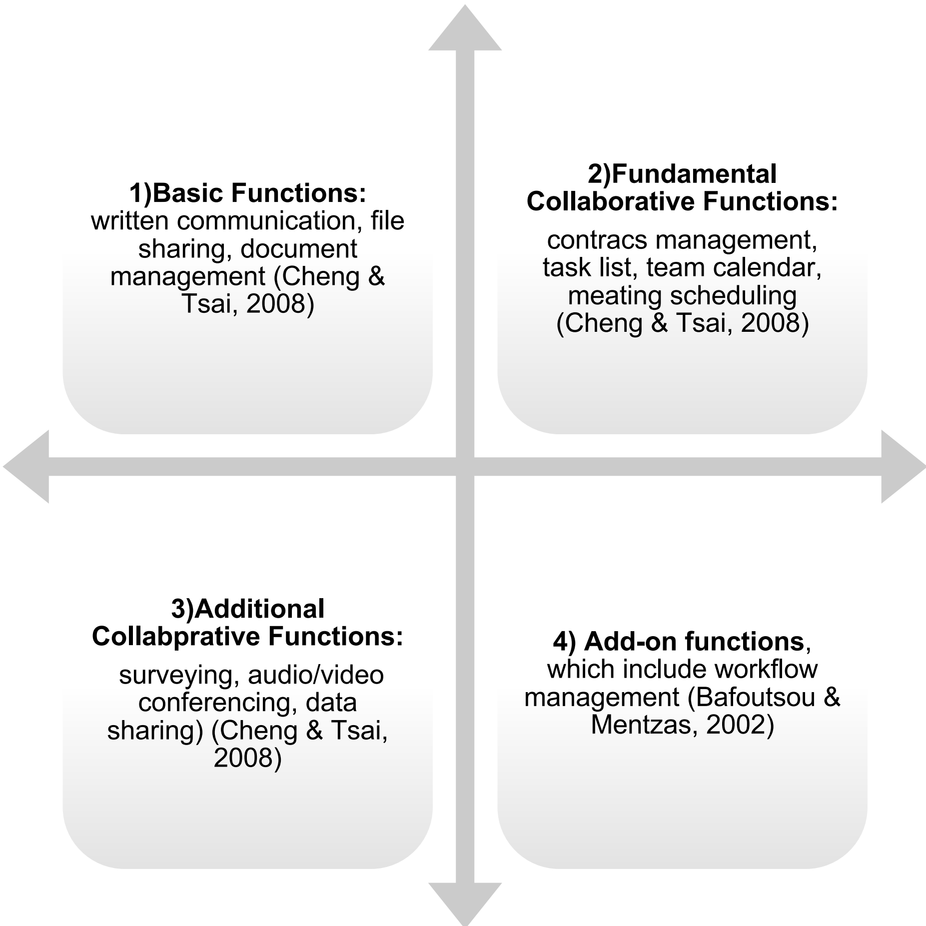

Figure 3: Classification of Collaborative Technologies

BIM and collaboration are two interconnected areas. BIM can help to execute tasks more efficiently, providing innovative opportunities. Construction assumes large amount of resources to be exchanged between various participants (Iskdag and Underwood, 2010). Thus, construction firms are most likely to find themselves relying on IT solutions such as BIM.

Building Information Modelling and Collaboration

Currently, BIM is the most common representation of the new approach to construction, design, maintenance and management of developments (Bryde et al., 2013). BIM can offer the key product/asset data, and a 3D computer-based models, to be used for efficient design, construction and management during the project lifecycle (HM Government, 2012). There is no single definition of BIM, but there are many interpretations, for example, Succar, (2009) defined BIM as a *"set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in a digital format throughout the building's lifecycle".* HM Government (2012 stated: "*BIM is a collaborative way of working, underpinned by digital technologies which unlock more efficient methods of designing, creating and maintaining assets" ... "It's a game-changing ICT & cultural process"*.

Therefore, BIM is not only about 3D modelling and information exchange, but also useful for project management. It might have the potential to act as a project manager's tool, for improving collaboration between stakeholders. This paper looks at BIM more as a "Process" rather than a "Technology".

Construction industry has been using IT to address the high complexity of contemporary projects (Chen & Huang, 2014). BIM provides a platform for collaboration, accessible to all parties. Drawing upon the literature, below are the key features of BIM, which can improve collaboration:

Single-Source Access to Information

Digital representation of functional/physical specifications, allows transferring the data among multiple software applications within the organisation as well as within the multidisciplinary inter-organisation teams (Miettinen and Paavola, 2014). After information is stored within the BIM database, it can be accessed, changed or managed by the necessary participants during the project-lifecycle. Thus, BIM allows an easier and more collaborative access to information. Single-source of information also covers communication aspects, allowing to eliminate the delays resulting from poor communication methods.

Collaborative Approach at the Front-End

Visualization and representation of building-models allow to solve problems, before commencing the construction process (Kassem *et al*., 2015). Even more, 3D-modelling allows clients to understand target results, by looking at virtual representations of completed projects. Thus, providing greater client-engagement. Also, BIM establishes platform (Qian, 2012), allowing efficient evaluation of options for decision-making earlier. According to the information gathered from the working group, on one of the off-site manufacturing projects (HM Government, 2012), BIM promotes an informed decision-making, and allows the supply chain to see the bigger picture.

Theoretical Framework

Research Gap

Recently, BIM is becoming seminal in government projects, including the Crossrail and High Speed Rail 2 (BSI, 2013). BIM sector is facing a rapid growths and economists estimated that the UK market for BIM-related services will be an annual £30bn by 2020 (Construction 2025, 2016).

According to the literature, main challenges of BIM are concerned with the implementation. However, there is a research gap in the "*body of knowledge*" regarding the weaknesses of BIM and the reasons of difficulties in its implementation. Based on the above, the paper aims to understand the relationship between the theoretical beliefs and the real practical situation. More specifically, looking at the main difficulties in BIM implementation, from the perspective of change, driven by innovation.

After compiling primary data and comparing it to the literature, this study aims to answer the main research question **"***To what extent can BIM facilitate collaboration within the construction industry?*", as well as 4 sub-questions:

- Sub-Question 1: *What are the main difficulties in collaboration, when deploying a traditional approach to project management?*
- Sub-Question 2*: How can e-collaboration such as BIM facilitate collaboration?*
- Sub-Question 3: *What are the main challenges with BIM and its implementation?*
- Sub-Question 4: *What should be the further steps for changing the industry through BIM?*

Methodology

The methodology approach follows the framework introduced by Creswell (1994), according to which the research plan involves:

- Specific philosophical worldview
- Research design
- Data collection method.

The "**Methodological Pyramid**" Zikmund (2015) (*see Figure 4*), illustrates the methodological concepts used in the current paper. The decisions to use the outlined methods have been mainly based on the Creswell's suggestions (1994:

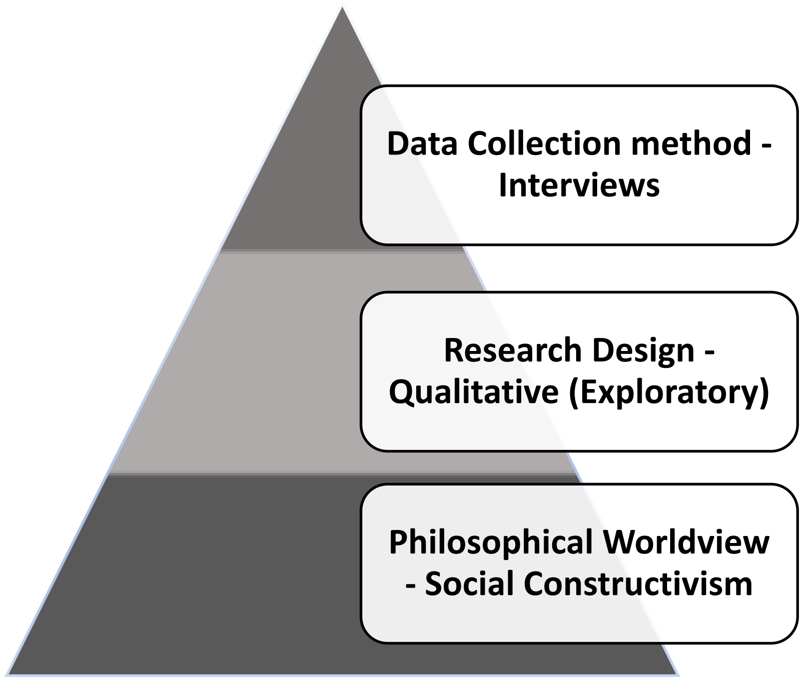

Figure 4: Methodological Pyramid (Zikmund, 2015)

Philosophical Worldview: Social Constructivism

As outlined in the Figure 4, the chosen worldview is social constructivism. It assumes that individuals seek understanding of the world in which they live and work (Creswell,1994). The opinions may often be subjective, and to obtain the comprehensive understanding on the research matters, study analyzed a set of different people. It is important to seek for the personal opinion of relevant individuals, including thoughts and beliefs (Crotty, 1998). Only by doing that, it is possible to get an alternative perspective on the knowledge, gathered from an academic literature.

Research Design: Qualitative

The paper focuses on BIM as on a process and specifically on how it can improve collaboration and is not delving into the technical characteristics and features of BIM, but instead draws upon qualitative data to describe collaboration with BIM. Qualitative data is “subjective” (Naoum, 2007) and depends on the actual experience of interviewees. As the study aims to understand practical situation, personal opinions of industry professionals are crucial. Qualitative data is more rich that quantitative. It is impossible to get “emotions” from quantitative information. Based on the above, the study only relies on qualitative data during the primary data collection, accomplished through a number of interviews.

Interview Protocol

How Interviews Were Conducted

All primary data were collected through the one-on-one semi-structured interviews. Some of the interviews have been conducted during the face-to-face meetings, to promote more dynamic conversations. However, due to busy schedule, or geographic location, some interviews have been conducted via Skype/Phone, making sure that interviewees had the necessary privacy (Zikmund, 2015). All the interviews have been recorded for transcription purposes.

Justification of the Interview Questions

We developed the questions to be broad, general and open-ended, so the interviewees could give their personal opinion on the topics. This approach removed the "barriers" during the interviews, giving freedom answer based on understanding of the question, level of knowledge and experience. The interviewees were allowed to take conversation in any direction they with, to outline their ideas (Zikmund, 2015), providing a room for "*improvisation*".

Regarding the creation of the actual questions, we developed them in the way to cover all the main areas. The core structure has been directed by the "Research Sub-Questions 1-4"**,** where each sub-question assumed a set of interview questions. We tried to apply the same of questions to each interviewee, however due to diversity of the participants' backgrounds as well as due to the open-ended style of questions, the application of the same template was not always possible. Nevertheless, the core structure with four sections have been kept the same.

Selection Criteria and Sampling Technique for Interviewees

The aim was to collect the primary data on the topic, from leading industry professionals. All the people that have taken part in the current thesis are directly relevant to the focus of the study and demonstrated the potential to add value to findings. As part of *constructivist worldview*, the interviewees have been selected in the way to bring diversified opinions. The selection criteria included sector, job specification, years of experience, geographic location and relation to BIM.

The chosen method of sampling is the "snowballing approach" Zikmund (2015). We identified several participants, based on the criteria mentioned in previous section, and contacted the most "convenient" ones. After each conducted interview, we asked them for further recommendations.

We followed the snowballing technique, until reaching the "saturation point**"** Zikmund (2015), as the "population of the sample" was not defined from the outset. We justified that the saturation was achieved, when interviewees stopped adding new information to the collected "body of knowledge". At this stage, we moved further into a discussion stage, with the sufficient primary data collected.

Table 1: Profiles of Interviewees

Identifier	Job Title	Career Experience Highlights
A	Professor of Construction and Infrastructure Policy	• 30+ years of experience in private and public sectors • Civil Engineering background • 2010/2011 President of Institute of Charted Engineers • 2012/2015 Government Chief Construction Advisor • Overseen the delivery of "Construction" 2025
B	Director in a Project Management Consultancy firm (Head of Public Sector Projects)	• 30+ years of experience • Civil Engineering background • Delivery Director of BIM Level 2 • 24 years in Ministry of Justice

C	Research Fellow at University	• 10 years within the industry • Civil engineering background • Worked on Crossrail project • Ph.D. in BIM & Facility Management
D	CEO and Founder of a private company (BIM Consulting)	• 25 years within the industry • One of the earliest BIM promoters in private sector
E	Director of construction related MSc Programmes at University	• 30+ years within industry • Economics background • Worked for contractors, consultants and clients as project manager
F	Digital Build Britain advisor; Digital Asset Advisor in a construction software company	• 17 years of consulting experience • Part of government BIM task group • Worked on Crossrail project
G	Digital Build Britain advisor; Digital Strategy Advisor in a construction software company	• 15 years of experience • Specialist in innovation and digital strategies • Huge experience in delivering digital change • 5+ years working on digital transformation
H	Professor of Build Environment at University	• 30+ years of experience in private sector • 22 years at construction and professional services firm • Ex-President of Institute of Charted Engineers • Ex-CEO of a construction firm • Involved in UK's strategic implementation of BIM

Data Analysis

After completing the primary data collection, raw data was obtained. To complete the "data reduction", all transcripts were "coded" (Miles & Huberman, 1994).

- The "*1st – order"* of coding has been undertaken though the software "NVivo", and focused on the actual language used by the interviewee (Strauss, 1987).
- Afterwards, the "*1st – order*" codes have been utilised further using an Excel. This gave us the "*2nd – Order*" codes.
- Finally, the "*2nd- Order*" codes have been allocated into the "*Aggregate Dimensions*", based on the Research Sub-Questions
- The "*Aggregate Dimensions*" participated in creation of a transparent structure, so readers could get a better understanding (Gioia *et al*.,2012).

By using the described coding techniques, an Analytical Framework for Primary Data was developed as shown on Figure 5.

Primary Data Presentation and Analysis

This section contains the primary data collected from the interviewees, as a part of current study. The data presentation is following the four-stages analysis (*see Figure 5*), introduced by Zikmund (2015):

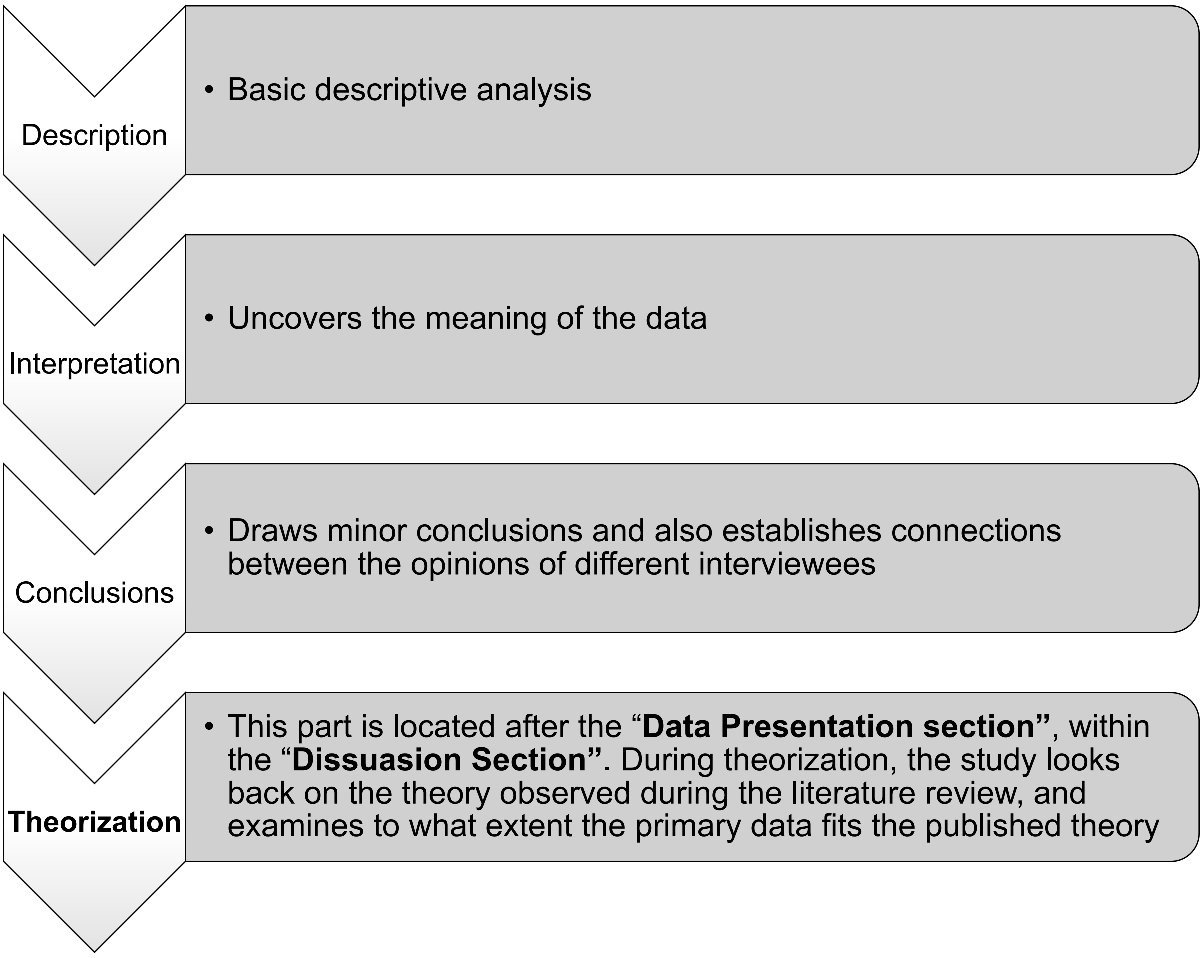

Figure 5: Four stages for analysis (Zikmund, 2015)

Each quotation is cited using the interviewee's identifier, which is shown by letters and a quotation number.[1] There is a separate sequence of numbers for each interviewee. All opinions have been taken in consideration, however some interviewees have been quoted more often than others.

[1]Example of citations for interviewee C: C-1, C-2, C-3 etc.

Main Problems with Collaboration During Traditional Approach to Project Management

This section contains most important codes, related to the **Sub-Question 1**: "What are the main problems with collaboration, during traditional approach to construction projects?". Most of the interviews started with the general question, about the traditional collaboration, and the opinion of all interviewees coincided with each other. Some examples are presented below:

> *"There are huge problems with traditional ways of collaboration".* (B-1)
>
> *"It is probably easier to discuss projects, which did have collaboration in the first place".* (E-1)
>
> *"Overall, there are many, many examples of poor collaboration in construction industry, during the Pre-BIM".* (A-1)

Participants believed that traditionally, collaboration in construction tended to be very poor. In the sub-sections below, the study is looking deeply into specific problems with collaboration.

Poor Front-End Definition

The interviewees suggested that value for collaboration is lost at the front-end phase. The collaboration is likely to be affected because of poor efforts during the briefing stage (E-2). Moreover, interviewee "B" has specified that "*this is not necessarily down to the client, that can be down to the professional service provider*" (B-3). Therefore, interviewee "B" points out that briefing is a collaborative process, and requires teamwork.

As a result of poor briefing, the supply side claims to deliver the project within a certain price, to get competitive advantage, but actually have no intentions of working within that cost (B-6). While clients simply choose the "*lowest tender"* (F-1).

Not Integrated Working Process

Furthermore, some respondents suggested that the problem of poor collaboration can occur not only between the Demand and Supply sides, but also between the internal parties within the same project, due to not integrated working process. More specifically, the reasons are as follows:

- Code: Design Clashes

Based on primary data, *"...poor collaboration occurs between design disciplines, so you will get many clashes between them..*" (A-2). Thus, the working process is not being properly integrated, while the participants are working in their own groups separately.

- Code: Virtual Teams

Again, the problem has been mentioned by interviewee "B", while reflecting on the "*Virtual Working"*. Traditionally virtual working has been causing problems:

> *"When we try to work remotely with traditional methods of construction, it is difficult, because we are not working on a common data platform. Having a remote control in traditional methods haven't really worked that well".* (B-7)

While interviewee "A" said historically, different set of drawings were produced in different places, by different disciplines and needed coordination. "*You get difficulties in communication, so there have been lots of problems related to virtual working*" (A-16).

- Code: Stakeholder Diversity

Based on primary data, most PBO don't have generally aligned KPIs (B-8). Thus, there is a common misunderstanding between parties, arising from separation on disciplines. Because of such diversity, the environment in construction industry is very dynamic (B-10). To be effective, all disciplines should work together and have mutual aims, while traditionally "*everyone is losing sight on the end goal*" (B-9).

- Code: Poor Knowledge-Transfer

Partly because of "*Not Integrated Working Process*" and "*Stakeholder Diversity*", there is a problem with "*Knowledge-Transfer*", which "is aggravated by the fragmentation between the different disciplines"*(A-10).* In PBO, transfer of knowledge takes place mainly though people and gets dispersed with the project team (H-1).

How can BIM Facilitate Collaboration

This section contains most important codes, obtained from the second part of interviews, which is about the *Sub-Question 2* "*How can e-collaboration such as BIM facilitate collaboration?*". Most important ideas have been grouped into subsections, as follows:

Integrated Working Platform

- Code: Integrated Working platform

As mentioned by the interviewee "G" - "*One single discipline cannot improve the whole project. Everything should be integrated, to be able to exploit the benefits*" (G-1). Interviewee "B" suggested that BIM can improve collaboration, by establishing the integrated common data environment between all disciplines in a "*federated form*" (B-13). Furthermore, BIM can solve the problem of "*Stakeholder Diversity*", because all the parties are now working on a common platform, instead of being locked up in "*silos*".

- Code: Single Point of Access to Information

During the traditional ways of working, the information reliability may be questionable because: " *There is no single source of truth and you do not know where the right information is* " (G-2). Whereas BIM can solve the problem, as mentioned by interviewee "A":

> *"Each specific set of drawings is produced at a certain date. Version Control in BIM means that everybody will be working on the latest versions simultaneously".* (A-18)

Minimisation of Late Changes

Many interviewees have been saying that changes in early stages are much cheaper – "*There is this Front-End curve, all the sensible changes early on got minimum costs*" (H-4).

- Code: Clear Evaluation Platform

As already outlined in "*Poor Front End Definition*" section, supply side often claims to deliver something, without having intentions to actually deliver it. The BIM process brings a clear evaluation platform, by implementing additional "information requirements" during the tendering stage. So "*the process in BIM sits there to be able to make sure that – 'I have asked for this and this is what I get*" (B-14).

Therefore, late changes in budget are less likely to appear, because contractors will introduce the practical cost from the very beginning.

- Code: 3D Visualisation

The other reason for late changes – changes driven by the client. Interviewee "A" said that "*good thing about BIM is that you can build the digital model of an asset, before you even start work*" and "*walk the client through the model*" So, changes are made before construction.

Furthermore, the benefits of 3D Visualisation were highlighted by majority of interviewees. Interviewee "B" has provided an insightful example, where the use of 3D visualisation allowed to save £800'000 on the Cookham Wood Project, by highlighting issues which "*would have never been picked up by the operational team of the prison in 2D drawings*"(B-15).

Current Industry Status in Relation to BIM

After obtaining the opinions of interviewees regarding benefits of BIM, the primary research has focused on getting an insight into the current position of BIM within the industry. An important role in BIM implementation is played by the Government, that have mandated BIM level 2, for the public sector starting from 2016. Some interviewees have been directly involved in the mandate, therefore it is relevant to get an insight into what the Government tried to achieve.

- Code: Government Mandate

It is extremely relevant for the current research, to highlight the opinion of Interviewee "A", who was responsible for the "*Construction 2025*" and has been involved in 2016 mandate itself. Interviewee "A" pointed that such mandates are usually there to set an overall direction for the industry and facilitate change, rather than to aim for the 100% accurate compliance (A-7).

Following-up to that point, interviewee "B" who was also involved in development of BIM Level 2 said that

> *"…The mandate was for the 6 key departments: **Environment Agency, Ministry of Justice, Highways England, Ministry of Defense, Department of Health, Department of Education**. And they have all achieved targets, by the key date".*
> (B-20)

Generally, it is not typical for UK Government to impose the mandates in the first place, but Interviewee "A" explained why the situation with BIM is an exception:

> *"It is very unusual for the Government to mandate change in the industry. But the advantage that Government have in Construction is that the Government is the client for 40% of the industry. Government got a purchasing power. As a client, it can dictate the terms. While in other sectors, like agricultural or automotive, the Government is not the client, so cannot make the changes happen though its purchasing power".* (A-9)

- Code: BIM Adoption

Interviewee "B" mentioned that since 1934, Government tried to implement a large amount of improvement programmes, including the Eagan and Latham reports, but most of them failed. However, BIM is different because "*central government have kept their shoulder behind the initiative. Now we have created what BIM level 2 is, we have created the standards, the key public sector procurers, that are now using it*" (B-21).

With all the standards in place, the 6 government departments have made massive improvements in BIM (B-22). Interviewee "A" has been positive about the adoption of BIM, saying that "*it is just the matter of time, a few years, before the only way in which we design will be BIM*" (A-15).

Main Challenges of BIM implementation

Now, the study is focusing on the challenges with BIM implementation, based on the primary research. Most often interviewees have been highlighting the factors related to "Non-Collaborative Culture", which restricts knowledge-transfer, innovation and change. This fact was very unexpected and should be considered as the main finding. The issue of culture has been raised at least ones by each interviewee, while the issue of culture was supported by 30 quotations, which is more than any other topics.

- Code: Low-Margin Business Model Leads to Non-Collaborative Culture

Some interviewees believed that construction industry is not collaborative because of the business model, where the profit-margin is very low, while uncertainty is very high:

> *"I think the industry is slow to change, but one of the reasons is that there is a very low-margin. Contractors are going to make around 1 ~1.5 % of the project's cost."*. (B-24)

> *"The culture of the lowest tender price, it is a big motivator for people to act in a very old-fashioned way"*. (E-10)

Therefore, interviewees believed that for consideration/profits that contractors get, the risks are too high. The uncertainty is high as well, so contractors need an innovative, collaborative and organic organisational structures. Whereas on practice low-profit margin have affected the industry on a cultural-level, making it very fragmented. Interviewee "E" said that "*lots of the problems arise because of the contract structure*" … "*if you are working to a lump sum contract, your aim is simply to minimise your costs*" (E-11).

- Code: BIM being implemented, but to minimum requirements

Because contractors tend to minimise risks, "*BIM is being applied only as a formality, while benefits are not realised*" (D-2). Moreover, both interviewee "D" and interviewee "E" said that requirements of Level 2 are very basic and doesn't make a big difference and should be more specific (D-3; E-12).

- Code: Underestimating importance of culture

The culture is very important, but is being underestimated: "*The government have established the BIM task force...That was good and necessary. However they helped to change the process, but no one helped to change the culture*"(H-10).

Furthermore, interviewee "H" added that "*…according to experience that I have got on the technology-enabled change, a part of it is about technology, may be 10%. A part of it about changing processes, maybe 20%. The rest is about changing*" (H-11).

- Code: Supply Chain Refusing to Change

Because culture is not being tackled, people are not willing to change. For example Iinterviewee "B" said,

> *"People are operating in an environment that has been good for them, and they can still feed from traditional pool for a while, but the interest starts to drop. So those members of supply chain that didn't move to a different mode, are going to be cut out". (B-26)*

Similar opinion has been raised by interviewee "D" - "*It is very difficult to change the industry that have been operating in decades using the same approaches*" (D-4). Moreover, private sector clients often do not realise the benefits of BIM. Interviewee B further mentioned that *"we are still in the position, when clients ask for something, but actually they are still asking for BIM*" (B-31), without realising it.

Discussion

In this section, the 4th stage of data analysis is being applied, which is “**Theorization”** as have been explained earlier in Figure 5**.** The primary data is being compared with literature and discussed further.

After analysing primary data, we have identified that the majority of problems mentioned in the literature review regarding the traditional approach to project management does take place. This includes problems regarding the dis-integrated working process. More specifically diversity of stakeholders and “silos-working”, no common understanding of the end-goal, and delays regarding virtual working. The problems concerned with poor front-end definition and poor knowledge transfer have been also raised by interviewees, similar to literature review. Moreover, the benefits of BIM to collaboration mentioned during the literature review have also been supported by the interviewees. Both sources of data agreed that BIM brings an integrated working platform and improve transfer of knowledge among the parties.

Bridging the Research Gap: Cultural Barriers for Change

As already mentioned in the research gap section during the literature review there was a gap in the "body of knowledge" regarding challenges of BIM implementation. This is why it was decided to apply Sub-Question 3[2], and obtain primary information. Primary research identified a number of problems, where some were related to the capabilities of supply chain, some were more technical problems such as data security. However, the main finding is related to Culture, as interviewees have been highlighting non-collaborative culture as main challenge inhibiting the full implementation of BIM, moreover it was the issue most often referred to.

As it was shown through the paper, benefits of BIM are obvious. Actually, if we look in detail at the challenges of implementation, they all arise because of the cultural assumptions within the industry. This finding was unexpected, prior to commencing the research. When we speak about the implementation of BIM, it should be defined as a "*change driven by technological innovation, while promoting collaboration*" (see quotation H-11). Therefore, additional literature has been researched, to reflect on the cultural change and innovation.

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[2] Sub-Question 3: What are the main challenges/problems with BIM and its implementation?

Cultural Elements

Organisational Culture can be defined as "*a pattern of shared basic assumptions learned by a group, which have worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think and feel in relation to those problems*" (Schein, 2010). The culture contains four elements: **artifacts, norms, values/beliefs**, and **underlying assumptions** (Cummings and Worley, 2014). They are best described by the "*Iceberg Model*" (Schein, 1985). The visible part is at the tip of the iceberg, which can be seen and is easy to change. The other part is not easy to spot, and even harder to change:

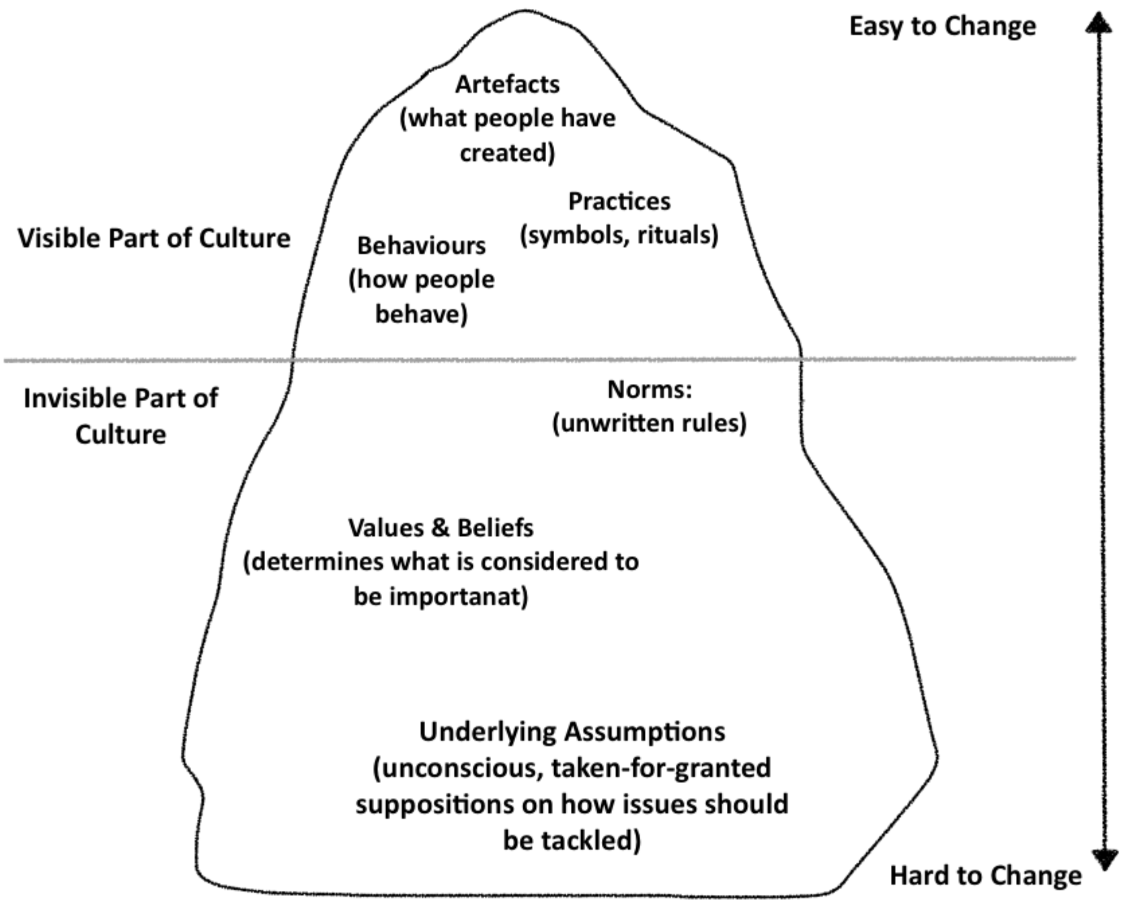

Figure 6: Iceberg Model (Schein, 1985)

The resistance is absolutely normal (Coghlan, 1993) and it is the part of human nature to maintain the "*status quo*". Change is affected by the tension of forces, because different stakeholders have different expectations (Lewin,1947). Based on the reflections offered by those interviewed, the culture of the construction industry is formed in a way which inhibits collaboration, and this in turn affects innovation. Eagan (1998) stated that construction industry's performance indicators concerning innovation are not efficient. The reason lies in the way construction parties interact (Dubois and Gadde, 2002), meaning that collaboration is crucial for innovation.

BIM is about collaboration and there are barriers in the form of cultural elements presented in the Iceberg Model. As mentioned by interviewee "H" (*H-10*), the efforts have been shown to "*change the process, but not the culture*". Many interviewees not directly, but in the core of their quotes mentioned that currently change is tackling mainly the artefacts. In our case the **artefacts** are 3D models. Interviewees complained that industry is only willing to improve CAD characteristics, while the collaboration is not being improved, because invisible part of the iceberg is not being tackled. Because culture is not taken into consideration, people refuse to change based on the Primary Data (D-4; B-26). Industry has "*operated for decades using the same methods*", so has developed '**norms'** (H-11). It is impossible immediately implement BIM, and make people accept it.

"Highly-Uncertain Project Environment ***vs*** Low-Margin Business Model***"***

Now have reached an interesting point. Literature says that *'highly-uncertain project-environment'* requires collaboration, continuous innovation and organic structure (*Burns and Stalker, 1961*), to achieve a high level of efficiency. While primary data suggest that because of *"low-margin business model*" stakeholders have to minimize all possible risks (B-25; E-10). So, the business model does not match its environment. Thus, collaboration is restricted, which leads to lack of innovation and fragmented structure. Figure 7, was developed to illustrate the impact of combined

"*Highly-Uncertain Environment*" and "*Low-Margin Business Model*" on the overall efficiency. The illustration on the left demonstrates an actual situation, while the illustration on the right demonstrates an "*ideal world*":

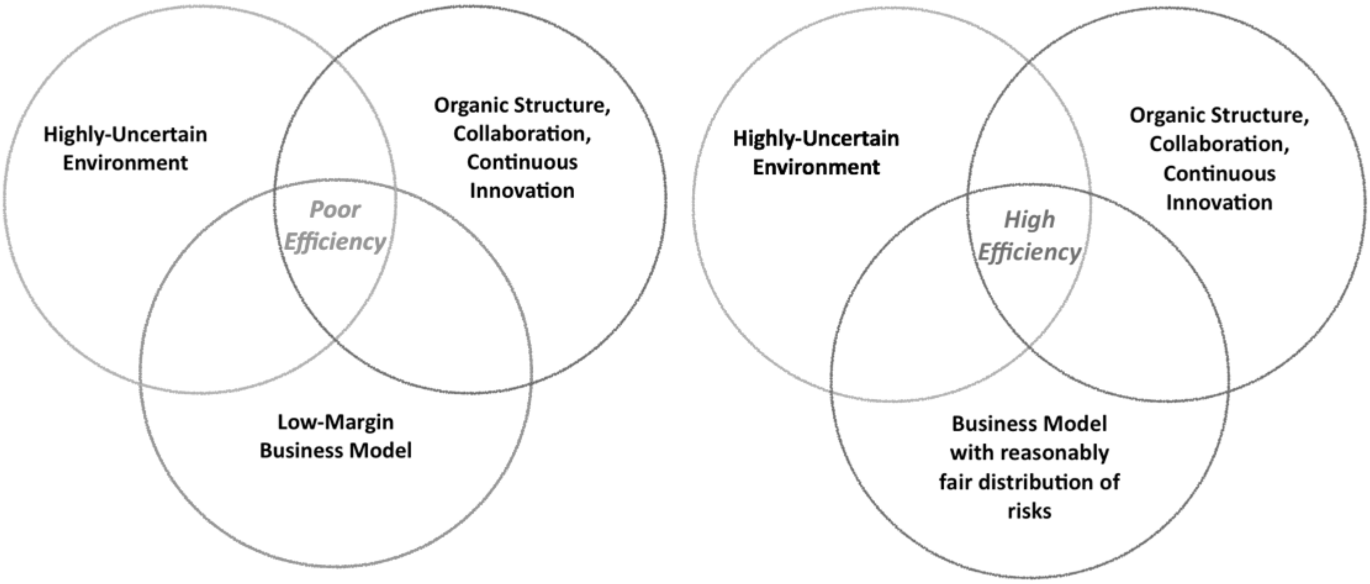

Figure 7: Highly Uncertain Environment vs Low-Margin Business Model

So, the business model within construction, resulted in non-collaborative '**values & beliefs'**. Because of high uncertainty, contractors tend to minimise the risks and win the tender by any means, including the provision of a "*false*" tender price to the client (B-6). While clients are also affected by the values & beliefs, because they aim to choose the "*lowest tender, without taking final costs into consideration. Thus, culture is non-collaborative from the both sides*" (F-1).

The '**underlying assumptions'** located at the deepest part of the culture. They underpin people's feelings in different situations and they are the hardest to change (Schein, 2010). As already mentioned by interviewee "B", since 1934, lots of improvement programs failed as soon as government reduced control (B-21), because processes may have changed, but cultural assumptions didn't. The same can be said of BIM, if people wouldn't be willing to the change, change wouldn't succeed (Carpenter, 2013*)*. We need to get "*hearts and minds, to get willingness*" (H-12).

The researcher reaches the conclusion that it’s not BIM that should be the focus of change, it should be the culture. To change the culture, it is important to consider the Schein’s (2014) model, with “*Three Principles of Cultural Change*”. Current research recommends the industry to considered these points as foundations for developing the next steps of BIM Implementation:

- **Proposition 1:** “Change should be defined correctly, in terms of a desired goal”

In current situation, the goal should be to improve collaboration, not to implement BIM at the minimum requirements. If people are willing to collaborate, they are then willing to use BIM. Collaboration should be clearly defined as outlined in the *Figure 1*.

- **Proposition 2:** “Old cultural elements can be destroyed by eliminating people who “carry” those elements. But new cultural elements can only be learned if new behavior leads to success”.

Therefore, some industry bodies might not be able to adopt changes, due to their financial model, organisation structure, or even their age. For example, “*some older architects are not willing to work with BIM”* (A-14). In such cases, these members of supply chain will eventually be eliminated (B-26). Because the context is on an industrial scale, this is only likely to happen when the next generation replaces the current one (A-15). The second part is about ensuring that collaboration brings success. This should be done by educating/training younger generation from the very beginning.

- **Proposition 3:** "Cultural change is always a transformative change, which expects a period of unlearning, that is psychologically painful".

Sometimes change is about not resisting the learning of new things. In the case of construction, the industry has developed routines and processes that have become norms. The new approaches, such as BIM seems inadequate. People "*can still feed from traditional poo*l" (B-26) so we are in a transition. Unlearning is partly facilitated by mandates, but another way to tackle the norms is through changing contracts, because people then should "*comply with the new processes*" (F-3) , such as the **New Engineering Contract 4**, which "*almost requires*" collaboration (H-13). People then start to see benefits of collaborating, while BIM is a tool to facilitate it even further. Change can be effective only when people embarked upon it of their free-will (Lewin 1947).

Implications for Practice and Research

Practical Recommendations

Below are the recommendations to industry bodies, which should be applied in consideration with the "*Three Principles of Cultural Change*", mentioned earlier (Schein, 2010). During the primary research, many interviewees mentioned that BIM implementation needs more time. As already said by interviewee "A" - "*it is just the matter of time, a few years, before the only way in which we design will be BIM*" (A-15).

However, construction has traditionally been facing difficulties in adopting innovations. There has been a number of improvement programmes in the past, which have not been successfully implemented. For example, the ideas from Eagan and Latham reports (see quotation B-21). Therefore, considering the nature of the industry, there should be a leadership to "walk" the industry through this change. Based on the primary and secondary data, the government has all necessary capabilities to successfully facilitate this change. As identified, the government is the client for ~ 40% of industry (see quotation A-9) and has an ability to play the role of a "change-agent". Comparing to industries such as agriculture or manufacturing, in construction the government has a high purchasing power and therefore high influence. Some of the problems with the adoption of BIM mentioned by the interviewees were as follows:

- Private sector clients have little or no motivation to use BIM or do not fully understand the benefits (B-31)
- Smaller segments of the supply chain refusing to change due to culture (D-4; B-26)
- Not enough qualified workforce to deliver BIM capabilities (E-3)

Overall, the above problems are concerned with the private sector. Whereas in the public sector, the BIM level 2 Mandate has targeted 6 Government departments (see quotation B-20). All of these departments have achieved the capability to deliver BIM, while some of them are even going beyond the minimum Level 2 requirements (see quotation B-22). This is most likely to happen, because people are starting to realise the benefits of innovation. Thus, the interventionist government strategy appears to be working.

Because of the government's involvement up to date, the industry now has clear standards and common terminology, which is actively being used. So, people are "*speaking the same language*" when it comes to BIM. By taking the lead, Government is setting an example (see quotation A-7) and it brings results. Most of interviewees believed that it is just a matter of time until the private sector will start to actively use BIM (see quotation A-15).

Nevertheless, the change cannot be effective, unless it is desired by all parties. This is about collaboration and people should be willing to change. At the moment, we are in the situation similar to "*turning a supertanker*" (see quotation A-7), which cannot be done at one go. Government can point the direction and provide favourable conditions (terminology, standards, regulations), but people are the ones who should take actions.

It would be a massive support if professional bodies and higher education become involved. As mentioned by Interviewee E, "*We need to have a better educated and informed workforce, from the ground-up. Not just the executives*" (E-3). Therefore, such institutions as Royal Institute of Chartered Surveyors could require to include BIM- and collaboration- related modules into the structure of universities' modules, in order to awards accreditation. This will help to increase the amount of qualified workforce to deliver BIM and to promote the concepts of collaboration among younger generations. Furthermore, the industry could tackle the contractual structure. It is important to outline from the very beginning that parties are expected to collaborate, which was done in the "**New Engineering Contract 4"** standard templates. It is recommended to develop ideas from NEC4 even further to facilitate collaboration. People should be encouraged to collaborate.

By doing the above, the "*tip of the iceberg*" is going to be impacted (artefacts & norms), eventually making people realise the benefits and change their Values/Beliefs. This can promote new, more collaborative culture. Nevertheless, some big members of supply-chain representing an "old-culture" will eventually be "cut-out" (B-26).

Recommendations for Further Research

It is suggested that further research should look deeper into the Schein's (2014) ideas, regarding the cultural "iceberg" elements (artifacts/norms/values/assumptions), in relation to construction industry, and more specifically collaboration. There are many strategies for cultural change, but because of massive scale, we suggest to look at the "***grand technocratic model***" (Alvesson and Sveningsson, 2008), which contains the following:

1-Evaluating the situation/determining goals

2-Analysing the existing culture and sketching a desired culture.

3-Analysing the gap between what exists and what is desired.

4-Developing a plan for developing the culture.

5-Implementing the plan

6-Evaluating changes, making efforts to go further and/or to sustain the cultural change.

It will be relevant to apply these steps and develop a strategy for cultural change within construction industry.

Conclusions

After studying the relevant literature on collaboration, project-based organisations and BIM, as well as conducting a set of interviews with industry professionals, and subsequently analysing the data, we were able to compile the following findings. The main research question addressed: "*To what extent can BIM facilitate collaboration within the construction industry*"? The direct answer to this is that BIM definitely has the potential to facilitate collaboration. The benefits of BIM for collaboration are obvious, based on the findings from this study. BIM can provide better utilization of information, integrated working platforms, clear evaluation, lifetime approach and increase the overall efficiency. However, there are problems related to the implementation of BIM. The reason is that cultural elements within the construction industry restrict any form of collaboration. Therefore, the main focus should be on changing the culture, making it more receptive to collaboration. As this is being achieved, BIM should be considered as a tool to enhance this collaboration further. If the culture remains non-collaborative, as it is now, BIM will continue to face the same difficulties during implementation, despite all of the benefits it offers. On the other hand, if these cultural predispositions can be overcome and a more collaborative norm can be established, then this would accelerate the implementation of BIM. Thus, by tackling the culture, industry will "*kill two birds with one stone*".

Overall, construction constitutes one of the oldest and one of the biggest industries in the world. The responsibility that industry professionals shoulder, is huge. They have a very significant impact on the way the modern world is being shaped. The results of construction projects permeate every aspect of our lives and can be seen in the form of the state-of-art buildings, the infrastructure of contemporary cities, winding highways, highly-efficient power stations and further multiplicity of developments that have a crucial impact on the whole of humanity. Concluding the current thesis, the researcher again wishes to specify the importance of developing and facilitating collaboration, as well as promoting the values of collaboration on a cultural level. By improving collaboration, the efficiency of construction projects can be increased and therefore offer tremendous benefits for our planet.

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