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Digital leadership framework to support firm-level digital transformations for Construction 4.0.

Purpose: Against a background context of Construction 4.0 this work explores what Digital Leadership in construction firms is, why it is necessary, and what considerations it involves. It provides a digital leadership considerations framework to aid organisational digital digit.

Design/methodology/approach: To address the research question informing what digital leadership involves, an interpretivist study was conducted. Eleven purposively selected expert practitioners, including construction business leaders and company digital champions were surveyed using in-depth semi-structured interviews. This obtained insights and reflections on how construction leaders can impel digital transformations.

Findings: How construction leaders can embed the skills to drive such transformation in their firms; what the essential digital skills for construction businesses now are in Construction 4.0, and how leaders can attempt to evaluate the value of digital technology for their business practices, are all crystallised. Impacts of digital transformations on the construction workplace are also highlighted.

Originality: Clear definitions of digital transformation and digital leadership are provided, and a digital leadership considerations framework is provided to support firm-level digital transformations for Construction 4.0.

Implications: Because of this work business leaders will be better equipped to lead and support further digital transformation efforts in Construction 4.0. Future research directions aid academics.

Keywords: Construction 4.0, Diffusion, Digital Leadership, Innovation, Information Management, Information Technology, Innovation Diffusion.

1. **Introduction**

The 4th Industrial Revolution (4IR) is a new era of economic innovation because of the range and novelty of opportunities afforded by digitalization and the enhanced connectivity of technology and people (Beale and Reynolds, 2021; Oberer and Erkollar, 2018). This follows: a 1st Industrial Revolution, that exploited mechanical-, water-, and steam-, power efficiencies; the 2nd Industrial Revolution, with its harnessing of electricity and mass production via assembly line productions, and; the 3rd Industrial Revolution where the diffusion of computer processing power and thereafter automation was enabled. Indeed, a reason we are now within the 4IR is due to a rate of innovation that is without precedent (Alaloul et al., 2020). Because of the greater connectivity of cyber-physical systems and use of data and analytics, 4IR is disrupting almost every line of work globally. For example, at 2025 the value creation potential of 4IR for manufacturers and suppliers is estimated at $3.7 trillion (Garms *et al.*, 2019). Operationally intense, yet repetitive industry sectors like retail, logistics, and manufacturing, are comparatively more likely to experience disruptive changes due to labour intensive tasks ripe for automation or digitalization. McKinsey & Company (2022), estimate circa 58% of work activity could be automated using present technologies. Though not as repetitive because of its project-based nature, the global construction sector also faces 4IR disruption.

The concept of Construction 4.0 was initially popularised by the European Construction Industry Federation (FIEC). It was an offshoot to the introduction of 4IR in Germany, itself a strategic response to competition brought on by Asia's accelerated industrialization (Forcael et al., 2020; Oesterreich and Teuteberg, 2016). FIEC (n.d.), note how "*the construction industry is undergoing a significant transformation, which includes revolutionary new approaches such as digitalisation and automation. This 'fourth industrial revolution', known for all EU industry as "Industry 4.0", is known in our sector as Construction 4.0*". Using bibliometric analysis (Forcael et al., 2020), surmise that 2014 was the first year when 4IR was related to the construction sector, and 2016 was the first point that Construction 4.0 was established as a concept by the German consultants Roland Berger (Berger, 2016). Though there is presently no widely accepted definition of Construction 4.0, as illustrated in Figure 1, Sawhney et al., (2020) suggest it uses cyber-physical systems (CPS) to create interconnected environments for the purposes of designing, constructing and operating assets.

INSERT NEW FIGURE 1

Figure 1: Cyber-Physical Systems (CPS) connected in Construction 4.0.

Figure 1 shows CPS connections across digital and physical layers. The digital layer consists of construction digitalization elements including the digitisation of information, the digitalisation of processes, and the use of digital ecosystems and technologies that enable digital transformations to occur. Similarly, the physical layer contains aspects of construction industrialization with examples including the use of computer aided design (CAD) and manufacture (CAM), computer numerically controlled (CNC) fabrication, as well as offsite manufacture or more sophisticated design for

manufacture and assembly (DfMA) approaches. Connections between these are achieved via synchronous integrations between digital signals and physical actions. The connection of these layers involves 4IR innovations which can generally be categorised across four types of disruptive technologies: Connectivity, Data, and Computational Power; Analytics and Intelligence; Human-Machine Interaction(s), and; Advanced Engineering. Examples of applications of these as used in Construction 4.0 are displayed in Table 1.

INSERT NEW TABLE 1

Table 1: Examples of 4IR innovation types in Construction 4.0.

As inferred in Table 1, such innovations offer non-trivial improvements for construction firms. The likes of Artificial Intelligence (AI) for example, can assist with general modelling, pattern detection, prediction, and process optimizations. Big data analytics can also aid data-driven decision-making by way of the various data recording, processing, integration, analytics, and reporting stages (Rawat and Yadav, 2021; Yousif *et al.*, 2021). Data analytics themselves can be descriptive (*what happened?*), diagnostic (*why did it happen*), prescriptive (*what should be done about it?*) and predictive (*what is likely to happen?*). Such approaches can aid with more rapid decision making for challenges such as sustainability and other key drivers of opportunity and change. Whilst it is outside of the scope of this article to detail all of the examples of 4IR innovation types in Construction 4.0, it is not hyperbole to suggest Construction 4.0 brings vast possibilities vis-à-vis digital transformation. This is because a global population of better-connected professionals and researchers who work in/adjacent to construction now have access to knowledge, and higher levels of data storage and computing power than ever before.

Because of the pace and complexity of industry change, firms are under increasing pressures to adapt. Managed adoption of such innovation offers construction firms market competitiveness opportunities (Gledson, 2022). The responsible management of any digitally instigated organisational change is crucial if organisations are to survive and thrive and suitable leadership and managerial skills are required. If firms are to achieve this, appropriate digital transformation strategies are required, as success requires not only technological understanding, but also appropriate organisational management (Zulu and Khosrowshahi, 2021). Bolpagni et al., (2022) identify how the necessary skills and knowledge of the modern construction professional are evolving, and that in addition to conventional hard skills (e.g., of construction technologies and process) and soft skills (e.g., of leadership, problem-solving, and communication etc), the required knowledge and skills for the Construction 4.0, now include (amongst others): knowledge and application of relevant construction digital technologies; appreciation of big data, cloud computing, and blockchain; and being able to work in more agile, and collaborative ways. Though increasing numbers of studies focus on the increasing efforts around digitalisation of construction firms, there remains comparatively fewer qualitative efforts on digital leadership in construction firms (Morgan and Papadonikolaki, 2022;

Statsenko *et al.*, 2022; Zulu, Saad, Ajayi, *et al.*, 2023b). This issue of developing digital leadership capabilities is therefore important. Against this background context of Construction 4.0 disruption and the need for more developed leadership capabilities, this work advances knowledge by exploring the concept of digital leadership in construction organisations. It employs exploratory interviews with expert practitioners to address the research question of: *what does Digital Leadership in the construction context involve?*

Having now established Construction 4.0 as background context and posed the research question, the work is structured thus: first, a working definition of digital leadership is provided, followed by a narrative literature review that demonstrates the relationship between key concepts uncovered and the interview questions; next, methodological rationale and detail of the method used for this interpretivist study is provided. Presentation, analysis and discussion of results then occurs before a framework of digital leadership considerations in construction firms is provided as a novel knowledge contribution. Finally, conclusions, limitations and avenues for future research are given.

2. **Literature Review**

Briefly, leadership is the action of leading a group of people or an organization. There are several recognised schools of thought, or classic leadership styles which are well established. These include trait theory/charismatic theory; autocratic, democratic, and laissez-faire leadership styles; situational leadership; transactional leadership; and of most relevance to this study, transformational leadership (Bass and Riggio, 2006; Ytterstad and Olaisen, 2023). Transformational leadership is relevant for digital leadership as this relates to the ability to get people to want to change and improve. Socio-technical theories of innovation and change are also relevant to Digital Leadership. 'Digital' itself simply involves or is related to the use of computer technology. As elaboration it relates to using, or storing data or information in the form of digital signals. To expand: data are things known or assumed as facts, making the basis of reasoning or calculation, and information is data as processed, stored, or transmitted by a computer[1]. Dorner and Edlman (2015), advise how 'digital', should be seen less as a thing and more a way of doing things. In discussing how firms become digital organisations, Kane et al. (2019) emphasises the importance of their leadership and talent. Morgan and Papadonikolaki (2022) advise that digital leadership is about steering organisations to take the advantages presented by digital innovations. Zulu and Khosrowshahi (2021) categorised digital leadership types under six themes, leaders that are either: proactive and forward-thinking; supportive; uncoordinated; cautious; resistant and visionless or undriven leaders. Given this background, a definition of digital leadership is here offered, as the action of leading a group of people or an

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[1] It's useful here to remind of the relationships between *data*, *information, knowledge,* and *wisdom*, as these are generally discussed within the conceptual framework of the 'DIKW hierarchy'. As related to digital leadership, it is useful to also reflect on this framework and recognise the boundaries between what these days can be digital (i.e., data and information only) and what remains cognitive (i.e., knowledge, wisdom).

organization involving the use of computer technology. To help address the main research question and to provide greater definitional clarity around digital leadership, within the interviews participants were asked: "*What does digital leadership mean to you?*"

In this study, definitional clarity of digital transformation is also important. Kane (2019) describes digital transformation as the process of how firms change/adapt from being conventional/or tangible legacy companies to being competitive in a more digital era. In his work, how firms navigate digital disruption, and how they become digital organisations are identified as being important. Adding more detail to this Jacobsson and Linderoth (2021), outline three key conditions necessary to achieve true digital transformation. The first requires investment in and implementation of digital tools to convert analogue information to digital (aka '*digitisation*'), which is followed by two sociotechnical aspects: a technological adaptation of an organisation and its processes (aka *digitalisation*), along with a necessary change in the mindsets and behaviours of employees. These researchers argue that all three conditions are required to enable digital transformation. To uncover more about this, interview participants were also asked: "*What does digital transformation mean to you?*"

Above, digital leadership and digital transformation were discussed in general terms, but this study explores this in the context of construction, a project-based sector. A relevant study commissioned by the Association for Project Management (APM) by Thomson et al. (2019) was undertaken of 438 organisations surveyed about the future of project management across all sectors. Their research noted several skills required to be able to cope with future challenges. Amongst these, over 80% of firms surveyed rated 'leadership and management skills', and 'digital skills' as being important. Despite this, Zulu et al., (2023) raised concerns around low levels of digital literacy of construction firm employees. Therefore, in the interviews, a relevant question, informed also by the work of other researchers (Kane, 2019; Kane *et al.*, 2019; Omar El-Sawy *et al.*, 2016; Petry, 2018) was asked: "*How can organisations build the right skills so that digital strategies can be effective and transformative?*".

As heads of firms Kane (et al., 2019), describes how leaders require more a form of general 'digital literacy' to be aware of emerging developments and understand their value/risks to a firm, but stresses they do not require specialist technical skills of data science or computer coding. Instead, they advise how leaders can employ experienced anchor hires, such as Chief Digital Officers (CDOs) to initialize matters. Petry (2018) supports this, advising that many firms are introducing a Chief Digital Officer (CDO) type executive roles to be: "…*responsible for driving and coordinating the overall digital transformation in the company*". Further down within hierarchies specific digital competencies are more typically required for organisational competitiveness[2]. To find out more about awareness of this,

[2] The Skills Framework for the Information Age' (SFIA) version 8 (https://sfia-online.org/en) is a useful reference model as a "*global skills and competency framework for the digital world*". It contains four categories that focus on Digital Transformation with skills that Digital Leaders would be expected to have familiarity with.

or the needed digital skills or competencies in general interview participants were asked: "*What digital competencies are now essential for construction businesses?*".

Though digital technologies have begun to penetrate the construction sector, their implications for revenues, profits, and opportunities could yet be dramatic. Bughin et al. (2017), surveyed perceptions of digital penetration across several sectors and found that on average, industries are less than 40% digitized, despite a comparatively deep penetration of digital technologies in more advanced media, retail, and 'high tech' sectors. In their survey of 1,573 participants, they note profit gaps are now appearing between the top and bottom quartiles of companies: "*Bold, tightly integrated digital strategies will be the biggest differentiator between companies that win and companies that don't, and the biggest pay-outs will go to those that initiate digital disruptions* […] *Fast-followers with operational excellence and superior organizational health, surely won't be far behind*". Recognising the importance of how digital transformation can improve organisational performance through the exploitation of business opportunities, Zulu et al., (2023b) explored leaders perceptions of digitalisation in the construction industry and found that crafting compelling arguments in any business case increases persuasion towards digitalisation and subsequently, performance. Recognising the importance of this issue, interviewees were asked: "*In what way does digital leadership mean thinking differently about business models?*" and also "*what business opportunities does digital transformation enable?*"

Petry (2018), advocates a model of digital leadership he labels as NOPA+ (Network; Openness; Participation; Agility; + Trust), and advises how digital leadership should be open leadership, and that certain aspects of leadership should now be decentralized and shared. He also emphasises how leaders cannot know everything so need to better empower the collective intelligence of their network and their firm to stay abreast of latest developments. Informed by this work we asked interviewees: "*how can business leaders increase knowledge of the digital tools available?*" and "*how can business leaders provide the knowledge to support the successful introduction of digital solutions?*". Finally, as informed by the work of several researchers (Hull et al., 2007; Rosin et al., 2020) around measuring *benefits of digital,* within the interviews we asked: "*how can business leaders evaluate the (often indirect or intangible) benefits of a digital solution?*"

This review uncovered several prominent concepts surrounding Digital Leadership in Construction Organisations, around which interview questions were constructed and employed in semi-structured interviews as now discussed.

3. Methodology

This study is informed by the research philosophy of interpretivism as its epistemology. To explore the phenomenon of digital leadership of construction firms this work uses an inductive approach, employing qualitative semi-structured interviews to aim to better understand perspectives of digital leaders. The use of a qualitative approach aids capture of deeper insights and reflections around how construction industry leaders aim to drive digital transformations in their firms. An expert interview approach was employed. Via non-probability sampling efforts, eleven purposively selected participants were identified based on criteria of expertise, experience and credibility (von Soest, 2022). Employing expert interviews has several advantages. Though expert judgements may not necessarily be replicable, experts instead can advise of the reality of practice, and data obtained from them can be of high practical relevance. Dexter (2006) advises that an experts are persons who have specialized information, having been involved in the social process of interest. von Soest, (2022) notes experts can be inside-experts (i.e., decision makers), or outside-experts (i.e., analysts), and can also occupy mid- or even low-level positions as opposed to expert persons always occupying top positions. Further, Maestas (2015) notes experts might be academics, practitioners, managers, or other individuals with sufficient specialized experience or knowledge. In this study, experts involved: business leaders and company digital champions from construction related organisations, consultants, industrial researchers and academics with much experience working with industry on digital transformation projects. As before, the broad research question was *'What does Digital Leadership in construction contexts involve'?* After three initial in-depth pilot interviews were deemed successful with minimal enhancements made to validate the research instrument, the remainder semi-structured interviews followed. All interviews were synchronous and online using the MS Teams video-conferencing tool, commencing during the COVID-19 pandemic, and running over a 21-month period between July 2021 – March 2023 by which time sufficient data were collected to reach the saturation point[3], and address the research purpose (Bryman, 2015; Crouch and McKenzie, 2006; Galvin, 2015; Mwita, 2022). Table 2 provides details of the participants surveyed and summarises their industry experience. It also reminds of the interview questions generated from the literature review.

Table 2: Interview questions and participants

INSERT TABLE 2

Most interviews were concluded within a 45–60-minute timespan. They were recorded, and transcribed using a denaturalized transcription approach (Nascimento and Steinbruch, 2019). Use of the Computer Assisted Qualitative Data Analysis (CAQDAS) tool, NVivo 12 supported coding and the

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[3] Zulu, Saad and Gledson (2023a) note the number of interviews to reach saturation is subjective and contextually dependant, they identify where researchers have been satisfied variously with 5, 8, 10 and 12 interviews to achieve this.

subsequent exploration and analysis of this rich dataset. A reflexive thematic analytical approach (RTA) was adopted whereby these analytical phases occurred: data familiarisation; initial coding; initial generation of candidate themes; reviewing and defining final themes (Byrne, 2022; Williams and Moser, 2019). Results are now reported on, and a thematic map is provided at the end of the next section as a framework of Digital leadership considerations in construction firms.

4. **Results, Analysis and Discussion**

Across the interviews, questions on the following concepts were posed:

Digital Transformation

Participants were asked: *What does digital transformation mean to you?*

As above, Kane (2019) describes digital transformation as the process of how firms adapt to become competitive in the digital era. Against this question, digital transformation was variously described as a way for organisations to improve how they do what they do, through better ways of managing data and information to perform well in their marketplace. Participant C advises: "*…digital transformation is about understanding how technology in any of its formats can align with business objectives to improve processes and activities, to ultimately give an edge, and make it competitive against other organisations…*". Correspondingly, Participant D acknowledges: "*…digital transformation means to improve your business's processes, underpinned by software and technology* […] *to become more efficient, reliable, improve quality, and also, reduce errors*". Digital transformation was also described as a way to do things differently and broaden company offerings: "*…we're specifically trying to distinguish between just doing* [the same] *things in a digital way, or doing things differently because we now have digital tools or new opportunities from digitisation*" (Participant E). It was also described as a strategic plan to aid this process: "*…digital transformation is [about] the roadmap for how we get from where we are, to where we want to be in five to ten years*" (Participant E). Interestingly, most views aligned with the lesser 'digitalisation' aspect of Jacobsson and Linderoth's (2021) definition of digital transformation and neglect the change in employees mental models needed to actualise full organisational digital transformation.

Digital Leadership

Similarly, participants were also asked: *What does digital leadership mean to you?*

As above, in explaining how firms become digital organisations, Kane et al. (2019) emphasises the importance of their leadership talent. Unsurprisingly, responses focused upon some traditional aspects of leadership – of having vision, formulating strategy and communicating it to followers, and predicting and realising benefits. For example, on vision, Participant B advises: "*digital leadership is where you have leaders of the business who can see the benefit*[s] *of adopting digital ways of work to meet their business objectives: to drive efficiency; to improve productivity; to improve data capture,*

[and]; *to help them make informed decisions*". Participant H adds: *"the leadership of it is critical. Because leadership and that vision is what sets the strategy around how people implement, how and what they implement, and why they're implementing it. The leaders set the why and set the strategy."* Participant A agrees adding: "*The role of leaders and integration with digital is about setting out what is wanted and where it needs to go before developing something*".

On how to do it, participants advised: "*digital leadership has to start from the top-down with somebody who can see how technology and IT-enabled change will support the business*" (Participant B). Participant H adds: "*build a cohort of enthused people, get some quick wins and build from there. Translate it. Socialise it within the team and company.*" Similarly, Participant A agrees that: "*part of the leadership piece is explaining to people. Taking them on a journey* [and] *knowing the end of the journey before you start it".* Returning to this, Participant A adds importantly that as leaders: "*part of our mission is to really accurately describe what we want out the back-end".* These responses call-back to John Kotter's eight-stage approach to managing organisational change (Kotter *et al.*, 2021). Digital Leaders themselves are described by Participant D as: "…*the right people in the organisation to lead the transformation of digital whilst promoting its benefits but also dealing with the challenges that come along with that transformation*".

Skills Building
Participants were then asked: *How can organisations build the right skills so that digital strategies can be effective and transformative?*

Here respondents focused mainly on the need for the upskilling of existing staff, rather than bringing in new hires with desired skills. The need for firms and individuals to be outward looking, to be able to learn from outside, and how to incentivise engagement in such training was also discussed. Also discussed was the alignment of training opportunities, against the demands of present job role(s), as well as concerns around opportunities to apply any training.

For example, as regards leadership approaches for upskilling existing staff, some recognise 'the law of marginal gains' when discussing how smaller incremental improvements can add up: *"we look at everybody's individual roles, and where they can enhance their skills with some digital aspects. For some people, that might simply be, have they thought of doing their records on a* [tablet] *screen, rather than doing it on paper? It's about taking everybody across the business and building another 10% onto their skillset"* (Participant E). This developmental approach coincides with the findings of Zulu, Saad and Gledson (2023a) who identify how staff need to first become digitally literate as a foundation for developing further digital competency. Participant A instead discusses their buddy-systems that aim to cross-pollinate construction knowledge and digital skills across staff with differing levels of competence in each: *"From our staff, there's a lot of people who are incredibly experienced, have a huge wealth of* [construction] *knowledge but are not as IT literate as the youth coming through. Because they didn't grow up with computers and* [weren't] *part of the digital generation* […] *It puts*

them at a disadvantage. But on the other side we also have a lot of younger, junior staff who don't have the construction experience but have IT skills. So, as leaders when we build teams we put them together and buddy them up, to get the transfer of knowledge". Use of this 'buddy-system' echoes how Jacobsson and Linderoth (2021) espouse the benefits of reverse mentoring noting the role that newly graduated students play in helping construction organisations adopt and make use of digital innovations. Participant A further advises: *"We've had some incredibly successes. We manufacture situations where it will happen naturally, eventually. Apprenticeships work both ways. It's a pair sharing knowledge".*

As for the 'how-to' of building skills, whether the training is internal or external the most important findings were about training access, timeliness, relevancy, and staff engagement.
On access, Participant H notes: *"You need access to the right resources, and you need to know where to go to get them".* Closely linked is the timespan between receiving training and being able to apply newly gained skills. Here Participant G advises: *"we found out that the training as-is, is not really effective. We noticed that after training, if people didn't immediately have a project to apply software, methodology etc skills on, then* [they] *forget as they don't see the value".*

This leads into the issue of *relevancy*. Participant F notes how the construction sector should now move away from generic training to instead providing what is required in a specific role: *"Digital training is still in its infancy. Most is 'blanket training'. Very standards heavy – not practical. To build the right skills for people to operate in a digital process, training needs to directly correlate with what they are doing".* He adds: there is a *"misalignment of the material being delivered versus the actual day-to-day working* […] *make the training specific on a discipline-by-discipline basis.* Participant G agrees with this adding more personalised training is needed: *"analyse the different job roles, different responsibilities and then create tailored training based on a project that they are doing".* These aspects of access, timeliness and relevancy are reminiscent of the arguments put forward by researchers who propose solutions such as greater use of virtual environments and short-but-relevant training content authenticated via micro credentialing to address these concerns (Gao *et al.*, 2019; Kassem *et al.*, 2017; Wakefield and Kassem, 2020)

Interviewees also discussed the importance of *staff engagement* in skills building activity. Participant C notes: *"this comes down to leadership trusting employees to make decisions and feed-back about technologies that would support growth. It's about exposing colleagues to digital environments, and once you've empowered them to make some decisions about what's useful or not, put them through training to build skills to use that technology. If you just force it top-down it's much harder than getting your buy-in from exposing people to the technologies and them having that lightbulb moments themselves".* The building of trust reinforces the NOPA+ model introduced by (Petry, 2018). However, Participant H notes: *"The other side, is that people have got to want to build those skills. The best organisations we work with are the ones that are the most engaged and enthused, rather than having*

been told that they must do it by government or mandating, [who are] *still very negative in outlook. This harks back to 'build an enthused cohort' right at the start of transformation"*.

Essential digital competencies
Participants were asked: *What digital competencies are now essential for construction businesses?*

Responses focused on digital competencies at individual staff-, or firm-, levels. When discussing individual competencies, interviewees identified necessary personal characteristics, the need to have an appreciation of/skill in data- and information- management, as well as the ability to think and work in model-based ways.

For example, Participant C advises on the importance of having 'adaptability': "*Technology changes so rapidly that you can be trained on software one day and it can be obsolete by next year, so what you need is the confidence to be able to self-learn and not be afraid of technology or try out new things*". Adaptability, along with digital literacy were identified as key skills for success in a digital workplace by Kane et al., (2019). Most participants raised the importance of data -storage, -access, and -usage, noting "*a skillset widely under-represented within construction is just basic data science* [management], *how to move data from one place to another, how to make systems talk to each other*" (Participant F). Closely related to this was the importance of competence in information management: "*Standardisation of file naming. Common data environments. How you revision things*" (Participant D), and ultimately, the value of data and information: "*Everything you do has an impact. All of us produce and review information, so we need to understand that everything we do e.g., planning, design, construction, maintenance* [etc.,] *creates a thread of information. Be mindful that other people can find that information and use it to inform their decisions*" (Participant G). Participant H further advises of the importance of data/information when working collaboratively: "*in an accommodating environment, which is absolutely essential for sharing information in the right format, in the right way, as one source of truth*". Model-based thinking and ways of working are also now considered essential: "*We've now tried to upskill everyone just to have a general understanding of what a model is. What's in it. What it is and isn't used for. And* [provided] *basic navigational skills*" (Participant F). Similarly, "*from a design perspective* [competency in] *model authoring platforms is essential. Being able to build a building virtually, and proliferate all your drawings off that* […] *Alongside that,* [competency with] *analysis platforms is key* (Participant H).

When discussing the necessary digital competencies required at firm-level, areas that companies are targeting include greater application of systems-based thinking, increasing the use of automation, ensuring ease-of-use with systems, and ensuring appropriate infrastructure is in place,

As regards the move towards tool, rather than application -based thinking. Participant E advises; "*We've seen that people like a 'one-stop place'* [i.e., particular software] *for doing all their digital things, everything goes through* [one] *system which is going to do everything that we want it to do. But*

there needs to be a shift in focus, so you instead have the right tool for the right deliverable. The backing of that needs to be full interoperability, but understanding that way of working is a key thing for the shift that we're seeing". Participant E adds that another key item for businesses moving forwards involves embedding opportunities for greater automation: *"how can we use computers to make everyday life much more efficient? What processes as a business can we automate and make more consistently applicable? It's a critical thing".* Automation links to ease of use, and on this Participant A offers: *"We've learned during the last couple of years that if you make it easy to use, people will use it. If it becomes even vaguely challenging … If it's more than three clicks to get to the end of the menu, it just falls over because it's just too many clicks – 'I can't do it'.*

Infrastructure was another firm-level consideration and here Participant A reflects on an important changes in how their construction business now provides office- and site-based internet connections, advising their firm has moved away from use of limited 3G/4G site Data Cards: *"We used to have rules that said depending on how many people are on a jobsite determines how big an internet connection you get. Now that's false economy. Instead, we now are moving the majority of our stuff – not all of it, for security reasons – to hosted cloud environments …. and we assess what the local infrastructure can provide in terms of internet connection speeds to move data around. Then we buy the biggest broadband you can get".* They further reflect on how the global COVID pandemic acted as an accelerant for changed ways of working: *"The one good thing that did come up in the last 18 months is getting to grips with* [Microsoft] *Teams and SharePoint* [because of this] *we are sharing data now a lot better than we were".*

Business Models

Participants were asked: *In what way, does digital leadership mean thinking differently about business models*?

Interviewees had competing perspectives on this question, ranging from pessimistic views of how construction is too constrained by its conventional business-as-usual approach, to more optimistic perspectives recognising new opportunities afforded by digital approaches.

On the former, Participant F opines: *"construction hasn't really caught onto how it can potentially leverage data for other income streams".* He adds that at the C-Suite are: *" 'old school' leaders, who haven't really grown up around technology and digital pieces,* [but] *are very concerned with the here-and-now and the day-to-day, and the year-end results etc. They don't really take a step, and think – 'digitisation is coming. How can we actually leverage this and make money from this, rather than just seeing it as a cost?' "* Focus on convention and near-term results contrasts with the forward-thinking required of digital leaders as espoused by El-Sawy et al., (2016) who argues how leaders should now be considering different kinds of business models, supported by different kinds of business strategy.

However, recognising how digital transformations can improve business performance, in alignment with Zulu, Saad and Gledson (2023b) other participants instead discussed how anything that adds value to the construction industry or makes savings helps, and identified and anticipated newer business models. Here responses ranged from broad considerations of more rigorous selection of supply chain partners, through to spotting more discrete value propositions, where leveraging data can commercialise data-driven systems. On the latter, Participant H advises: *"There is an inevitability about shifting from a low-margin, high-transaction type business model, which construction ultimately is, through to a very data-driven business model. But we're a long way off that."* Here, participants provided several current examples including: subscriptions to software-as-a-service (SaaS) type platforms; Common Data Environments (CDE); the creation of bespoke dashboards enabling visual data analytics (*e.g., for clients about their assets*); onsite production scanning for site inspections and as-built validations; real-time visibility and tracking of material resource (*e.g., for transparency on supply chain procurement, live data around just-in-time delivery, and updates when materials arrive onsite and securely stored/installed*) – and of plant resource (*e.g., for managing onsite equipment via dashboards that provide visual information about tasks undertaken, location deployment, overall utilisation*). Even better management of onsite labour resource was being considered through verification of personal competence (*e.g., qualifications, known skillsets, Health and Safety training received*) as-scanned at the point of site entry.

Further Participant F argues construction companies could expand value realisation considerations by having broader focus of their involvement the project lifecycle: *"I was looking at a digital twin platform for the operational phase of an asset .. and [realised] that potentially there is a whole other income stream there. In construction, we very much tend to focus on production stage, but when we're done, the ultimate gains are during the operational phase. Construction companies should be targeting more income streams that are based in the operational phase of an asset to extend the tail of our work.*

Business Opportunities
A related question was asked: *What business opportunities (i.e., process improvements etc) does digital transformation enable?*

Responses typically were on the optimisation of internal processes as the area where the greatest value can be added, or alternatively how digital transformation can aid organisation learning. To the first point Participant E notes: *"the revenue that we can make from digital is not significant in comparison to our overall revenue streams. We don't see it as a product that we are going to put into the market to make money from. It's not our expertise. We are not a digital business. We are sticking to our expertise … [but] … how we deliver it in the most efficient, and effective way is probably where we see the most opportunity.* On the latter Participant A adds: *"we talk about the power of experience, As so often, experience is gained and hard won, then through a lack of corporate memory – is lost. People move on, change roles. We see an opportunity that if we collect all that data, it becomes reusable. It becomes a method to teach other people … it actualises the knowledge management*

system". This coincides with the work of researchers who advise how such experiences can aid organisation learning in construction project-based organisations (Chiponde *et al.*, 2022; Gardner, 2022).

Other responses identify how firms can learn more about working approaches: "*You learn more about your employees* […] *but you've got to think about the ethics of how you are using your data*" (Participant C). This is picked up by Participant G: "*using digital processes we were better able to measure and evidence [productivity] because everything is tracked. You can see who is doing what, and the time of day they are more productive".* This was further reflected on: *"we received resistance, it comes back to culture and the importance of leadership, because people feel that if people monitor what you do and can see when you open the computer, how many times you stay on the internet, then there's surveillance. You need also to give the right message that it is done, but is not to be used against them. However, you can monitor people that are too slow to do things."* (Participant G). Worryingly, such admissions of monitoring and surveillance of employees work practice aligns with prior explorations about the 'dark sides' of digital technologies (Davies and Harty, 2012; De Vaujany *et al.*, 2021).

Leaders learning
Participants were asked: *How can business leaders increase (their own/organisational) knowledge of the digital tools available?*

"*There're two ways that it happens. One is* [recognising] *we have a problem, so go looking for a solution. It's a big part of what I do, advising on what that solution could be. It's not particularly easy. You end up with some Google searches and so on, but also reach out to other people within the industry, who may have done this before. Going out and asking questions, and talking to real people, seems to be one of the best ways to find new solutions … the other side* [is when] *we don't necessarily have a specific problem, or we've got so many problems, but we're not trying to target one of them now, just trying to understand what is being done in the industry, what's out there".*

This from Participant E indicates how leaders get their digital knowledge from external or internal sources. It aligns with part of Petry's (2018) NOPA+ model of digital leadership discussed earlier regarding harnessing the collective intelligence of networks. Externally, respondents identified sources for their learning as including: Working groups; Academics/Academia; Conferences; Consultants, and; Professional organisation like CIOB or RICS. Media was identified as another route, as discussed variously: "*Twitter, LinkedIn are vital for me in terms of following the right type of people that populate new stuff all the time*" (Participant H); "*I subscribe to various magazines, digital publications, news publications, just keeping on top of what's happening, and try and have a good awareness of the tools that are out there*" Participant E), and; "*you've just got to read. You've got to look outside your organisation. And you've got to learn from others*" (Participant B).

As for internal sources of learning, participants evidenced the importance of empowering employees, and the role of trust. On the former, Participant C reveals: *Some of the big organisations have got lots of teams, chances are you can learn more from your employees than you can from outside the company. You've got some incredibly talented individuals in those organisations. They've got their eye on the ball with new technologies, new ways of thinking. Do knowledge sharing sessions where you can learn from your employees* […] *It's just about some of your time being allocated to [true] business development*".

Per Innovation Diffusion Theory (Gledson, 2022; Rogers, 2003), in construction the judgment of near-peers, and importance of personal networks continue to play a role as to the learning of leaders: *"I can lean on my Commercial Manager, who I've worked with for 15 years, I trust their judgement, I will put my bottom dollar on what they're going to tell me and believe that person over someone I'd paid £1,000 for a day, to come and talk to me, to sell me something"* (Participant D). However, Participant F advises the importance of leaders 'going to Gemba' rather than rely on second-hand information: *"the first step on that journey, from my experience, is that leaders firstly have to acknowledge their importance and significance … CEOs generally just basically hire someone who knows about them who reports back … but to truly get it, they have to see and experience it, rather than being told what it is … they* [need to] *reduce the gap between strategy and operations.*" This insight aligns with some of the concerns of Zulu, Saad, Ajayi, et al., (2023a) in discussing the dangers of having limited digital experience amongst top management.

Implementation
Next question: *How can business leaders support the successful introduction of digital solutions?*

Most responses focused on supporting inter-organisational efforts, discussing how they go about this, or the importance of people in any process. Aligning with the concept of gradual-(innovation) adoption introduced by Gledson (2022), Participant E gives an overview of how their firm supports the introduction of digital solutions, discussing aspects of the persuasion-decision-implementation stages of the innovation decision-process: *"We create narratives about why we are implementing a new solution,* [so] *people understand why we are making a change. Throughout the organisation, that's a different narrative for an executive versus the yard supervisor […] we get feedback on that, and get buy-in. We understand there's a learning process that we have to map out. Then, once we've had an impact we try and get some early wins, see the benefits, and track and report on those benefits. We might do this in a small pilot which works quite well. You've then got a good narrative for the next phase, where you try and roll it out to the business.*"

Meanwhile Participants C and H emphasise the importance of trust and empowerment of employees, specifically those tasked with leading any implementation efforts. *"It's about appointing the right people. Empowering, trusting the people with the right skillsets to implement whatever that leader and organisation believes is the right digital solution for them"* (Participant H). In contrast, Participant

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D discusses how individuals particularly in construction, can derail efforts meaning there is a need to persuade these persons: "*In construction there are very strong-willed people, probably more so than in any other industry you'll ever experience in your life, very different* [than] *in consultancy. In construction, those are the kind of people you come up against, and they're the ones that can kill an idea dead*". This concern aligns with the work of Zulu, Saad, Ajayi, *et al* (2023b), who identify lack of drive and motivation of firm leaders as a barriers to digital transformation.

Other notable responses discuss the importance of supplying ongoing support on projects. At Tier 1 level, Participant A advises: "*It's supportive training. It's having recognised knowledge experts, potentially centrally, that live on an overhead, that people can call on. And it's facilitating that training and getting the right solution*". Participant G also discusses how their (large) Tier 1 organisation brings other firm with them when appointing them on projects as Tier 2/3 firms: "*We have* [training] *for our supply chain, so when they work with us, we teach them how to do things … for example, we teach them how* [digitally] *to do* [model-based] *scheduling, how to cost using models, how to do visualisation, so for example,* [our] *project directors on sites can open the model and visualise and navigate. It's how we want them to work on our projects*".

Evaluation
Final question: *How can business leaders evaluate the (often indirect or intangible) benefits of a digital solution?*

Succinctly: "*Have we made more money from it, or have we reduced costs?*" (Participant F). Whilst some of the responses were about skills/capacity building and process improvements (e.g., Participant B: "*will it save them X number of hours/days per week?*"), recalling that benefits are measurable, most responses tended to focus on actual or hypothesised gains or losses in either financial or productivity terms, which aligns with prior digital benefits evaluation work (Hull *et al.*, 2007; Rosin *et al.*, 2020)

For example, when discussing potential financial losses Participant E discusses the need to be able to deliver what the customer wants, advises how their firm analyses client demand, and that digital working is being identified as a requirement by industry clients and partners: "*I don't talk about revenue generation from digital, but I do talk about revenue risk. We have around 2% of our customers where if we don't do digital working, […] they will not work with us. It's not very many, only 2%, but those 2% account for 25% of our revenue. So, if we cannot work in this way* [digital]*, we are putting 25% of our revenue at risk*". Participant B in contrast used profit-margins, work-winning track-records and repeat-business received from clients as evaluation metrics.

Participant F advises how their firm will use comparator and subjective metrics of, for example, fewer numbers of RFIs or 'clashes' than expected as compared against previous similar projects. Thereby hypothesizing reduced costs rather than making more money: "*Most* [construction] *businesses*

recognise that they want to see their site managers spend more time onsite, than in the office doing paperwork. So, one thing that I have been measuring is how many fewer forms are we generating. How many [fewer] issues are there [being raised]*?".* This aligns with recent findings exploring use of mobile technologies to lower paperwork, and improve efficiencies in site administration (Jowett *et al.*, 2023).

Similarly Participant G looked at production gains, as measured through tracking of design work produced via digital means and on-site installations: "*we now use historical data, and are able to compare projects, so you start to see the benefits because it shows how much time was taken to create a particular package, for example, to put in the foundation for that particular building and in that particular area. So, then it enables us to do predictions, to say we are in a similar area. This is a similar project, … so, it's helping us to do better planning.*" This coincides with work by Tallet et al., (2021) exploring the range of design and buildability gains that can be facilitated through digitally-enabled design management.

To close, Participant A provided a rich narrative that illustrated the direct benefits of their firm using digital working: "*I said we should do* [site-based] 'digital QA'. *I pilfered the stationary budget to buy people iPads but had to demonstrate a return on investment. I had £30,000 to spend which was the stationary budget for three years […] I took a very conservative estimate of: when we fill a piece of paperwork traditionally, we have to find the template, print it, take it out on-site, fill it in, bring it back, file it, fill the register in, and archive it at some point. Let's* [conservatively] *estimate that takes one minute admin time By the time we'd finished the job, because we had it digitally, we could tell exactly how many forms we'd filled in. When you ran the numbers, we'd saved 1.8 person years […] Say the average salary in Company X is £33,000 … I've just saved nearly £60,000 and I only spent at the outset on some iPads*".

They go on to advise of some of indirect benefits that were not initially measured, but which were caused by unintended consequences or 'reinvention' of this particular innovation:
"*At the end of the project people needed to give them back to me/IT because the project stopped paying for them. I went to the first people leaving and tried to get them off them, and it was like pulling them out of their cold, dead hands. They knew the minute they let go, they lost something – they'd actually fought quite hard against, initially – and now it was 'I don't have to do all this admin. It's great. It saves loads of time' […] then it all came out. 'actually, I'm not just using it for that. I don't print drawings anymore. I put PDFs on my iPad and take that out with me, that saves us money, also, by the way, there's an app for our document management system, so, I can check I've got the latest drawing. I use it to take site progress photos, and when I'm filling in an NCR or an RFI I take a picture and don't have to print to annotate it. I can do that; then just send the email and it's gone' So there was a huge number of intangible benefits they'd been sitting on for years and hadn't shared with us*".

Participant A provided additional examples of how Digital QA has since reduced admin function on projects, how their archiving department has been significantly reduced, and how they are now better equipped to evidence against potential defects and claims.

5. Framework

By critically analysing perspectives using a reflexive thematic approach, various considerations around aspects of digital leadership in construction firms have been uncovered. These findings were synthesised, lead to the formation of a digital leadership considerations framework shown in Figure 2. Frameworks are supporting structures useful to support the planning or building of something (Partelow, 2023). This particular framework is for use in the Construction 4.0 context by leaders faced with the management of organisational elements for successful digital transformation. It is structured into strategic-, operational-, project- or staff-levels, and level-appropriate core concepts around digital leadership are identified and communicated accordingly.

INSERT FIGURE 2 HERE.

Figure 2: Framework of Digital leadership considerations in construction firms.

6 Conclusions

Against the background context of Construction 4.0, this work explored what digital leadership in construction firms is, and what considerations it involves. Through thematic analysis of expert interviews, a digital leadership considerations framework is established which can aid organisational digital transformation for industry leaders, or act as a springboard for future research efforts. Digital leadership is the action of leading a group of people or an organization involving the use of computer technology. Results reveal that digital leaders of construction businesses strategically see the benefits of adopting digital ways of work to meet business objectives, and enable this to help their firms make better, data-informed decisions, drive efficiencies; and improve productivity. More broadly, digital leadership in Construction 4.0 can help the industry address grand challenges, such as those related to sustainability and the decarbonization agenda. At firm-level, through better ways of capturing and managing data and information, digital transformation can help construction organisations improve how they deliver projects to better compete in the marketplace. Operationally, facilitating good staff engagement is crucial, and organisations can build their digital skills capacity typically by upskilling existing staff, possibly through reverse-mentoring or alternatively - albeit less frequently - by bringing in new hires with the desired skills. Though firms may need to look outward for quality education and training, the need for this to be accessible, relevant, and timely for it to be impactful for staff is reinforced. Additionally, facilitating good staff engagement is crucial. The necessary personal characteristics of individuals working with digital technologies in construction include adaptability and openness. Regarding digital competencies, an appreciation of and basic skills in, data- and information- management, as well as the ability to think and work in a model-based ways are now critical. Digital considerations at firm-level involve systems-based thinking, seeking to increasing the

use of automation, ensuring ease-of-use of systems, and ensuring appropriate site and office infrastructure is in place. Whilst construction can be too constrained by its conventional business model many digital leaders recognise also new opportunities afforded by digital approaches. There are several business opportunities around the optimisation of internal processes or through the improvement of organisation learning that can be actualised. Business leaders can increase their own knowledge of the digital solutions from networks of external or internal sources, but bidirectional trust and staff empowerment remain important concepts here. Business leaders can also support the successful introduction of digital solutions by creating narratives about why new solutions are needed, and obtaining feedback and commitment and reporting on wins in any pilot before wider roll out. Finally, business leaders can evaluate the benefits of digital solutions in terms of organisational capacity building and through considerations of gains or losses in either financial or productivity terms.

Limitations and recommendations for further research
The limitations with the greatest potential impact relate to the works non-probability nature, its purposive sampling approach, and the number of research participants selected for expert interviews. It is accepted that because of this, the ability to make generalisations about the wider construction population is restricted, though the researchers do consider the work to be contextually relevant and ecological valid. It offers a number of various departure point for further research. For example, follow-on studies could focus on any of the examples of 4IR innovation types in Construction 4.0 listed in Table 1 to further investigate how their use is improving project delivery, construction performance, or management practice. Additionally, the themes contained within the digital leadership considerations framework could benefit from other means of empirical underpinning which could be done in any confirmatory research. Additionally, though this work has focused on uncovering what digital leadership is, further research could instead focus more on organisational followers by further determining the digital capabilities, competencies and skills necessary for modern construction staff, as well as exploring the challenges of developing these in project-based organisations. Additionally, given concerns around control and surveillance, the negative consequences of digital leadership and digital transformation requires further study. The merging contexts of work and the workplace would benefit from further exploration for similar reasons.

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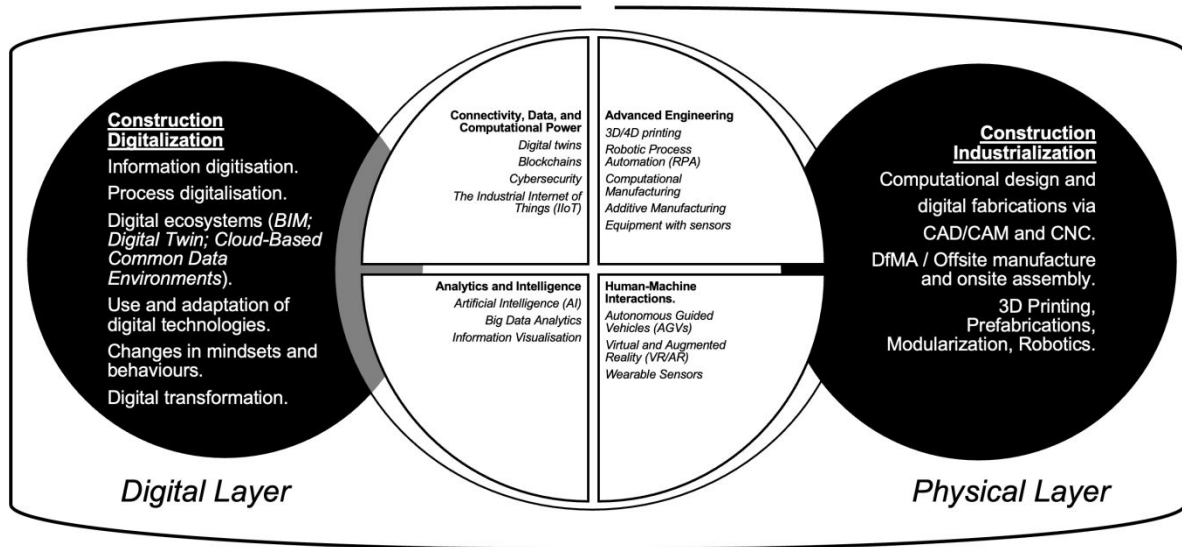
Figure 1: Cyber-Physical Systems (CPS) connected in Construction 4.0.

Table 1: Examples of 4IR innovation types in Construction 4.0 with supporting studies.

CATEGORIES OF DISRUPTIVE TECHNOLOGIES.	4IR INNOVATIONS Brief definitions of, and (non-exhaustive) examples of applications of 4IR innovations in Construction 4.0:	SUPPORTING STUDIES. For more detail, refer to:
Connectivity, Data, Computational Power	Digital twins: Cyber environments bidirectionally linked to real-life replicas to enable simulation and data-centric decision making to occur. Useful in Construction 4.0 for creating, simulating and monitoring replicas of real construction spaces.	Agrawal et al (2022); Boje et al (2020); Joe Opoku et al (2021); Shahzad et al (2022)
	Blockchain: Distributed ledger maintained across computers linked via peer-to-peer networks, containing secure lists of records and transactions. Useful in Construction 4.0 for supply chain accountability.	Lee et al (2021; Li et al (2019)
	The Industrial Internet of Things (IIoT): Interconnected sensors, instruments, and other devices networked together with computers for industrial applications. Useful in Construction 4.0 for monitoring performance.	Edmondson et al (2018); Statsenko et al (2022); Tang et al (2019)
	Cloud Computing: Using network(s) of remote servers hosted on the internet to outsource the storage, management, and processing of data. Useful in Construction 4.0 for enhancing collaboration.	Oztemel and Gursev (2020); Statsenko et al (2022)
	Cyber Security: Preventing cyber-attacks and protecting networks, systems, programs, devices and data by applying appropriate processes, technologies, and controls. Useful in Construction 4.0 for protecting asset-, project- and firm-data.	Oztemel and Gursev (2020); Statsenko et al (2022)
Analytics and Intelligence	Artificial Intelligence (AI): Simulating human intelligence through machines, especially computers. Useful in Construction 4.0 for general modelling, pattern detection, prediction, and process optimizations.	Klashanov (2016); Pan and Zhang (2021)
	Big Data Analytics: Analysis of datasets too large and/or complex to be processed using traditional applications. Useful in Construction 4.0 for mitigating risks and leveraging productivity.	Oztemel and Gursev (2020); Rawat and Yadav (2021); Statsenko et al (2022); Yousif et al (2021)
Advanced Engineering	3D/4D printing: Construction a three-dimensional object from a digital model through additive manufacturing processes. In 4D printing, the initial 3D printed shape morphs to different forms over time. Useful in Construction 4.0 for the creation of new structural forms on-site or manufacturing components off-site.	Alves et al (2023); Camacho et al (2018); Hannibal and Knight (2018); Tay et al (2017)
	Robotic Process Automation (RPA): Software robots used to digitally automate routine/monotonous tasks in workflows. Useful in Construction 4.0 for regular material orders, data entry, and scheduling.	Cai et al (2019; Waqar et al (2023)
Human-Machine Interactions	Autonomous Guided Vehicles (AGVs): Mobile driverless vehicles or robots. Useful in Construction 4.0 for transportation of materials.	Yang and Pan (2021); Zhang et al (2023)
	Virtual- (VR) Augmented- (AR) Mixed- (MR) Extended- (ER) Realities: Mixing or replacing users views using digitally generated content. Useful in Construction 4.0 for design optioning.	Bosch-Sijtsema et al (2021); Oztemel and Gursev (2020); Wu et al (2023)

Table 2: Interview questions and participants

| Interview Questions	Participant Details inc. role and experience
1. What does **digital transformation** mean to you?	Participant A (Male). Technical Lead with 18 years industry experience. Employed at industry leading privately owned Top 10 UK based construction business that funds, designs, manufactures, constructs, and maintains the built environment.
2. What does **digital leadership** mean to you?	Participant B (Female). Digital Director with 27 years industry experience. Employed at industry leading global Project Management consultancy business serving clients in the real estate, infrastructure, and natural resources sectors.
3. How can organisations **build the right skills** so that digital strategies can be effective and transformative?	Participant C (Female). Now a Senior University Academic (Computing Sciences) whose research and consultancy work focuses on developing digital solutions and skills for the building industry. In their 21 years relevant experience they led several construction digital transformation projects collaborating across industry and academia.
4. What **digital competencies** are now **essential for construction** businesses?	Participant D (Male). Pre-Construction Manager / Technical Design Lead with 11 years industry experience. Employed at one of the UK's top 20 most successful, privately-owned construction and development groups. Former Head of Digital at the UK's leading independent construction and property services company.
5. In what way does digital leadership mean thinking differently about **business models**?	Participant E (Female). UK Digital Engineering Manager with 9 years industry experience at one of the leading manufacturers and suppliers of formwork and scaffold systems in the world. Formerly, Senior Digital Engineer at an industry leading privately owned Top 10 UK based construction business.
6. What **business opportunities** does digital transformation enable?	Participant F (Male) is a BIM Manager with 9 years industry experience at one of the top 15 largest privately-owned construction, development, and property services companies in the UK.
7. **Learning about digital solutions:** how can business leaders increase knowledge of the digital tools available?	Participant G (Female). Head of BIM (International) and Associate Director at a leading global built environment consultancy/top 10, construction company . 20 years industry experience.
8. **Leading implementation:** how can business leaders provide the knowledge to support the successful introduction of digital solutions?	Participant H (Male). Director of a medium–sized firm of digital construction consultants that have established a centre of excellence for Building Information Modelling (BIM) to support industry in BIM adoption. 18 Years industry experience.
9. How can business leaders **evaluate** the **benefits** of a digital solution?	Participant I (Male). Former Head of Digital Delivery at a County Council (North, UK) and now a managing consultant at a consulting firm focused on digital transformation, data, cloud, and engineering. 21 years industry experience.
	Participant J (Female). Digital Construction Consultant and former Research Impact Manager at a UK leading smart construction and infrastructure company. Circa 10 years industry experience.
	Participant K (Male). Industrial researcher at a UK leading Digital Construction Constancy with specific interests in digitally-enabled asset management. This firm is an established a centre of excellence for Building Information Modelling to support industry in BIM adoption. Just under 5 years industry experience.
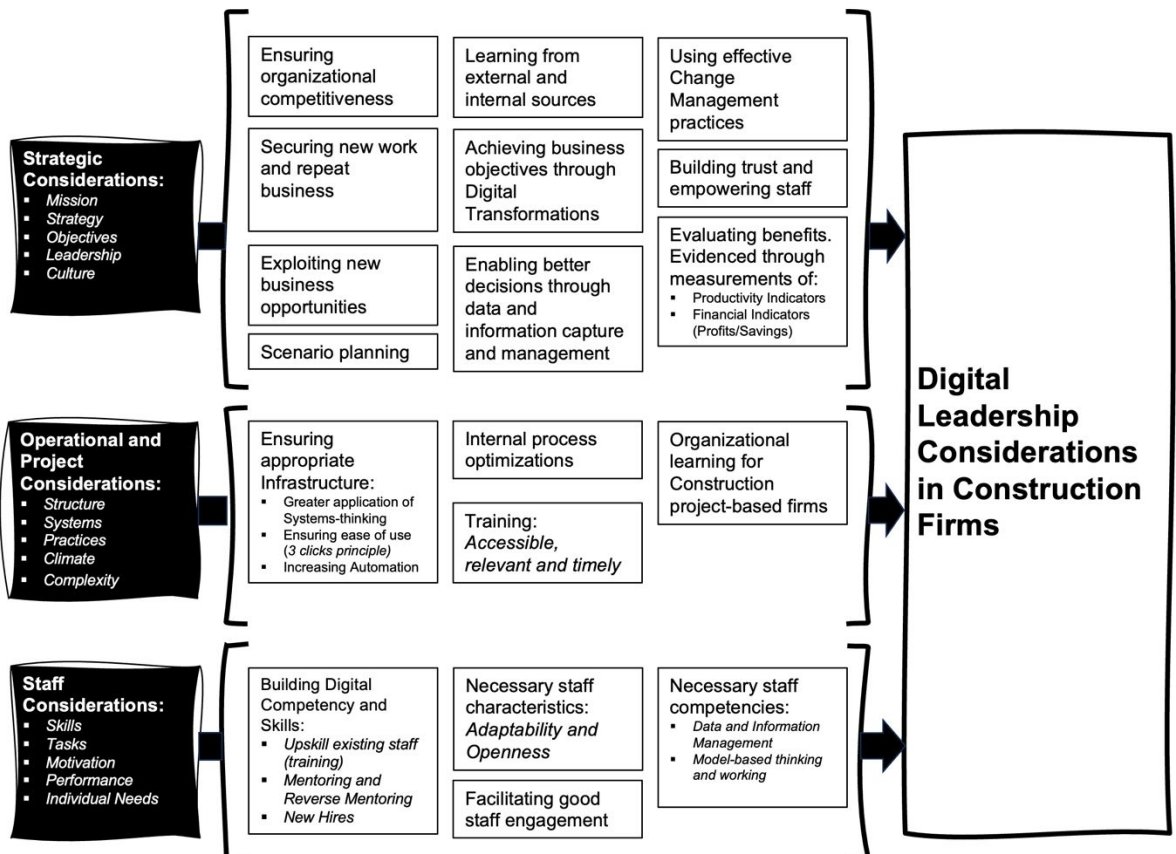
Figure 2: Framework of Digital leadership considerations in construction firms.

Authors General Response to Referee Comments (Minor Revisions)			
The researchers thank the referees for their time and very useful insights in their second review.			
Thanks also for again identifying several minor revision areas which have been actioned wherever possible, as these greatly helped in the strengthening of this work.			
The minor revisions opportunity also allowed the researchers to further reflect on the merits of their own work, which has even further enhancements to also be made.			
The **editorial team** and the **reviewers** will note again that blue font has been used in this manuscript for any new text and/or text amendments to address the minor revisions comments made by the reviewers and/or add necessary content.			

Review 1 Accept	General Comments	This reviewer thanks the authors for addressing all his/her queries and concerns. Good luck!	The researchers thank the referee for their kind words. Appreciated.
	AQ1	*Originality: Does the paper contain new and significant information adequate to justify publication?:* Yes, the paper has been substantially improved.	The researchers thank the referee for their comments and for recognising the originality of the work.
	AQ2	*Relationship to Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?:* The paper now includes an adequate literature review.	The researchers thank the referee for these comments.
	AQ3	*Methodology: Is the paper's argument built on an appropriate base of theory, concepts or other ideas? Has the research or*	The researchers thank the referee for these

		equivalent intellectual work on which the paper is based been well designed? Are the methods employed appropriate?: The methodology section has also been significantly improved.	comments.
	AQ4	**Results:** *Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper?:* The results are clearly and analyzed appropriately.	The researchers thank the referee for these comments.
	AQ5	**Implications for research, practice and/or society:** *Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?:* The authors have made an effort to include a new section "Framework" that allows showing implications for researchers, practitioners, etc.	The researchers thank the referee for these comments.
	AQ6	**Quality of Communication:** *Does the paper clearly express its case, measured against the technical language of the fields and the expected knowledge of the journal's readership? Has attention been*	The research team wish to thank this referee for their comments throughout.

		paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc.: Acceptable. Flow could be improved. The paper is clear and well written.	

| **Reviewer 2**

Minor Revision | General Comments | Sound introduction and methodology however I think it would be a good idea to spend some time actually referencing the themes and elements that Construction 4.0 is, as you are heavy in the transition from existing to new business models, but lack the expression of what Construction 4.0 could (or should be).

This would add greater novelty, create new areas for research and bolster your position within the area of applying intelligence and innovation. For example, there's little mention of AI, data driven decision making, the advantages of rapid decision making for challenges such as sustainability which are all key drivers of opportunity and change. | The researchers thank the referee for their kind words. We have addressed these aspects through new content (blue font) in the contextual/introductory section, from Page 2, Line 21 through to Page 3, Line 20. The addition of a new Figure 1 titled "*The Connection of Cyber-Physical Systems (CPS) in Construction 4.0*" and a new Table 1 titled "*Examples of 4IR innovation types in Construction 4.0*" also helps provide further and better detail on what Construction 4.0 is and the themes and elements that it consists of.

Following Table 1, we have also specifically drawn attention in the text to the possible use of AI to address these challenges on Page 3, Lines 12-19. This theme is also returned to briefly in the conclusion section specifically on page 18, lines 25-27. |
| | AQ1 | ***Originality:*** Does the paper contain new and significant information adequate to justify | The researchers thank the referee for their comments and for recognising the originality of |

| | | *publication?:*

It does in that there is great novelty in the semi-structured questionnaires undertaken with a diverse range of stakeholders.

However, the title itself doesn't fully reflect the content within and I was expecting it to be positioned more towards Construction 4.0 linking in advancing in AI, challenges and opportunities rather than limited to the transition to enhanced digital engineering organisations. | the work. They have provided valuable feedback that the title of the work should be updated to better reflect the focus and contribution of the work.

The title has therefore been updated from the original "*Exploring Digital Leadership of Construction 4.0 Organisations*" to the better "*Digital leadership framework to support firm-level digital transformations for Construction 4.0.*" The researchers feel that this now does best evidence a key contribution made, and also more fully reflects the focus of the work (i.e., the framework assisting firm-level changes toward Construction 4.0). |
| | AQ2 | ***Relationship to Literature:*** *Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?:*

There is a good foundation of literature and justification on sample size etc. but it is limited as per comment one, whereby the paper is focused on the transition from paper to digital methods and the justification. | The researcher thanks the referee for recognising that the paper addresses this criteria.

As above comment, much new written content has been added from Page 2, Line 21 through to Page 3, Line 20 to provide further and better detail on what Construction 4.0 is, and the themes and elements that it consists of. In this new content additional literature has been used to discuss Construction 4.0. Also, the new Table 1 "*Examples of 4IR innovation types in Construction 4.0*" assists here by citing/identifying many relevant that provide further detail around applications of 4IR innovations in Construction 4.0. |

	AQ3	*Methodology: Is the paper's argument built on an appropriate base of theory, concepts or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed appropriate?:* Absolutely however I think the author could have extended further into the realms of the unknown and explore the challenges such as productivity, data driven decision making, sustainability and carbon transition as well as a deeper dive into what these core areas area (forming part of Construction 4.0).	The research team thanks the referee for recognising first that the methodology section is now appropriate. The research team are also hopeful that the additions previously discussed addresses this concern. Again, it is noted that challenges mentioned here are explicitly discussed in the text on Page 3, and briefly returned to in the conclusion section (Page 18, lines 25-27).
	AQ4	*Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper?:* They are presented clearly, but I feel it would add strength by creating a visual map of what the themes of Construction 40 are via more research references and industrial case studies. Furthermore, some of the descriptions of the 'anonymised' stakeholders make it very easy to find out who these person(s) are..	The researcher thanks the referee for these comments. Though we have included these in the contextual/introductory section, we feel that the inclusion of new Figure 1 and new Table 1 (as per details above) addresses this requirement to map the themes of Construction 4.0 within the work. We have now also removed some of the more detailed descriptions (number of employees, turnover etc) so as to better anonymise interviewees.

	AQ5	*Implications for research, practice and/or society:* Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: I feel this could be strengthened in a roadmap or proposal for the next steps to realizing this, and generating further research areas towards transparency and opportunity.	The researcher thanks the referee for these comments. We have provided additional text in the updated "*Limitations and recommendations for further research*" section on Page 19, Lines 16-20 to identify areas of possible enquiry for follow on researchers. We hope that this, coupled with the new visual content contained in new Figure 1 and new Table 1 (as per details above) helps addresses this requirement to identify opportunities of possible further Construction 4.0 related research.
	AQ6	*Quality of Communication:* Does the paper clearly express its case, measured against the technical language of the fields and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc.: Acceptable. Flow could be improved.	The research team wish to again thank this referee for their comments throughout. We do recognise that the revisions made to address these, have ultimately strengthened the work.

| | | The paper reads well however as per my above points I would expand further into the subject matter (title) and not simply the transition into digitisation and digitalisation. | |