

Cambridge Centre
for Housing &
Planning Research

Understanding the socio-economic inhibitors to the take up of digital innovation in construction

State of the nation sector report

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1. Introduction

It is widely believed that while most other industries have taken advantage of digital innovations over recent decades, the housing and construction sectors have been reluctant to fully embrace the latest technological opportunities.

Labour productivity and production processes have not seen the improvements that could be expected, given the developments across the broader digital landscape. A diverse range of internal and external barriers to digital innovation have been identified by existing research, including fragmentation of the industry, inadequate collaboration with suppliers and contractors, a lack of vertical and horizontal integration, lack of an appropriately skilled and trained workforce, and insufficient knowledge transfer from project to project.

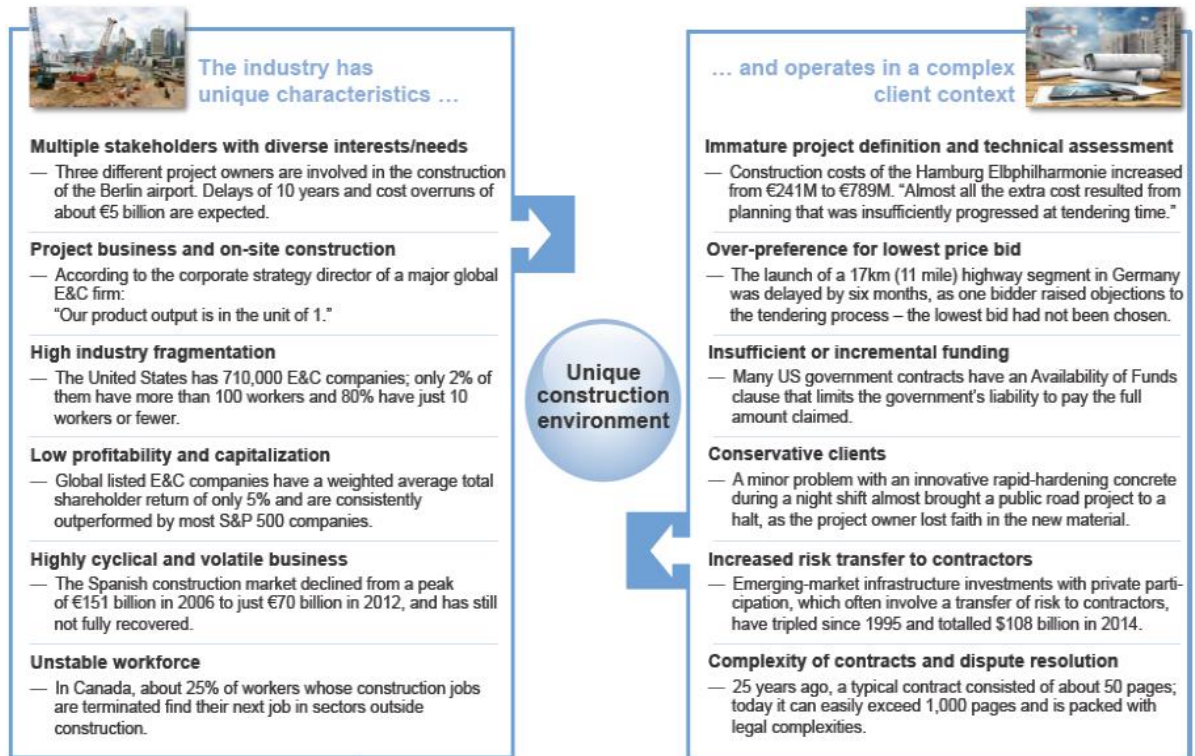
This report will lay out the nature of the UK construction industry and highlight the challenges it is facing. It will discuss the megatrends of digitalisation that are likely to impact upon construction globally and locally and identify the need for the digital transformation of the UK construction industry. Then, it will elaborate on the non-technical barriers to an industry-wide uptake of digital technologies in the UK.

1.1. Fragmentation of the UK construction industry

The inherent complexity and unique characteristics of the construction sector have been highlighted in wide-ranging literature and reports (for example, see Figure 1). The UK construction industry is, and always has been, varied and complex and, since the 1950s, the modern construction industry has become increasingly fragmented. This development has resulted in "poor performance, low investment, poor skills and a lack of innovation"; design, build and procurement routes have become more complicated; and there is complexity in building processes (Designing Buildings, 2018)¹. It tends to prevent single contractors from carrying out all necessary work and having all the required skills - contractors have to employ subcontractors to complete the construction.

¹ Fragmentation of the UK construction industry, Jun.2018

Figure 1 Characteristics of the construction environment



Source: World Economic Forum (2016); The Boston Consulting Group

A report published by EC Harris in 2013 suggested that, for a large building project in the £20 - £25 million range, the main contractor may be directly managing around 70 sub-contracts of which a large proportion had a relatively low value of £50,000 or less.² Construction 2025³ highlighted a high degree of fragmentation in comparison to other sectors but also in comparison with the construction sectors in other countries, such as Germany, France and the USA. The UK has a higher level of subcontractors driving the relatively high proportion of self-employment and a high number of small and micro-businesses. The Government Construction Strategy 2016- 2020 (published in 2016)⁴ reported that the industry was dominated by a staggering 956,000 SMEs, which accounted for 99% of businesses. Construction 2025 indicated that the "industry's customer base was even

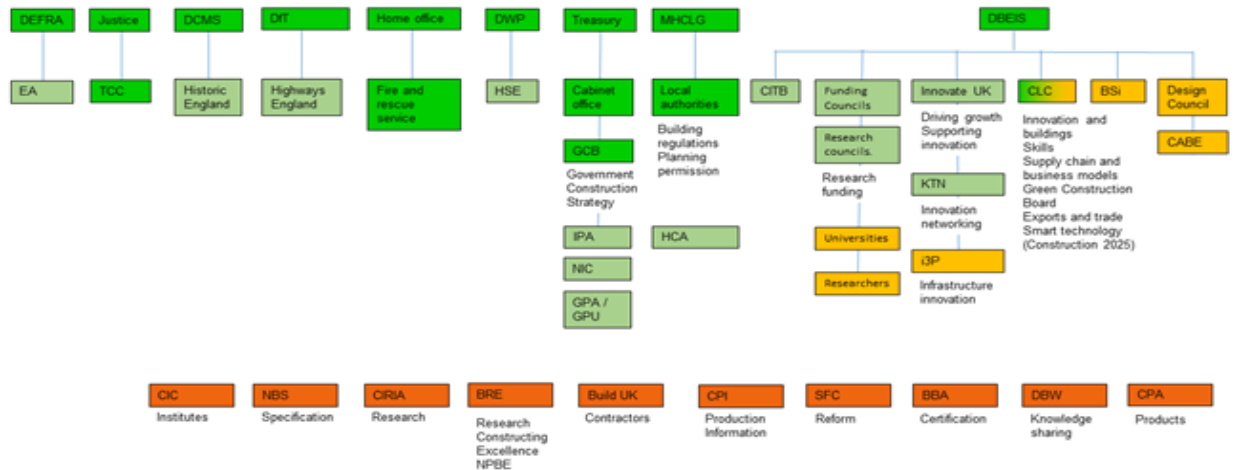
² EC Harris for BIS (2013) Supply Chain Analysis into the UK Construction Sector

³ Construction 2025, HM Government, Industrial Strategy: government and industry in partnership, July 2013

⁴ Government Construction Strategy 2016-20, March 2016

more fragmented, with much of the industry's workload coming to it on a one-off, piecemeal basis" (Designing Buildings 2018, P.2)⁵.

Figure 2 A snapshot of the structure of the UK construction industry 2018

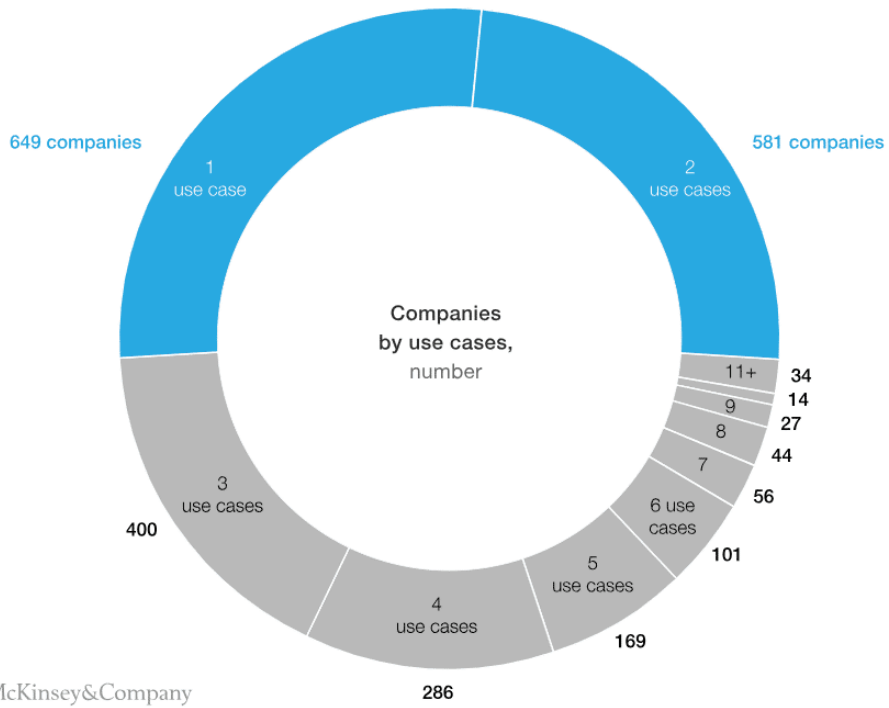


Fragmentation of the UK construction industry, Jun.2018

Fragmentation is not limited to the construction industry, but also could be observed across use cases with more than half of companies addressing one or two use cases (See Figure 3). In the construction technology ecosystem, there are four main constellations of a connected digital solution emerging around established use cases which indicates what technology and digital innovation are receiving more attraction. "The four constellations encompass 3-D printing, modularisation, and robotics; twin models; and artificial intelligence and analytics; and supply chain optimisation and marketplaces. Within each constellation are three or more use cases that span the three use case clusters, including back office, digital collaboration and on-site execution"(Blanco et al. 2016, P.1) ("McKinsey & Company: Pushing the construction technology ecosystem to new limits," n.d.). Each constellation could contain different use cases. For example, digital collaboration use case includes laser scanning, virtual reality and design simulation. Only a few companies engaged a technology solution that addressed more than one of the three clusters. It shows that most companies taking part in digital solutions dealt with a particular, narrow application rather than more integrated solutions.

Figure 3 Use cases

⁵ Fragmentation of the UK construction industry, Designing Buildings, Jun 2018



1.2. Adversarial behaviour in the UK construction industry

The construction industry is characterised as being adversarial; that is, it often involves confrontation, opposition, dispute and conflict between parties. Across the supply chain, conflicts have been identified, aptly captured by the National Audit Report that there “is a tendency for an adversarial relationship to exist between construction firms, consultants and their clients and between contractors, sub-contractors and suppliers” (NAO, 2011, p.4)⁶.

Contradictory supply chain relationships also impact the uptake of new methods and skills. There are several reasons for the inherent adversarial feature of the industry. The one-off nature of construction projects can mean that project teams are unlikely to work together repeatedly, preventing the development of relationships and trust. In addition, professionals in the industry tend to work in silos without cross-disciplinary collaboration or interaction. The traditional procurement route means that discrete actors (designers, contractors, suppliers and clients) often only link through legally-defined, reciprocal contractual relationships.

As a supply chain extends and engages with an increasing number of contracts, it frequently becomes a threshold of conflict, something which may be exacerbated by dispute resolution through the UK legal system, inherently adversarial itself, rather than through more informal, innovative and collaborative methods (Designing Building, 2019)⁷. Traditional forms of contract do not always allocate risk fairly between parties, setting an adversarial tone. It has been noted that “inertia is prevalent in the industry and embedded cultural behaviours are difficult to change” (Designing Building, 2019, P2). Moving away from the preceding norm would require a significant cultural change.

⁶ National Audit Office, Modernising Construction, January 2011

⁷ Adversarial behaviour in the UK construction industry, April 2019

2. Megatrends: the impact on the construction industry

Construction firms are increasingly faced with a plethora of changes at environmental and structural levels in addition to challenges posed by the organisational characteristics of these firms (Shibeika & Harty, 2015). Four megatrends have been identified as having a significant impact on the construction industry globally. These relate to: markets and customers; sustainability, society and workforce; and politics and regulation (Figure 3). The industry needs to examine these megatrends and apply the most favourable responses to them while considering the opportunities they propose and simultaneously the challenges they impose (World Economic Forum, 2016).

Figure 4 Megatrends: shaping the future of the construction industry



Source: Press reports; World Economic Forum; The Boston Consulting Group

2.1 Markets and customers

Demand for housing and infrastructure has been rising, and the construction industry needs to identify the technological advances which will help the UK to build in a faster, cheaper and high-quality way. The fact that the industry is affected by a high degree of fragmentation prevents it from making the most of the advantages that innovation can bring. In this market,

those companies with the ability and determination to adapt their business model to new markets will survive. Ageing infrastructure is one of the challenging issues that the construction industry is facing. It is impossible to fill the infrastructure gap with public funds alone, and private capital is required, and private-public partnerships are one of the construction industry trends.

2.2 Sustainability, CO₂ emissions reduction and energy conservation in buildings

The importance of sustainability has transformed into an essential, rather than an optional, characteristic of construction both in terms of the built asset usage and the actual construction process. Currently, it has been reported that 10% of UK emissions are associated with the manufacture and transport of construction materials (Uponor, 2019). With the UK government targeting an 80% reduction in carbon emissions by 2050, the pressure for those involved in the delivery of construction projects and management of built assets to be sustainable will only increase (HM Government, 2018).

Even a small imperfection in construction can have remarkable implications in achieving the level of energy standards predicted. "There may need to be considerable changes in attitude to new construction techniques, accompanied by an understanding of the impact of actions and inactions by an individual on the final energy certificate" (SAMI, 2008, P2). Given that the construction sector produces a huge amount of waste, using and recycling raw material efficiently, even a small improvement, can generate an enormous benefit. (Industry Agenda Shaping the Future of Construction A Breakthrough in Mindset and Technology Prepared in collaboration with The Boston Consulting Group, 2016)

2.3 Society and workforce

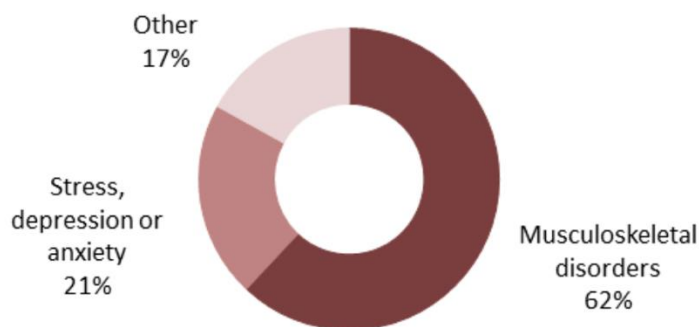
Growth in the UK's urban population has led to an increasing need for affordable housing in urban areas, which traditionally face barriers such as land scarcity and insufficient, inadequate infrastructure. Furthermore, the UK is currently facing another demographic challenge in the form of a shifting age profile.

The growing proportion of older adults in the UK has affected the construction industry in two key ways. Firstly, it generates a need to provide appropriate accommodation for the ageing population. Secondly, this ageing demographic profile proposes that special measures will be demanded to maintain sufficient numbers of new recruits into the industry. The provision of training at all levels in the industry will be needed to meet future skills requirements. Furthermore, new technologies require a highly skilled workforce, and this

creates opportunities for the construction industry to change, recruiting new digital talent and investing in training and education for the current workforce.

Statistics in 2019 in the UK construction sector indicate 79,000 workers suffering from work-related ill health and 62% were musculoskeletal disorders. In addition to physical injury, almost 16000 work-related cases of stress, depression or anxiety are reported (HSE, 2019).

Figure 5 Work-related ill health in the construction sector



(HSE, 2019)

The construction industry should consider the health and safety of workers and end-users of the products who live or work in the buildings.

2.4 Regulation

The construction industry faces several challenges linked to regulation, bureaucracy and instability. Regulation is deemed to be one of the most fundamental and significant stimulators of complexity in the construction industry, playing the role of both barrier and enabler. Governmental regulations and the provision of incentives have been recommended for some time (Smith, 2000). "The industry is especially affected by changes in health and safety requirements, financial and labour legislation, and environmental standards. New regulations in any of these areas can affect business operations adversely. If designed thoughtfully, however, regulation can prove advantageous to companies." (World Economic Forum Report, 2016, p.14).

3. UK construction trends for 2020

The emergence of technology constellations constitutes a radical change to the scenery in the global construction industry. The UK government has a national strategy, Construction 2025, emphasising that the industry must be more efficient and technologically advanced. It includes the goals of a 33% reduction in the initial cost of construction and a 50% reduction in the overall time, from inspection to completion, for new build (HM Government, 2013).

The UK construction-specific trends which may have a significant bearing on the future of UK construction are listed as below.

Building information modelling

BIM technology has led to a fundamental transformation across all stages of construction projects and has been defined as the process of generating, storing, managing, exchanging, and sharing building information in an interoperable and reusable way (Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013).

Modern Methods of Construction and Prefabricated Buildings

The UK government has prioritised the use of offsite manufacturing and other modern methods of construction to improve the cost-effectiveness, productivity and speed of construction delivery. The government vision is to transform construction into "a sector that can build new homes in weeks – and even days – rather than months; that can deliver new buildings at a third of the cost;" to provide affordable, energy-efficient homes (Industrial Strategy Construction Sector Deal, P.3). Offsite manufacturing and digitalisation are two key areas for reaching the preceding goals.

Besides, the trend towards prefabrication or offsite construction will continue to increase as a result of Brexit. The uncertainty around Brexit, accompanied by ambiguity over careers within construction, has put a squeeze on skilled plumbers and heating engineers entering the market. Prefabrication is the ideal solution for this situation, as it reduces the amount of labour required, decrease cost and enhance the probability of delivering a project on time (Construction trends in 2019 | Uponor).

Information and Communication Technology (ICT)

The current trends towards greater adoption of integrated information systems seem likely to continue, particularly in innovative circumstances. Professionals in the construction sector need to uptake ICT to integrate design, construction, logistics and manufacturing (SAMI, 2008).

Green Construction Methods

The Government set an ambition for the construction sector to deliver a 50 per cent reduction in greenhouse gas emissions in the built environment. Adopting new technologies is vital to improve energy and heat efficiency, which will help reduce carbon emissions and tackle fuel poverty.

In order to go ahead with the government plan, BREEAM (Building Research Establishment Environmental Assessment Method) was created as a sustainability standard within the industry. The government has now set targets around projects meeting this stamp of approval.

Smart Home technology

As reported by IHS Markit, the global smart home market is set to increase by 250% between 2017 and 2019. This growth has been fuelled by growing technology and customer preferences towards automation and being able to control lighting, heating and TV from the touch of a button. Recently, the Building Research Establishment (BRE) launched the Centre for Smart Homes and Buildings (CSHB) to aid the UK housebuilding industry and promote the installation of smart technology in homes.

Virtual Reality

The construction industry is beginning to pay more attention to this area and take note of the benefits it can have. For example, in the housing market, JLL and Balfour Beatty have begun experimenting with headset technology which allows designers and developers to predict and dimension objects within a home.

3.1 UK companies involved in digital transformation

UK Digital Construction Week 2019 provided an opportunity for key players in the digital transformation market to profile their products and services. At the exhibition, participating companies are categorised into five streams:

3.1.1. Geospatial technology

Geospatial technology is seeing a change like never before and, in the digital world, a precise understanding of the physical environment is essential for improving project management and delivery. It allows actors to understand better, plan, predict and deliver construction projects through greater access to, and improved analysis of, data to help solve some of the

many challenges found in the built environment. Geospatial technology encompasses photogrammetry, the connected site, data management, remote sensing, GIS mapping and Data Capture, laser scanning, and GPS and satellite technology.

Example organisations: Datumate, GroupBC (Business Collaborator Ltd), Topcon Positioning Systems (Great Britain) Ltd

3.1.2 Building Information Modelling (BIM)

BIM plays a role as a facilitator and enabler of many other technologies that enhance the quality and safety of construction.

Example organisations: Allplan, 4PS Construction Solutions Ltd, Elecosoft plc, BIMObject, Paperless Construction, ActivePlan

3.1.3 Visualisation

Visualisation technology includes innovative technologies such as 3D modelling, mapping and rendering, as well as virtual, augmented and mixed reality. These allow actors to see and interact with projects, offering greater insight and understanding of the physical environments, before, during and after construction.

Example organisations: ALICE Technologies Inc, Igloo Vision Ltd, One Creative Environments Ltd, Revizto

3.1.4 Industry 4.0

Industry 4.0, which includes the Industry Internet of Things (IIoT), is a new way of delivering a better, more efficient and ultimately profitable construction process, through improved interconnectivity. It encompasses modern methods of construction, offsite manufacture, prefabrication, advanced engineering, additive manufacturing, robotics, materials, and plant. "In recent years, Industry 4.0 has been introduced as a popular term to describe the trend towards digitisation and automation of the manufacturing environment." (Oesterreich and Teuteberg, 2016, p.121)

Example organisations: Builderbox, Build Safe, Cloudalize, RPC UK Ltd

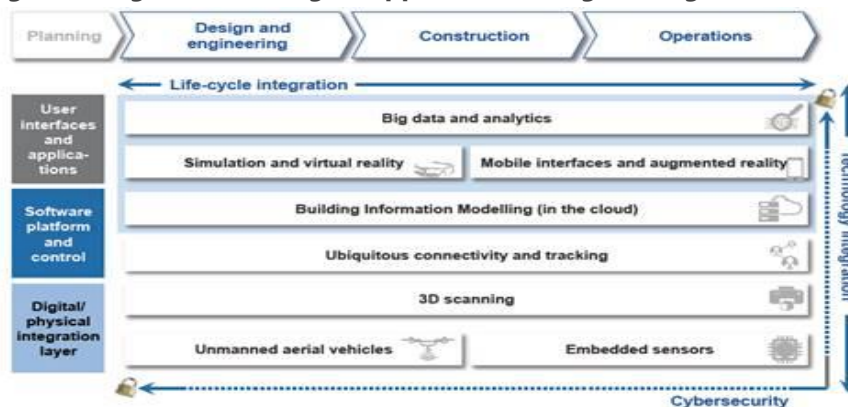
3.1.5 Skills

Having a workforce with the necessary skills is a crucial element to the successful digital transformation of the construction industry. According to the Government's 'Construction 2025' strategy document, attracting, developing and retaining a talented and diverse workforce is one of the five key aspirations for UK Construction.

Example organisations: Construction Industry Training Board (CITB), BSI Group

Above mentioned innovations enable new functionalities along the entire value chain, from the early design phase to the very end of an asset's life cycle at the demolition phase (See Figure 6). Each of these innovations such as BIM needs to be implemented through the entire project lifecycle (Shibeika & Harty, 2015)

Figure 6: Digital Technologies Applied in the Engineering and Construction Value Chain



Source: World Economic Forum; The Boston Consulting Group (2016)

4. Internal challenges

Productivity improvements in the UK construction industry have been negligible to date when compared to those in other industries. Due to being slow in adoption innovation, emerging technologies have not yet created significant change. Several underlying causes have been attributed to such a disappointing performance, including (World Economic Forum Report, 2016);

- Lack of innovation and delayed adoption

Research and development (R&D) are vital to ensure that industries remain productive and progressive. The construction industry operates as a project-driven business, meaning that where long term benefits require current investment, e.g. through R&D, these costs cannot be incorporated.

- Production process and procurement

The implementation processes usually pursued by construction companies suffer from a lack of meticulousness and consistency. It is prevalent in the industry to focus more on the final product rather than the execution process.

- Lack of vertical and horizontal integration

The conventional construction process is generally sequential, reflecting the input of the project owner, designers, constructors and key suppliers at different stages of the project. This current setup hinders the knowledge of stakeholders along the value chain to be completely deployed from the early stage in the design and planning process.

- Insufficient knowledge transfer

"A site and project-specific culture do not support innovation being carried forward from one project to the next" (SAMI, 2008, p.10). However, the more standard processes of construction are replicated in their requirements from project to project, and there are opportunities for useful lessons learnt to be applied to future projects.

- Weak project monitoring

When compared to many industries, the construction industry has relatively under-developed monitoring systems and quality checking processes. Manufacturing industries, for example, consistently track their operation systems and detect faults.

- Institutional and organisational culture

Relative to the companies in other industries, construction companies are conservative and prefer to pursue their own, traditional ways. Looking at construction projects shows little change in the construction process over the last fifty years.

- Shortage of young talented and digital specialist workforce

The construction industry struggles to attract young people. It needs to work towards ensuring the current and future workforce has the right digital skills. This has implications for business leaders, who need to be equipped with the requisite skills and knowledge to implement digital technologies, processes and competencies in their business.

The challenges mentioned do not imply that the industry is inherently capable of reform. The construction industry is capable of transformation despite them, and change is dependent on the commitment of stakeholders.

5. Socio-technical, cultural and economic barriers to wider uptake of digital innovation

This report discusses barriers to BIM adoption as a representative of inhibitors to the broader uptake of digital innovation. BIM is selected among all types of digital innovation for two reasons.

Firstly, BIM is one of the most promising technological developments for the Architecture, Engineering and Construction sector and plays a fundamental role as it is the key enabler of and facilitator for many other technologies. Secondly, The UK government is mandating the use of BIM in large public projects by 2016. As a result, engineering firms are encountering challenges associated with embedding new technologies and related working practices for the digital delivery of significant infrastructure projects.

Previous research on BIM has raised the issue of adoption and recognised technological, legal, economic and social barriers. The result from meta-analysis research addressing the barriers to BIM adoption indicated that social barriers of BIM are the most important barriers to its widespread adoption. It concluded that “compared to the social barriers, purely technical rooted adoption barriers are rather rare and less critical” (Oesterreich & Teuteberg, 2019, P418).

Barriers to BIM implementation are grouped in four clusters encompassing structural dimensions, people dimensions, technology dimensions and task dimensions.

5.1 Structure

- Legal and contractual uncertainty
- Lack of demand
- Lack of awareness about BIM benefits
- Lack of government incentives and regulation
- Lack of necessity
- Non-widespread use

Regarding structural inhibitors, legal and contractual uncertainty is the most frequently cited inhibitor and lack of awareness about BIM along with lack of government incentives and regulation are the most significant (Eadie et al., 2013, Oesterreich & Teuteberg, 2019, Porwal & Hewage, 2013). Governments must offer clearly defined legal and contractual regulations

and create the macroeconomic situation within which the technological opportunities and capabilities of firms are shaped. Legal issues are discussed in the literature concerning the ownership of property and contractual arrangements.

There are several government initiatives supporting technological innovations, e.g. Industry 4.0, Internet of Things and Smart Manufacturing (Kagermann et al., 2013). Government involvement offers the opportunity for construction firms to be aware about new technologies by promotional schemes, subsidies and an appropriate legal environment (Moon and Bretschneider, 1997).

The lack of standards and interoperability is noted as a significant barrier for widespread BIM adoption in the construction sector since it concerns communication and collaboration (Eadie et al., 2014). Markus et al. (2006) highlighted that the diffusion of the developed standards must be ensured. This could be achieved by involving highly influential participants into the standard development process and by committing them to adopt later the standards, which may set an example for others. In line with this, the UK BIM Alliance has been established to support common understanding and provide a standard for all firms intending to use BIM.

There is an interesting point here that although clients benefit more from BIM implementation, the lack of their desire to apply BIM is one of the most important obstacles (Eadie et al. 2013).

5.2 People

- Resistance to change
- Lack of expertise
- Lack of skilled personnel
- Lack of training
- Lack of information sharing, collaboration and trust
- Lack of management support

Resistance to change significantly sets back BIM adoption. Information system literature usually expresses resistance as the normal but complex behaviour of individuals and groups towards the uncertainty and perceived negative consequences related to change. Peoples' preference to continue their old habits coupled with the fear of job loss can lead to various form of resistance to implementation (Hirschheim and Newman, 1988).

The level of resistance is also affected by the coherence between the presumed and actual organisational culture within the implementing organisation. The major dimensions of organisational culture contain the innovation and action orientation, the willingness to take risks, the autonomy in decision making and performance or reward orientation (Pliskin et al., 1993).

Lack of expertise and lack of skilled personnel, as well as lack of training, are among the major inhibitors which have an impact on the people dimension. Some early studies concentrated more on personal innovation adoption behaviour, which includes knowledge, persuasion, decision, implementation and confirmation processes (Rogers, 1962, 1983, 2003; Rogers and Shoemaker, 1971). Arendt (2008) also concludes that the lack of knowledge, education and skills constitutes the major reasons for the low level of information system adoption among SMEs. Later on, further studies explored the diffusion of more complex technological innovations like business processes or information systems in heterogeneous social systems such as organisations (Rogers, 1995, 2003; Ven et al., 1999). Such studies claimed that the innovation adoption process is more complex in organisations than among individuals (Shibeika & Harty, 2015).

Management support is essential for the introduction and implication of new technology; however, it is not easy for senior managers to recognise the monetary value of BIM implementation (Eadie, 2014). Arayici et al. (2011) report that a bottom-up approach is a more efficient mode of BIM adoption and dealing with the resistance to change better than a top-down approach.

5.3 Technology

- Lack of standards and interoperability
- Insufficient infrastructure
- Complexity of BIM
- Time-consuming adoption
- Lack of applicability and practicability
- Availability of BIM
- Poor quality of the model information

BIM technology is criticised for its complexity and its lack of applicability and practicability. Besides, the poor quality of model information has also been brought up as a technological barrier, but the importance of this barrier is comparatively low. According to the technology

acceptance model proposed by Davies (1989), perceived usefulness and perceived ease of use are the major variables that motivate users to employ an information technology or information system.

5.4 Task

- High investment costs
- Lack of proven benefits
- Lack of investment capital

Implementing BIM imposes costs to organisations and necessitates them to purchase the license of the software and train their staff in the use of that software.

The impact of this cost and the firms' attitude differs according to the financial status of the firm. In spite of existing case study research demonstrating the benefit of using BIM in reducing delays and cost (Aranda-Mena et al., 2008), the high implementation cost has been still perceived as a significant barrier (Eadie et al., 2014).

6. Research direction: towards widespread industry uptake

Despite various supportive governmental measures (implementation strategies, initiatives and BIM mandates), the overall digital innovation adoption rates are progressing more slowly than anticipated (NBS, 2016). The government mandates fail to have the expected impacts, which might result in the lack of required social climate and infrastructure or readiness (Venkatachalam, 2017).

Reviewing the literature revealed that less attention was given to the organisational structure and multiple adopting units within one firm. There is a need to conduct research on unbounded and mutating digital innovation, iterative processes over time, complex and changing contexts and the reciprocal interaction between digital innovation and organisation (Shibeika & Harty, 2015, P.454). Besides, most of the research mainly concentrates on providing quantitative results.

Therefore, the proposed research intends to employ a qualitative approach to elaborate on each inhibitor of the dimensions mentioned above and extract the reason for them by finding out each stakeholder's view. It also will examine the similarities and differences between the adoption barriers to BIM and other types of digital innovation.

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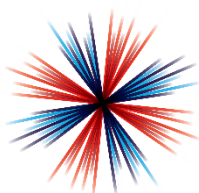
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