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Lack of digital twin policy as a barrier to sustainability, carbon targets, and sdg achievement

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Abstract

The Sustainable Development Goals (SDGs) are a comprehensive set of targets aimed at improving global conditions, including a focus on reducing carbon footprints. Adopting Digital Twin (DT) technology will aid the achievement of the SDGs. However, there is an inconsistent procurement and policy environment around the development of DTs that can be problematic for those striving to achieve the SDGs. There exists a paucity of research around the interconnections of national policy, DTs, and SDG achievement. This paper addresses this gap by ascertaining how procurement and policy environments impact DT adoption, and in turn how DT adoption can serve to help or hinder SDG achievement. Adopting an interpretivist ontological methodology, this inductive research explores the perceptions of DTs and SDGs as independent concepts (stage one and two), before further interviews are conducted (stage three) which focusses on how DTs and SDGs interact with one another. In total, twenty-five semi-structured interviews with leading professionals are conducted, with narrative analysis utilised as a means of interview structure and analysis. Analysis of the results found there is an inconsistent global policy and procurement environment. In the UK this is hindering DT adoption. Whilst numerous SDG strategies exist, these strategies are often undermined by wider government policy limitations and contractor practices. This original paper calls for an immediate re-think of national policies on DT development, without which, SDG achievement strategies will ultimately be doomed to fail.

Keywords: Collaboration, communication, government policy, innovation, sustainability

INTRODUCTION

The construction industry plays an integral role in global society. However, despite its significance, it has been viewed as fragmented, uncollaborative, and slow to adopt new technologies[1]. Despite this, the industry is viewed as one that can make a substantial positive impact on the achievement of the Sustainable Development Goals (SDGs). These goals have been developed by the United Nations (UN) and were launched in 2015 covering a diverse collection of targets, each with tangible metrics to aid and monitor performance progress[2]. Despite their global significance, achievement of the SDGs by their 2030 target date is currently viewed as "off track"[3]. To address this, recent research has started to consider how technology can aid the achievement of the SDGs, with an increasing focus on the role Digital Twins (DTs) can play. The potential of DTs however, is arguably limited without appropriate policy in place to facilitate their growth. Despite the clear links between technology adoption and sustainable progress, there remains a gap in existing knowledge around how policy can enhance the use of DTs. This research addresses this policy awareness gap and aims to identify how policy can be used to support DT development, which in turn will then help achieve the SDGs.

First, this paper introduces the size and scope of the construction industry. How the construction industry intersects with the SDGs is then presented. Next, the UN SDGs are discussed, and their global significance outlined and DTs are defined with their links with sustainability explored. The current policy landscape is then analysed, focussing around where policy (or lack thereof) supports DT development. The interpretivist methodology is then outlined and the research instrument of semi structured interviews presented, with narrative analysis used to both structure the questions asked and assist with the thematic analysis of interview data. Finally, the research findings are outlined and significant themes presented. This paper concludes with original and internationally significant findings that highlight how specific policy can be introduced to promote DT adoption which in turn can help SDG achievement. Clear recommendations are made for industry, future research agendas, and both national and international public policy makers.

THE CONSTRUCTION INDUSTRY

The construction industry can be described as the design, construction, maintenance, refurbishment, and ultimate demolition (disposal, waste management and recycling) of built assets, infrastructure, and engineering works. A globally significant industry, construction accounts for approximately between 5%-7% across all countries[4]. In the UK the construction industry is responsible for 6% of national employment[5], with similar national employment percentages experienced by the USA[6], Nigeria[7] and Australia[8]. The economic contribution by the Australian construction industry is reported to be around 9%[8]. In the UK this amounts to an annual economic contribution of over £99bn[5]. The significance of the construction industry to global economies cannot be understated.

The industry is also arguably unique in that it operates almost wholly in the public eye. This increased visibility results in greater industry scrutiny over its performance and indiscretions. This industry also suffers from a negative historic image due to its high raw materials use, exploitative practices, bipartisan approaches, unfriendly reputation, and general wasteful nature[9]. The industry has also been highlighted as one that has a fragmented structure, slow to adopt technology, and has generally inefficient workflows[1]. However, contrary to the belief of perhaps some professionals who operate within it, construction is a multi-disciplinary collaborative environment that is dependent upon a multitude of professionals for projects to be delivered successfully. It has long been argued that for project success to be achieved, factors such as teamwork, relationship building, and cooperation of key stakeholders need to be considered[10]. Such calls for collaboration have been echoed frequently in previous decades, including notably in the Government backed industry report "Constructing the Team"[11] and then followed later by "Modernise or

Die"[12]. Given the 22 year gap between these reports and that the calls for collaboration remain the same, it appears, perhaps pessimistically, that such calls may be going unanswered.

The industry also faces a wealth of often competing demands. These include the traditional, arguably client driven focus, upon time, cost, and quality, of the projects themselves. Although these success factors have arguably evolved over recent years to now encompass all manner of "contemporary" factors such as social value and sustainability based criteria[13]. The importance placed upon such criteria by differing stakeholders has also been explored. One robust study examined project success through intensive stakeholder interviews pertaining to three Nigerian mega projects and concluded that "success" in a construction project means different things to different stakeholders[14]. Through an extensive systematic review of 124 international bidding related articles published over the last 40 years another study found that increasingly diverse procurement criterion has evolved in tandem with an increasingly competitive global construction bidding environment[15].

Due to the global significance of the industry, its high impact on both the built and natural environments, and the increasing stakeholder and societal expectations for positive change, the construction industry is now viewed in how it responds to the contemporary global sustainability challenges. Procurement is often the vehicle through which client sustainable agendas are achieved and so the links between the construction industry and the achievement of the SDGs cannot be ignored. Sustainability now often features as a procurement criterion and can result in the difference between procurement success and failure for those tendering. However, despite the increasing sustainable movement in the UK construction industry, the in dustry has been described as one of the least sustainable[16]. In an effort to refocus the global agenda and encourage collaboration in achieving specific sustainable goals the UN drafted the SDGs.

THE UN SUSTAINABLE DEVELOPMENT GOALS

The SDGs were formally adopted in 2015 by all UN member states and set clear targets across a range of seventeen different goals deemed to be internationally significant[13]. The seventeen SDGs cover diverse areas [Figure 1], yet each have tangible performance driven metrics by which progress against each goal can be held to account[2].

The SDGs call for collaboration between developing and developed countries and recognise the interlinked and interdependent nature involved in achieving each of the goals[18]. As part of their sustainability focus, and in line with several SDGs, the UK Government launched a Net Zero target for carbon of 2050[19]. One Ghanian study that conducted interviews with key energy industry stakeholders concluded that SDG success depended upon the collaboration and cooperation of both private sector and public sector partners[20]. However, there is often a siloed approach taken in attempting to work towards achieving the SDGs, with stakeholders focusing on individual SDGs that they feel more able to contribute to. In a review of 101 research papers published between 2015 and 2020, one study found that environmental themed goals were focused on more than others, and that there exists a disconnect between planned SDG strategies and the actions required to achieve such strategies[21]. Another study utilised intensive practitioner workshops and found that many SDG strategies neglected biodiversity initiatives despite the them being crucial to SDG achievement[16]. In a recent review of construction industry contractors, one study conducted a Qualitative Content Analysis of the published sustainability reports from leading main contractors and compared the findings to extensive industry interviews. The study found inconsistent SDG organisational knowledge and that contractors focused on the same select few SDGs[13]. This echoed warnings from previous studies that argued the SDGs were not on track to be achieved and that further collaboration and support from governments and industry was required[16]. Research has shown that whilst awareness of the SDGs is key to

Figure 1. The Sustainable Development Goals[17].

helping their achievement become reality, individual and collective education regarding SDGs is often limited, thus serving to restrict SDG progress[22].

To aid collaboration, and develop methods by which the SDGs can be achieved, sustainability focused research has expanded in both breadth and depth in recent years. For example, the onset of Artificial Intelligence (AI) has led to studies considering how such technology can support the SDG achievement, with one study finding that AI has the potential to both help and hinder SDG achievement[23]. Research has also explored the intersection of AI and SDGs and the beneficial use of big data[24]. However, research into AI and SDGs remains in its infancy and to date there are limited examples illustrating the practical benefits that can be achieved. There has been research highlighting the potential use of innovative technology in helping achieve the SDGs, but again adopting a theoretical stance with little practical application[25]. Underpinning many of the goals is a focus on carbon footprint reduction with numerous studies illustrating the strong links between having a clear focus on carbon reduction and the achievement of the SDGs[26,27].

REDUCING CARBON FOOTPRINTS

An extensive bibliometric review of 2,113 journal publications between 2007 and 2022 confirmed the global significance of carbon footprint research[28]. China and USA lead the way in influential publications and citations, yet European countries have the most productive research teams with the results illustrating clear links between carbon footprint research and broader concepts such as climate change, emissions, and sustainability[28], all concepts that overlap significantly with the SDGs[26]. One study quantifies the carbon footprints of buildings and reviews the decarbonisation technologies available to reveal inconsistencies in global databases, unclear terminology use, and inaccurate models of building energy consumption[27]. The research concluded that all these factors serve to limit the potential of carbon footprint reduction, and therefore all serve to undermine the achievement of the SDGs[27]. Studies have also considered how

contemporary technology, such as AI can aid carbon footprint reduction[29]. Yet, despite the frequent research undertaken into reducing carbon footprints and achieving the SDGs, the most recent update report from the UN described SDG progress as "severely off track"[3]. However, the same report advocates that increasing technology use can aid the SDG achievement by the 2030 deadline[3].

DIGITAL TWINS

Innovation has been described as the "vehicle of development"[30], with numerous studies illustrating the broader benefits increased innovation can achieve within the construction industry. This includes enhanced site safety management[31], efficient procurement practices[32], and increasing effective supply chain communication[33]. Studies have also revealed a link between the lack of technological adoption and broader negative ramifications. For example, one South African study reveals how a lack of innovation adoption can limit adaption and growth[34]. Research has also explored how technology adoption can reduce the information gap, eliminate data discrepancies, and improve collaboration[1]. The benefits for technology adoption are therefore broad and can assist the construction industry in meeting many of its expectations. One such study argues that it is only through adopting innovative technology that the industry can achieve goals such as sustainability with the Chinese construction industry leading the way in green technology adoption[35]. Indeed, another study, again adopting a systematic literature review approach, argues the existence of a link between increasing the digitisation of the construction industry and enhanced sustainable processes[32]. In an effort to enhance its innovative practices, and achieve its sustainable expectations, whilst simultaneously increasing efficiency and remaining competitive, the construction industry has started to explore the benefits of utilising DTs.

A DT can be described as "A relevant, virtual representation of the state and behaviour of something physical or non-physical with a functional output in the real-world"[36]. Utilising a DT allows improved decision making by providing greater availability, clarity, and accuracy of information[37]. Introduces at NASA in the 1960s before entering mainstream terminology in the early 2000's DTs can now no longer be classed as in their infancy[38]. It has been argued that the application of DT technology will help revolutionise the performance of the construction industry as it allows digital simulations to utilise real time data for the benefit of both natural and physical assets[39]. The increasing significance of both the DTs and SDGs can be ascertained via Google Trend data. This is freely available and illustrates the online search history for selected key terms over a set period. Figure 2 reveals the search trend increase for the terms "Sustainable Development Goals" (blue) and "Digital Twins" (red) since the start of 2014.

A similar search for the combination of these words ("Sustainable Development Goals Digital Twins") does not yield enough data to populate a graph, arguably illustrating that whilst these terms are increasing in popularity individually, it is in isolation from one another. However, there are an increasing number of studies that consider the combination of these concepts, and how specifically the wider use of DTs can aid SDG achievement[40-42]. Through an extensive literature review one study found DTs can aid SDG achievement in industries such as agriculture, education, healthcare, manufacturing, urban planning, and construction[38]. With another study illustrating the beneficial application of DTs in the sustainable improvement of waterways resulting in a decreased water demand, a reduction in carbon emissions, and enhanced cost savings achieved[37].

Despite its reputation for not embracing technological advancements, the construction industry has been an early adopter in DTs in the form of Building Information Modelling (BIM)[38]. However, despite the technology existing for wide scale BIM use, leading to full DT adoption, there persists barriers to DT adoption that have to date prevented its widescale growth. Nevertheless, the introduction of the BIM

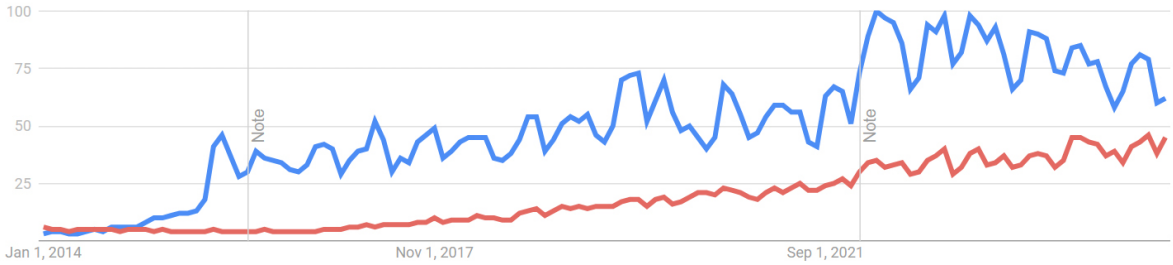

Figure 2. Results adapted from Google Trends data of searches since 2014 for "Sustainable Development Goals" (blue) and "Digital Twins" (red).

mandate by the UK Government in 2016 is widely regarded as being the catalyst that pushed the technology forward[43]. Studies have illustrated the benefits BIM mandates have had in Poland[44], and the potential benefits to be achieved if BIM is to be mandated in Ireland[45]. One comprehensive study reviewed BIM mandates across thirteen different countries including the UK, China, Hong Kong, Australia, USA, and Denmark found the countries with the most government backed BIM support were the countries that experienced the greatest benefits from BIM adoption[46].

One study found that DT adoption can be improved by changing the mindset of those professionals in the industry who view themselves as "bystanders" in technology adoption to having the self-perception of an "enabler"[47]. However, the study also finds that there is limited broader support in changing individual actors from that of DT "bystander" to "enabler" from policy makers[47]. Other studies have also reached similar conclusions, with one study finding that a lack of clarity around Government guidance and a dearth of legislation can explain why the construction industry finds it difficult to overcome barriers in technology use even where clear sustainable benefits exist[48]. It has been argued that the power to enact transformational digital change throughout the construction industry rests with policy makers[49].

DTs have been described as on the cusp of construction industry transformation[1] yet the ability to scale DTs and facilitate their growth is hindered by many barriers. One of the largest and most under explored of these barriers, is the policies in place that support DT growth and usage.

THE POLICY LANDSCAPE

Policy refers to the formal initiatives, advice, legislation, and guidance offered by public bodies, notably Governments, in order to aid and govern behaviours. Construction industry focused policy has long been researched and often blamed for a plethora of failed initiatives and unfulfilled productivity promises. Indeed, many research papers on seemingly disparate innovations applied to differing areas of the industry all converge in the need for policy to overcome the barriers discussed. Notwithstanding the calls for policy as a silver bullet to solve the ails of the construction industry, there are studies that identify how policy implementation can lead to significant construction industry improvement[50].

Through an in depth analysis of policy instruments one study found that Government policy can drive market demand, yet there exists a paucity of technology focused policy surrounding tax and financial incentives[51]. Another study specifically considers the role of science, technology, and innovation with regards to the SDGs and finds that the policy environment needs to evolve to consider these previously siloed areas if future policy is to be meaningful[52]. It has also been discussed how governance barriers through a lack of current policy are fundamental in preventing DTs from helping to achieve SDG 11 (Sustainable Cities and Communities)[53].

Despite the increasing focus on the interconnection of DTs and SDGs, there remains a gap in existing knowledge around the role policy guidance has on the use of DTs in the construction industry to help support the SDGs. This is especially pertinent from the perspective of industry practitioners with most previous studies drawing conclusions from literature reviews. This research aims to ascertain which policy environments help and hinder DT technology, and therefore which serve to help or hinder SDG achievement.

METHODOLOGY

Whilst sustainability is arguably an interpretivist ontological concept, the SDGs metrics and targets adopt a more positivist perspective. DTs also follow suite with a clear definition and standard criteria around what is and is not a DT. Despite the concepts under investigation holding strong positivist ontological perspectives, an interpretivist approach is adopted for this research. It is the understandings and perceptions of each concept that are sought. Therefore, a constructivist approach will enable deeper insights to be ascertained pertaining to the barriers encountered by participants. Such barriers will be understood through an interpretivist epistemological approach, whereby enquiries are made into subjective knowledge and shared meanings of social actions[54]. This approach lends itself to the collection of qualitative data. Qualitative research methods attempt to explore understandings that cannot be easily expressed in numbers and figures and instead place a greater focus on deeper meanings[55]. There are ongoing academic discussions pertaining to the SDGs and a small but growing body of literature regarding SDGs and the UK construction industry, and even smaller body that also discuss DTs. This paper, therefore, adopts an inductive approach to address the current paucity in contemporary research. This research seeks to utilise the capture and analysis of qualitative data to ascertain which policy environments help and which hinder DT technology adoption, and therefore which serve to help or hinder SDG achievement.

As a qualitative research strategy advocates a focus on understandings and interpretations, this research adopts interviews as the most appropriate research tool to capture participant thoughts, ideas, and perceptions[56]. Semi-structured interviews are adopted as these allow interviews to be structured around the areas of core importance but allow interesting and applicable avenues of information that arise during the interview to be pursued[55]. Semi-structured interviews allow complex topics to be discussed, and a greater level of insight to be gained than through alternative methods such as open ended questionnaires, as well as allowing follow up questions to be asked if initial responses lack clarity or focus[57]. The research was divided into three distinct stages to gain a greater insight into the different phenomena under investigation. For each stage a process of purposeful sampling was undertaken to identify those participants who were best placed to inform the topics discussed. Narrative analysis was used as both a method of structuring the interview questions and analysing the results gained. Narrative analysis is essentially a method of utilising stories in an attempt to gain insights into a participant's knowledge and understanding[58]. It allows such insights to then be compared and analysed, with similarities, differences, and trends identified across participants[58] and has been increasing utilised across the construction management literature in recent years[59,13].

The first research stage investigated the SDGs. It considered participant reflections on the barriers, enablers, and SDG progress. Questions included "What do you think are the biggest barriers to achieving the SDGs?" and "Can you think of an example where you have witnessed an initiative focused on the SDGs?". Ten semi-structured interviews were conducted as part of this research stage with Table 1 illustrating the interviewee details of those who participated:

Table 1. Interview participants

Participant code	Job role	Experience (years)	Organisation type
Stage 1 - SDG interviews			
A	Construction Manager	5	Contractor A
B	Project Manager	8	Contractor A
C	Project Manager	6	Contractor B
D	Quantity Surveyor	5	Contractor B
E	Quantity Surveyor	4	Contractor C
F	Project Manager	9	Contractor D
G	Construction Manager	4	Contractor D
H	Architect	13	Consultant A
I	Sustainability Consultant	7	Consultant B
J	Sustainability Consultant	4	Consultant C
Stage 2 - digital twin interviews			
K	Digital Lead	10	Contractor A
L	Project Manager	13	Contractor B
M	Innovation Manager	20	Contractor E
N	Project Manager	11	Contractor F
O	Digital Consultant	4	Consultant B
P	Digital Lead	9	Consultant D
Q	Digital Project Manager	11	Consultant E
R	Architect	7	Consultant E
S	Digital Director	18	Consultant F
T	Facilities Manager	15	Consultant F
Stage 3 - digital twin & sustainable development goal interviews			
U	Chief Technology Officer	10	Consultant F
V	Facilities Manager	8	Consultant G
W	Digital Manager	15	Consultant H
X	Head of Sustainability	17	Consultant I
Y	Sustainability Director	12	Consultant J

SDG: Sustainable development goal.

The second research stage consisted of a further ten semi-structured interviews and investigated the use of DTs in the construction industry, their evolution, and barriers. Questions were asked such as "Can you discuss a situation where you have felt a DT would be of benefit?" and "What do you think are the current barriers to DTs in the construction industry?". Analysis of the interview data from both the first and second research stage then informed the development of the third research stage. This third stage consisted of a further five semi-structured interviews with current professionals whose professional role includes both sustainability and digital focused elements. Questions were asked such as "Have you witnessed any progress in digital technology that have aided sustainability?" and "Can you think of any policy that currently supports or hinders Digital Twin advancements?".

FINDINGS AND DISCUSSION

Through the extensive semi-structured interviews and analysis of the data this paper identified four major themes. These are the changing focus of the construction industry towards a sustainable focus, the interlinkage between the SDGs and carbon footprints, how greater DT technology use serves to reduce carbon footprints and increase SDG delivery success, and the need for both DT policy and procurement. These findings serve to underpin the substantial changes needed across industry to ensure long term

positive impact is achieved through the development and delivery of strategic change.

The changing focus of the construction industry

Despite the construction industry often described in the literature as one of the least sustainable[16], the interview results revealed a wealth of sustainability actions undertaken, with many quantifiable benefits experienced. Participant J stated:

"we've made some great progress over the last few years…fully electric fleet, introducing electric vehicles on site, paperless offices…and we recently hit our 100% recycle target".

Similar positive accomplishments were also echoed by participants B, E and N who represented different contractors, illustrating the positive achievements realised across the construction industry. Participant J went into more detail regarding their organisation's Net Zero target which was 2040 (already ten years ahead of the UK Government target) but stated the organisation was currently exceeding all interim targets and was on track to achieve Net Zero by 2035.

All those interviewed across all three research stages were aware of the Net Zero 2050 UK Government target, and all those organisations represented in the first research stage had their own Net Zero target in place. However, the findings did reveal that strategies to achieve Net Zero and the broader SDGs are more developed than the actions required for implementation. This finding aligns with research that suggests SDG strategies receive greater focus than the actual actions required to achieve the targets set[21]. However, this research develops existing literature further, by exploring the barriers and factors limiting the achievement of planned strategic actions. This is illustrated well by participants D, E and F, who have similar responses despite working for differing contractors, with participant E stating:

"We all see the strategies when they're launched, and there's an internal roll out to all staff, but we don't often get asked to do anything differently, and no one ever questions what we're doing on a daily or weekly basis on site…we just get asked to fill out records and logs…every few months".

Participant X offered an insight into this disconnect between strategic plans and operational delivery:

"I've participated in a few research projects previously, and the questions asked are always around strategy, no one then ever asks to speak to the site staff about how the strategies we [management] impose impacts them".

Whilst this may not be reflective of all studies as many do investigate SDGs from the operational perspectives, it does illustrate where a lot of the research focus is. Expanding on this Participant X stated:

"I am the most visible…with my profile and job…it'd be much harder for [a researcher] to reach out and find suitable site based staff to speak to".

This was echoed by Participant C, who confirmed:

"we're all really busy on site, it's go go go…and we have too many different initiatives, every day the toolbox talks have to mention one thing or another that isn't focused on safety…you can see eyes roll when we talk about sustainability, Net Zero, Social Value…the operatives just want to get on with their jobs".

Despite the operational challenges, and competing demands, it does appear the construction industry is embracing sustainability, and these strategic initiatives are starting to filter down to site based operatives. However, at present research is focused on the strategic delivery levels due to site based personnel being harder to reach and having a primary focus on traditional construction tasks. Nevertheless, initiatives aligned with SDG achievement are filtering through to construction projects, and the industry is arguably becoming more sustainable each day.

The interlinkage between carbon footprint and SDGs

Analysis of the results revealed that there are clear links between carbon footprint perceptions and the SDGs. For example, participant K highlighted the connectivity of innovation, sustainability, and data driven environments. Participant H expanded upon this by unpacking sustainability and the SDGs into their disparate areas of focus:

"Carbon offsetting was an early focus of ours. The SDGs sort of absorbed this…all under one heading".

This was also discussed by participant V who explained the links they specifically experienced between DTs and carbon:

"We have embraced Digital Twinning of all our assets. All are at different stages with different clients…it has helped us significantly reduce our carbon…through comprehensive scenario modelling"

Such findings contribute to those in the literature that link carbon footprint reduction to innovative technology use[28]. However, the findings also build upon studies that focus on highlighting the barriers to technology that prevent carbon footprint reduction[27] by revealing how innovative technology usage, in the form of DTs, can aid in the reduction of carbon footprints from building stock. This interlinkage, supported with Government focused policy will help drive the awareness and achievement of the concepts. For example, if reporting on DT and SDGs was mandated, it would enforce engagement across industries and allow for direct benchmarking and comparison of performance levels. It would also further illustrate and evidence the connection that exists between carbon footprint reduction and increased DT usage.

Collaboration and establishing a link between DTs and the SDGs

This research also established a clear link between DT's and the SDGs. This became apparent in the third research stage, with all five Participants confirming their respective organisations had invested in DT technology for a range of reasons, including sustainability, as highlighted by Participant W:

"The seamless integration of data interoperability across diverse systems enables sustainability to be achieved in complex data driven environments".

The example provided by Participant W was a DT of a real city and its population so the human behaviour impact could be modelled for a switch from cars to e-scooters.

Participant U offered another practical example of clear links between DTs and SDGs, and how the development of DTs is compelling behaviour change amongst often disparate stakeholder groups:

"We are currently developing DTs of our factory ecosystems…so the factories themselves can be replicated and installed all over the world, and all monitored in real time to ensure optimum performance and maximum sustainability, all from our UK head office…we can proactively replace parts and have them

shipped direct to the factory location before any emergency repairs are necessary because we can see the exact remaining lifespan of every part of the factory…it leads to minimal downtime".

The future potential of exploring greater links between DTs and the SDGs was also explored by Participant U who stated:

"There are significant opportunities to explore the integration of DTs and sustainable initiatives…heat from large data exchanges could be re-directed to provide heating for housing estates".

Participant U went on to discuss how the adoption of DT technology would allow simulations to evidence how an increase in stakeholder collaboration would lead to the realisation of sustainability benefits, and how the DT would allow real time performance mapping. This need for collaboration also echoes calls raised in the literature for more stakeholder collaboration in achieving broader industry targets[10-12].

Analysis of the findings indicates that adopting DT technology will support collaborative approaches, with the SDGs then more likely to be achieved. These findings build on the calls in the literature for more practical solutions to addressing the links between SDG and technology use[25]. This research find that with a government backed cohesive strategy underpinning a collaborative drive across DT adoption and SDGs action, mechanisms can be put in place to strengthen the cross-discipline collaboration. It is this collaboration that will drive forward DT adoption and enable the SDGs to be achieved, resulting in a reduction in global carbon footprints.

The need for both DT policy and procurement

The literature illustrates the evolution of procurement criteria from primarily a time, cost, and quality focus, to one embracing broader factors such as social value and sustainability based criterion[13]. Analysis of the interview results reinforces this as all interview participants confirmed that all public sector procurement requirements, and increasingly private sector procurement, have sustainability based questions as part of the tender requirements. When this was explored further, it was revealed that broader organisational sustainability practices were often the direct result of procurement requirements. This is illustrated by Participant X:

"We have an organisational wide tree planting policy as part of our sustainable identify…this was first proposed as part of a specific tender. We were successful…and the initiative stuck [after the tendered project had been completed] …and we still do it now".

Participant H also confirmed the positive impact procurement proposals often have on broader organisational strategy:

"A few years ago we tendered to get on a framework…we would have implemented the strategies eventually, but the framework forced us to move quickly…sensor lighting, our recycling policy…electric change points, we had to have these very specific inclusions in our strategy in order to get on the framework and we didn't have them before [we bid for the framework].

It was not simply the benefits of procurement criteria for driving change that became apparent in the interview analysis, but the mandating of policy and practices from a government level. Participant V believed:

"Since the BIM mandate, the level of information we receive to manage buildings has increased…it is still often sporadic and inconsistent, but it is definitely more substantive than previous, and this is across both public and private sector projects".

This aligned with findings in the literature that Government policy can drive market demand[51]. Interestingly, the results of this study built on these literature findings by exploring the barriers currently preventing wider DT adoption. Participant S summarised these quite well, which reflected the points made by numerous other participants:

"We currently have greater BIM and DT technology capacity than contractors want… we can offer so much more, but mostly where we really innovate…it's for internal use only…to showcase what we can do…we sell such basic products that customers call DTs but really they're not DTs at all".

This was further articulated by Participant U who stated:

"Our customers [both contractors and clients] want DT technology and capability because they will either gain a competitive edge in procurement] or because they are being forced".

The findings of this study agree with those in the literature that policy needs to be specifically focused on technology adoption incentives[51] and build on such findings by illustrating the real time benefits that can be achieved with a more DT focused national policy.

The project described by participant W of the city wide DT used to model transport changes was created directly to inform policy, so the advantages of the change could be established and communicated alongside the introduction of policy requirements. Adopting such an approach on a broader policy related scale could yield sustainable benefits. Just as literature confirms the UK Government BIM mandate of 2016 drove the adoption of BIM[43], and answering the calls for an evolution of the policy environment to help support SDG achievement[52]. Analysis of the interview results also reveals the need for both mandated policy and procurement in order to drive forward DT technology adoption and help achieve the SDGs. It appears only through forced change, such as a government mandated requirement or introduction of a procurement criterion, will contractors truly embrace collaborative DTs. It is only though the use of DTs that sustainability targets, such as the SDGs, can be achieved. Therefore, specific policy changes need to be implemented. Analysis of the research findings indicates the priority should be on a procurement based policy that requires DTs to be undertaken for all future projects, for both public and private sector assets. Procurement as a policy tool is key and serves to drive behaviour change across contractors. The Government could also introduce broader incentives such as green tax breaks for projects implementing DTs and financially support both public and private sector projects that embrace such technologies and approaches. Accompanying the introduction of DT focused procurement changes should be clear Government guidance on the links between SDGs, carbon reduction, and DTs. This will provide comfort and reassurance to those organisations and professionals seeking to utilise DTs to achieve sustainability targets, and help broaden education around the interlinkages and interdependences of DT and carbon reduction, serving to further the evolution and achievement of both.

CONCLUSION

The evolution of Digital Twin's has afforded the construction industry the opportunity to embrace a new technology that can aid in the support of achieving the Sustainable Development Goals. Despite the increasing focus on the interconnection of DTs and SDGs research, there remains a gap in existing

knowledge around the role procurement and policy guidance has on the use of DTs in the construction industry to help support the SDGs. The aim of this research is to ascertain which policy environments help and hinder DT adoption, and therefore in turn which serve to help or hinder SDG achievement. Through in depth interviews with twenty-five professionals that span the SDGs, DTs and the construction industry, the role of procurement and policy was explored. Analysis of the results revealed the construction is more sustainable than perhaps given credit for in existing literature. Collaboration is still not occurring at a wide enough scale. This lack of collaboration is hindering achievement of the SDGs. However, through the introduction of specific procurement requirements, and mandated policy around DT usage, positive change can be driven through the industry with regards to DT adoption. This will force collaboration and in turn help achieve the SDGs.

All participants were consistent in their views that Government backed policy is needed, yet all were reluctant to invest resources in DT or SDG initiatives without policy or procurement requirements in place. This research concluded that whilst policy would support the further development of DTs, and aid in the achievement of the SDGs, the lack of it is hindering development. This research recommends that formal Government policy is introduced mandating the need for DT adoption and inclusion of clear procurement criteria pertaining to DT usage. This can take the form of mandatory reporting, enforced procurement requirements, and tax based incentives for use. Adopting a variety of such methods can lead to greater collaboration across industry stakeholders, and increased use of DT which will in turn lead to greater SDG achievement and a global reduction in carbon footprints.

DECLARATIONS

Authors' contributions

Formal analysis, investigation, writing - original draft preparation and review and editing process: Watts, G.; Munir, M.; Underwood, J.; Hales, D.; Sadabad, M. M.; Balogun, T.; Coates, P.; Lim, L.

Availability of data and materials

All published studies are available from the referenced sources. Anonymised transcripts and summarises of the data collection are available from the corresponding author.

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

All ethical approvals were gained from the University of Salford (Panal Review Decision 1154). Prior to any interviews being undertaken. Informed consent was obtained from all participants.

Consent for publication

Not applicable.

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