Welsh Economy Research Unit

Yr Uned Ymchwil i Economi Cymru

Superfast Broadband Business Exploitation Project

Digital Technologies and Future Opportunities for the Construction Industry in Wales

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Summary

This report considers the future role of broadband and its related digital technologies to help strengthen the construction industry in Wales. The key findings can be summarised as follows:

- There is a heightened industry and policy recognition on strengthening the digital capacities and innovation of the construction sector as a response to the social, economic and political challenges it faces.
- The construction industry remains one of the least digitally mature industries – supported by both existing research and WERU's ongoing interview and survey data.
- Despite the growing awareness and investment in supporting the digital capacities and innovation of the construction industry there remains a number of difficult hurdles for construction SMEs in Wales, including the skill set of the workforce, culture of resistance and diminishing resources.
- A range of existing and emerging digital technologies are applicable to the construction sector in Wales. This includes incremental adoption of broadband-enabled digital technologies, which is likely to be the most fruitful for SMEs given the remaining barriers, as well as more radical tools (such as BIM), particularly relevant to larger firms.
- The challenges for policy makers will require it to work closely with industry trade bodies, and to devise targeted support to address the upgrading of the digital capabilities of SMEs, but also sector wide through initiatives targeting skills deficits.
- Given the strong supply chain structure in the construction sector there is opportunity to encourage and support greater co-learning, including in-house training and sharing of skills. This may require partnership and support with sectoral bodies and large construction firms.

1. Introduction

The construction industry accounts for almost six percent of the Welsh economy's output (Welsh Government, 2019a), as well as employing nearly one in ten people in the UK (HM Government, 2018). Covering three broad areas (construction of buildings, civil engineering and infrastructure, and specialised trade construction activities), construction crosses other industries (particularly manufacturing and engineering) and relies on local supply chains (HM Government, 2018). In the UK, policy makers, industry leaders and key stakeholders are working together to strengthen the construction industry. One of the ways in which they aim to achieve these goals is through a heightened emphasis on integrating digital innovations (McKinsey Global, 2017; HM Government, 2018). This responds to the construction industry traditionally lagging behind other sectors in terms of digital innovation and the adoption of digital technologies (National Building Specification, 2019).

Yet, the construction industry faces a number of social, economic and political challenges (McKinsey Global, 2017) that may interfere with these developments. These include fluctuating public sector demand and high levels of cyclicality (McKinsey Global, 2017). These obstacles can distort the market, creating a highly fragmented and risk adverse environment coupled with a skills deficit and underinvestment in research and development (R&D) and innovation (McKinsey Global, 2017). Alongside these challenges, the construction industry is also going through a period of heightening industrial regulation, including the introduction of foundation classes (IFC), geographical information system standards (GIS) and the Construction Operations Building information exchange format (COBie). Responding to these challenges there is a push to improve productivity, efficiency and exports for businesses, alongside a heightened recognition of the need to improve the working conditions for the occupations supporting the construction industry (CITB, 2018a).

While digital technologies may provide a way to tackle some of these problems, there remains a number of hurdles. For example, the construction supply chain relies on collaborations with customers and subcontractors that each need digital maturity to succeed (Oesterreich and Teuteberg, 2016). Additionally, the industry comprises of a large number of small-to-medium enterprises (SMEs) with varying resources to invest in digital technologies. The work itself is largely remote, site-based and fixed term, with complex tools, procedures and regulations. Adding to this fragmentation, is a need for shared leadership (Farmer, 2016) coupled with an underinvestment in research and design (R&D). These challenges are aligned to a perception of short-term thinking and a culture that is resistant to change, including a resistance to investment in broadband enabled digital technologies (McKinsey Global, 2017).

The report draws on existing literature alongside the Welsh Economy Research Unit's (WERU) interview and survey data to evaluate how broadband-enabled resources may help Welsh construction SMEs overcome existing hurdles and take advantage of the improvements in connectivity supported by programmes such as Superfast Cymru programme (and its successor), part-funded by the European Regional Development Fund (ERDF) through Welsh Government. In particular, the report recognises the variations across the three construction subsectors, evaluating the potential opportunities and barriers for digital technologies for the various elements of the industry. To do so, the report first maps out the construction industry in Wales, identifying its strengths and weaknesses, alongside the current policy and industry developments. Second, the report focuses on both radical and incremental digital developments being applied across the construction industry, evaluating their potential role within construction SMEs in Wales. Third, the report details the WERU interview and survey data to identify key themes emerging for construction SMEs in terms of their adoption of superfast broadband enabled technologies. Fourth, the report breaks down these findings and assesses the potential implications for each of the three subsectors. Finally, conclusions and policy recommendations are outlined.

This paper forms part of a series of Horizon Scanning reports which are available on the Cardiff Business School website: http://www.cardiff.ac.uk/superfast-broadband-project/horizon-scanning

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2. An overview of the construction industry in Wales

Construction is a primary industry in Wales, accounting for nearly six percent of the Welsh economy (Welsh Government, 2019a). There are an estimated 38,000 construction businesses in Wales, employing around 82,000 people (Welsh Government, 2018). Construction is both highly connected with other industries (particularly manufacturing and engineering) and reliant on local supply chains (HM Government, 2018). It can be broken down into three broad areas, namely construction of buildings, civil engineering and infrastructure, and specialised construction activities. As a central part of the Welsh labour market, construction encompasses a number of non-manual (e.g. construction project managers and business process managers), manual (e.g. labours, plasters, civil engineering operatives) and professional occupations (surveyors, civil engineers, architects). Public and private spending on construction also brings direct and indirect local and regional economic benefits to the United Kingdom. For example, recent input-output analysis by the Office for National Statistics (ONS), suggests that for every £1 spent on the construction sector then an additional 86 pence is created in demand in the supply chain. Furthermore, for every £1 spent on wages, the sector generates an additional one pound in the wages of supplier industries (ONS, 2018).

Despite prolonged periods of growth in Wales, the forecasted output and employment estimates are showing signs of decline. In 2018, a Construction Industry Training Board (CITB) report pointed to encouraging estimates, putting average output growth as high as 4.6 percent per annum and employment growth at 2.2 percent between 2018– 2022 (CITB, 2018b). Both of which were significantly higher than the UK average of 1.3 percent and 0.5 percent respectively. The most recent report for the 2019-2023 period presents a more challenging summary, with the average annual output growth estimates falling to 0.5 percent and employment at 0.7 percent (CITB, 2019a). The reduced growth predictions in part reflect the suspension of large-scale infrastructure projects, such as the Wylfa nuclear plant. These challenges are notwithstanding the recent announcements surrounding the suspension of the M4 relief road and the Swansea Tidal Lagoon. It is likely that infrastructure will be the most impacted, with forecasts predicting no significant growth in the 2019 report, in contrast to previous predictions putting the average growth at 14.2 percent a year in the 2018 report (CITB, 2018b) and as high as 25 percent annual growth in the 2017 report (CITB. 2017a). Instead, the remaining modest construction growth estimates reflect the expansion of private housing, with plans to build up to 20,000 new affordable houses by 2020/2021 (CITB, 2018b). While benefits can be seen in terms of housing construction, the forecast is more cautious for commercial construction which is likely to be impeded in the short-term by caution surrounding Brexit (CITB, 2018b).

In addition to challenging growth estimates, the construction industry faces a number of social, economic and political obstacles (McKinsey Global, 2017; NBS, 2019). These include relatively low productivity, issues over sustainability, and problematic economic competitiveness operating alongside societal demands for improved and more efficient provision of housing stock (NBS, 2019). Brexit also poses a potential threat to the construction industry in Wales. Whilst in the EU, Wales receives funding for infrastructure from a number of sources, including the Connecting Europe Facility (CEF), European Regional Development Fund (ERDF) and Horizon 2020. Potential consequences of the UK's withdrawal from the EU include a reduction in the amount of funding available for infrastructure projects, fewer funding options, and remaining available funding being allocated to UK priorities rather than EU (CITB, 2019c). In addition to resource constraints, there are also concerns that Brexit will result in amplifying the skills deficit, with the industry struggling to fulfil the workforce demand (CITB, 2019c).

Policy makers and industry stakeholders are looking for ways to respond to the challenges. The UK Government has set out targets in Construction 2025 to reduce the cost of construction and the whole life cost of assets by 33 percent; a 50 per cent reduction in the time taken from inception to completion of new build; a 50 per cent reduction in greenhouse gas emissions; a 50 per cent reduction in the trade gap between total exports and total imports of construction products and materials. A part of the strategy involves integrating more digital innovations, creating an industry that is both efficient and technologically advanced (HM Government, 2018). Supporting these improvements is the Industrial Strategy Challenge Fund (ISCF), where Transforming Construction has pledged £170 million from public and private partners to bolster the industry. A central part of this programme is a heightened focus on digital solutions, including building information modelling (BIM), sensors, data analytics, smart technologies and information management landscape (IML) which can help to improve the efficiency of construction techniques.

In Wales there has also been heightened policy commitment, illustrated through the Welsh Economic Growth Fund and Construction Sector Development Fund. Additionally, the Construction Futures Wales (CFW), Construction Excellence Wales and Construction Industry Training Board (CITB) have been established in response to these calls for greater business and workforce support (CE Wales, 2019; Welsh Government, 2019b). The business improvement programme aims to equip the industry with the support and training needed to respond to the existing challenges. One of the ways to do so is through the establishment of a digital platform and portal to support construction careers, namely GoConstruct. Additionally, an Inspiring Construction campaign was launched by the CITB in partnership with Build UK to promote careers in construction for the next generation. Moreover, programmes are also being trialled that aim to build on and extend skills in the construction industry by maximising the digital opportunities and modern methods of construction. To scale up innovative training models the CITB has invested £34million across the UK. The importance of collaboration across industry and policy is central to these advancements. This is further acknowledged by recent Welsh Government policy with the establishment of a Construction Innovation Index and Innovation Zone (Welsh Government, 2019b). Central to these programmes is a focus on investing in R&D and introducing new techniques and technologies into design and manufacturing (Welsh Government, 2019b).

3. Wales' Construction Industry and Digital Technologies

There are continued calls for the construction industry to build on available digital technologies and digital innovations to respond to the current sectoral challenges (McKinsey Global, 2017; Welsh Government, 2019b). Greater utilisation of digital advancements offers one means for the construction industry to advance its opportunities and respond to its current challenges. Advancements in broadband-enabled digital technologies include the more radical and resource-intensive developments as well as more incremental and everyday adjustments. The radical advancements can be grouped under smart technologies or simulation and modelling (Oesterreich and Teuteberg, 2016). These are considered alongside the incremental digital tools below, examining their potential benefits and barriers for Welsh construction SMEs:

3.1. Smart technologies

An important technological development relates to the advancements in smart technologies, including the integration of the Internet of Things (IoT) and Internet of Services (IoS). IoT refers to the multifaceted use of sensors, cloud applications, enterprise resource planning (ERP) and business intelligence that can be embedded into physical objects (e.g. robotics, equipment) and be commanded through the Internet. IoS draws together all the services, platforms and infrastructure needed to use software applications through the Internet (Moreno-Vozmediano et al. 2013). Together, these create technologies that can support a 'smart' and semi-automated factory environment. Implementing smart construction may help to improve productivity while reducing the whole life cost and increasing sustainability (Construction Leadership Council, 2018). Estimates suggest the application of these advanced digital tools could save construction between $160 billion to $930 billion annually (McKinsey Global, 2017).

Other industry transforming technologies include additive manufacturing (AM), where complex architectural components can be manufactured using digital tools connected to the Internet. AM is often referred to as 3D printing, representing a computer-controlled process that creates 3D objects by successively adding material layer by layer (Camacho et al. 2017). Yet, these developments remain largely in the proof of concept stages, offering a future way of mitigating some of the challenges in the industry (Camacho et al. 2017). A more commonplace digital technology used in the manufacturing process is modularisation, otherwise known as prefabricated construction. The process involves manufacturing larger building components offsite, usually under controlled conditions. Potential benefits include improved productivity, greater return on investment, a competitive advantage and increasingly a response to client demand (McGraw Hill Construction, 2011). It is estimated that the process can be up to 50 percent quicker while adhering to the same codes and standards as conventionally built facilities (Modular Building Institute, 2019).

A further area that may revolutionise the construction industry as it develops is robotic technology. While innovative and experimental robotics are being highlighted in the literature, their application in practice remains minimal. Prototypes include robots that fulfil everyday construction and operations activities, including bricklaying, waste management, asbestos removal and flooring (Oesterreich and Teuteberg, 2016). While these offer benefits in terms of safety and business efficiency, they also create risk to employment through job automation. Drones are also gaining attention, with their use being aligned to site surveillance, provision of progress reports, monitoring deliveries and automated bulldozing (Oesterreich and Teuteberg, 2016).

These smart technologies are transforming construction businesses and offer more advanced digital maturity. However, they are often resource and knowledge intensive, requiring large sums of upfront investment and worker training. While these developments are becoming a necessity for large scale infrastructure and housing projects, their integration into commercial and specialist construction is likely to be more incremental. Similarly, the expensive training required may make them more difficult for micro businesses (with less than ten employees), and small businesses, to implement. This is particularly acute for some of the more advanced tools, such as robotics, which remain in the developmental stages.

3.2. Simulation and modelling

One prominent industry wide development is the increasing adoption and regulation of building information modelling (BIM). BIM allows greater design specification and increasingly is becoming the industry norm. BIM enables the integration of data across the construction lifecycle and value chain (Oesterreich and Teuteberg, 2016). As such, it is having an increasingly integral role in the design and management of complex construction projects, especially when adopted alongside the IoT (Oesterreich and Teuteberg, 2016). By combining various aspects of the construction project's lifecycle, BIM brings together an assortment of data with a collaborative plan and design. The information contained with the integrated package includes designs, plans, project schedules, costs, materials and technical information. BIM is most successful when integrated with cloud packages and mobile computing (Oesterreich and Teuteberg, 2016). In addition, BIM also integrates big data attained from sensors, computers and machines to help inform future decision making and mitigate against risk. As such, BIM provides an opportunity to improve on-site monitoring of materials, labour and equipment, as well as boost productivity and the availability of digital collaboration (McKinsey Global, 2017). It is estimated that onsite productivity can be increased by as much as 50 percent by assembling cloud systems that enable the real time sharing of data (McKinsey Global, 2017). BIM is recognised in Wales as offering notable benefits to the sector, yet there is greater need to promote and support its integration.

Another area where digital development may impact the construction supply chain relates to the adoption of virtual reality (VR) for learning and training, augmented reality (AR) for communication and defect management and even a more toward mixed reality (MR) whereby the user can interact with 3D models without the use of a headset (Oesterreich and Teuteberg, 2016).These technologies have the potential to transform the construction industry. Already, AR and VR are becoming commonplace tools used at all stages of the project; from design through to preparation and completion (Wang et al. 2018). Additionally, these tools are being used for training and education, supporting improvements in training programs and training performance (Wang et al. 2018). As technologies improve, there are increasing attempts to integrate VR with BIM, thereby allowing the client to be included into the design process (Davidson et al. 2019).

3.3. Incremental advancements

Incremental and everyday digital innovations that can save time and resources are vastly important to construction businesses (NBS, 2019). These broadband-enabled technologies can help improve communication, collaboration and knowledge exchange among construction businesses and workers (NBS, 2019). Using a survey of 500 participants, the NBS report provides some noteworthy examples of these incremental benefits supporting businesses and workers in the construction industry. The findings point to the following examples and benefits:

- Use of remote collaboration tools that facilitates communication between customers and workers.

- Use of visual plans that can be shared on cloud-based platforms to enable collaboration and team working in real time.

- Greater visualisation and coupling of software tools through BIM – bringing together a diverse workforce of architects, engineers and designers, as well as allowing real time updates from clients.

One important example is cloud computing, which supports the storage and access of data and software over the Internet. Cloud is the most pervasive broadband-enabled tool used by the industry, with 63 percent of respondents in a recent 2019 NBS survey using cloud technologies in some form (NBS, 2019). These platforms can be used to integrate the services developed along the construction supply chain.

Additionally, social media tools can be used to aid internal and external communication. In contrast to other industries that rely on social media for advertising and promotional purposes, there is an emphasis on sharing information with employees, clients and contractors. For example, applications such as PlanGrid or blueprint to enable teams to annotate and share blueprints.

3.4. Evaluating digital diffusion of construction businesses

The scope and benefits of utilising broadband-enabled digital technologies are wide ranging, including cost and time reductions, improved ability to meet stringent deadlines, heightened quality, facilitating communication and collaboration, improved customer experience, safety advancements, improved industry image and greater sustainability (Oesterreich and Teuteberg, 2016). For example, the potential benefits from greater integration of digital technologies along construction supply chains and into business models include productivity gains of up to 50 to 60 percent (McKinsey Global, 2017). Moreover, greater uptake of digital advancements could provide the construction industry benefits in terms of safety and value (NBS, 2019).

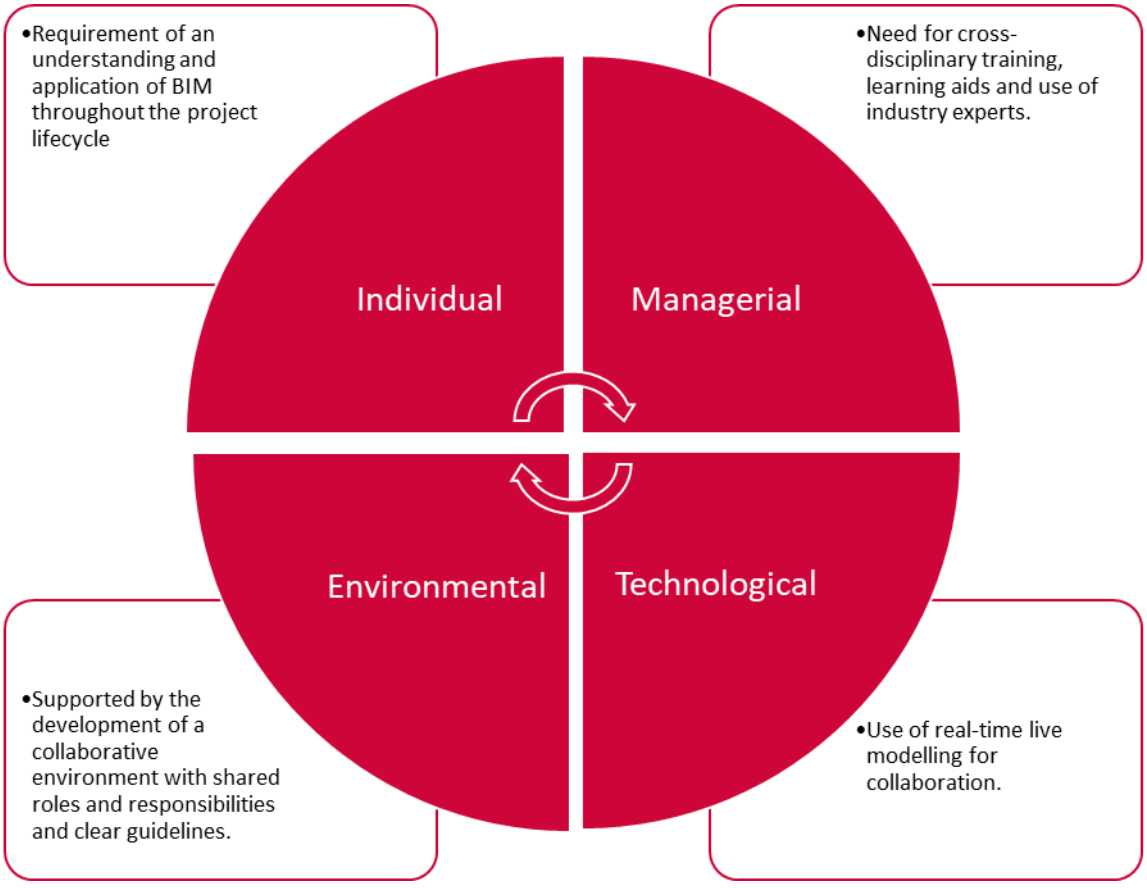
Despite these developments, the construction industry remains one of least digitalised sectors (McKinsey Global, 2017; NBS, 2019). While broadband-enabled technologies offer an important and underdeveloped opportunity for Wales' construction industry, there remains a behavioural and cultural barrier that further prevents their development. As the NBS (2019) survey details, business leaders continue to see digitalisation as a risk. There is a greater need to experiment and invest in digital solutions, both radical and incremental. However, the workforce also needs time, encouragement and freedom to learn and experiment. There is a need to "embrace a culture of digital transformation" (NBS, 2019).

Oesterreich and Teuteberg (2016) summarise the challenges facing the construction industry's implementation of digital technologies, including:

- Industry, business and individual resistance to adoption
- High implementation costs that are not easily accessible to SMEs
- A requirement for large scale organisation and procedural restructuring
- Industry-wide ICT skills deficit
- Lack of consistency and guidance from industry regulations and requirements
- Need for greater data security and protection
- Requirements for improvement to the communication and data sharing networks
- Regulatory compliance and continued uncertainty surrounding the legal and contractual expectations

There remains notable variations in digital uptake, with some construction businesses attaining high levels of digital maturity while others do not use computers or digital tools in their day-to-day activities (Mershbrock and Munkvold, 2015). The varying diffusion of digital technologies in construction businesses responds to individual (e.g. IT skills, capability to learn, experience), environmental (e.g. sharing environment, knowledge exchange), management (e.g. ICT support, managerial culture) and technological factors (functionality, speed and accessibility) (Peansupap and Walker, 2005). Applying these factors to the construction of a hospital, Mershbrock and Munkvold (2015) show the interconnection between the enabling factors and the processes underlying the construction supply chain:

Figure 1: Digital diffusion in the construction of a hospital: adopted from Mershbrock and Munkvold (2015).



While the availability of superfast broadband most overtly impacts the fulfilment of technological factors it remains a prerequisite for the successful attainment of the other factors. Connectivity barriers would impact upon the online development and application of digital skills, the ability to internally and externally communicate and collaborate in real time, and the feasibility of enabling and supporting an ICT infrastructure.

4. Applying WERU Case Study and Survey Data

Building on the existing research, this report uses a combination of interview and survey data compiled by the Welsh Economy Research Unit (WERU) to assess digital barriers and enablers for Welsh construction SMEs and workers. The report sets out data derived from the 2018 WERU Digital Maturity Survey, including a comparison of how construction SMEs are performing in terms of access and utilisation of superfast broadband and enabled digital technologies compared to the other primary sectors in Wales. The report then evaluates key themes emerging from nine interviews with construction businesses across Wales.

4.1. WERU Digital Maturity Survey 2018

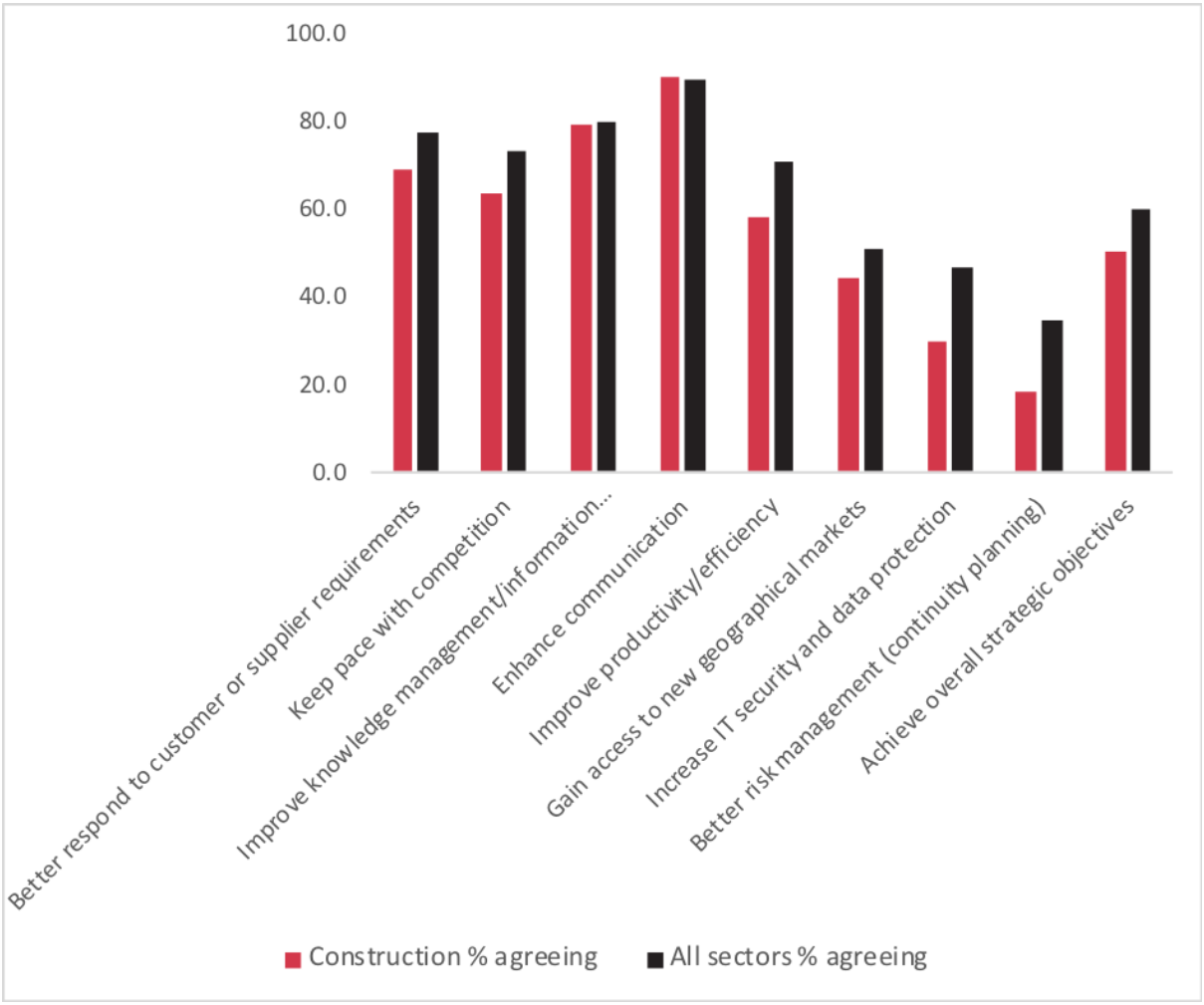
The Digital Maturity Survey is undertaken on an annual basis, measuring Welsh SME's access to, and use of, superfast broadband enabled digital technologies. The 2018 survey included 45 construction SMEs out of its total 479 respondents. Of the 45 SMEs, 53.1 percent reported the adoption of superfast contracted speeds of 30Mbps and above. Table 1 provides a comparison of the percentage of the construction SMEs accessing and using broadband enabled tools, alongside accommodation and food services; business and other services; information and communication; manufacturing; and wholesale and retail.

Table 1: Digital Maturity Survey 2018: Use of Digital Infrastructure

	% of sector using digital infrastructure, tools and software						
	Construction	Accom and food services	Business and other services	Information and communication	Manufacturing	Wholesale and retail	All
Use of a foundation cloud service	**70.2%**	85.2%	87.7%	84.3%	87.1%	72.1%	79.4%
Use of an advanced cloud service	**65.7%**	67.5%	78.7%	81.6%	72%	71.4%	72.3%
Use of a website	**77.8%**	94.1%	94.2%	97.4%	85.4%	93.1%	88.5%
Use of social media	**57.1%**	91.1%	80.7%	86.9%	81.2%	88.1%	75.6%
Dedicated ICT budget	**6%**	13.2%	12.4%	15.6%	22.6%	13.4%	11.9%
Employment of an ICT specialist	**18.4%**	51%	40.2%	83.1%	56.2%	39.3%	37.7%

Many of the digital tools analysed are the incremental and everyday use of digital technology within the business, such as of foundation or advanced cloud services, use of a website, social media, and the businesses' ICT skills and resources. As Table 1 shows, the construction businesses surveyed performed below the overall average and below the other primary industries across both access and use of digital tools. Only 52.1 percent of SMEs surveyed reporting access to superfast broadband and only 70.2 percent used some form of foundation cloud service. This is in contrast to other industries, such as business and other services where 87.7 percent of businesses used at least one form of cloud services. Particularly stark is the small number of businesses reporting a dedicated ICT budget, falling in at six percent, some 16.6 percentage points lower than for manufacturing. Similarly, only 18.4 percent of construction firms reported employing an ICT specialist, in contrast to 83.1 percent of information and communication firms. A further finding relates to the lower reports of ICT skills at intermediate level and above- construction respondents reported that only 57 percent of the workforce held this skillset, in contrast to 91.3 percent for IT, 83.6 percent for business services and 73.6 percent for manufacturing.

Figure 2: Digital Maturity Survey 2019: Reported benefits of digital maturity



The survey data also sets out SMEs' reported benefits derived from implementing broadband-enabled digital technologies into their business. The benefits include a better *ability to respond to customer or supplier requirements, keeping pace with competition, improved communication, productivity and efficiency gains, and access to new markets, risk management and overall strategic objectives*. Figure 2 shows the variations in reported benefits for construction businesses when compared with the overall average for all sectors. The findings highlight that the percentage of construction businesses reporting these benefits are lower than the overall average across all metrics studied, with the exception of improved communication. The differences were particularly notable in relation to productivity and efficiency gains; increased IT security and data protection; and better risk management planning.

4.2. Welsh Construction SME case studies

WERU's case study programme includes nine construction businesses out of the 31 businesses studied over the past four years. The business performance benefits for these SMEs were analysed and collated using the qualitative data analysis software NVivo. Many of these businesses discuss the incremental benefits from broadband enabled technologies. Key benefits discussed by the SMEs interviewed include *incremental innovation that may lead to improved communication and collaboration; heightened quality of product and service offering; enhanced efficiency; and improved transparency* when adhering to the industry's regulatory requirements. Again, our research suggests that the digital technology implemented by businesses need not be as technically advanced as AI or precision agriculture. A number of benefits can also be achieved through utilising cloud-based programmes, digitalised business processes and enhanced communication tools.

Construction Business	Region	FTEs
Sean Carr Lining Technology	North Wales	22.5
Siltbusters	South East Wales	40
Vault Consultancy	South West Wales	6

Construction Business	Region	FTEs
Celtest	North Wales	134
F.P.Hurley&Sons Ltd	South East Wales	143
Diack Ltd	South East Wales	17
Carreg Construction	South West Wales	17
Wynne Construction	North Wales	38
Hazelwood	South East Wales	32

Innovation emerged as a recurrent theme throughout the interviews conducted. The innovations outlined were predominately incremental, referring to small improvements to existing processes and methods used in the business:

> "*From an estimating point of view, it has changed the way we work. They won't send out a letter, they'll send an email out as a letter to whoever we're sending the price to, and that could be accompanied by something that we've put together, like a bid document, telling those people about the company, if what we've had in is based on early stage design*." (Hurley Construction)

The construction businesses discussed the ways in which they were able to incorporate digital advancements into their business models without having to vastly alter their business processes and in line with budgetary restraints. While more radical innovations are occurring in the industry, there were concerns that implementing these developments too quickly might create tensions in terms of available resource and staff uptake. As the previous sections detail, construction businesses rely on the skills and tacit knowledge of their employees. Since the workforce is made up of a large proportion of workers aged 50 and above, there is a challenge when attempting to alter the longstanding methods and approaches used. As such, a recurrent theme was the need to gradually incorporate these digital developments whilst ensuring necessary and tailored staff training. One way in which the businesses were mediating the potential tensions of these adaptions was through co-learning, through pairing up team members with differing levels of ICT to ease the transition and training period:

> "*We have a continuous training programme. We have younger people coming into the business, they tend to be early adopters, so again they're taking the older workforce with them. It's a work in progress*." (Hazelwood Construction)

One of the most frequently discussed benefits are the improvements to both *internal and external communication and collaboration* brought through the utilisation of broadband-enabled digital technologies. The communication improvements include enhancing workplace flexibility when sharing information and schedules both on and offsite. One digital tool used by businesses is the instant messaging platform WhatsApp. Communicating through WhatsApp better responds to the remote and flexible working policy within the business. As Diack Ltd Construction explains:

> *"We're all in one WhatsApp group for talking and rotas, and everything else. It just makes it easier to communicate. We tried emails but it's not as fluent as WhatsApp. If the guys need any questions they'll just send it on WhatsApp and we can chuck an answer."*

A further cloud-based tool being used by construction businesses is Dropbox as a convenient and easy to access means of storing and sharing information both with employees and clients. Other firms selected more tailored communication and collaboration software packages, for example 4Projects:

> *"To make that work and to be more efficient, we have to be able to share that information collaboratively. So, we then use another piece of software, 4Projects, which is a collaborative-sharing tool, which allows everybody involved in a project to see everything, to see a trail through. When a drawing is issued, those that need to see it, including our supply chain, designers, consultants, clients and any other stakeholders, can see what's been issued."* (Wynne Construction)

As the description details, using broadband-enabled communication and collaborative software supports team working on shared projects. This extends beyond collaboration between employees and includes designers, consultants and clients within the supply chain. By providing a virtual log of the supply chain activity it helps to improve transparency and greater coordination between businesses. In addition to the supply chain connections providing a benefit, businesses discuss digital enactment as increasingly becoming a prerequisite of working with clients and suppliers. By sharing information in real time, there is an additional benefit of improved transparency, which is becoming particularly important in line with industry regulation:

> *"There's more transparency in the processes. We can share, collaboratively, a lot more than we ever did, which makes for better communication, so it makes for faster project delivery. Earlier sign-off of packages: it's much quicker because of the digital technologies and the software we're using*." (Wynne Construction)

Linked to innovation is the improvements it brings to the *quality of the products and services* offered by the businesses. Advancements to the consultation and design for construction projects were particularly noteworthy, such as the ability to tailor and edit 3D designs and share these in real time with contractors and clients:

> "*But the quality spike is the 3D bit. You've gone from 2D plan drawings printed out from a piece of paper, to a 2D screenshot of working on some things, and now with 3D which is more detailed at the early stage of a job, so the quality should be better*." (Hurley Construction)

The incremental adoption of digital innovations also brings *efficiency related benefits* for businesses. Processes that previously had to be undertaken manually were time-consuming and often repetitive. These processes can be automated reducing the time and resources needed to fulfil the same task. However, the digitalisation of routine tasks also relies on access to reliable bandwidth, especially when transferring large files such as 3D drawings. As such, the requirements of the industry mean that faster and more reliable Internet is increasingly becoming a necessity:

> "*One of the problems we had when we had slow Internet, we would send a file out and it would bomb out the whole company because we're sending drawing files that used to be, say, a couple of megabytes and now they're probably 500 MB, 600 MB because they're 3D."* (Hurley Construction)

Overall, the interview data supports and adds to, and extends, the previous studies undertaken on the construction industry's use of digital technologies. While more radical advancements are important for the industry, many Welsh SMEs are benefiting from the more incremental and everyday advancements that support streamlined, transparent and collaborative working environment. However, even these developments need to be implemented in accordance with industry specific restrictions, such as the differences in the ICT and digital skills among the workforce; resource and capital restrictions; and differing digital maturity in the construction supply chain. Developments should therefore be tailored to meet the needs and scope of the business, with greater emphasis on flexible training and co-learning opportunities.

5. Breaking down the digital challenges and opportunities for Wales' construction industry

As mentioned throughout this report, construction represents a diverse range of business activities. The sector comprises a number of broad areas, with large scale heavy construction (civil and industrial work; large scale housing) running alongside a large number of highly specialised businesses (McKinsey Global, 2017). With these variations, there are also differences in terms of their outputs. For example, the industrial infrastructure attains high levels of productivity (124 percent of the industry total), followed by civil construction (119 percent of total) and large-scale building contractors (104 percent of total) (McKinsey Global, 2017). In contrast, trades subcontractors receive significantly less outputs with productivity falling 20 percent below the industry average, despite accounting for a large proportion of the small real estate and refurbishment projects (McKinsey Global, 2017). The differences across the areas also means that the enablers and barriers when adopting broadband enabled digital technologies will be different. As such this section of the report breaks down the construction industry into three core components (infrastructure; housing; and commercial), applying the findings from the above sections and offering potential recommendations for SMEs and workers falling within each category.

5.1. Infrastructure/Civil

The infrastructure and civil engineering category encompasses the construction of the natural and physical environment, covering the construction of roads, railways and buildings. These have traditionally been labour and capital intensive (PwC, 2019). However, the large-scale and resource intensive nature of these projects also means that it is likely to be impacted greater by both the technological opportunities and external challenges. For example, external shocks have impacted the forecasted trajectory, with growth predictions declining as large-scale infrastructure projects have been abandoned in recent years (CITB, 2019). The infrastructure and civil sector comprise many large businesses that are likely to have adopted many of the incremental digital technologies noted in this report. Supply chain businesses, however, may still face the challenge of adopting such technologies. In such cases there may be opportunities to diffuse incremental technologies across the supply chain. In relation to more radical technology solutions the opportunities may require more industry and public support to develop technology solutions appropriate for the sector. Here, despite the declining forecasts, such technologies provide a number of opportunities - such as the introduction of AR, autonomous vehicles, 3D printing, drones and IoT (PwC, 2019). There is a potential for these tools to be deployed at scale, offering opportunities for productivity and quality benefits. Such challenges will likely require support from industry bodies to encourage development and dissemination of such technologies, and support to ensure that the skills base is available for businesses.

5.2. Housing

The second key area of construction is housing. In Wales, there is a heightened focus on providing sustainable and cheap housing, driving forecasted growth in this area over the coming years (CITB, 2019a). This growth runs alongside heightened industrial regulation, where greater transparency from digital advancements can be maximised. Digital technologies may support the storage and sharing of safety and regulatory checks, saving time and resources while supporting adherence to legislation and safety requirements. Additionally, some of the more resource and capital intensive digital tools may allow for improvements alongside the business model. BIM for example is becoming a mandated requirement when constructing new houses (Burgess et al. 2018). It is claimed that its integration will bring reduced costs, greater accuracy and fewer defects in new homes (Burgess et al. 2018). However, a number of challenges remain. Adoption of BIM for house building companies involves a large investment in time and resources and there remains a skills shortage across the industry (Burgess et al, 2018). Responding to these challenges there continues to be a need to raise awareness of the potential benefits coming from digital technologies and provide ongoing training and support for their adoption. These challenges will need to respond to the different types of supply chain businesses that are present in the sector, where needs (radical or incremental) are likely to vary.

5.3. Non-housing, commercial and specialised

Specialised construction includes the activities that support the construction of parts of buildings and civil engineering works. This might include demolition of a site; electrical, plumbing and other installation activities; plastering; painting or roofing activities. These are often referred to as allied construction activities, referring to their role in the preparation for construction. Applying UK proportions for construction sector industrial breakdown to Wales data (Department for Business, Energy and Industrial Strategy, 2018) suggests that there are around 22,000 such businesses in Wales, the vast majority being micro businesses. The resource and knowledge intensive digital technologies may resultantly be less suitable for this area of construction. Instead, incremental benefits are fundamental. This includes improving collaboration and communication both internally and along the supply chain. Here the DMS findings show that the construction sector in Wales is at the lower end of the digital maturity scale. This suggests that there are opportunities to be gained to support the upgrading of the sector through targeted support for digital skills and adoption of technologies.

6. Conclusion and Policy Implications:

The results of this Horizon Scanning report point to the growing recognition by industry and policy that strengthening the digital capacities and innovation of the construction sector is an important priority, in relation to the social, economic and political challenges it faces.

While there is growing awareness and investment in supporting the digital capacities and innovation of the construction industry there remains a number of difficult hurdles for construction SMEs in Wales, including the skill set of the workforce, culture of resistance and diminishing resources. Indeed the construction industry remains one of the least digitally mature industries – supported by both existing research and WERU's ongoing interview and survey data.

A range of existing and emerging digital technologies are highlighted in the report, as being applicable to the construction sector in Wales. This includes incremental adoption of broadband-enabled digital technologies is likely to be the most fruitful for SMEs given the remaining barriers, as well as more radical tools (such as BIM), particularly relevant to larger firms.

The policy implications of the findings suggest than no single approach can be adopted for this sector. Rather, digital support for the sector will need to respond to the composition of the sector and the strong industry stakeholder grouping. In this respect there is an opportunity for policy to target existing supports more closely on the SME elements of the sector to raise its digital maturity (for example, Superfast Business Wales), and wider awareness raising. This is an area where adoption of such technologies has the potential for greater efficiency, new ways of communicating with partners, and managing business processes.

For larger construction businesses the opportunity is to work with industry trade bodies to devise targeted support to address wider challenges such as improving digital skills deficits, as well as the development and diffusion of advanced digital technologies (this may also be a role for UK government). In light of the supply chain structure of the construction sector there may be an opportunity to encourage and support greater co-learning, including in house training and sharing of skills. This may require partnership and support with sectoral bodies and large construction firms.

Finally, the challenges and opportunities associated with digital technology adoption in the sector are predicated on the availability of high-speed broadband (fixed and mobile) infrastructure. This is an area where the Welsh Government and commercial partners have supported the roll out of technologies. Continuing to ensure that Wales does not fall behind other parts of the UK with respect to such infrastructure will be important, as will keeping at the forefront of new network infrastructure opportunities such as IoT.

7. References

Burgess et al. 2018. BIM in the UK house building industry: opportunities and barriers to adoption. Cambridge Centre for Housing and Planning Research [online]. Available at: https://www.cdbb.cam.ac.uk/system/files/documents/BIMandUKHouseBuildingFinalReportforCDBB.pdf [Accessed: 15 August 2019].

Camacho et al. 2017. Applications of Additive Manufacturing in the Construction Industry – A Prospective Review. 34th International Symposium on Automation and Robotics in Construction. Available at: https://pdfs.semanticscholar.org/a931/76652b665f71cb9c9c3909b672ac1f75aff6.pdf [Accessed: 3 September 2019].

Constructing Excellence, 2019. The latest in constructing excellence in Wales. Available at: https://www.cewales.org.uk [Accessed: 1 September 2019].

CITB, 2017. Industry Insights: Construction Skills Network Forecasts 2017-2021. CITB [Online]. Available at: https://www.citb.co.uk/documents/research/csn%202017-2021/csn-national-2017.pdf [Accessed: 1 July 2019]

CITB, 2018a. CITB Research: Unlocking construction's digital future: a skills plan for industry. CITB [Online]. Available at: https://www.citb.co.uk/about-citb/construction-industry-research-reports/search-our-construction-industry-research-reports/innovation-technology/unlocking-constructions-digital-future/ [Accessed: 01 May 2019].

CITB, 2018b. CITB Research: The construction skills network in Wales. CITB Wales [Online]. Available at: https://www.citb.co.uk/documents/research/csn-reports-2019-2023/construction%20skills%20network%20report%20for%20wales%202019%20-2023.pdf [Accessed 2 August 2019].

CITB, 2019a. Construction Skills Network Wales 2019-2023. CITB Wales [online]. Available at: https://www.citb.co.uk/documents/research/csn-reports-2019-2023/construction%20skills%20network%20report%20for%20wales%202019%20-2023.pdf [Accessed: 1 September 2019]

CITB, 2019b. National Plan, Wales 2019-2021. Construction Industry Training Board [online]. Available at: https://www.citb.co.uk/documents/businessplan/wales-nation-plan-englishlg-2019-2021.pdf [Accessed: 2 July 2019]

CITB, 2019c. Building after Brexit: An action plan for industry. Construction Industry Training Board [online]. Available at: https://www.citb.co.uk/about-citb/what-we-do/mission-and-plans/ [Accessed: 2 July 2019]

Welsh Government, 2017. Construction Sector. Welsh Government [online]. Available at: https://gov.wales/business-economy-innovation [Accessed: 1 May 2019].

Construction Leadership Council, 2018. Smart construction: a guide for housing clients. Construction Leadership Council [online]. Available at: http://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2018/10/181010-CLC-Smart-Construction-Guide.pdf [Accessed 2 May 2019].

Davidson, J., Fowler, J., Pantazis, C., Sannino, M., Walker, J., Sheikhkhoshkar, M. and Rahimian, F.P., 2019. Integration of VR with BIM to facilitate real-time creation of bill of quantities during the design phase: a proof of concept study. *Frontiers of Engineering Management*, pp.1-8.

Department for Business, Energy and Industrial Strategy, 2018. Business Population Estimates for the UK and regions [online]. Available at https://www.gov.uk/government/statistics/business-population-estimates-2018 [Accessed 10 September 2019].

Farmer, M. 2016. The Farmer Review of the UK Construction Labour Model. Construction Leadership Council [online]. Available at: http://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2016/10/Farmer-Review.pdf [Accessed: 07 June 2019].

Go Construct, 2019. Inspiring Construction. Go Construct [online]. Available at: https://www.goconstruct.org/inspire/inspiring-construction/ [Accessed: 2 July 2019].

HM Government. 2013. Construction 2025. HM Government [online]. Available at: https://www.gov.uk/government/publications/construction-2025-strategy [Accessed: 04 June 2019]

HM Government, 2018. Industrial Strategy: Construction Sector Deal. HM Government [online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/731871/construction-sector-deal-print-single.pdf [Accessed 04 May 2019]

McGraw Hill Construction, 2011. Prefabrication and Modularisation: Increasing productivity in the construction industry. National Institute of Standards and Technology. Available at: https://www.nist.gov/sites/default/files/documents/el/economics/Prefabrication-Modularization-in-the-Construction-Industry-SMR-2011R.pdf [Accessed: 19 August 2019]

McKinsey Global Institute, 2017. Reinventing construction: a route to higher productivity. McKinsey & Company [online]. Available at: https://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/Reinventing%20construction%20through%20a%20productivity%20revolution/MGI-Reinventing-Construction-Executive-summary.ashx [Accessed: 1 July 2019].

Modular Building Institute, 2019. What is modular construction? Modular Building Institute [online]. Available at: https://www.modular.org/HtmlPage.aspx?name=why_modular [Accessed: 3 September 2019].

Moreno-Vozmediano, R. et al. 2013. Key challenges in cloud computing: enabling the future Internet of Services. *IEEE Internet Computing*, *17*(4), pp.18-25.

NBS. 2019. Construction technology report 2019. NBS [Online]. Available at: https://www.thenbs.com/knowledge/nbs-construction-technology-report-2019 [Accessed: 01 May 2019]

Oesterreich, T.D. and Teuteberg, F. 2016. Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry* 83, pp.121-139.

ONS. 2018. Input–output supply and use tables: summary tables. ONS [online]. Available at: https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetablessummarytables [Accessed: 01 September 2019]

Peansupap, V. and Walker, D. 2005. Exploratory factors influencing information and communication technology diffusion and adoption within Australian construction organizations: a micro analysis. *Construction Innovation* 5(3), pp.135-157.

PwC, 2019. Six technologies that are transforming infrastructure. PwC [online]. Available at: https://www.pwc.com/gx/en/industries/capital-projects-infrastructure/publications/six-technologies-that-are-transforming-infrastructure.html [Accessed: 2 August 2019].

UKRI. 2019. Transforming Construction. UK Research and Innovation [online]. Available at: https://www.ukri.org/innovation/industrial-strategy-challenge-fund/transforming-construction/ [Accessed: 10 May 2019].

Wang, P. et al. 2018. A critical review of the use of virtual reality in construction engineering education and training. International journal of environmental research and public health, 15(6), p.1204.

Welsh Government, 2018. National Statistics: Business population estimates 2018. Welsh Government [online]. Available at: https://www.gov.uk/government/statistics/business-population-estimates-2018 [Accessed: 01/09/2019]

Welsh Government, 2019a. Index of Production and Index of Construction for Wales: 2018 Quarter 3. Statistical First Release. Welsh Government [online]. Available at: https://gov.wales/sites/default/files/statistics-and-research/2019-01/index-of-production-and-index-of-construction-july-to-september-2018.pdf [Accessed: 01/09/2019]

Welsh Government, 2019b. Construction Futures Wales: About us. Welsh Government [online]. Available at: https://businesswales.gov.wales/constructionfutureswales/what-construction-futures-wales-and-how-can-you-benefit [Accessed: 2 July 2019].

Welsh Government, 2019c. CFW Innovation Database. Welsh Government [online]. Available at: https://businesswales.gov.wales/constructionfutureswales/cfw-innovation-database [Accessed 1 July 2019].

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