SCENARIOS FOR THE DIGITALISATION OF THE CONSTRUCTION INDUSTRY

Anil Savio Kavuri[1], Robby Soetanto[2], Chris Goodier[3], Danny Murguia[4] and Mike Szczygiel[5]

[1,2,3 & 4] *School of Architecture, Building and Civil Engineering, Loughborough University, Leics, LE11 3TU, UK*

[5] *System Loco, Parkfield, Greaves Park, Greaves Road, Lancaster, LA1 4TZ, UK*

Digital technologies have the potential to help address some of the key challenges facing construction. Thinking and planning for the future, including unexpected events, is vital if the implementation of digital technologies is to realise their benefits. Four plausible future scenarios for an industry transformation enabled by digital technologies were developed using scenario-axes approach. The underpinning empirical work involved a review of literature, 20 semi-structured interviews and five focus groups/ workshops with industry practitioners. Qualitative data were analysed to identify emerging themes, which were subsequently conflated to determine the two main driving forces/ uncertainties underpinning the digitalisation in the industry: the extent of Innovation, Research and Development (IR&D), and the extent of integration/ collaboration. They were adopted as two axes to provide a framework to develop four plausible scenarios, named as 'bleak segregation', 'utopia transformation', 'lonely investment', and 'cheap combination'. Feedback from industry practitioners was generally supportive to the scenarios. The scenarios do not only describe how external factors impact on digitalisation, but they also raise many questions on what the industry stakeholders could do to influence the outcomes, particularly on those related to collaboration and investment. These will determine the pathways and the level of competitiveness of the industry, the companies and the individual stakeholders. Based on this, it could be argued that appropriate strategies and actions of the construction stakeholders themselves can, to a great extent, shape the future outcomes. Apart from the resulting scenarios, the research highlights the benefits which could be derived from the process of developing scenarios for the participants.

Keywords: digitalisation, future studies, Industry 4.0, scenarios

INTRODUCTION

The construction industry is faced with fundamental challenges of low labour productivity and low-profit margins (Turner and Townsend 2018, EY 2018). Globally, over the last 20 years, the growth of labour productivity in the construction industry has been only 1% compared to 2.8% in the wider world economy (McKinsey and Company 2017). Furthermore, profit margins are the lowest of all sectors apart from retail (EY 2018). These issues have hampered project performance and quality of the built environment, resulting in high profile and very public cases, such as Cross

[1] a.s.kavuri@lboro.ac.uk

Kavuri, A S, Soetanto, R, Goodier, C, Murguia, D and Szczygiel, M (2020) Scenarios for the Digitalisation of the Construction Industry *In:* Scott, L and Neilson, C J (Eds) *Proceedings of the 36th Annual ARCOM Conference,* 7-8 September 2020, UK, Association of Researchers in Construction Management, 425-434

Rail and Grenfell Tower in the UK. In order to address these considerable and persistent problems, there is a need for radical solutions to transform the production and delivery process in the construction industry. Digital technology, the move to Industry 4.0 and related business model innovations offer an opportunity for radical transformation. The UK Government attempted to facilitate a transformation of the construction industry through the launched of Industry Strategy Challenge Fund (UKRI 2016), with an inspiration of faster and cheaper construction, and reduced carbon emissions. Specifically, the Transforming Construction Challenge (TCC) initiative promotes exploration and development of digital manufacturing in construction, amongst other initiatives. Given the many previous initiatives and current impetus for change in the digitalisation of construction, it is critical that possible pathways to move from the current state to transformed futures are explored, determined and examined, so that appropriate strategies can be devised.

There are several recognised approaches to formulate and examine possible pathways to the future. There are three reasons for selecting scenario planning approach. Firstly, by nature, the future is very uncertain. Schoemaker (1995) argues that scenario planning is one the most effective tools to deal with uncertain events and to plan for 'a range of possibilities in rich detail'. Secondly, it can reduce errors in the analysis, in particular the treatment of exogenous and endogenous variables. Chermack (2004) highlights that scenario planning can mitigate this problem, but also address many other decision errors including the ingrained mental models. Thirdly, the end goal is to ensure appropriate strategies can be developed. Schoemaker **1(**995) and van Notten *et al.,* (2003) argues that scenario planning is very useful for strategy development at the national, firm and even project level. Scenario planning has also been applied in the construction industry (Goodier *et al.,* 2010). Although with a long history, there are limitations of previous applications of scenario planning. For instance, Harty *et al.,* (2007) critically examined 13 construction-related futures scenario studies and concluded that these studies did not provide anything substantially different than studies related to the present due to a lack of attention to uncertainties and the failure to connect the present and the futures. Given the general low take-up of innovation in construction (Gruneberg and Francis 2019), and uncertainties posed by the adoption of digital technology, scenario planning could be applied to enhance understanding of the required changes for a more digitalised industry (Lavikka *et al.,* 2018), and to develop appropriate strategies in a more proactive and holistic manner. The strategies should address all elements in the eco-system, hence promoting a radical change in the production and resultant quality of the built environment.

DIGITALISATION OF THE CONSTRUCTION INDUSTRY

Digitalisation is the use of digital technologies, particularly technologies that use digital data, to generate insights into new business models and processes such as supply chain management, e-governance, smart transport, etc. (Boulton and Lamb 2019). The UK's Centre for Digital Built Britain (CDBB) proposes a data-centred digital landscape for the construction sector. Data-driven decision making is thought to bring efficiencies in design, construction, operation, and integration of the built environment with the services they deliver. A well-managed digitalisation of the construction industry could improve building performance, reduce impact on the environment, and deliver better public and social services (Neely *et al.,* 2019). Building information modelling (BIM) is a key driver and enabler of the digitalisation of the sector. However, there are other technologies that have a role in further

digitalisation of the sector, such as the Internet of Things (IoT), big data analytics, and machine learning. Neely *et al.,* (2019) argued that more research is needed to exploit the role of digitalisation in improving the design and development of services that are linked with assets and the interplay of costs and returns. Business models research addresses the ways in which investments could be integrated to develop new design and construction services in the built environment. Despite this potential, the 'environment' in which this digitalisation (and its new business models) could be nurtured and stimulated needs to be identified and understood; future scenarios are one way of doing this. These scenarios provide critical links between digitalisation and socio-economic, structural and cultural context of construction; thus, allowing grounded and realistic (adoption) strategies to be developed.

Scenario Building Approach

There is a general lack of consensus on the most appropriate approach to scenario building. Instead, literature suggests several techniques and methodologies for generating scenarios with common characteristics (Amer *et al.,* 2013). Scenario-axes is a common approach to structure thinking and discussion about future scenarios and recommended as a useful tool to construct images of the future in a coherent and systematic manner (van 't Klooster and van Asselt 2016). It has been used in a number of studies (e.g. Arup 2019). In this research, the approach was adopted because it allowed development of explorative scenarios to respond to what can happen to the development of external factors (which are beyond the control of the users/ actors) and how strategies (and other internal factors) could be devised/ considered by the users to cope with the issue(s) at stake (Börjeson *et al.,* 2006). The approach identifies the two most important driving forces/ uncertainties that could have a decisive impact on the digitalisation (adoption of digital technologies) in the construction industry, applies them as axes, and then generates scenarios that represent combinations of extreme, but plausible situations from the axes (van 't Klooster and van Asselt 2016). There are competing approaches to determine the axes, but the most common approach is to identify the two most important uncertainties (ibid.). Plotted on a Cartesian graph, there are four plausible scenarios with each scenario representing one quadrant. Based on an extensive review of literature, Amer *et al.,* (2013) suggest that three to five scenarios are considered appropriate by most researchers. Further, the number of scenarios (four) produced in the research here was considered optimum to aid the practical administration of the scenario building process and the communication of the results to industry practitioners. Less scenarios begin to limit variety, and more become difficult to communicate. To identify the two axes, a series of semi-structured interviews and focus groups/ workshops were conducted to identify the two axes (Börjeson *et al.,* 2006) and generate the scenarios, explained in the following section.

METHODS

The research adopted qualitative research methods. Data were collected through 20 semi-structured interviews and five focus groups/ workshops with both construction and non-construction stakeholders. The interviewees were from a range of disciplines (e.g. engineering, IT, economic) and roles (CEO, management, technical, sales). Two key questions for the interviews are: (i) What do you think are the key (social, environmental, political, legal, economic, technological) factors that could impact the future adoption of the digital technologies in construction? (ii) What are the barriers that might limit the adoption of these digital technologies? The questions were meant

to initiate discussion and generate ideas, with follow-on questions to prompt and pursue any interesting ideas and clarify the discussion. The aim was to identify uncertainties, trends and barriers to the adoption of digital technologies (Lavikka *et al.,* 2018). Each interview lasted for about 30 minutes. All interviews were conducted face to face, in-person, and the majority being audio recorded and then transcribed (few were not willing to be recorded, but responses were note-taken).

Five focus groups and workshops were conducted to populate the content/narrative of the scenarios, refine and validate the scenarios. Table 1 describes the main expertise of participants, the number of participants, and the objective. The focus groups/ workshops represented a progression of the research to substantiate the findings from the interviews. One focus group/ workshop was informed by the previous and inform the subsequent focus group/ workshop. The main difference between focus group and workshop was the number of participants and their grouping. Focus groups were attended by fewer participants who were engaged in a single group discussion, whilst workshops were attended by more participants who were divided into groups of 4 or 5 participants (except the online workshop where participation was facilitated interactively). In the last two workshops, feedback on the scenarios were sought and presented in this paper.

Table 1: Focus groups/ workshops (in chronological order), main expertise, number of participants, and objective

Focus group/ Workshop	Main expertise	Number of participants	Objective
Workshop 1	Project management from construction and non-construction, digital technologies, AI	22	To identify emerging themes and narrative for input to scenario development
Focus group 1	Digital technologies across different industries	3	To identify emerging themes and narrative for input to scenario development
Focus group 2	Housebuilding, manufacturing, project management, digital technologies, AI, robotics	5	To identify emerging themes and narrative for input to scenario development
Workshop 2	Construction	23	To generate feedback and response strategies on the scenarios
Workshop 3 (online)	Construction, digital technologies	18	To generate feedback and response strategies on the scenarios

RESULTS

The uncertainties, trends and barriers to digital technology adoption were classified into emerging themes. Figure 1 shows the arbitrary grouping of the emerging themes into driving forces, barriers, policies, and business models. The next step was to conflate these themes into two intersecting axes. The emerging themes were subsequently grouped into two key uncertainties, ‘integration/ collaboration’ and ‘innovation, research and development’ (IR&D), as depicted in Figure 2. The inclusion of the themes in the two groups was determined based on evidence obtained from the interviews that suggested association with the group in which the themes belonged. To determine the appropriate axes, our approach was to uncover connections between themes and determine what axes would best represent them. We undertook a thematic categorisation to identify key themes which represented the data. The analysis then involved compiling numerous potential names of the axes and

analysing whether they were appropriate to capture the themes identified. The themes were then mapped into four different quadrants (shown in Figure 3). Every theme was used in at least one of our four scenarios. The themes are the explicit link between the findings in the interview data and the scenarios and the axes. Most emerging themes were best represented and related inclusively to one uncertainty.

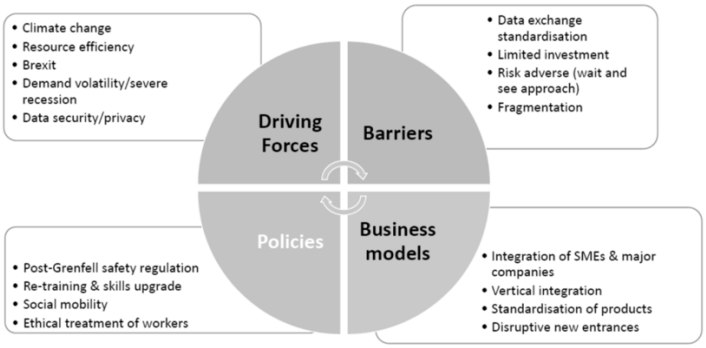

Figure 1: Emerging themes from the interviews

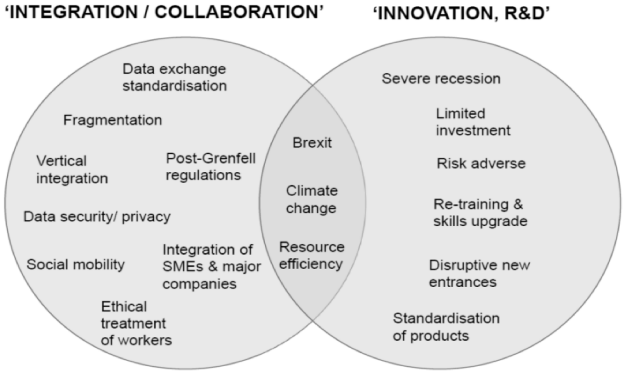

Figure 2: Grouping of emerging themes into two key uncertainties

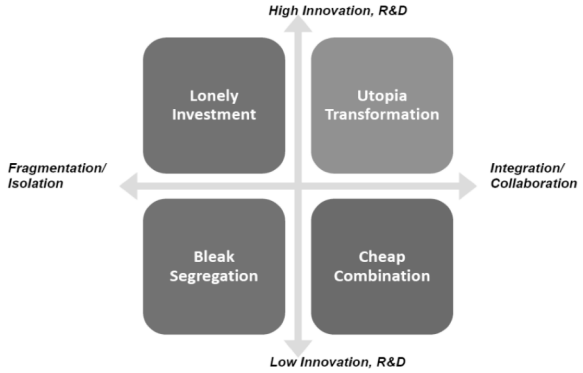

Figure 3: Four scenarios based on two key uncertainties

Several key themes, including 'Brexit', 'climate change', 'resource efficiency' were considered to fall into both groups. For example, poor trading deals with Europe resulting from 'Brexit' hits profit margins and hence impacts upon IR&D. In addition, Brexit impacts the extent (and nature) of collaboration with Europe and elsewhere.

The scenarios were named to reflect the content, 'bleak segregation', 'utopia transformation', 'lonely investment', 'cheap combination' (Figure 3). Each scenario's narrative was then developed from the data. Due to space constraint, the full narrative

is not included in this paper. Instead, a summary of each scenario with its dominant drivers and outcomes is presented in Table 2.

Dominant drivers include 'self-interest/ isolationism', 'global concern', 'investment', and 'corporate movement', which represent synthesis of the scenario narrative. In the 'outcomes' row, we can see how the scenarios produce different outcomes.

Table 2: Four scenarios with their dominant drivers and outcomes

Dominant drivers	Scenarios			
	'Bleak Segregation'	'Utopia Transformation'	'Lonely Investment'	'Cheap Combination'
Self-interest/ Isolationism	Increased insolation, started by Trump's foreign policies. No deal Brexit restricts labour movement.		Self-preservation drives competition at corporate level.	
Global concerns	Trade war leads to collapse of housing market and global recession.	Australian bushfires trigger climate change rallies; increasing environmental concern.		Coronavirus provides impetus for collaboration. Coronavirus leads to recession.
Investment		Synergy between private 'bottom-up' investments (including merger & acquisition, such as Google, Goldman Sachs) and public 'top-down' investments (such as ISCF, Innovate UK).	China and India invest heavily in R&D and become hubs for the development of new digital technology. 'Top-down' UK government interventions and investments and subsidies, but lack 'bottom-up' initiatives from private sectors.	Stagnant IR&D investment due to global recession. General reluctance to invest in IR&D (particularly by private sector), investments are driven to obtain competitive advantage in the open market.
Corporate movement	Large firms maintain status quo to dominate small firms.	Increased collaboration between construction and technology (such as Google); disruptive new entrants.	Lack collaboration at corporate level.	SMEs suffer from recession, and are taken over by big players.
Outcomes	Limited investment in innovation, R&D; increase fragmentation and distrust.	Open source technologies/ communities, and Industry 4.0 revolution. Combined 'top-down' interventions and 'bottom-up' efforts, yield optimum outcomes (i.e. competitive construction industry, able to compete in international market).	Large government investment in IR&D does not really match 'isolated' investments by private sectors (mainly major companies, such as Google, Goldman Sachs), hence creating 'hot spot' success stories of best practice. Wide-spread take-up of innovative approaches is still a way to go.	Industry becomes more integrated. Investments are to obtain competitive advantage, with little regard to common good and sustainability for the majority of public.

PRACTITIONER FEEDBACK ON THE SCENARIOS

Feedback on the scenarios from industry practitioners was ascertained in the last two workshops (see Table 1), across three questions, as follows.

Question 1: Do the scenarios make sense to you? Are they logical and plausible?

Workshop participants were generally in agreement that the scenarios presented to them make sense and were logical and plausible. One participant mentioned that the scenarios would likely to be very different post-Coronavirus pandemic. This pandemic could be considered a 'wildcard' in the development scenario. The impacts may be long-lasting in most aspects of life but are difficult to predict with a high degree of certainty. One feedback considered that three scenarios are sufficient with two extremes, i.e., 'bleak segregation' and 'utopia transformation', and 'cheap combination' in the middle, driven by difficult economic circumstance in the post-pandemic context. Another participant mentioned that 'lack of internal investment due to poor profitability' gives support to scenarios with low IR&D (i.e. 'bleak segregation' and 'cheap combination').

Question 2: What are other potential dominant drivers that need to be considered?

One participant drew attention to the 'bigger picture' in relation to 'circular economy thinking' and 'doughnut economics'. The latter highlights the need to bring social and environmental considerations in pursuing economic efficiency imperative in construction. The issue of 'leadership' was also coined as a potential dominant driver. This is related to investment, highlighting 'Government capacity for investment' and 'the willingness to share between companies and governments'. Investment was considered a dominant driver in Table 2. It could be most effective when there is a synergy between 'top-down' government and 'bottom-up' private sector initiatives. A couple of participants highlighted the need for thinking new business models, based on data centric works on standardised platforms, and the potential of Artificial Intelligent (AI) and robots taking over the workforce in digitalised construction. The

issue of 'availability, adoption and acceptance of new technology e.g., drones and data analytics' were also proposed.

Question 3: What changes of current practices and strategies are needed in order to respond to the scenarios?

Some participants considered re-orientation of current business model from short-term outputs to solutions that bring long-term benefits and values for the customers and wider society. Few issues came up within this new business model, including the provision of rewards, supply chain practices and strategies, risk allocation and collaboration, contractual, intellectual property and insurance issues that inhibit digital collaboration. One participant suggested the need for more collaboration, open source working and trust, with more active benchmarking. Another participant highlighted the need for an improved climate/ carbon literacy, and to consider nature and complexity of supply chains in the new strategies. The need to adopt strategies that look at other industries outside the construction industry, e.g., automotive industry, was also suggested.

Specific feedback on each scenario

Participants also gave specific feedback on each scenario. One group argued that rather than having firms become less efficient in 'Bleak Segregation', firms and people may create innovative ways to work more efficiently. The group also suggested that, during difficult business environment, firms have always found IR&D investments in the core of their business (e.g. labour and energy efficiency).

One group argued that 'Utopian transformation' should be viewed on a moving timescale with continuous revision of the target. This scenario is the ideal for nurturing 'circular economy' and 'doughnut economic thinking'.

A criticism of 'Lonely investment' was distinguishing between geographic fragmentation and sector-specific fragmentation. The participants argued that, in the industry, fragmentation refers to the lack of continuity between asset owner, designer and builder in the procurement method, not to geographic fragmentation. This group also mentioned that fragmentation could lead to builders using the best technologies to build at the lowest cost. The group pointed out that the scenarios should consider the data exchange problem. They argue that firms are reluctant to share information to avoid other companies taking advantage of their knowledge.

Regarding, 'Cheap combination' a group pointed out that limited investment would challenge the achievement of TCC target via digital manufacturing. Nonetheless, the new global compassion to collaborate may bring new opportunities for targeted global cooperation to tackle global challenges.

DISCUSSION

The scenarios have been developed to portray plausible future environments which may have implications for the development and take up of digital innovations, business models and corporate strategies within the construction industry. They are also aligned with TCC agenda, particularly contribution to faster and cheaper construction, and importantly facilitating digital manufacturing in construction.

The scenarios presented reflect different environments in which companies and sectors of the industry could respond to facilitate adoption and implementation of digital technologies. If 'utopia transformation' represents an ideal scenario for successful implementation, then it would be logical if strategies should be devised to

shift the other three scenarios closer to 'utopia transformation'. The strategies/ actions for this beneficial shifting could be explored through several key differences between the scenarios, explained as follows. Considering dominant driver 'investment' in Table 2, in the 'utopia transformation', there is a synergy between public and private investments, whereas in the 'lonely investment', the investment is predominantly public, with little private sector contribution. This suggests that shifting from 'lonely investment' to 'utopia transformation' would require a more significant level of investment/ effort from the private sector. It is important to encourage private investment in IR&D, which is historically low in the current (contracting) business model (Gruneberg and Francis 2019). In the 'lonely investment' in contrast to 'utopian transformation, we foresee little collaboration. Nonetheless, we foresee UK unilateral policies driving digitalisation in the UK and in the construction sector. These policies can include (i) environmental standards, (ii) regulations to ensure safety, transparency, quality and accountability, and (iii) IR&D subsidies.

Considering dominant drivers of 'corporate movement' and 'outcomes' in Table 2, in 'utopia transformation', integration means collaborations amongst construction and other disciplines (which are external to construction, such as technology and investment companies), whereas in 'cheap combination', integration occurs internally within the construction industry to obtain competitive advantage with little regard to a wider public common good and sustainability. This suggests that 'utopia transformation' requires a shift in modus operandi that encourages more multi-disciplinary working, open innovation, and cross-sector participation. Digitalisation also means that we should consider training existing workforce with digital skills, and employing staff with different skill sets, such as data analytic skills. The industry would also need to be open to inputs from the manufacturing and digital sectors. Construction industry stakeholders should not feel threatened by investment made by other sectors, such as IT companies and investment banks, and instead, learn and adopt these innovations. Disruptive new entrants such as Google, leads to a significant amount of digitalisation in the sector. In the 'cheap combination', the Coronavirus pandemic leads to collaboration between WHO workers, global experts, governments and partners to rapidly expand scientific knowledge to protect health and prevent the spread of the virus. However, despite increased collaboration, recession leads to little money available for digitalisation. Consequently, there is a lack of technology adoption in the construction sector.

Despite a preference towards ideal scenario of 'utopia transformation', the other three scenarios have their own merit in bringing or providing environment for digitalisation. For example, 'bleak segregation' scenario may be the key to uncovering business opportunities and becoming more efficient out of necessity. We found in the focus groups/workshops that our scenarios provoked optimistic insights and imagination. The participants were optimistic with relative consensus regardless of the scenario. We also discovered imaginative/ creative ideas from the discussions including the development of modular building for electric vehicle parking that actively generates its own energy for battery charging in the discussion on 'utopia transformation'.

Feedback from the participants was generally supportive towards the scenarios. Participants of the workshop emphasised the need to depart from the current (contracting) business models to more long-term solutions that bring wider benefits and values to customers and society. To facilitate this, construction stakeholders should consider the provision of reward systems, active benchmarking, allocation of risk, contractual, intellectual property and insurance issues. The strategies should also

consider complexity of the currently fragmented supply chain. It is imperative that successful digitalisation for industry transformation would require radical change in the structure and culture of the industry to provide fertile ground for new business models to flourish. Here, the essential role of leadership and collaboration cannot be overemphasised.

CONCLUSION

Based on interviews and focus groups/workshops with industry practitioners, four scenarios for digitalisation of construction have been developed using scenario axes approach. Not only the scenarios describe how external factors provide environment for and impact on digitalisation, but they also raise many questions on what the industry stakeholders could do to influence the outcomes, particularly on important issues in relation to collaboration and investment. These factors are within the control of stakeholders, and to a large extent, will determine the pathways and the level of competitiveness of the industry, the companies and the individual stakeholders, derived from digitalisation. Based on this premise and the absence of ideal 'utopia transformation' scenario, appropriate strategies and actions of the construction stakeholders themselves can, to a great extent, shape the future outcomes. For instance, 'bleak segregation' scenario could lead to firms collaborating, investing in digital technology and becoming more efficient in order to survive. Alternatively, it could lead to firms being too apprehensive about the future and limiting investment.

The research has a few limitations. More data from wider participants may bring nuances to the scenario. However, careful analysis was undertaken to ensure that the scenarios reflect the opinions of the participants. Towards the end of the research, the Coronavirus pandemic struck, and the last workshop was organised via online mode. Participation during the workshop may have been impacted, but arguably, the online mode may also bring benefits, particularly, in terms of ability to solicit succinct and 'to-the-point' responses. Although the Coronavirus has been incorporated in the scenarios, its impacts on the industry are likely to be wider and more significant than what was originally thought. There are considerable uncertainties on this.

During the progressive development of the scenarios, the engagement with participants has provoked questions, stimulate discussions and debate on topics related to digitalisation. This is useful to identify and enhance understanding of problems and knowledge gaps in the journey of transforming construction. Apart from the resulting scenarios, the research highlights the benefits which could be derived from the process of developing scenarios for the participants (Soetanto *et al.,* 2011).

ACKNOWLEDGEMENT

Digital Enablers for CONstruction Transformation (DECONT) project was funded via the Transforming Construction Network Plus. The Transforming Construction Network Plus is funded by UK Research and Innovation (UKRI), an investment supported by the Industrial Strategy Challenge Fund (ISCF). The authors wish to thank for this funding, support provided by N+ team, support at the early research stage of the project provided by Rinicom Ltd., System Loco Ltd., Innovare Systems Ltd., Innovative Manufacturing and Construction Solutions, and to all participants of the workshops, focus groups discussion and interviews.

REFERENCES

Amer, M, Daim, T U and Jetter, A (2013) A review of scenario planning, *Futures*, **46**, 23-40.

Arup (2019) 2050 Scenarios, London: Arup.

Börjeson, L, Höjer, M, Dreborg, K H, Ekvall, T and Finnveden, G (2006) Scenario types and techniques: Towards a user's guide, *Futures*, **38**(7), 723-739.

Boulton, C and Lamb, K (2019) *Capability Framework and Research Agenda for Digital Built Britain*, Cambridge: Centre for Digital Built Britain

Chermack, T J (2004) Improving decision-making with scenario planning, *Futures*, **36**(3), 295-309.

EY (2018) *How Can Technology Improve Challenges Faced Within the E&C Industry?* London: Ernst & Young LLP

Goodier, C I, Austin, S A, Soetanto, R and Dainty, A R J (2010) Causal mapping and scenario building with multiple organisations, *Futures*, **42**(3), 219-229.

Gruneberg S and Francis, N (2019) *The Economics of Construction*, Newcastle upon Tyne: Agenda Publishing Limited.

Harty, C F, Goodier, C I, Soetanto, R, Austin, S A, Dainty, A R J, Price, A D F (2007) The futures of construction: A critical review of construction futures studies, *Construction Management and Economics*, **25**(5), 477-493.

Lavikka, R, Kallio, J, Casey, T and Airaksinen, M (2018) Digital disruption of the AEC industry: Technology-oriented scenarios for possible future development paths, *Construction Management and Economics*, **36**(11), 635-650.

McKinsey and Company (2017) *Reinventing Construction: A Route to Higher Productivity*, McKinsey and Company, Available from https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution# [Accessed 18 June].

Neely, A, Schooling, J, Boulton, C and Lamb, K (2019) *Developing the Capabilities for a Digital Built Britain: Technical Report*, Cambridge: Centre for Digital Built Britain.

Schoemaker, P J H (1995) Scenario planning: A tool for strategic thinking, *MIT Sloan Management Review*, **36**(2), 25-40.

Soetanto, R, Dainty, A R J, Goodier, C I, Austin, S A (2011) Unravelling the complexity of collective mental models: A method for developing and analysing scenarios in multi-organisational contexts, *Futures*, **43**, 890-907.

Turner and Townsend (2018) *International Construction Market Survey 2018*, Turner and Townsend, 108.

UKRI (2016) *Industrial Strategy Challenge Fund*, Swindon, UK: UK Research and Innovation.

van 't Klooster, S A and van Asselt, M B A (2006) Practising the scenario-axes technique, *Futures*, **38**(1), 15-30.

van Notten, P W F, Rotmans, J, van Asselt, M B A and Rothman, D S (2003) An updated scenario typology, *Futures*, **35**(5), 423-443.