Build Digital

Digital Leadership & Cultural Change

International Best Practice in Digital Construction Adoption

www.builddigitalproject.ie

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Preface

The Build Digital Project intends to support the digital transformation of the Irish construction and built environment sectors. They will enable stakeholders, particularly SMEs, clients, and suppliers, to develop, maintain, and continuously improve their capabilities as digitally-enabled, standards-based, agile, collaborative, and sustainable participants in the delivery of Project Ireland 2040.

Build Digital, co-funded by the Department of Public Expenditure, NDP Delivery and Reform (PENDR), is one of the seven priority actions implemented by the Construction Sector Group Innovation and Digital Adoption Sub-Group.

A vital tenet of Build Digital is the adoption of a bottom-up approach where the voice of the customer is heard and acted upon. Build Digital has embedded over 50 industry members from across the construction supply chain within its five pillars.

Digital Leadership and Cultural Change, Pillar 1, will drive the cultural change required to realise the digital transformation of the Irish construction industry in support of innovative, effective, and sustainable evolution in mindset and practice. To achieve this, Pillar 1 will provide evidence and develop tools to assist the industry in its digital adoption journey.

Digital Standards, Pillar 2, will champion the benefits of common rules, guidelines, and workflows that facilitate the improvement of information flow and information management across full asset life cycles. Digital standards provide a common language that can be translated to technical specifications enabling clients, designers, contractors, and facilities managers, irrespective of their preferred tools, to communicate efficiently and reduce cost, rework, and disputes. To achieve this, Pillar 2 will develop tools with the assistance of the Digital Procurement pillar for the industry to better understand and work to standards

Digital Education and Training, Pillar 3, are key to the digital transformation of the Irish construction sector. Clients, managers, professionals, and all workers need to have relevant knowledge and abilities to collectively advance the design, construction, and life cycle management of the built environment. To achieve this, Pillar 3 will develop a comprehensive inventory of upskilling courses available for high-quality, consistent delivery across Ireland, supported by a wide range of professional bodies, representative groups, and public and private educational organisations.

Digital Procurement, Pillar 4, will bring national and international expertise on best practice in sustainable digital procurement and digital product supply chain practices to the forefront of the Irish sector. This pillar will drive greater efficiency, sustainability, and productivity in delivering successful construction project outcomes by enabling an integrated green, lean, and digital thread of information across the project life cycle. To achieve this, Pillar 4 will develop tools that will make it easier for SMEs across the entire construction supply chain to learn how to adapt to more agile, digitally-enabled procurement practices.

Sustainability and Circular Economy, Pillar 5, will encourage the industry to move towards a more circular economy with a built environment sector that prioritises designing out waste while viewing products, components, and assets as valuable resources that should retain utility for as long as possible. To achieve this, Pillar 5 will develop a number of tools for SMEs and clients that enable a reduction of consumption by designing out waste and enabling a more circular approach in Irish construction.

Table of contents

List of Figures

List of Tables

Abbreviations

AEC	Architecture, Engineering, and Construction
BCF	BIM Collaboration Format
BEP	BIM Execution Plan
BIM	Building Information Modelling
BREEAM®	Building Research Establishment Environmental Assessment Method
bSI	buildingSMART International
CAD	Computer Aided Design
CDE	Common Data Environment
CEN	European Committee for Standardization
ECMS	Engineering Content Management System
EIR	Employer's Information Requirement
EU	European Union
EUBIMTG	EU BIM Task Group
GDP	Gross Domestic Product
GIS	Geographic Information System
IDS	Information Delivery Specification
IFC	Industry Foundation Class
ISO	International Standardisation Organisation
IT	Information Technology
LOF	Learnings Outcomes Framework
MVD	Model View Definition
OGC	Open Geospatial Consortium
OTL	Object type library
PLCS	Product life cycle support
PTNB	Plan Transition Numérique dans le Bâtiment
R&D	Research and Development
SC	Steering Committee
SME	Small and Medium-Sized Enterprises
USB	Universal Serial Bus
XML	Extensible Markup Language

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Executive Summary

Build Digital seeks to support digital transformation within the Irish construction and built environment sectors, thus enabling all stakeholders, particularly small and medium-sized enterprises (SMEs), clients, and suppliers, to develop, maintain, and continuously improve their capabilities as digitally-enabled, standards-based, agile, collaborative, and sustainable participants in the delivery of Project Ireland 2040. To inform the Digital Leadership and Cultural Change pillar of Build Digital, a global study of international best practice in digital adoption within the built environment sector was undertaken and presented here.

Eight countries were included in this study to identify key learnings for Ireland in digital transformation: Denmark, Finland, the Netherlands, Germany, the United Kingdom, New Zealand, Australia, and Singapore. These countries were selected for various reasons, including the level of digital maturity, the scale of the built environment sector, and geographic spread. Building on previous research in Ireland, five of these countries (i.e. Australia, Denmark, Netherlands, New Zealand, and the UK) were included in the study entitled 'Economic Analysis of Productivity in Irish Construction Sector' (KPMG & TU Dublin, 2020). Research of each of the jurisdictions mentioned above was considered under the following criteria:

- Industry context;
- Drivers;
- Leadership and cultural change;
- Measurement metrics;
- Barriers and challenges;
- Benefits;
- Resources and innovations.

A secondary research methodology, also known as desk research, was adopted for the current study with sources of information including, but not limited to, government and European Commission reports, industry studies, syndicated information services, and peer-reviewed journal and conference papers.

Key data for each country is included to allow context comparison with Ireland regarding the economy and scale of the construction industry. A common characteristic is the large number of SMEs operating within the built environment context. Consequently, the sector's digital transformation will need to be cognisant of the many actors in the sector.

The countries considered in this study have varying levels of digital maturity, with some, such as Denmark and the UK, having mandated the adoption of BIM, while others have or are adopting a similar approach to Ireland. While mandating BIM creates a 'push' to drive digital transformation, many common challenges continue to be reported in such countries. The level of success through mandating BIM is not clear from the review of existing literature, and this is perhaps due to the difficulty in developing appropriate metrics and methodologies to undertake such analysis. By way of example, two of the primary methodologies used include industry surveys and stakeholder interviews.

A point worth noting is that Build Digital has been initiated at a very appropriate time, given similar emphasis on digital transformation in the other countries included in the study. The primary pillars of Build Digital align well to address key challenges facing the sector in terms of digital transformation, namely leadership and culture change, capability and capacity of the workforce, and the need for common standards and appropriate procurement strategies while supporting the overarching aim of addressing climate change and realising sustainable development of the built environment.

The Digital Leadership and Cultural Change pillar aims to develop intrinsic motivation within the industry to progress the digital agenda in supporting more productive and sustainable outcomes. Consequently, the pillar will need to make the case for digital transformation while simultaneously developing enablers to support the required cultural change. Based on the study of international best practice, exemplar projects in the shape of case studies and test/pilot projects appear to be the preferred approach to raising awareness and building an appetite for progress within the stakeholder community. A key enabler to the latest evolution of digital transformation and BIM support in the countries included in the study is developing a digital hub to act as a repository of information including guidance, roadmaps, toolkits, templates, exemplar projects, etc. This approach aligns with the Build Digital Exchange Hub, an integrated project outcome (IPO) for Build Digital. The exemplars identified as part of the current study should inform the format and content of the Exchange Hub.

Finally, in the case of all countries considered in this study, government is the primary leadership agent, while government agencies as clients play a key role as drivers by mandating BIM to various levels. Consequently, the initiation and funding of Build Digital by the Irish government is an appropriate and timely development that aligns with best practice internationally. The important role that government agencies could play in supporting the digital transformation agenda must be explored further to develop the optimum roadmap towards high levels of digital maturity throughout the built environment sector.

PART 1

Introduction

1.1. Context

Globally, labour-productivity growth in construction continues to lag well behind manufacturing and the total economy, as highlighted in the McKinsey report *Reinventing Construction: A Route to Higher Productivity* (McKinsey & Company, 2017), illustrated in Figure 1. While there are a number of contributing factors to such lacklustre growth, from skills shortages to misaligned contract and incentive structures, the lack of investment in leveraging the best available technology and digitisation remains one of the key factors. The 2021 *European Construction Sector Observatory (ECSO)* analytical report identifies the importance of digital transformation and the issues which exist in construction (European Commission, 2021a):

> "*Digital technologies and their integration in the construction sector are often viewed as a key element that can help tackle some of the challenges mentioned above. However, the construction sector is one of the least digitalised sectors in the economy*".

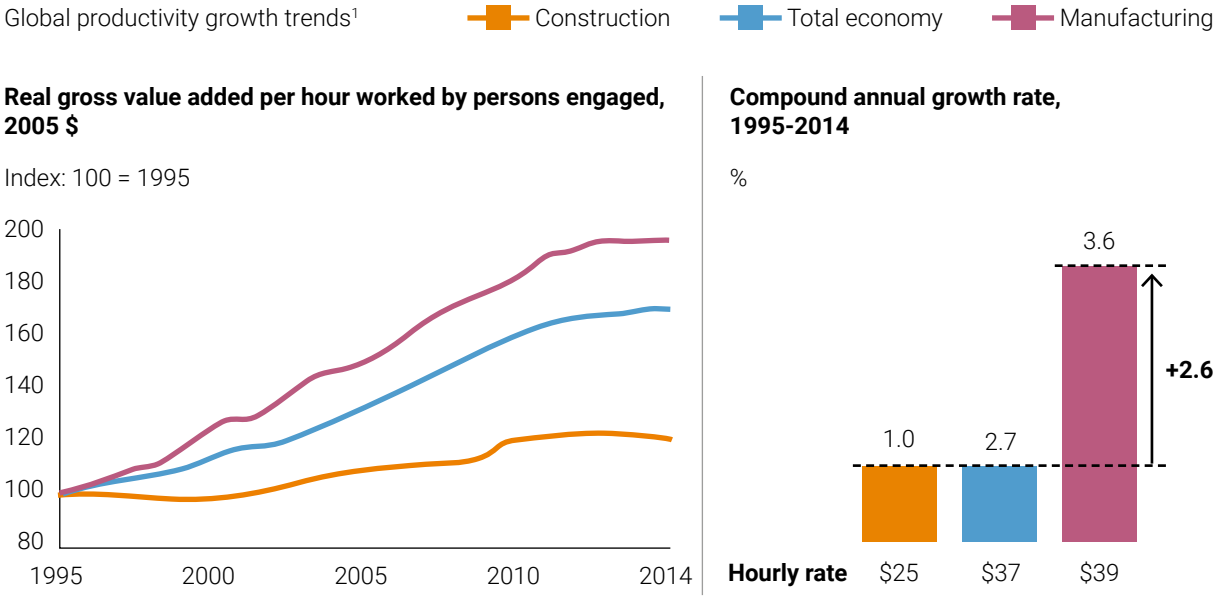
At a European level, the *Digital Economy and Society Index (DESI)* measures a country's performance in digitisation across four key metrics including:

- **Human capital**: Internet user skills and advanced digital skills.
- **Connectivity**: Broadband take-up, coverage, and prices.
- **Integration of digital technology:** Business digitalisation, and e-commerce.
- **Digital public services**: e-Government.

Across Europe, countries recognise digitalisation's role in achieving enhanced efficiencies and productivity in all industries, particularly construction. A 2019 study of productivity in the Irish construction sector also notes the slow uptake of new technologies which, in conjunction with the fragmentation of enterprises across a large number of micro and small companies, varying construction processes and projects, and associated difficulties, contribute to current low levels of productivity (KPMG & TU Dublin, 2020). This has implications in the wider context, as Hall et al. (2022) cite Ozturk et al. (2010) in positing that the construction industry acts as a key driving force in most countries globally. This is evidenced in Ireland, where concern in relation to issues with infrastructure, including the availability of electricity, water and housing for the workforce, is considered a potential obstacle to investment and growth (Goodbody, 2022).

Exhibit E1

Globally, labor-productivity growth lags behind that of manufacturing and the total economy



1 Based on a sample of 41 countries that generate 96% of global GDP.

SOURCE: OECD; WIOD; GGCD-10, World Bank; BEA; BLS; national statistical agencies ofTurkey, Malaysia, and Singapore; Rostat; McKinsey Global Institute analysis

Figure 1
Global Productivity Trends – Construction, Total Economy and Manufacturing (Ashima Bhutani, 2019)

While digitisation is quite a broad term encompassing many different but interlinked technologies, the following are identified as those technologies with the most significant potential for digital transformation within the construction sector (European Commission, 2021a):

1. Digital building logbooks;
2. Digital building permit system;
3. Digital Twins;
4. Building Information Modelling (BIM);
5. 3D printing;
6. 3D scanning;
7. Drones;
8. Sensors;
9. Internet of Things (IoT);
10. Robotics;
11. Virtual and augmented reality;
12. Artificial intelligence.

Of the above list, BIM may be viewed as the most influential as it offers the framework for integrating a number of the other listed technologies (Hall et al., 2022). Consequently, the level of BIM maturity within a particular region might be considered a reasonable initial measure of digitisation within the construction sector for that region. It is very evident that the level of digital maturity within the construction industry globally varies significantly.

1.2. Aims and Objectives

Build Digital seeks to support the transformation of the Irish construction and built environment sectors by enabling all stakeholders, particularly small and medium-sized enterprises (SMEs), clients, and suppliers, to develop, maintain, and continuously improve their capabilities as digitally-enabled, standards-based, agile, collaborative, and sustainable participants in the delivery of Project Ireland 2040. As one of five pillars of the project, the Digital Leadership and Cultural Change pillar has set the following vision:

"To develop, inform, and enable leadership in driving the cultural change required to realise digital transformation in support of innovative, effective, and sustainable evolution in mindset and practice within the Irish construction and build environment sectors".

As a study of international best practice in digital transformation within the construction sectors globally, the primary aim of this report is to inform the selection of optimum direction and methods to support digital transformation within an Irish context. To address this aim and identify key learnings for Ireland in digital transformation within the construction industry, research was undertaken relevant to eight countries (Figure 2). As Scandinavia is considered a leader in this space, Denmark and Finland were included in the study. Two further EU member states were included in the form of the Netherlands and Germany. The UK was also considered a global leader in mandating BIM through government policy, while Ireland and the UK share significant commonalities between their respective construction industries.

Further afield, Australia, New Zealand, and Singapore were also included in the study. By way of building on previous research in Ireland, five of these countries (i.e. Australia, Denmark, Netherlands, New Zealand, and the UK) were included in the study entitled *Economic Analysis of Productivity in Irish Construction Sector* (KPMG & TU Dublin, 2020). Research of each of the jurisdictions mentioned above was considered under the following criteria:

- Industry context;
- Drivers;
- Leadership and cultural change;
- Measurement metrics;
- Barriers and challenges;
- Benefits;
- Resources and innovations.

Figure 2
Countries Included in the Current Study

1.3. Methodology

A secondary research methodology, or desk research, was adopted for the current study. Secondary information typically comprises data sources and other information collected by others and archived in some form (Stewart and Kamins, 1993). The sources of information used in this study include but are not limited to: government and European Commission reports, industry studies, syndicated information services, and peer-reviewed journal and conference research. This approach is considered appropriate as secondary information offers efficient and inexpensive insights and is almost always the point of departure for primary research (Stewart and Kamins, 1993) or, in this case, the initial phase of Build Digital.

1.4. Report Structure

The report is presented such that all the countries included in the research study are considered in Part 3. A review of Ireland is included in Part 2, with the criteria of interest to the study consistent with those presented in Part 3. The research presented in these two sections is analysed and evaluated to inform key findings from studies of international best practice. The key learnings relevant to digital transformation within the context of the Irish construction sector are synthesised in Part 4.

PART 2

Context in Ireland

2.1. Context

One of the challenges for this research in assessing the barriers, drivers, benefits, and measurement of digital adoption in the Irish construction sector is the lack of a clear definition of how desired digital adoption is defined. Research indicates that digital adoption is an ongoing process described at times as a journey instead of a single point of achievement. Although a continuous process, some researchers and agencies look at digital adoption in phases often titled 'Digitisation', 'Digitalisation', and 'Digital Transformation'. Enterprise Ireland describes the stages as 'Digital Discovery', 'Digital Process Innovation', and 'Digital Transformation'. This means that digital adoption can exist in the ranges from a firm using e-mail and digital spreadsheets to one deploying geo-spatially enabled drone and smart sensors, employing big data analytics on a fully integrated BIM project. In an attempt at clarity and simplicity, this research, when appropriate, describes the issues surrounding digital adoption in the Irish construction sector from an early-stage adopter viewpoint and the perspective of the more advanced on the digital adoption journey.

In preparing this document, research was found in relation to various issues surrounding the more advanced stages of digital adoption, such as BIM, Cloud Computing, and Big Data. However, there is a shortage of research relating to early-stage digital adoption in the construction sector in Ireland. Similarly, very little research was found examining or exploring cultural change requirements or attitudes to cultural change within the Irish construction sector. Although the requirement for leadership was a common theme in many of the reports and studies used to compile this research, no studies were found that explored or examined leadership or leadership requirements for digital adoption in the Irish context.

Sources used to compile this document include Irish construction industry body reports (professional representative bodies, BIM Council, CitA), academic research papers focused on digital adoption in the Irish construction sector, reports from the European Commission and the Irish government (various government departments, ESRI, OECD, Euro Stat), and reports from Irish developmental agencies (Enterprise Ireland, Skills Ireland).

2.2. Drivers

The drivers of digital adoption in the Irish construction industry vary and depend on the organisation's stage in its digital transformation journey. Drivers of digital adoption have been categorised in different ways, often as digital customer drivers, digital technology drivers, and digital organisational behaviours.

2.2.1. Government

A significant external driver of digital adoption in Ireland is governmental policy. The government recently published its strategy, *Harnessing Digital; The Digital Ireland Framework,* aiming to be a digital leader at the heart of European and global digital developments (Government of Ireland, 2022). The strategy outlines key dimensions of digital transformation, digital infrastructure, digital skills, and the digitalisation of public services (Government of Ireland, 2022). Targets for each area have been published which, if achieved, will significantly impact digital adoption within the construction sector. Enterprise Ireland is the government organisation responsible for developing and growing Irish enterprises. It plays a role in encouraging digital adoption through financial subsidies, matched funding for digital transformation projects, and information and guidance on accessing expert advice on digital adoption. The organisation plays a role in raising awareness of the benefits of digital adoption for construction firms and, as such, can be seen as one of the drivers.

2.2.2. Education and Training

Education is a driver of digital adoption in the Irish construction sector. Education and training are important factors for competencies and developing awareness of the need and benefits of digital adoption. The education sector, particularly the third-level institutes, is responding to the need for digital adoption in construction (McAuley et al., 2018; Skills Ireland, 2018). Through courses and course content with a digital focus, third-level institutes provide companies with highly trained employees aware of the benefits of digital adoption. The digital literacy of graduates and new entrants to the workforce acts as a driver towards more data-driven decisions and applications (Skills Ireland, 2018). Some actions have proved particularly effective in bridging the knowledge gap by raising awareness of the benefits of digitalisation by providing education and training to students, including learning platforms, guidebooks, and online digital assessment tools (EIB, 2019a). Employees with BIM knowledge would strongly influence the application of BIM within a small organisation, further emphasising education as a driver of digital adoption (McAuley and Carroll, 2017).

2.2.3. External Organisational Influence

There are several organisations in Ireland whose role is to encourage firms within the construction industry to develop digital capacity and practices and, as such, act as drivers of digital adoption. The Construction IT Alliance (CitA) is a non-profit organisation with the vision of harnessing the potential of ICT in the Irish construction industry. CitA publicises the latest information on technology trends through monthly events and annual conferences with experts in key areas of construction firms. It also provides access to training grants and networking opportunities. Other industry representative bodies also act as drivers by raising awareness of the benefits of digital adoption

through publications and forums and by offering continuous professional development initiatives.

2.2.4. Technology and Awareness of Benefits

Awareness of the operational benefits of digital technologies is likely to be a significant driver of digital adoption. A recent report which involved firms in Northern Ireland found that management perceptions of digital technology are likely to be a more potent driver of digital adoption than purely economic or cost-benefit beliefs (Wishart and Roper, 2021). In the construction sector in Ireland, digital technologies and their integration have the potential to address challenges related to labour shortages, competitiveness, resource and energy efficiency, quality, and productivity while boosting construction output, especially in the residential sector (Government of Ireland, 2022). Benefits such as improved productivity and efficiency, early integration of stakeholders, improved communications, saving time, better contract documentation, improved design quality/visualisation, reduced design errors/rework, and competitive edge have been reported as benefits (Saka and Chan, 2020).

The availability of new technologies on the more advanced end of the digital transformation scale can also act as a driver. Digital twin technology and cloud computing are important driving forces for the construction industry's digital transformation (Li et al., 2022). The ubiquity of communications and teleconferencing applications, such as Zoom, Microsoft Teams, etc., have helped digital adoption for those firms at the beginning of the digital adoption journey. Increased profitability of a company will result in an advantage over its competitors (Saka and Chan, 2020).

2.3. Leadership and Cultural Change

Leadership as a requirement for digital transformation across the sector is a common theme in research and industry reports (Hore et al., 2017; National BIM Council, 2020). The National BIM Council roadmap suggests that the government needs to play a key role in encouraging digital adoption. The European Commission strategy document, *Shaping the Digital Transformation in Europe,* takes a similar view that government policies that effectively encourage the creation, uptake, and dissemination of new technologies can aid in realising the potential of the digital age for the good of all citizens, in a fair and long-lasting way. However, proactive governmental management of the transition is needed (European Commission, 2020).

The Irish government plays a role through its Build Digital, Harnessing Digital, and Digital Ireland programmes (Government of Ireland, 2022). The government has set targets for levels of desired digital adoption across all enterprise sectors. Through Enterprise Ireland, the government has developed a suite of supports and information campaigns to assist Irish construction companies to begin or further their use of digital technologies (Enterprise Ireland, 2022). The government is also leading by moving the planning system towards e-planning and encouraging the use of digital processes, including BIM, in public sector construction projects (Government of Ireland, 2022).

Industry organisations such as the National BIM Council and CitA are playing a leadership role by supporting research on BIM implementation producing strategic plans, notably the roadmap for digital transition. Although leadership is mentioned broadly in the reports and research surrounding digital adoption in the Irish construction sector, there is little commentary or discussion about the leadership or cultural change requirements within firms that are needed for effective digital adoption. Research has shown that the role of executive orchestration is critical to successfully implementing digital adoption (Brosnan, 2022; Brown et al., 2014; Cichosz et al., 2020). Skills Ireland alludes to the leadership requirements by saying that digital change requires diverse skills, from change management and content presentation to facilitation and conflict resolution (Skills Ireland, 2018).

2.4. Measurement Metrics

The measurement and metrics of digital adoption are challenging to define, as there are no clear definitions of an acceptable level of digital engagement. Skills Ireland has attempted to measure digital adoption rates through a survey. However, the responses suggested that the digitalisation/digital transformation process was ongoing across the board and comprised the use of many differing technologies (Skills Ireland, 2018). Assessment and measurement of digital adoption is not a simple divide between firms with and without digital capacity but rather an ongoing journey of integrating digital technologies and processes (Wishart and Roper, 2021).

On a macro level, the Irish government has set targets for digital adoption across all industries, which could be adapted and used as an element of measurement:

- Target 1: By 2030, 75% of all enterprises in Ireland are using cloud computing, big data, and artificial intelligence.
- Target 2: 90% of all SMEs operate at a basic digital level by 2030.

A recent survey involving 62 companies in Irish AEC industries relating to digital readiness found that 35% of organisations embrace digital technology within resource limitations but have an appropriate digital presence. Only 11% of the sample claimed to be late adopters (McAuley et al., 2020). Furthermore, the third national survey to benchmark the level of Building Information Modelling (BIM) adoption across the architects, engineers, and contractors of Ireland revealed that 76% of the industry sample were confident in their skills and knowledge to deliver BIM which could indicate a high degree of digital awareness if not adoption. However, the 2022 *Digital Economy and*

Society Index (DESI) report on ICT usage found that up to 40% of SMEs in Ireland completely lack digital technologies, with a further 30% having only between four and six digital assets (European Commission, 2022a). In the context that the most significant single sector (21%) of SMEs in Ireland are construction firms, a significant proportion of construction firms likely have yet to commence a digital transformation journey.

2.5. Barriers & Challenges

Digital adoption can be described as an ongoing process with different stages along a pathway to digital transformation. As a result, examining barriers to digital adoption at different stages of that journey is likely helpful. According to the European Investment Bank's 2019 report *The Digitalisation of Small and Medium Enterprises in Ireland,* notable barriers to digital adoption in Ireland include a lack of knowledge of the opportunities presented by digital solutions, technical expertise, and finance availability (EIB, 2019b). However, Hore et al. (2020), in their research relating to BIM in Ireland, cite client awareness, lack of standardisation and protocols, lack of in-house expertise, and issues regarding data ownership and liability as key barriers to implementation.

It is probable that Irish companies on a BIM journey or considering BIM implementation are at a relatively advanced stage of digital adoption compared to companies within the AEC sector that have yet to embrace digitalisation. It follows that barriers to digitisation vary according to how much a firm has advanced its digital adoption journey. At the earlier stages of adoption, the barriers will likely be knowledge of digital opportunities, know-how, and financing (EIB, 2019b). As the organisation matures in its digital transformation, the barriers around protocols, standardisation, client awareness, and data ownership become more relevant (Wang et al., 2022).

Many businesses consider digital technology investment costs rather than long-term opportunities (Government of Ireland, 2022). Although cost is considered a significant barrier in early-stage digital adoption (EIB, 2019b), it becomes less significant as the organisation moves towards digital maturity.

Barriers to digital adoption at the early stages of the digital transformation journey include a lack of knowledge about digital solutions and their advantages, access to investment capital, and skills (OECD, 2021). Furthermore, privacy and security concerns and access to infrastructure, such as high-speed broadband, are additional obstacles to adopting digital technologies (Government of Ireland, 2022). The geographical location of a construction firm has been identified as a potential barrier to digital adoption (Wishart and Roper, 2021). Rural firms experience different barriers to digital adoption than their urban counterparts. A recent report which examined companies in Northern Ireland found that 42% of rural firms, compared to 31% of urban firms, cited broadband capacity as a significant obstacle to digital adoption. Rural firms were 10% more likely to point to internal resistance to change (39% vs. 29%) as an obstacle to digital adoption than their urban counterparts (Wishart and Roper, 2021).

The type and function of the company within the construction sector can be a barrier to digital adoption. The level of awareness and adoption varies across the different professions within the construction sector, with a high level of awareness and adoption often recorded in consultancy firms. Architecture and engineering companies face fewer challenges than builders because of their familiarity with Computer-Aided Design (CAD) applications. Also, their function differs, and this would influence their engagement with digital technologies (Saka and Chan, 2020).

The age profile of employees within an organisation can be a barrier to digital adoption (Accenture, 2022). Studies focusing on the construction sector in other jurisdictions have indicated that compared to employees younger than 30, an older workforce is negatively related to the probability of technology adoption (Papadonikolaki et al., 2020). Resistance to change is seen as a significant barrier to digital adoption. Several studies relating to the Irish construction sector have highlighted that resistance to change is a barrier to technology adoption, specifically for BIM tools, digitalisation, and automation in the construction sector (Brosnan, 2022; Scully et al., 2012; Shirish et al., 2022).

Barrier	Description
Costs	Perception that digital adoption is a significant cost outlay and lack of access to finance.
Knowledge Gap	Lack of awareness of digital solutions available and their benefits.
Access to Infrastructure	High-speed broadband access and hardware.
Location	Rural firms face greater cultural change and infrastructure barriers.
Age Profile	An older workforce is negatively related to the probability of technology adoption.
Firm Type	The level of awareness and client requirement for digital adoption is likely higher in consultancy firms such as architecture and engineering than in construction firms.

Source: (CECE, 2019; EIB, 2019a; Abdullahi B. Saka and Chan, 2020; Ghadimi et al., 2021; NESC, 2021; OECD, 2021; Turk and Turk, 2021; Wishart and Roper, 2021; Brosnan, 2022; Government of Ireland, 2022; IBEC, 2022)

Table 1
Barriers to Commencement of Digital Adoption in the Irish Construction Sector

Barriers relevant to firms at a more advanced stage of digital adoption highlighted in Hore et al. (2020) found a lack of in-house expertise to be the number one barrier to using BIM. The primary barriers to BIM implementation in Ireland are a lack of in-house expertise (74%), no client demand (67%), and a lack of training (67%). The absence of an established contractual framework for working with BIM is also seen as a key barrier. In their study on the construction sector, Charef et al. (2019) found that Irish firms considered the interoperability of software and data translation to be a significant barrier to the adoption of BIM.

Legal issues surrounding how contracts are put together, with many organisations and individuals involved, act as a barrier to Building Information Modelling (BIM) systems (Skills Ireland, 2018). Issues around data generation and sharing can act as a barrier. According to the National BIM Council, data exchange is uncommon in the built environment sector. Information is traditionally exchanged in paper-based documents or multiple independent file formats that may be compatible or adhere to similar standards. Without consistent rules or standards for machine-readable data, it is very challenging to verify if the information that has been provided complies with the requirements or follows industry norms (National BIM Council, 2020).

Barrier	Description
Knowledge Gap	Lack of understanding of advanced digital capabilities and benefits. Lack of in-house expertise to implement advanced digital tools such as BIM, AI, robotics, Big Data, and cloud computing.
Client Demand	Lack of a push from clients to deploy advanced digital systems, likely due to a lack of knowledge on the client side.
Contractual Issues	Lack of a clear contractual framework (BIM).
Cost	Infrastructure, hardware, software, and training costs.
Interoperability	Differing procedures and adoption rates between companies. Differing software protocols.
Lack of Awareness of Benefits	Lack of awareness of the efficiency, productivity, reputational, and financial gains available.
Data Management	Issues of data storage, data ownership, data exchange, and data tracking.
Lack of National Standards	Lack of adoption of clear national standards across the differing degrees of digital transformation (not confined to BIM).

Source: (Skills Ireland, 2018; Charef et al., 2019b; Hore, Mcauley and West, 2020; Day et al., 2021)

Table 2
Barriers to Advanced Digital Adoption in the Irish Construction Sector

2.6. Benefits

According to the Irish government's *Digital Ireland Framework,* digital technologies and their integration by the construction sector can address challenges related to labour shortages, competitiveness, resource and energy efficiency, quality, and productivity while boosting construction output, especially in the residential sector (Government of Ireland, 2022).

Cloud computing is an enabler for other more advanced digital technologies such as BIM, digital twins, Internet of Things, virtual reality, drones, and geo-enabled technologies, all of which have the potential to bring further benefits to Irish construction firms (Skills Ireland, 2018). The benefits of BIM to the construction industry have been well documented (Hore et al., 2020, 2017; West et al., 2021). One of the most significant benefits of BIM is the increased cooperation and collaboration across project teams. BIM facilitates the immediate and accurate comparison of design options, providing economic, productivity, and efficiency benefits

(Ghaffarianhoseini et al., 2017). Deployment of BIM offers tangible cost savings and better prediction of budgets. It can increase client communication and satisfaction (Eadie et al., 2013). BIM can reduce the carbon footprint of construction projects through waste reduction and more efficient materials planning. Real-time reporting can overcome cost overruns and scheduling delays (McAuley et al., 2015). Research has also found that BIM delivers further benefits in reduced conflicts during construction and improved collective understanding of design intent (Scully et al., 2012).

Digital twins enable simulations of change to a project or building before any physical alterations or interventions are made, thereby bringing benefits to cost preparation and predictability of construction projects. Reporting from construction organisations appears to add weight to these perceived benefits. According to the operations manager of the construction firm BAM Ireland, the company has realised a 20% improvement in on-site quality and safety and a 25% increase in staff time spent on high-risk issues, resulting from better visualisation using digital twins and VR (Autodesk, 2021).

On a macro level, digital adoption is expected by some estimates to add 2% to the existing workforce directly employed in the construction industry (Skills Ireland, 2018). Adopting digital technologies can contribute towards Ireland's climate commitments by supporting companies in tracking and measuring their energy consumption and carbon footprint across the supply chain (OECD, 2021).

2.7. Resources and Innovations

2.7.1. Innovation

The BIM Innovation Capability Programme (BICP) in Ireland was an initiative that was launched to promote the adoption of Building Information Modelling (BIM) across the Irish construction industry (CitA, 2017; McAuley, 2017). The BICP aimed to facilitate the Irish construction sector's transition to a more efficient, digital, and collaborative working method. The BICP was initiated by Enterprise Ireland, a government organisation responsible for developing and growing Irish enterprises in global markets, in collaboration with industry stakeholders, academic institutions, and other relevant bodies.

The main objectives of the BICP were:

- To raise awareness and understanding of BIM among the Irish construction sector.
- To develop a national BIM strategy and roadmap for the adoption of BIM across the industry.
- To support the development of BIM capabilities and skills within Irish construction firms.
- To encourage collaboration and knowledge sharing among stakeholders, including contractors, designers, and clients.
- To promote the use of international standards and best practices in BIM implementation.

By driving the adoption of BIM, the BICP aimed to enhance the competitiveness and productivity of the Irish construction industry, enable better project delivery, and reduce costs and environmental impacts. Since the program has finished, its legacy remains in the form of increased BIM adoption, published case studies, and the continued growth of a more efficient and collaborative Irish construction sector (CitA, 2017; McAuley, 2017).

2.7.2. Case Studies and Exemplar Projects

The BICP prepared a series of case studies highlighting BIM's practical application in the Irish construction industry (McAuley, 2017). These case studies focused on key aspects of BIM adoption, such as implementation, collaboration, cost and time savings, facility management, and sustainable construction. By showcasing real-world examples, these case studies provided valuable insights for industry professionals, demonstrating the tangible benefits of BIM and promoting best practices in BIM implementation (McAuley, 2017).

In addition to promoting BIM adoption, the case studies served as a valuable resource for architects, engineers, contractors, and other stakeholders in the Irish construction sector. By sharing lessons learned and offering practical guidance, the BICP case studies contributed to the growth of a more efficient, competitive, and collaborative construction industry in Ireland, ultimately leading to improved project outcomes and a greater emphasis on sustainable practices (McAuley, 2017).

2.7.3. Resources

In recent years, several professional bodies in Ireland have released both guidance information and template documents to facilitate the implementation of Building Information Modelling (BIM) in Irish construction projects, and this includes the Royal Institute of the Architects of Ireland's (RIAI) comprehensive *BIM pack* (RIAI, 2022). This resource aimed to enhance industry professionals' understanding of BIM processes and technologies by providing essential guides and resources covering BIM fundamentals, standards, execution planning, software selection, training, and real-world case studies. By offering a cohesive and academically rigorous set of materials, the RIAI's BIM pack sought to empower professionals to confidently adopt BIM, leading to improved project outcomes, increased efficiency, and a more competitive construction sector in Ireland (RIAI, 2022).

2.7.4. Financial Support

Enterprise Ireland is the government organisation responsible for developing and growing Irish enterprises. It provides a range of support for construction sector companies to assist in digital adoption at all stages of the digital journey.

For construction companies who wish to begin their digital adoption journey, Enterprise Ireland can fund a Digital Discovery Grant to cover up to 80% of a seven-day consultancy engagement (to the value of €5,000). Eligible projects should consider:

- Skills assessment, culture of innovation, and digital mindset in the company;
- Process flow efficiency in the operations (Lean & Digital);
- Opportunities to deliver new value-added digital services or products;
- Use of digital systems to measure and reduce energy, emissions, and waste;
- Review of cyber-security strategy and processes.

For companies that have commenced digital adoption but wish to develop digital processes further, Enterprise Ireland can help fund the cost of a digital improvement programme.

- The LeanPlus programme can be used to offset salary costs for up to 10 project team members alongside the cost of external expertise to a maximum grant of €50,000 (50% of eligible costs).
- For larger innovation projects, the Digital Process Innovation offer can be used to support project costs. Maximum support is still 50% but with grants of up to €150,000.
- Support for capital investment projects for SMEs (10-30% depending on location and size). This covers capital investment in new production equipment and systems.
- The LeanTransform programme can support training costs covering leadership, lean/process, and new technologies with grants of up to 50-70% for larger programmes.

The Innovation Voucher Programme was developed to build links between Ireland's publicly funded knowledge providers (i.e. higher education institutes and public research bodies) and small and medium-sized businesses. Innovation Vouchers worth €5,000 are available to assist a company or companies in exploring a business opportunity or problem with a registered knowledge provider. Each Innovation Voucher gives you €5,000 worth of time with an expert or third-level researcher to help develop a new product or crack an important business or technical challenge.

Enterprise Ireland also has specific support for BIM adoption. Their BIM Enable and BIM Implement programmes continue to provide critical funding support to the industry. The BIM Enable programme is a seven-day strategic consultancy programme designed to heighten BIM knowledge across business functions and deliver a bespoke roadmap to Level or Stage 2 BIM proficiency based on a company's vision and resources. The maximum grant funding available from Enterprise Ireland is €6,300. The BIM Implement programme represents the training phase of the BIM induction offer supporting knowledge transfer leading to increased competencies in BIM and a deeper understanding of supply chain implications. The aim is to embed BIM skills and knowledge across an organisation and equip the appropriate staff members with the competencies to manage a BIM project successfully. Assignments may vary in size and scope but will typically be of six months duration but may not exceed a total project cost of €70,000.

PART 3

International Context

3.1. Context

The level of digital adoption varies significantly across the globe. Research was undertaken relevant to eight countries to inform key learnings for Ireland in the context of digital transformation within the built environment sector. The countries included are Denmark, Finland, the Netherlands, Germany, the UK, Australia, New Zealand, and Singapore, while a comparison of key context-setting data for each country is presented in Table 3 and Table 4. In terms of population, Denmark, Finland, and New Zealand are mainly similar to Ireland. While New Zealand is at 9.1% and Singapore is at 7.4%, are higher in terms of percentage employed in construction, the remaining countries range between 3.7% and 5.4%. From the data, it is also clear that many enterprises are operating within the construction sector. Within a European context, the construction sector is characterised by a significant degree of fragmentation, with a significant proportion of SMEs often operating within specialist activities, thus leading to multiple actors involved throughout the life cycle of a built asset (European Commission, 2021a).

3.2. Drivers

As previously mentioned, the study entitled *Economic Analysis of Productivity in Irish Construction Sector* (KPMG & TU Dublin, 2020) is a precursor to Build Digital and highlights the importance of achieving improved productivity. This resonates with other studies which highlight the perpetually low construction productivity statistics when compared to other national production sectors (Statistics NZ (2012) as quoted by Adafin et al. (2022)). However, productivity is not the only driver. According to the European Construction Sector Observatory (ECSO) analytical report 2021, *Digitalisation in the Construction Sector*, key drivers of digitalisation within the construction sector across Europe (European Commission, 2021a) include:

- EU and National government policies and regulations;
- Government and business need for better access to information and better decision-making;
- Business needs to improve productivity and cut costs;
- Market demand;
- Business needs to remain competitive;
- Corporate social responsibility.

Description	Ireland	Denmark	Finland	Netherlands	Germany	UK	New Zealand	Australia	Singapore
Population	5.1 M[a]	5.85 M[a]	5.54 M[a]	17.53 M[a]	83.2 M[a]	67.35 M[a]	5.11 M[a]	25.74 M[a]	3.99 M[a]
Gross Domestic Product (GDP) - US $	656 B	41 B	3,740 B	332 B	1,258 B	5,371 B	242 B	1,595 B	558 B
Employment in Construction (,000)	165.2	194.4	185.0	414.8	2,577	2,179	301.7	1231.7	
% Employed in Construction	5.0%	5.2%	5.4%	3.7%	4.8%	5.1%	9.1%	7.4%	

Based on 2022 data unless noted othetherwise; [a] Based on 2021 data; [b] Based on 2020 data

Table 3
Comparison of Countries Included in the Current Study (OECD, 2023)

Description	Ireland	Denmark	Finland	Netherlands	Germany	UK
Total turnover in construction sector	€42.8 B	€71.2 B	€70.8 B	€192.4 B	€638.9 B	€494.6 B[a]
No. of employees in construction sector	159,300	322,456	341,031	832,573	4.51 M	2.23 M[a]
No. of enterprises in construction sector	83,577	71,924	89,079	308,707	715,198	551,212[a]

Based on 2020 data unless noted othetherwise; [a] Based on 2018 data

Table 4
Comparison of European countries in study (European Commission, 2021b)

In the context of the ECSO report, such drivers resulted from a desktop survey of public institution reports, a construction associations study, news articles, and statistical insights, which were available in parallel with semi-structured stakeholder interviews. Following the desk research and interviews, a survey was developed to test these drivers by asking policymakers, companies, associations, and academia to assess the extent to which these drivers are important for the take-up of digital technologies and tools in the construction sector. A more detailed overview of the survey results across all EU member states and the importance granted by the stakeholders to each of the drivers is presented in Figure 3. Upon review of the drivers that were identified as part of the ECSO research and survey, it is possible to categorise the drivers into two primary types, with both playing a pivotal role in digitisation within the sector (European Commission, 2021a):

- Public sector-led: development and implementation of government policies.
- Market-led: market drivers, e.g. productivity, sustainability.

The level of importance given to each of the drivers listed in the ECSO survey for respective member states is provided in Figure 4.

Policy drivers include EU and member state policies and funding and regulation. As per the ECSO survey, EU and national government policy is the only driver to be identified as necessary to a high or considerable extent by over 60% of respondents. A sample of the most influential policies across Europe includes (European Commission, 2021a):

- EU Clean package, which includes the Directive on the Energy Performance of Buildings.
- European Green, which includes a focus on the circularity of the construction sector.
- Innovation and digitalisation policy framework, which includes a number of digitalisation policies and programmes that will drive the update in the construction sector through the development of ICT infrastructure, the financing of research, and Digital Innovation Hubs (DIHs), all of which act as key enablers for construction companies on their digitalisation transitions.

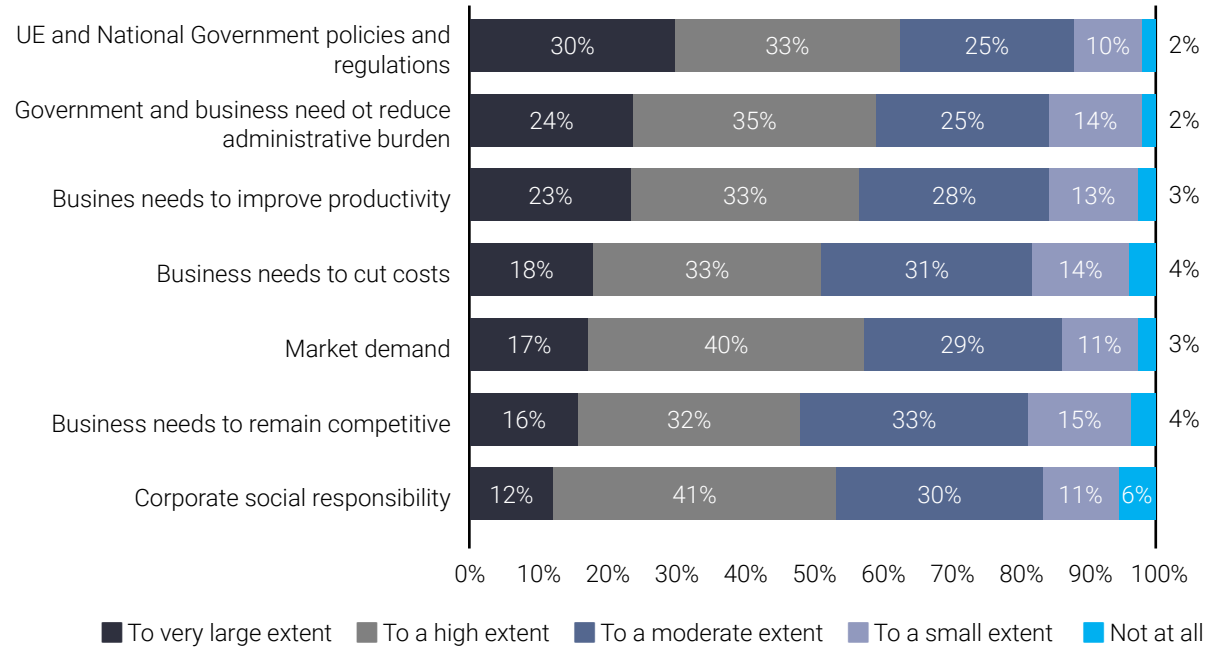
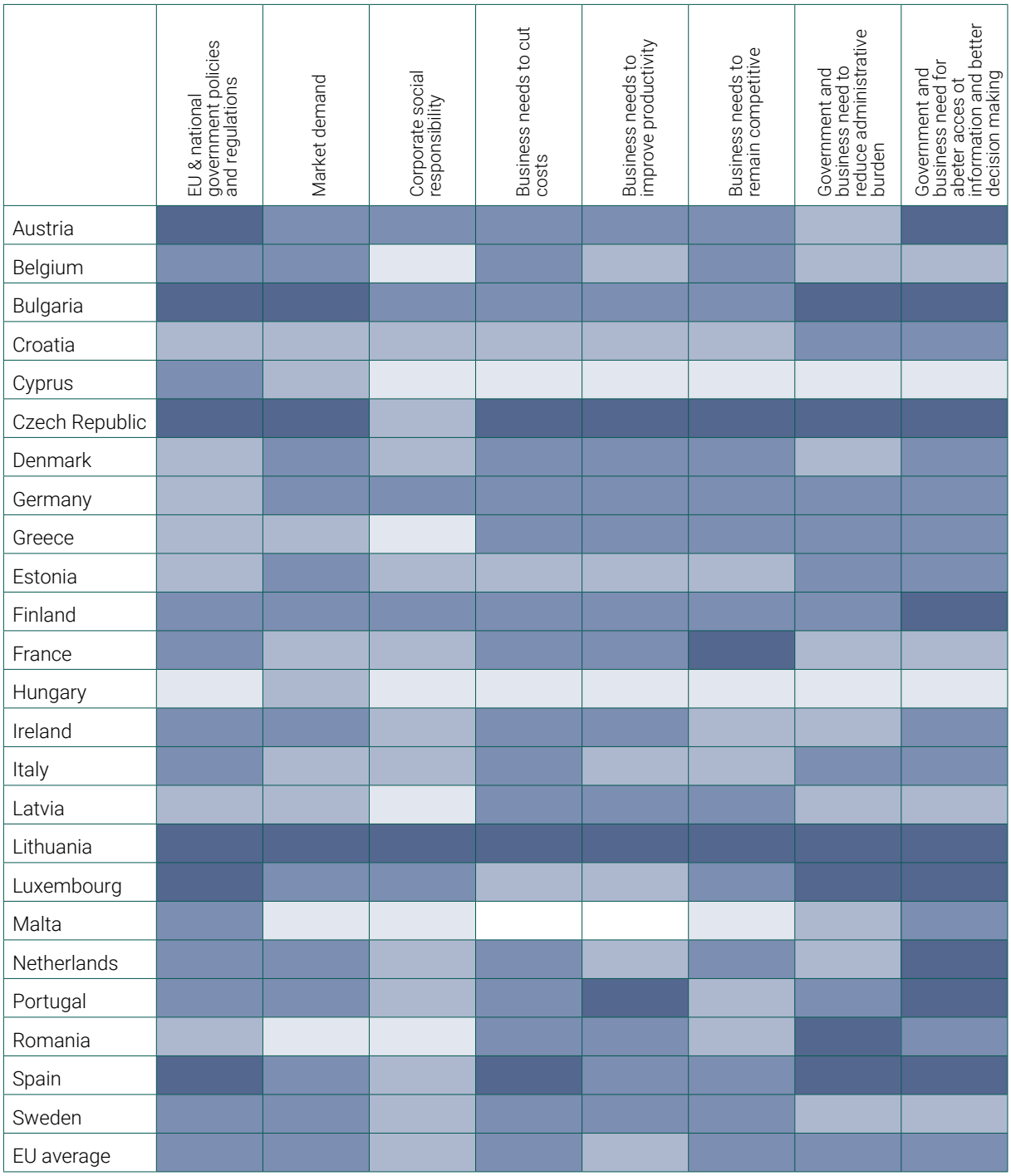


Figure 3
ECSO Survey – Importance of Drivers for Take-up of Digital Technologies across EU (European Commission, 2021a)



Source: ECSO survey, 2020

Figure 4
Digitisation Drivers Importance in Construction across EU members states (European Commission, 2021a)

Liao et al. (2020) reported research on drivers towards BIM implementation, noting that "design coordination between disciplines through clash detection and resolution" was the most popular driver, whereas "integrating model management tools with stakeholders' enterprise systems to exchange data" was the least popular driver. By way of example, a complete list of the final factors impacting BIM diffusion in Singapore is provided in Table 5.

	Drivers for BIM Implementation	No.of Studies
D01	Design coordination between disciplines through clash detection and resolution	17
D02	Training on new skillsets and new ways of working such as BMI management certification courses	15
DO3	All disciplines work together and share models	13
D04	Data sharing and access on BIM platforms	10
D05	Complex design analysis in sustainability, material selection, and	10
D06	BIM vision and leadership from the management	9
D07	Stakeholders seeing the value of adopting their own part of BIM	9
D08	3D visualization enabling design communication	9
D09	Enabling convenient production of models and drawings for construction and fabrication	9
D10	Organizational structure and culture changes in BIM wave	8
D11	Owner's requirement and leadership to adopt BIM	8
D12	Four-dimensional simulation before construction	8
D13	Enabling more off-site fabrication and assembly of standard elements	7
D14	Government support such as subsidizing training, software, and consultancy costs	6
D15	Lifecycle information management improving operations and maintenance	6
D16	Governance of BIM-related policies, standards, and guidelines	5
D17	New technologies such as computer numerically controlled machines	5
D18	Regulatory agencies' early participation in BIM use	4
D19	Gaining competitive advantages from successful BIM use	4
D20	OSM lowering safety risks by controlling work in factory 4	
D21	Better cost estimation and control in project lifecycle	4
D22	On-site work proceeds in parallel with off-site production	4
D23	OSM standardizes design and manufacturing processes, simplifying construction and testing and commissioning processes	4
D24	Increasing complexity in buildings, project delivery, and marketplace	4
D25	Enabling subcontractors to use lower-skilled labor on site	3
D26	High accuracy of model-based documentation	3
D27	Automatic model updating and drawing production to deal with design changes and their implications	3
D28	OSM produces building elements with better quality and consistency	3
D29	OSM reduces building waste, especially on-site waste	3
D30	Alignment of all stakeholders' interests	2
D31	Increasing use of design-build and fast-track approach	2
D32	Integrating model management tools with stakeholders' enterprise systems to exchange data	1

Table 5
Drivers for BIM Implementation interpreted from Liao et al. (2020)

As far back as 1999, Denmark sought to set focused goals regarding national digital transformation. In 2021, the government approached digitisation in construction by concentrating on the council sector as a test bed for digitisation throughout the whole life cycle of the asset with key aims as follows (Ministry of the Interior and Housing, 2021):

- Increased sustainability;
- Maintenance (of the council building stock) related to data collection;
- Maintenance planning leading to increased performance and prevention of further damage (preventive maintenance);
- Digital tools for renovation;
- Deployment of BIM for:
  - » Financial management;
  - » Time management;
  - » Site planning;
  - » Energy simulation;
  - » LCA (Life Cycle Assessment).

Jiang et al. (2022) reported that a government-driven approach was adopted in Singapore and the UK, where the government took a leading role in mandating BIM use. The UK mandate has been in place since 2016 with the intent to mandate formalised five years earlier in 2011. In contrast, the US adopted an industry-driven approach, and the government was less involved in promoting BIM implementation. A roadmap of BIM implementation is shown in Figure 5, with the government-driven approach illustrated along with the industry-driven approach (Jiang et al., 2022).

Regulation is another key enabler of digitalisation, and in recent years, the EU has been very progressive in developing the enabling regulatory framework that supports the uptake of digital technologies, making progress on issues such as data privacy and security, public procurement, and circular economy. In Germany, BIM was mandated for all public infrastructure projects in 2020, while the obligation was set to extend to buildings commissioned by the federal government towards the end of 2022. A phased approach to BIM adoption was considered important to ensure economic stability on significant projects during the transition period while also seeking to stimulate a change in culture within the private sector.

Finland is considered to be the leader in terms of digitisation within Europe (European Commission, 2022b), and in 2016, they launched the KIRA-DIGI (KIRA DIGI, 2018) project to encourage digitisation within the built environment within both public and private sector contexts. Australia has also established a number of public sector initiatives to drive BIM adoption, including Queensland Infrastructure, Transport for New South Wales (TfNSW), and the Victorian Digital Asset Strategy (VDAS).

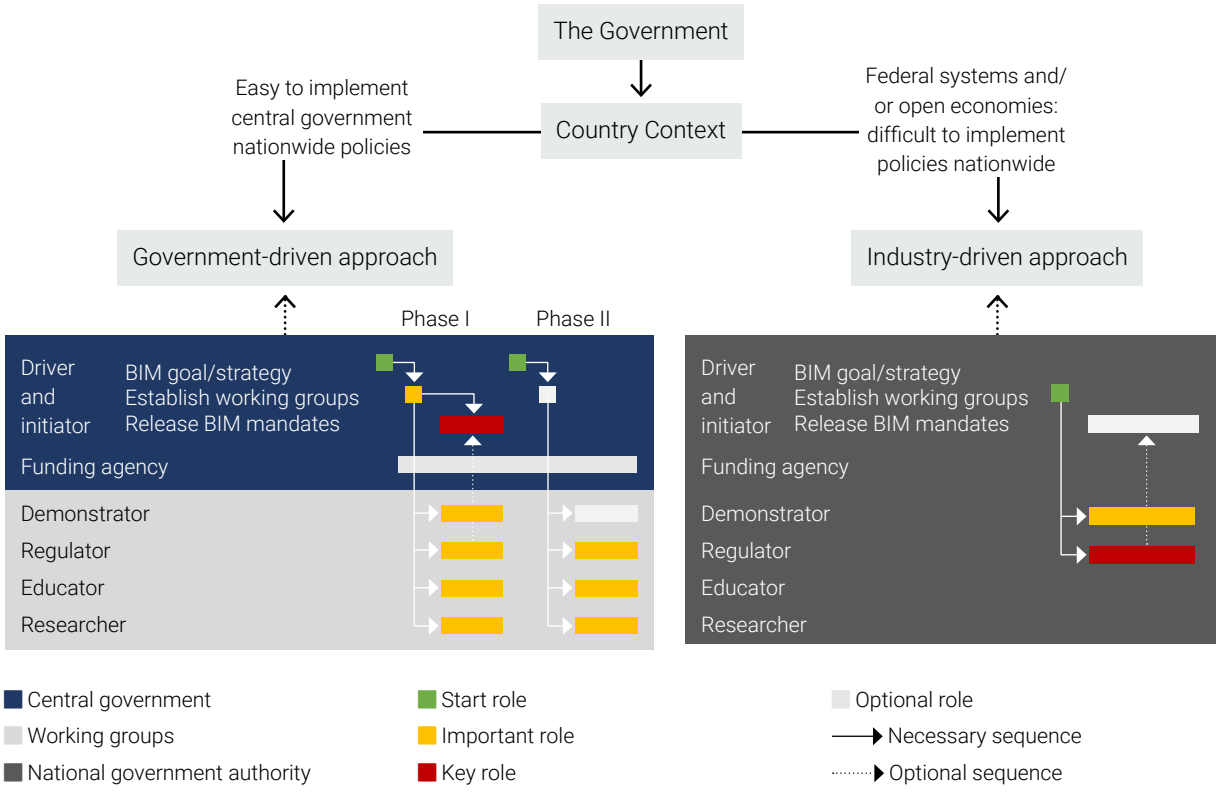


Figure 5
Roadmaps for BIM implementation (Jiang et al., 2022)

Market drivers for digital adoption at the enterprise level can include improved productivity, reduced costs, and remaining on a par with competitors in the uptake of digital technologies in the construction sector. These are increasingly relevant in a context where profit margins are tightening in Europe, labour and skills shortages are increasingly felt, and productivity has stagnated. Consequently, built environment stakeholders are increasingly aware that sectoral transformation must occur if the EU construction sector is to remain competitive in the mid to long term. While project owners (Gledson and Phoenix, 2017), clients, and end-users (Hardie and Newell, 2011) were cited as potential drivers of innovation, the regulatory environment was considered the most significant influence (Adafin et al., 2022).

Finally, it is also worth noting that a number of European Commission funding tools also exist to support digital transformation. However, uncertainty exists as to the extent that such funding initiatives will have on the construction sector (European Commission, 2021a).

3.3. Leadership and Cultural Change

In 2022, Jiang et al. discussed the suitability of government and industry-driven approaches for promoting BIM in Singapore, the UK, and the US. The research proposed a step-by-step BIM roadmap detailing items including government and industry leadership. It also stated that government intervention is a necessary strategy for promoting a wider and more efficient BIM implementation, especially for countries that have lagged behind in BIM adoption. Smith (2014) reviewed the BIM implementation of 10 countries and jurisdictions and identified government leadership as a critical driver. This study clearly shows that government plays a key role in providing leadership in digital transformation. In most cases considered in this study, leadership is typically provided by a hybrid combination primarily involving government and industry, however, academia is also included to varying degrees.

Denmark was an early adopter and has mandated BIM to increasing levels since 2007. Similarly, the UK is considered one of the leading nations of BIM adoption through its top-down mandate approach. In setting out their construction strategy document in 2011, the UK government recognised that they could significantly impact the sector's culture due to the scale of public sector works in renewing and expanding national infrastructure. After recognising their role as a potential agent for change, the UK government recognised that this significant transformation in the construction industry was going to take time, so a five-year plan was set out to prepare the industry in advance of the 2016 mandate, while supports to assist the supply chain were developed in the form of guidance documents and standards. The government-funded UK BIM Task Group led the initiative between 2011 and 2017, while leadership was provided by the Centre of Digital Built Britain (CDBB) from 2017 to 2022. The CDBB was established by the Department for Business, Energy & Industrial Strategy in partnership with the University of Cambridge.

In Germany, where mandates are now being initiated on a phased basis, leadership was provided by Planen-bauen 4.0, which is a non-profit organisation comprising 23 associations and 35 companies as shareholders representing organisations in the planning, building, and operating value chain. More recently, the Federal Ministry for Digital Affairs and Transport (BMDV) and the Federal Ministry for Housing, Urban Development and Building (BMWSB) jointly operate the national centre for digitising the building industry, i.e. BIM Germany. BIM Germany was founded in 2019 by the then Federal Ministry of Transport and Digital Infrastructure (BMVI) and the Federal Ministry of the Interior, Building and Community (BMI), while the Planen-bauen mentioned above 4.0 are a member of the consortium charged with undertaking work on deliverables of the initiative (BIM Germany, 2022).

While there is no mandate, top-down initiatives have been established across a number of sectors in Finland, with the 2016 KIRA-digi initiative being the one relevant to the construction sector. The Netherlands' leadership and cultural change approach is a hybrid between top-down initiatives and bottom-up movements (Bruggeman, E.M., 2020). Increased digital adoption has been led by a number of initiatives over the past 10 years, commencing with the Construction Digitisation Council (BDR), which is the successor to the original Building Information Council (BIR) that was formed in 2014, followed in 2015 by the BIM Locket (translates as BIM Desk) which is the national centre for the management and development of Open BIM standards (digiGO BIM Locket, 2022).

Similarly, a clear leadership initiative in New Zealand emerged in 2014 as the BIM Acceleration Committee (BAC), which comprised voluntary expert members from across the construction industry and the country. The BAC recently morphed into the BIMinNZ, which seeks to play a leading role within the building and construction industry (BIMinNZ, 2022). In a similar role to Build Digital in Ireland, from 2021, BIMinNZ will be responsible for activities such as developing and managing BIM networks, the bi-annual BIMinNZ conference, and future surveys while maintaining and updating the BIM Handbook. While BIMinNZ will primarily work within the bounds of a BIM context, efforts are ongoing to form the Committee for Digital Engineering in New Zealand (CoDENZ), whose remit will take a broader approach to the use of digital techniques within the construction sector, and will ultimately be the lead organisation for developing strategy in terms of digital transformation for New Zealand's built environment (EBOSS et al., 2021). In Australia, a number of public and private bodies provide leadership in digital adoption with a particular focus on BIM. However, the Australian BIM Advisory Board (ABAB) is the primary actor. The ABAB's goal is to influence and lead the adoption of BIM through a membership body comprising government

construction policy, peak construction, and standard-setting experts (NATSPEC, 2022a). The ABAB was established in 2016 by the Australasian Procurement and Construction Council (APCC), the Australian Construction Industry Forum (ACIF), NATSPEC, buildingSMART, and Standards Australia. Many of the previous leadership initiatives have changed name and structure over time. Singapore is different in that the Building and Construction Authority (BCA) has consistently championed the development and transformation of the built environment sector.

In 2017, the EU BIM Task Group identified government policy and public procurement methods as powerful enablers to support the digital transformation necessary in the sector, noting that an absence of such top-down leadership would limit productivity and economic value benefits (EU BIM Task Group, 2018). However, the group also stated that governments could not work alone and would need to collaborate with industry and be cognisant of commercial models, education, skills development, SMEs, and changes to current practices.

(Cheng and Lu, 2015) performed a systematic analysis of the potential roles of the government in BIM adoption based on a review of the public sector's efforts in 14 countries across four regions: America, Asia, Australasia, and Europe. Six potential roles of government in BIM adoption were summarised: initiators and drivers, regulators, educators, funding agencies, demonstrators, and researchers (Table 6).

Research by Liao et al. (2019) established that local government is dominant in driving BIM implementation. Moreover, the study also found that practitioners tend to be conservative about change and that most of the practitioners also adopt a wait-and-see attitude. Research by (Sompolgrunk et al., 2022) traditional evaluation techniques have difficulty to capture "the true value" of BIM from multiple levels and dimensions – as an effective evaluation method is supposed to. This study aims to identify the significant factors that affect BIM return on investment (ROI statistically showed that the main barriers to BIM implementation and diffusion continue to be a lack of evidence proving BIM's benefits. In practical terms, policymakers, professional institutions, and BIM advocates must focus and allocate resources to offer the industry a reliable quantification method for tangible and intangible returning factors.

Potential roles of the government	Definition/activities of each role
Initiator and driver	Setting BIM goals and requirements or publishing BIM roadmaps Establishing working groups or committees Requiring/Mandating BMI use no projects
Regulator	Developing BIM guidelines and standards
Educator	Providing BMI training programs, courses or training methods
Funding agency	Providing financial support for BIM programs or projects
Demonstrator	Demonstrating hte implementation of MBI through pilot projects Sharing success stories and lessons learned
Researcher	Internal R&D Colaborating with or supporting research institutions

Table 6
Potential Roles of Government in BIM Adoption (Cheng and Lu, 2015)

Research undertaken by Jiang et al. (2022) aimed to investigate the BIM implementation journey of three benchmark countries, namely Singapore, the UK, and the US. The countries were selected for the study because all three countries have a high BIM adoption level and BIM mandating experience. In addition, the UK is considered a leading country for mandating BIM implementation, and Singapore and the US are typically successful countries that have adopted the government- and industry-driven approach to BIM implementation. Furthermore, the three countries have a clear and mature BIM journey, which has been investigated with many studies and publications, e.g. reports, news and blogs. The study revealed that government efforts, such as published standards, mandating policies, and established BIM institutions, were key drivers in the BIM implementation phases (Jiang et al., 2022).

The approach to cultural change across the various countries considered in this study is difficult to assess. At its simplest level, identifying whether the approach is either a 'push' or a 'pull' is manageable. A 'push' strategy may be considered top-down communication with compliance-driven change, while a 'pull' strategy involves increased work in the early stages to plan and create readiness. Even in the case of the UK, where there has been a government mandate since 2016 (i.e. push strategy to cultural change), this was preceded by at least five years of formal enabling work, which might be considered a 'pull' strategy. It seems that market readiness is a concern for most countries, hence

the reluctance to set a mandate, while all countries continue to work with industry in various ways to build awareness, capability, and capacity within the sector.

3.4. Measurement Metrics

Limited examples of effective methodologies to measure digital maturity within the construction industry exist. The most common approach evident in the literature is the use of surveys. In all cases, sufficient representation of stakeholders is not clear. While the required response rate is ultimately dependent on the population size, tolerance for error (margin of error), and the confidence level required in the result, it is difficult to ascertain if reported surveys meet the criteria for a 95% confidence level recommended by survey researchers to indicate an "acceptable" margin of error. In the case of longitudinal studies, the variation of respondents to surveys year on year can also impact the validity of any findings.

At a European level, the Digital Economy, and Society Index (DESI) measures countries' performance in digitisation across four key metrics, including:

- Human capital: internet user skills and advanced digital skills;
- Connectivity: fixed broadband take-up and coverage, mobile broadband, and broadband prices;
- Integration of digital technology: business digitalisation and e-commerce;
- Digital public services: e-Government.

In 2009, the *BIM Quick Scan Tool* was developed in the Netherlands to benchmark the BIM use level (TNO, 2010). The tool combined quantitative and qualitative assessments of BIM's 'hard' and 'soft' aspects in an organisation through four main chapters: Organisation and Management; Mentality and Culture; Information Structure and Information Flow; Tools and Applications.

To achieve a more up-to-date measure of the current state of BIM adoption within the Netherlands, the first National BIM monitor was created in 2021 (USP Marketing and Universiteit Twente, 2021). This new venture was led by BIM Locket (BIM Desk), who engaged researchers from the University of Twente (UT) and USP Marketing consultancy to collaborate and conduct research. A real strength of the survey was that it targeted clients, architects, engineers, contractors, installers, and suppliers, while users and non-users of BIM were represented. Over 577 respondents were recorded, with the information primarily sourced through phone interviews. BIM users were presented with a set of questions to enable a BIM maturity score to be assigned. Non-BIM users were asked an adapted set of questions which focused more on their digitisation, leading to a Digital Maturity score (USP Marketing and Universiteit Twente, 2021). There were six key themes or dimensions related to the BIM questioning, including:

- Strategy;
- Organisational and task structure;
- Staff and culture;
- The BIM process;
- IT infrastructure;
- Data structure.

In Germany, the *BIM-Monitor* report was published by the Dusseldorf-based market data specialist BaulinfoConsult and set out to investigate some of the reasons behind the slow adoption of BIM methodologies and again considered both BIM users and non-users (BauInfoConsult and Drees & Sommer, 2022). In this case, over 300 companies were contacted by phone and asked about their opinion and experience of BIM. In Australia, the Australian Institute of Architects, in collaboration with NBS, published the *BIM and Beyond* report in 2021, thus collating the most recent data about adoption, drivers, innovation, barriers, and future challenges. In Singapore, Hwang et al. (2020) completed research that utilised a focused questionnaire and targeted follow-up interviews to explore the level of Integrated Digital Delivery (IDD) implementation and the subsequent perceived improvements in project performance.

The *NBS BIM Survey* in the UK is an example of a longitudinal study undertaken annually between 2011 and 2020 before being expanded in 2021. The survey sought to explore the use of BIM within the industry and to gauge changes in working methods and benefits over time. Another example of a longitudinal study is the BAC annual survey in New Zealand, which operated between 2014 and 2022. Initially, the series followed an industry control group of large and influential organisations in New Zealand's built environment, allowing BIM's use in construction to be tracked. In 2016, an additional client survey was introduced, which focused on asset owners and managers to gain an improved understanding of BIM's impact on facilities and asset management (EBOSS, 2016), while a further survey element focusing on subcontractors was added in 2020.

Research by Jiang et al. (2022) recommended that the BIM diffusion method is carefully selected based on the countries' contexts (e.g., government forces on policy implementation). In addition, BIM acceptance and maturity must be considered before taking actual actions for benchmarking (Kassem et al., 2015). In light of the preceding, the annual survey could prove the most efficient and effective way of measuring progress in terms of digital adoption in Ireland. However, the level of engagement of all stakeholders will need to be monitored to ensure the validity of the findings.

Obstacles	BAC Method	Outcomes
Implementing BIM within a company and industrywide requires a considerable build-up of expertise, especially appropriate employee training and substantial IT upgrading. Small companies will find that especially challenging, as they might struggle to afford the upfront investments.	Education and training	**A skilled and resourced industry**
Project owners will be slow to adopt the technology until they acquire a greater understanding of the benefits of BIM for them.	Government (and selected large) clients	**Informed clients who can procure BIM**
In BIM, data is created and shared in a more collaborative way, which leads to further issues regarding data ownership and liability.	New BAC project to begin in 2017	**Quality data to benefit all participants**
The benefits of large-scale BIM can only be realized when all participants along the value chain get involved; without this interlinking effect, there is little benefit for the first movers.	Supply chain clients	**Quality data to benefit all participants**
Technological standards have to be in place, and interoperability must be ensured so that the various stakeholders can share information and cooperate on planning.	Data standards for interoperability	**Agnostic standards used across NZ**

Table 7
Industry Context Data for Ireland (BIM Acceleration Committee, 2017)

3.5. Barriers and Challenges

In setting out its strategy to improve performance in the design, construction, maintenance and operation of all constructed assets, the BIM Acceleration Committee (BAC) in New Zealand were cognisant of the challenges of achieving widespread adoption of BIM. They noted key obstacles as identified by the World Economic Forum (2016) in citing Forschungsinitiative ZukunftBAU (2013) and developed appropriate methodologies to achieve particular outcomes as presented in Table 7 (BIM Acceleration Committee, 2017). Based on a literature review of the countries considered in this report, the obstacles identified by Forschungsinitiative ZukunftBAU (2013) in 2013 remain relevant today.

The barriers toward BIM adoption, as described by Jiang et al. (2022), include social-organisational barriers (e.g. lack of motivation, adoption of conventional practices and standards), financial barriers (e.g. BIM adoption cost), technical barriers (e.g. interoperability issues), contractual barriers (e.g. lack of a mature BIM contract), and legal barriers (e.g. BIM model ownership). The cost barriers, interoperability issues, BIM model ownership and the intellectual property rights concerns and issues related to the willingness to share data. The latter correlates with the UK, where online data security is challenging. In assessing the levels of diffusion of BIM in Singapore, Liao et al. (2020) reported a lack of studies holistically investigating the factors hindering and driving greater diffusion, and more importantly, few studies have examined whether different types of organisations perceive the hindrances and drivers differently. In an earlier study, Liao et al. (2019) argued that although the overall BIM adoption rate improved, BIM implementation tended to be fragmented with individual stakeholder adoption rather than based on project-wide collaboration. The main contract form is still based on the traditional adversarial system prohibiting collective benefits and shared risk.

A study by (Aarnio et al., 2020) identified issues such as uncertain stakeholder responsibilities leading to repetition of tasks, interoperability of digital tools, and issues with data (i.e. absence, quality, structure, format, conversion, and maintenance).

Research focusing on SMEs in Australia revealed that the lack of reliable quantification methods for the ROI factors associated with BIM significantly impedes commitments to implement BIM within enterprises (Sompolgrunk et al., 2022). Failure to adequately identify and assess benefits could result in systems not being appropriately implemented and supported by finance, where tangible ROI measurements are a priority. Available studies and documents released by state governments in Australia are dominated by deterministic recommendations that overemphasise positive aspects of BIM from a broad, strategic standpoint. However, little practical assistance or evidence exists to support the same (Sompolgrunk et al., 2022).

The most significant challenges to digitisation in Denmark included an absence of a digitalisation culture within organisations, issues with the current form of collaboration in the industry, inadequate digital competencies within enterprises and industry in general, and the high level of investment required. In Germany, barriers were considered under four headings, namely, technical, normative, economic, and educational.

The 2021 ECSO report *Digitalization in the Construction Sector* (European Commission, 2021a) identified the "lack of synergies and consistency between

technologies" (interoperability) as the most significant challenge, while "lack of skilled human resource" and a "lack of standards" were other challenges identified in the study. In moving from individual countries to a more holistic EU context, the recent study by the European Commission (2021a) on digitisation in the construction sector identified barriers linked to the fragmentation of the construction sector and its value chain, the shortage of qualified workers, concerns related to cybersecurity and the business perspective, and issues of standardisation of data and methods. While the extent to which each challenge affects the construction sector varies with significant variation in some cases, three main factors hindering a faster and broader digitalisation of the European construction sector are the cost of equipment and software, lack of a skilled workforce, and lack of awareness and understanding (Figure 6). The proportion of survey respondents that consider particular challenges as relevant is presented in Figure 7 in decreasing order of relevance.

Finally, the sector's low and uneven digital adoption and maturity will likely continue without top-down leadership, significantly limiting its opportunity to improve productivity and value for money (EU BIM Task Group, 2018). This is especially true within its large and diverse SME sector.

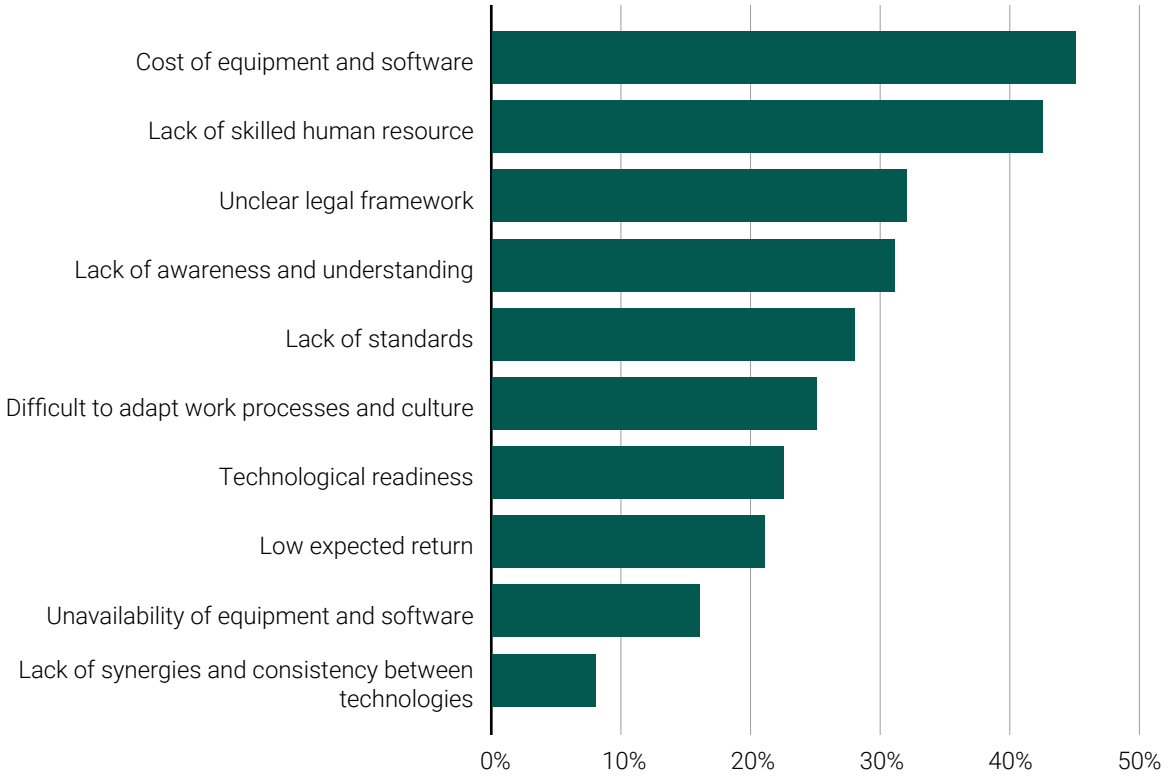
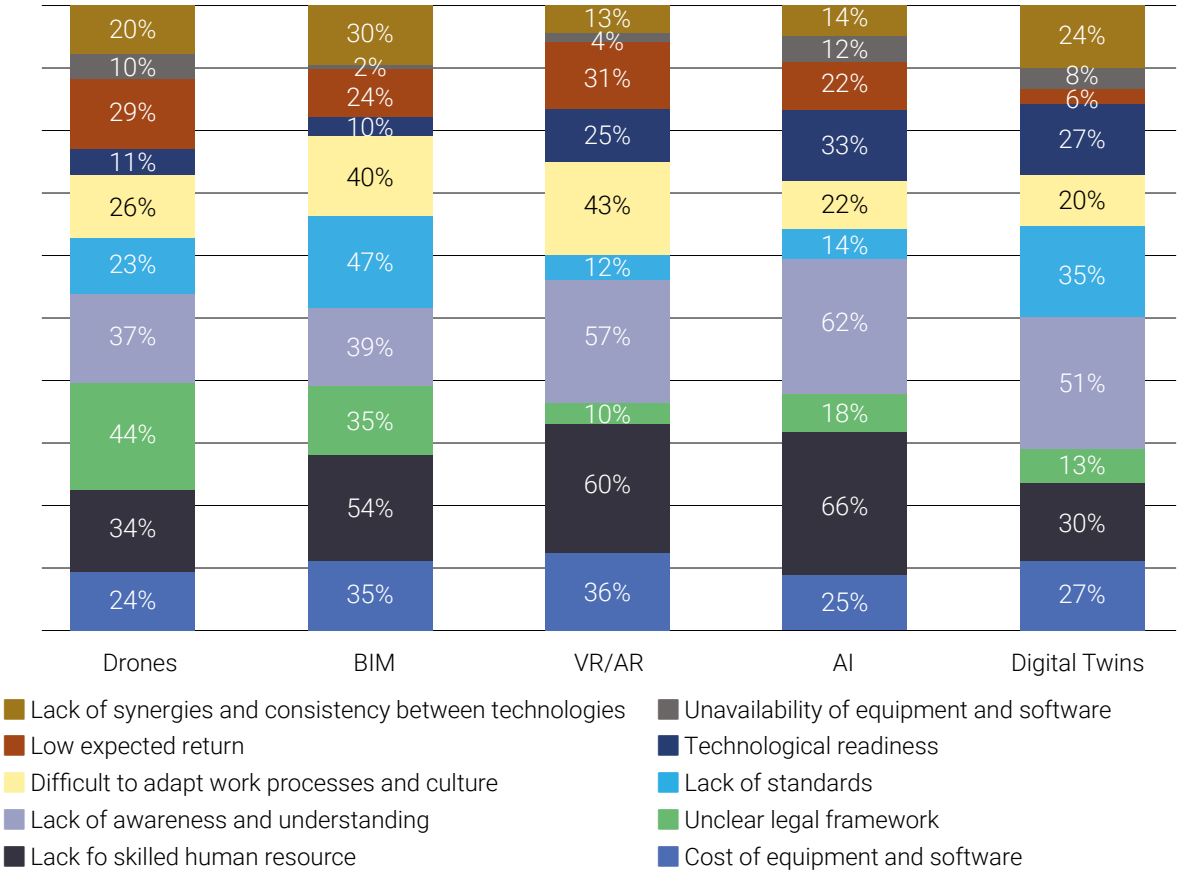


Figure 6
Percentage of Total Respondents to the Survey that Considers Each Challenge as Relevant (European Commission, 2021a)



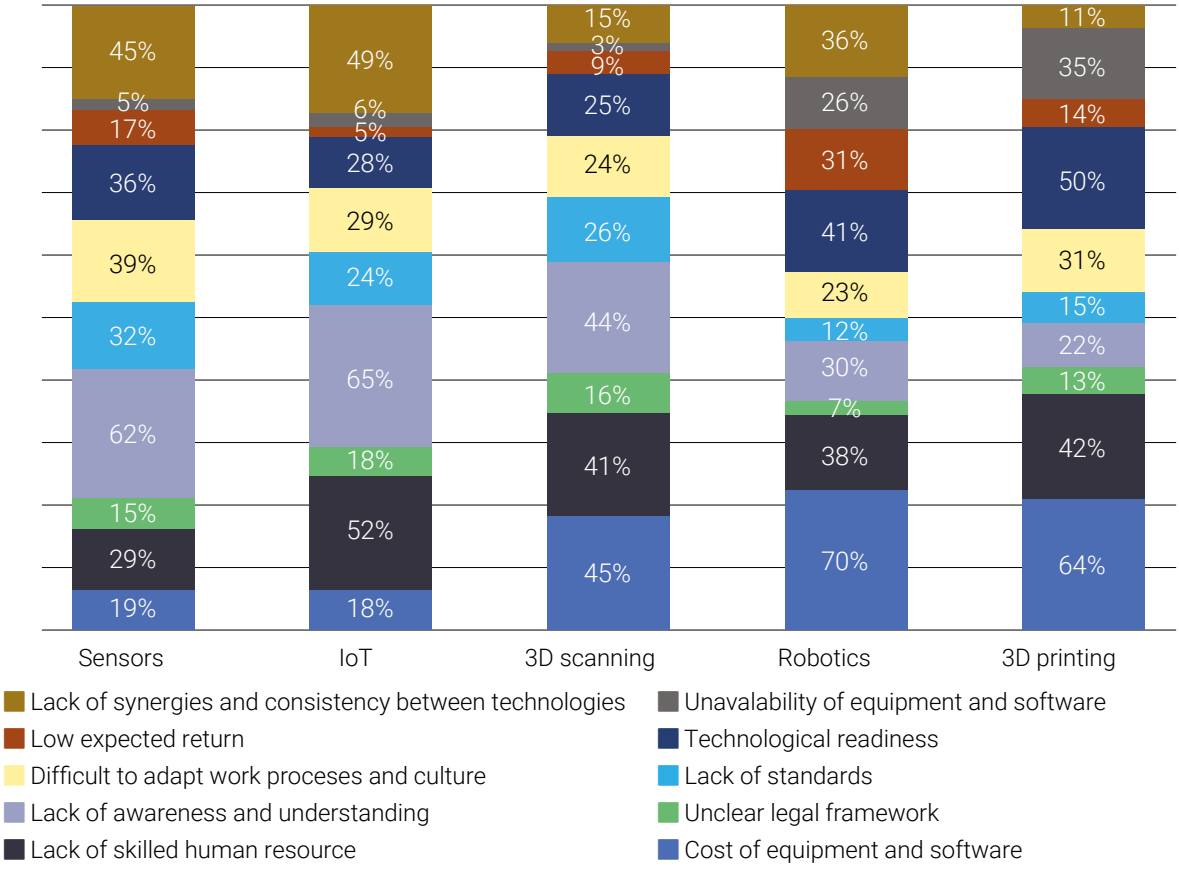


Figure 7
Relevance of Challenges per Each Technology – EU Weighted Average (European Commission, 2021a)

3.6. Benefits

Many commonalities exist with the benefits reported by the individual countries in this study. From an environmental perspective, waste reduction is a common benefit, while digital technologies can leverage data in running energy simulations to improve performance. The *New Zealand BIM Handbook* highlights the benefits of adopting BIM processes throughout the project life cycle while approaching such processes as a whole, which in turn supports more coordinated information sharing, thus enhancing the overall benefits of BIM. The following is a summary of benefits identified as part of this study:

- Economic benefits:
  - » Digitisation of repetitive tasks will release resources to work on increased value-added aspects of projects.
  - » Eliminates duplicated activities.
  - » Increased export potential for businesses operating at a high level of digital maturity.
  - » In the instance of digitally embedded MMC, improvements in precision increase the global export of prefabricated building components.
- Improved planning and reduced risk:
  - » Visualisation of planning alternatives.
  - » Less design errors through collision rendition and increased collaboration between stakeholders.
  - » In the instance of digitally embedded MMC, improvements in safety conditions and stability of employment have been outlined.
- Optimisation of life cycle costs:
  - » Potential for 15-20% reduction according to studies in the UK.
  - » Improved process efficiency.
  - » Reduction in waste through materials analytics.
  - » Precise assessments of cost increases caused by owners' change requests.
  - » Simulation of life cycle costs (including operation and maintenance costs).
  - » Provision of the digital model to the owner as a basis for facility management.
- Improved communication:
  - » Comprehensible visualisation of construction projects for maximum transparency.
  - » Increased understanding by non-built environment stakeholders and the general public.

In Australia, the StartupAUS et al. (2017) report describes how digital datasets open the possibility of big data analytics conducted via machine learning. Artificial intelligence analysis of vast datasets available through BIM will enable predictive indicators as one of the most powerful potential benefits of digitisation for construction firms. To realise such potential, the availability of accurate data in an appropriate format is critical and this is why many countries are significantly focusing on open data standards. For example, in the Netherlands, open standards are favoured over proprietary alternatives for the following reasons:

- Open and neutral standards should be developed to facilitate interoperability;
- Reliable data exchanges depend on independent quality benchmarks;
- Collaboration workflows are enhanced by open and agile data formats;
- Flexibility of choice of technology creates more value for all stakeholders;
- Automatic business reporting;
- Common standards for secure exchange of information;
- Good data and efficient data sharing;
- Transparent digital tendering procedures and procurement;
- Smart City development through common data on topography, climate, water, and energy.

The importance of effective open standards is not restricted to Australia, with Finland, Denmark, the Netherlands, and others also specifically targeting this aspect of digital adoption. It is therefore reassuring to know that open standards are currently being addressed within the Digital Standards pillar of Build Digital.

As Build Digital progresses, it is likely that similar benefits will be evidenced in the Irish context, where they are not already available. A key consideration for Build Digital will be the further effective dissemination of such benefits to promote the value of digital adoption within the sector.

3.7. Resources and Innovations

To varying degrees, each country considered in this study has developed a range of resources including, but not limited to, national frameworks, roadmaps, maturity levels, guidance documents, knowledge cards, templates, case studies, and test/pilot projects. Examples of guidance documents produced by various countries are as follows:

- The Construction Playbook 2022 (UK);
- The New Zealand BIM Handbook (New Zealand);
- Asset Information Requirements Guide (Australia);
- NATSPEC National BIM Guide (Australia);
- Singapore BIM Guide Version 2.0 (Singapore).

Various resources, including guidance documents and templates, have been developed for key BIM-related requirements such as *Employers Information Requirements* (EIR), *BIM Execution Plan* (BEP), and *Common Data Environment* (CDE). Initially, such guides were developed in response to the PAS/BS 1192 series of standards. However, more recent updates have been revised to reflect the recently developed international standards, i.e. ISO 19650 series of standards.

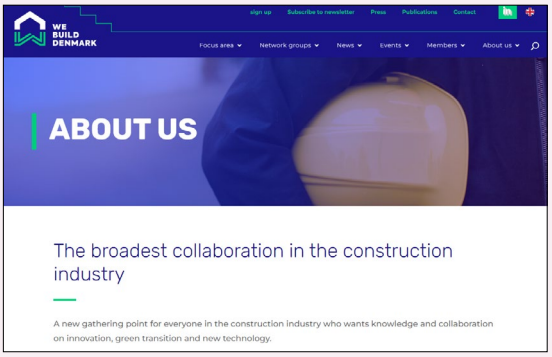
For each country considered in the current study, many of the above resources are shared via a designated central repository as an openly accessible web-based resource, which could be considered a digital hub. A summary of such resources is provided in Table 7, while these are illustrated further in subsequent pages of the report.

Country	Link to Resource
Denmark	https://biminfra.dk/ https://webuilddenmark.dk/om-os/
Finland	http://www.kiradigi.fi/en/info/vision-and-objectives.html
Netherlands	https://www.bimloket.nl/main.php https://digigo.nu/home/default.aspx
Germany	https://www.bimdeutschland.de/ https://planen-bauen40.de/#Projekte
UK	https://www.cdbb.cam.ac.uk/ https://bimportal.scottishfuturestrust.org.uk/
New Zealand	https://www.biminnz.co.nz/
Australia	https://www.abab.net.au/ https://bim.natspec.org/
Singapore	https://www1.bca.gov.sg/buildsg/digitalisation/integrated-digital-delivery-idd

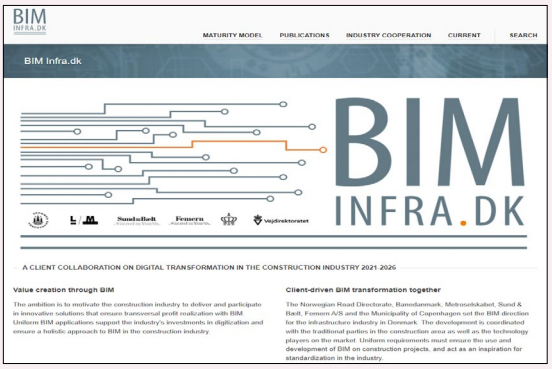
Table 8
Examples of Digital Hubs

Denmark

Link: https://webuilddenmark.dk/om-os/

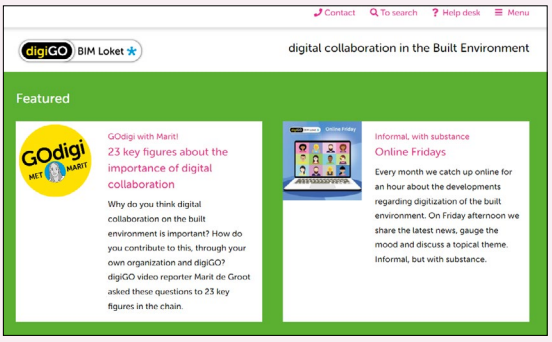


Link: https://biminfra.dk/

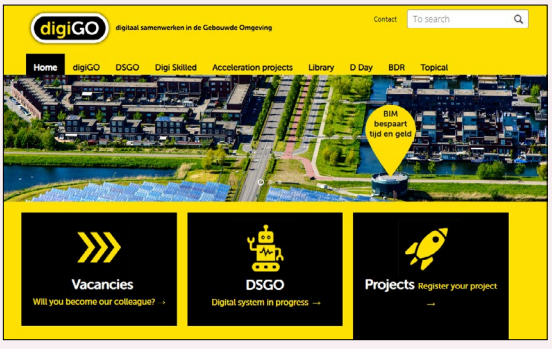


Netherlands

Link: https://www.bimloket.nl/main.php

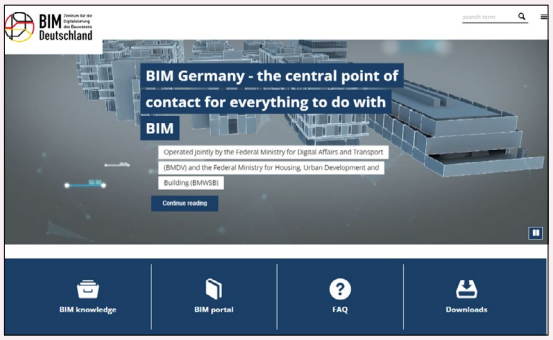


Link: https://digigo.nu/home/default.aspx



Germany

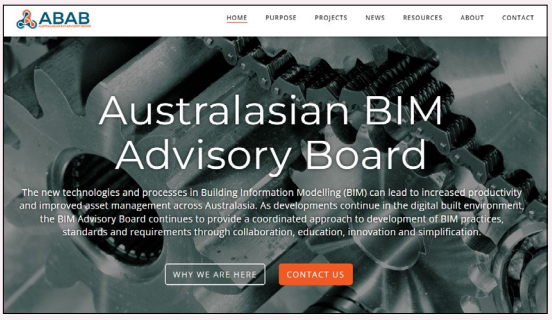
Link: https://www.bimdeutschland.de/



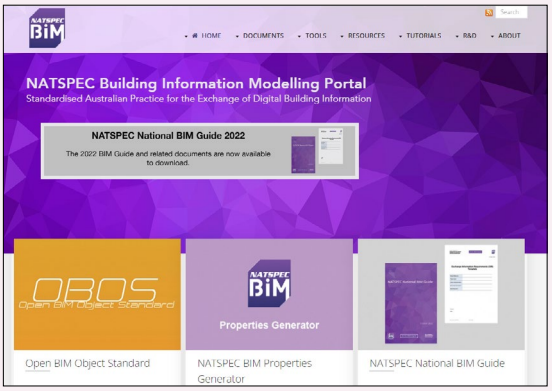
Link: https://planen-bauen40.de/#Projekte

Australia

Link: https://www.abab.net.au/



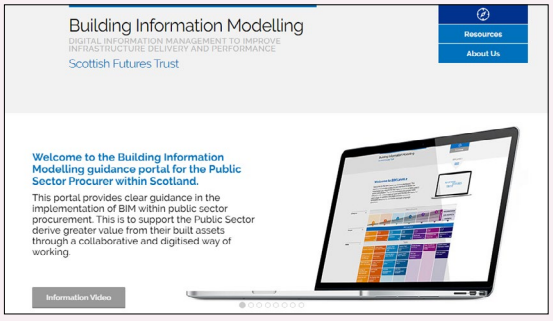
Link: https://bim.natspec.org/



UK

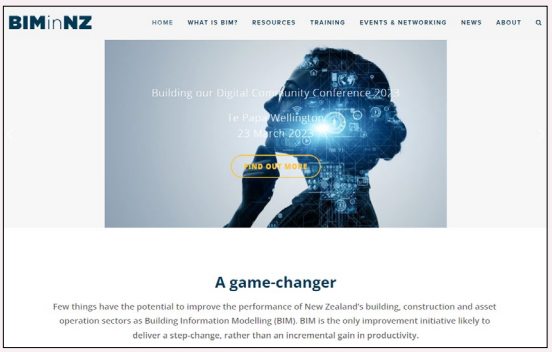
Link: https://www.cdbb.cam.ac.uk/

Link: https://bimportal.scottishfuturestrust.org.uk/



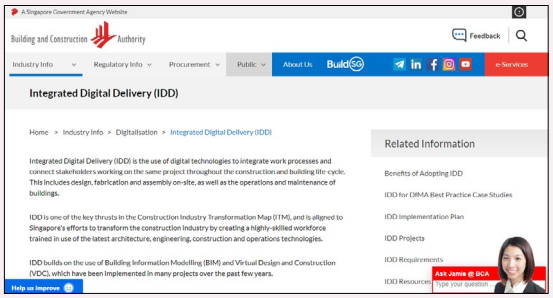
New Zealand

Link: https://www.biminnz.co.nz/



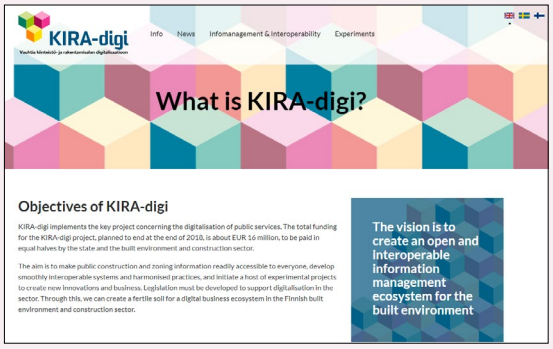
Singapore

Link: https://www1.bca.gov.sg/buildsg/digitalisation/integrated-digital-delivery-idd



Finland

Link: http://www.kiradigi.fi/en/info/vision-and-objectives.html



Regarding tools and toolkits, the *NATSPEC BIM Value Tool* and the *NATSPEC BIM Value Benchmarking Tool,* developed and deployed in Australia, are worth further consideration. The former is an open-access tool that enables stakeholders to identify benefits, metrics, and tools for BIM adoption by following a step-by-step guide. In contrast, the latter enables stakeholders to access contract information and calculate the value of benefits gained from adopting BIM (NATSPEC, 2022b). Meanwhile, the EU BIM Task Group has developed a handbook and associated tool to build the case for introducing BIM in public procurement for individual public projects by demonstrating costs and benefits from the perspective of public clients. This is one of the first deliverables of the Renovation Wave for the construction ecosystem (EU BIM Task Group, 2022).

An example of a test/pilot project is available from the *BIM Infra.dk* resource in Denmark, which presents a test model to support projects through a set of development frameworks and associated templates. In adopting the test model, projects can use and share experiences from other test projects while experiences are evaluated, shared, and incorporated into *BIM infra.dk* specifications and guidelines where appropriate (BIM Infra.dk, 2022).

PART 4

Learnings for Ireland

4.1. Context

As previously outlined, eight countries were selected to inform the study of international best practice. The countries included were Finland, Denmark, Netherlands, Germany, the United Kingdom (UK), New Zealand, Australia, and Singapore. Each of the countries considered has varying levels of digital maturity, with some having BIM mandates in place for some time now (i.e. Denmark, UK) while others are adopting BIM on a phased basis (e.g. Germany).

4.2. Drivers

Clients are key in driving digital transformation within the built environment sector. Many studies point to a lack of client demand when identifying reasons for the slow rate of digitisation within the sector. The UK recognised its role as the largest client in the construction sector and set about driving change by mandating BIM on publicly funded projects. Similarly, the government in Ireland is a significant client in the sector and has the opportunity to effect change through policy and regulation. While mandating BIM creates a 'push' to drive digital transformation, many common challenges continue to be reported in countries where it has been adopted. The level of success through mandating BIM is unclear from the existing literature review. This is perhaps due to the difficulty in developing appropriate metrics and methodologies for such analysis.

A surprisingly less prominent driver in the literature is evidence of the role of digitisation in supporting beneficial outcomes in the context of climate action and the move towards a circular economy. Given the increasing prominence of climate action and Sustainable Development Goals (SDGs) within the public consciousness, the role of digital construction in supporting the achievement of Ireland's 2030 carbon reduction commitments is worthy of further attention. In support of decarbonisation, opportunities are increasingly explored in terms of productization of projects, modularisation, and off-site construction to reduce the overall footprint of the construction process, which is a 'win-win' approach to building. It is widely accepted that digitalisation and BIM are fundamental to such endeavours.

4.3. Leadership and Cultural Change

It is clear from the current study that government plays a primary role in terms of leadership and cultural change. Through various funded initiatives, governments seek to ensure that the industry has the necessary knowledge and skills to realise the many benefits of digital adoption. In addition, government agencies are often the largest client within their respective state. They can, therefore, play a key role as a driver by mandating BIM on a phased basis and subsequently monitoring progress to evolve strategies for optimum inclusion of digitally enabled processes and technologies. Initiation and funding of Build Digital by the Irish government is an appropriate and timely development, while it correlates with digital transformation initiatives in the other countries included in the study.

Build Digital, through the Digital Leadership and Cultural Change pillar, should seek to present the business case for digital transformation and highlight the many benefits, including return on investment and meeting sustainability targets. Based on the study of international best practice, exemplar projects are the most common means of evidencing the same across all phases in the life cycle of a built asset. Case studies appear to be the dominant type, while test/pilot projects are used to a lesser extent. The important role that government agencies could play in case studies and test/pilot projects will need to be explored further to develop the optimum roadmap towards high levels of digital maturity throughout the sector.

To understand the complexities involved in technological transitions, reference may be made to the Multi-Level Perspective framework (MLP) developed by Geels and Schot (2007) to understand why it can take decades and, in the case of construction, significantly longer to adapt and transform. MLP describes how the socio-technical regime, which may be considered traditional practice, constitutes a 'deep structure' stable system that locks in the regime, thus forming significant inertia to change despite significant efforts at change. Despite construction companies continuing to invest significantly in digital technologies and modern construction methods, resulting momentum is insufficient in effecting significant and sustainable change within the regime. To alter the state of this locked system, pressure from either the landscape niche innovations or both is required. The construction sector in Ireland, and indeed globally, has been lacking the necessary landscape pressure for a technological change until the recent disruption caused by Covid-19 allied with the urgent environmental agenda. The World Economic Forum now acknowledges that the construction industry is beginning to change due to digitalisation. This is the landscape pressure that will create the much-needed window of opportunity for BIM to emerge, thus aligning with the potential of a mandate for digital adoption by the Irish government as they seek to lead the sector within an Industry 4.0 context.

4.4. Measurement Metrics

The two primary methodologies used to measure digital adoption within the countries considered in the study include industry surveys and stakeholder interviews. Interviews are typically done by phone and use structured questionnaires, while specialists in the area of market research often administer them. In existing studies, evidence of sufficient representation of all stakeholders is unclear. Without established measurement metrics, the structure and participation levels of the Build Digital annual survey will need to be further considered in the context of operating as a longitudinal study for measuring progress in digital adoption in Ireland. One example worthy of further consideration is the European Digital Economy and Society Index (DESI), which includes four key metrics to measure digital maturity: human capital, connectivity, integration of digital technology, and digital public services.

4.5. Barriers and Challenges

While key data is included in the study to allow context comparison between Ireland and the other countries in terms of the economy and scale of the construction industry, a common characteristic of all is the large number of SMEs that operate in the built environment sector. This is a key challenge, resulting in many interdependent actors, thus perpetuating the sector's fragmented nature. Added to this is that most enterprises tend to be conservative regarding change and adopt a wait-and-see attitude. An example of why this may be the case is evidence in a study of SMEs in Australia, where there is a lack of reliable evidence regarding the quantification of ROI factors. Other significant barriers and challenges identified in the study are common across the countries considered. Examples include a lack of evidence of benefits, lack of client demand, type and profile of enterprise, access to infrastructure, cost, existing contracts, and data security.

The primary pillars of Build Digital align well to address such challenges facing the sector in terms of digital transformation, namely leadership and culture change, capability, and capacity of the workforce, need for common standards and appropriate procurement strategies while supporting the overarching aim of addressing climate change and realising sustainable development of the built environment.

4.6. Benefits

When the benefits of digital adoption across the various countries included in the study were explored, it was clear that many were common. The benefits were summarised under economic benefits, improvements in planning, reduced risk, optimisation of life cycle costs, and improved communication and collaboration. With the advent of AI, the potential to leverage further benefits from the resultant data was highlighted, while the importance of open standards in supporting such endeavours was noted. The issue of open standards is being addressed within the Digital Standards pillar of Build Digital, which is most appropriate given the priority it continues to receive in many of the countries included in this study.

4.7. Resources

The development of an overarching guidance document is worthy of consideration with precedents of the same identified in this study, including *The Construction Playbook 2022* in the UK and *The New Zealand BIM Handbook* in New Zealand. A wide array of resources already exists and could be leveraged to support the digitisation of the sector in Ireland. Examples of these include, but are not limited to, the following, which offer insight into the 'What?', 'Why?' and 'How?' of BIM:

- What?: Arise Training Platform for Digital Construction (Arise, 2023);
- Why?: BIM Innovation Capability Programme (BICP) Case Studies (McAuley, 2017);
- How?: CIF BIM Starter Pack (CIF, 2018), RIAI BIM pack (RIAI, 2022), EU BIM Handbook (EU BIM Task Group, 2018).

Given the scarcity of resources to develop the wide range of supports required, existing resources should be integrated within Build Digital. New resources could be developed to address any identified gaps. In following the approach adopted by many of the countries included in the study, developing a digital hub to act as a repository of information should be considered a critical element of infrastructure to be developed through Build Digital. The digital hub should comprise a web-based central repository for guidance, roadmaps, toolkits, templates, exemplar projects, etc. At present, the *Build Digital Exchange Hub* is an integrated project outcome (IPO) for Build Digital and is an appropriate and critical aspect, while the exemplars identified as part of the current study should inform the format and content of the same.

PART 5

Conclusions and Recommendations

5.1. Conclusions

This international study of best practice was undertaken to inform the digital transformation of the built environment sector in Ireland through the work of Build Digital. Eight countries, namely Finland, Denmark, Netherlands, Germany, the United Kingdom (UK), New Zealand, Australia, and Singapore, were included in the study. The following conclusions are based on a desk study analysis of literature about the countries as well as the existing context in Ireland:

- Given the scale of public works in renewing and expanding national infrastructure, government agencies are often the largest clients within their respective states and can, therefore, be a significant driver in terms of digitisation of the industry.
- While government acts as a primary agent of leadership and cultural change, seeking to effect change and realise the many benefits of digital adoption via funded initiatives, policies and new contracts, leadership is typically provided by a hybrid combination involving government and industry.
- Varying levels of digital maturity exist in the countries considered in this study, with some having BIM mandates in place for some time now (i.e. Denmark, UK), while others are adopting BIM on a phased basis (e.g. Germany) to ensure economic stability on major projects. Reluctance in setting a mandate in many countries is due to concerns in terms of market readiness.
- Industry surveys and stakeholder interviews are the primary methodologies used to measure digital adoption within the countries considered in the study.
- The level of success through mandating BIM is unclear from the existing literature review. This is perhaps due to the difficulty in developing appropriate metrics and methodologies for such analysis.
- While mandating BIM creates a 'push' to drive digital transformation, many common challenges continue to be reported in such countries.
- A common characteristic and challenge in the built environment sector is the large number of SMEs, perpetuating the sector's fragmented nature.
- The benefits of digital adoption are common and comprise economic benefits, improvements in planning, reduced risk, optimisation of life cycle costs, and improved communication and collaboration.

The primary pillars of Build Digital align well to address key challenges facing the sector in terms of digital transformation, namely leadership and culture change (Digital Leadership & Cultural Change, Pillar 1), the need for common standards (Digital Standards, Pillar 2) and appropriate procurement strategies (Digital Procurement, Pillar 4), capability and capacity of the workforce (Digital Education & Training, Pillar 3) while supporting the overarching aim of addressing climate change and realising sustainable development of the built environment (Sustainability & Circular Economy, Pillar 5). Initiation and funding of Build Digital by the Irish government is an appropriate and timely development, while it correlates with digital transformation initiatives in the other countries included in the study.

5.2. Recommendations

In terms of learnings for Ireland, the following recommendations are considered key actions in supporting progress over the five-year Build Digital Project:

- The business case for digital transformation highlights the many benefits, including return on investment and meeting sustainability targets. Exemplar projects and case studies appear to be the dominant type, while test/pilot projects are used to a lesser extent.
- A critical element of infrastructure that should be prioritised for development through Build Digital is a digital hub to act as a repository of information.
- Development of a repository of support and guidance in the form of roadmaps, toolkits, templates, exemplar projects, etc., may be integrated into the digital hub.
- Without established measurement metrics, the structure and participation levels of the Build Digital annual survey will need to be further considered in the context of operating as a longitudinal study for measuring progress in digital adoption in Ireland.
- In terms of drivers, the role of digitisation in addressing climate change, delivering on SDGs and supporting a circular economy needs to be evidenced and reported.

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