Speculation beyond technology: building scenarios through storytelling

BUILDINGS & CITIES

Speculation beyond technology: building scenarios through storytelling

SPECIAL COLLECTION: MODERN METHODS OF CONSTRUCTION: BEYOND PRODUCTIVITY IMPROVEMENT

RESEARCH

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ABSTRACT

'Modern methods of construction' is a term largely synonymous with the prefabrication of product components in factories. Emerging technologies, *e.g.* robotics and artificial intelligence (AI), are redefining the concept of modern methods of construction and destabilising the structure of the sector to meet the conditions of their implementation. Robotics and machine-based automation, for example, are expected to transform construction manufacturing techniques in rapid and significant ways, but the extent of change and the associated impacts on organisations, supply chains and business models that constitute the sector remains unknown. Existing foresight is dominated by trajectorial perspectives that overemphasise technological predictions and underemphasise the contextual stories of implementation most helpful in understanding technology adoption. An alternative approach presented here focuses on storytelling, the design of the scenarios and the visual images used to help convey these scenarios. These allow practitioners to explore how robotics and machine-based automation may play out in different characterisations of the industry. The research involved the analysis of an existing dataset to create four scenarios, before adapting and extending these scenarios through participatory workshops and interviews. Project participants were comprised of seven small and medium-sized enterprises (SMEs) in manufacturing and architectural fabrication, one tier 1 contractor, and two acclaimed industry experts from an industry advisory board and education centre.

PRACTICE RELEVANCE

Robotics and machine-based automation are expected to transform the construction sector in rapid and significant ways, but the extent of change and associated impacts on organisations, supply chains and business models remains unknown. An alternative approach to foresight is presented that uses scenario creation to understand the

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implications of robotics and automation. The implications of robotics and automation are explored at the project, firm and industry levels. This will assist decision-makers to responsibly turn technological promise into substantive change. Four future scenarios of a construction industry where manufacturing robotics are business as usual are described. As an often-overlooked stakeholder, SMEs were at the centre of the scenario development process. Each scenario has a dominant player at the centre: tier 1 contractors, SME cooperatives, software vendors and original equipment manufacturers, and government. These scenarios illustrate the potential implications and non-technological innovations to resolve them (*e.g.* business model modification, development opportunities and contractual relationships), co-constructed with construction professionals.

1. INTRODUCTION

The construction sector would seem to be in an interregnum. Looking at industry commentary, it would seem the old ways of doing things the sector has deployed thus far are no longer effective, as implied by the continual discourse of change and steady introduction of new technologies. Under the umbrella of Construction 4.0, artificial intelligence (AI), big data, the Internet of Things, robotics and automation are on the horizon, making a clear statement that the sector's working practices are outmoded (for technology-centred reform focused reports, see Farmer 2016; and WEF 2016). However, new ways of working are still yet to be fully defined, much less an understanding of the specific cultural, societal and organisational impacts these technologies will have (*e.g.* Bademosi & Issa 2021; Dowsett *et al.* 2018; Dowsett *et al.* 2017; Sherratt *et al.* 2020; Garcia de Soto *et al.* 2019). What the impacts are and, more specifically, can they be better understood through better storytelling in construction foresight are the principal research questions this study seeks to answer.

The technological context of this paper is robotics and automation, a panacea promising to transform the construction industry through improvements in productivity, efficiency and safety (Gammon 2017; Bogue 2018). According to Frey & Osborne (2017), over the next 20 years around 50% of construction work could be automated using new and emerging technologies to support advancing automation. But whilst there is promise, there is also a tendency to focus innovation efforts at the scale of the tier 1 contractor and on technology development alone (*e.g.* onsite robotics, and flexible and offsite modular manufacturing). If robotics and automation are to transform the industry, then consideration needs to be given to the multiple and intersecting levels of impact these technologies will have. Industry understanding of these impacts could be expanded by focusing foresight activities further along the supply chain and downgrading the primacy of technology. Therefore, the focus here is on impacts at the scale of the small and medium-sized enterprise (SME), and on associated non-technological developments (*e.g.* supply chain configurations, trading relationships and business models). The focus on SMEs is justified because they constitute over 90% of construction businesses and are already reliant on mechanisation to provide specialist work, providing a seemingly 'low-hanging fruit' for automation and a greater catalyst for sectoral transformation. The focus is on non-technological innovation to pay specific attention to the challenges of contemporary construction processes and how they prevent SMEs from adopting robotics. Challenges include the lack of flexibility and standardised components, and fragmented supply chains (Goulding *et al.* 2015).

Thinking about the different ways that the construction sector and its processes could be reconfigured—with manufacturing robotics as a mainstay—might provide some insight into the characteristics of the industry that need to be reconsidered (and, in some instances, perhaps radically) to enable uptake. A foresight approach designed to provoke creative solutions to understand the impacts and characteristics of potential futures—and the interconnectivities between them—is important in turning technological promise into substantive sectoral change.

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The remainder of the paper is structured as follows. First, the implications of construction foresight are considered together with the role of agenda-setting in shaping how the future is organised. This is to position the adopted approach rather more broadly than the trajectorial technological predictions which usually prevail. Next, storytelling is explained as a key characteristic of this foresight approach and the use of visual images as a key mechanism with which to evoke creative and imaginative plotlines/narratives of radically transformed futures. The methods are then described for how the scenarios were co-constructed with the participants. The scenarios are presented and discussed in relation to how each story and associated visual images used to tell each story stimulated conversation and debate. Finally, the significance and implications of the study are discussed.

2. FORESIGHT AND INNOVATION IN CONSTRUCTION

The argument that overly rationalised, technology-dominated calls for change or visions of the future have tended to have little purchase on the sector is not new. Neither are explorations of the particular and contextualised ways change plays out in the sector. There is a long-standing body of work in the construction management field which more critically examines the ways in which externally imposed visions and interventions—policy diktats and directives, the emergence of new (and often integrative) technologies, advocating systems and practices from non-construction sectors—are examined, interpreted and mobilised in construction organisations.

For example, in examining partnering and alliancing—a three-decade-old panacea for the industry—Bresnen & Marshall (2000) point towards its overreliance on assumptions of shared attitudes, cultures and economic aims which do not reflect the multiple, contrasting and intersecting perspectives of construction sector organisations. Pluralism and customisation, sensitive to 'local conditions', is argued to be a more likely route to some form of success. When analysing the diffusion of management ideas from outside the sector, Bresnen & Marshall (2002) again emphasise the inherently socialised and politicised nature of implementing and diffusing new ideas and techniques, regardless of how rationally the argument for them is made. They also argue that the allure of new management approaches is related to the construction of management identity; that they serve to define and legitimise particular management roles and hence can be mobilised for or against particular interests.

Where innovation may have found some purchase, the impacts are often somewhat different from the rhetoric which extols their benefits. The lauded shift from delivering products to longer term, through life-service provision, perhaps most noticeably via public finance initiative/public–private partnership (PFI/PPP) arrangements in the early 2000s, arguably led to a secondary market for operation and maintenance contracts rather than the creation of integration between building and operation (Leiringer 2006). Going further, Leiringer *et al.* (2009) ascribe the whole rationale for through-life value and integration to the strategic outsourcing of asset management by construction client organisations creating a gap for construction firms to opportunistically fill with specialist units, without impacting pre-existing operations. The rhetoric of the value agenda becomes a sense-making device, skilfully used by practitioners to legitimise responsive reactions to changing and messy contexts.

These studies point to much more complex and manifold interactions around technological and process change. New initiatives might fail to find purchase within the messiness of practice, be deployed as rhetorical justifications against particular interests, or lead to unforeseen and even counter-intuitive outcomes. Hence, it could be said that innovation in construction is complex and unbounded (Harty 2005), and exploiting innovation opportunities requires careful consideration of those multiple contexts, particularly how actors and objects—mutually constituted in sociotechnical networks—reconfigure with the uptake of new technological developments (Schweber & Harty 2010).

Turning the focus to foresight, discourses of the future in construction tend to neglect this ongoing and uncertain reconfiguration of sociotechnical networks needed to take up new technologies (Chan & Cooper 2010). For example, prescriptive agendas (*e.g.* Farmer 2016) and foresight reports

(*e.g.* Bartlett *et al.* 2020) are often highly influential in catalysing industry adoption of technologies, but only provide a partial and often overly optimistic view of the future (Chan & Cooper 2010).

In addition, Chan & Cooper (2010: 3) point to how discourses of the future represent particular interests, often dominated by committees of government, industry and academic elites often disconnected from those 'operating at the coalface of operational realities in construction'. They are further seen to overemphasise the unitary aspects of technology and underemphasise social considerations. Foresight and prescriptive agendas in the industry appears to be more about setting expectations for technology adoption that should be adhered to than it is about exploring opportunities and aspirations.

For Brown & Michael (2003: 4), however, the future is not a 'neutral temporal space into which objective expectations can be projected'. Perhaps more importantly, thinking about futures is also important in constituting them. Images of the future are inevitably value-laden and reflect the values of those who are often in a position of power to set them, and to gain competitive advantage by being the first to 'colonize the future' (Selkirk *et al.* 2018: 3). Hence, ideas about the future are constituted by values that can guide and exclude particular understandings of the present.

The value-laden nature of foresight, and the implications of this on future-making activities, is increasingly acknowledged by scholars adopting a materialist understanding of the future. Here, the future is not just imaginary: it has a 'real' or material existence (Adam & Groves 2007; Jasanoff 2015; Tutton 2017). Adam & Groves (2007), for instance, discuss how latent characteristics of the future at some point become 'actual forms' materially and discursively enacted within the present. Visions of the future are therefore not just representations, they are performative. Prospective stories of how the world might change appeal to the interests of necessary actors and groups (investors, regulatory actors, users, *etc.*) and broker relationships between them (Borup *et al.* 2006). Through these practices, material and institutional orders associated with technologies emerge (such as prescriptive agendas, pilot projects, innovation networks, *etc.*) and let 'loose both intended and unintended consequences' (Tutton 2017: 488). With these conceptualisations in mind, foresight in construction becomes more than just sterile speculation or abstracted idealised guesswork; it has structuring effects that set out the conditions and practices of the present. And since images (or scenarios) of the future have the capacity to initiate sociotechnical change, developing effective scenarios becomes a key consideration for transformative construction foresight.

Accordingly, this paper adopts the position that foresight in construction could benefit from scenario-building through the emergence of complex stories of technology implementation from those at the operational level. In doing so, it sets aside technological prediction and prescriptive agenda-setting to speculate about the sociotechnical implications of different futures. The reason for doing so is to better contextualise the future of construction and broaden the opportunities for change, improve decision-making around technology implementation, and reduce the uncertainty surrounding unintended consequences. This positioning, however, inevitably raises the question of what such an approach looks like. The following section discusses the role of storytelling, touching on the use of visual images—objects, images and narratives—as an important mechanism through which to make sense of future possibilities and allow the complex stories of technology implementation that are missing in normative foresight approaches to emerge.

3. STORYTELLING IN SCENARIO PLANNING

Stories are an innate and powerful means through which humans communicate and cooperate, and are 'the preferred sensemaking currency of human relationships' (Boje 1991: 106). Gabriel (1991: 857) defines stories as:

> narratives through which events, at times major, at others trivial, become charged with symbolic significance.

With special attention paid to character and plot, stories can shape the social relationships and contexts in which they are told. It is this aspect of stories that make them a critical characteristic of scenario planning.

Scenarios inherently involve stories about how the future may unfold (van der Heijden 2005). As imagined events in the future with multiple narratives constructed around them, scenarios involve storytelling whereby reciprocal meaning-making occurs to build an understanding of complex and layered plots. Acknowledging that scenario planning involves storytelling helps to reposition foresight to emphasise the intricacies of sociotechnical change.

Construction, however, tends towards trajectorism, often relying on top-down centralised planning approaches to scenario planning. For Harty *et al*. (2007), trajectorism occurs because the scenario development process tends toward the extrapolation of current trends instead of exploring the interconnectivities between drivers (*e.g.* technology, environment, *etc*.) within radically transformed futures, which is the real utility of scenario generation. Paying more attention to the process of storytelling may help to recognise the multitude of interconnectivities involved in the implementation of new technologies.

Storytelling has long been used in organisational and strategic management research as a powerful means of presenting meaning and gaining access to organisational realities connected to members' experiences (Gabriel 2000). In the face of novel situations, stories and plotlines are used by organisations as interpretative templates to understand and cope with the predicament of uncertainty and change (Czarniawska 2012).

Storytelling has, therefore, unsurprisingly, become a widely used technique in scenario planning for strategic development and decision-making (Wilson & Ralston 2006). However, whilst effective storytelling has the potential to engender understanding and draw out new insights about a situation, a weak story can 'call into question the very possibility' of making sense of the same situation (Gabriel 2000: 239). Indeed, stories with strong plots—whose popularity and persuasiveness have the power to influence social practice (Czarniawska & Rhodes 2006)—act as a vehicle to structure thinking and identify opportunities to address complex organisational problems (Kociatkiewicz & Kostera 2016). Conversely, weak plots, or a limited repertoire of strong plots to draw upon, can hinder the ability to explain and deal with institutional crises (Czarniawska 2012).

For many scholars of foresight and scenario planning, it is the plausibility of a scenario that determines its strength and quality of discussion that can be had about the future (Selin 2011; Selin & Guimarães Pereira 2013), particularly since future-oriented knowledge is non-verifiable (Guimarães Pereira *et al.* 2007). Eidinow & Ramirez (2016), for instance, hold that the plausibility of a narrative rests heavily on evoking reactions and feelings that hold fast to the perceived social reality of a culture or community. Crafting the 'right', or plausible, story involves appealing to or challenging the overriding social reality of said culture or community (Eidinow & Ramirez 2016: 48). Stories that are too distant fail to express their implications or provide relational links to a personal experience fail to become plausible and fail to invoke action. Crucially, though, plausibility must be co-constructed in conversation whereby ideas and opinions of what is plausible are criticised and qualified to reach a 'good' story (Wilkinson & Ramirez 2010).

The effectiveness of scenarios, therefore, ultimately depends on how the stories are told. Selkrik *et al.* (2018), for example, argue in favour of visual images, such as exhibitions of art, design and performance, in serving as a conceptual space to explore multiple futures. Storytelling, using images and objects, invoke a different, yet complementary, response to a descriptive narrative, and when intentionally designed, open up new worlds and foster new ideas (Akrich 1992; Selin *et al.* 2015; Salter *et al.* 2017). The novelty that visual images can bring to storytelling changes the way an audience engages with a story in terms of their ability to experiment with and relate viscerally to the plot. It is not always the final story that is important for stimulating reaction and imagination, but the process of creating the storyline through dynamic social interactions (Bowman *et al.* 2013).

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It is contended here, then, that through plausible storytelling, *i.e.* the co-constructed and emergent development of emotive plotlines, the process of foresight in construction could be better positioned to explore the consequences of sociotechnical change. Plausible storytelling also moves construction foresight away from trajectorial perspectives of the future favoured by those most often found doing 'future-making' (Adam & Groves 2007), *i.e.* those with the power, capacity and resource to colonise the future (Selkirk *et al.* 2018). As such, three concurrent principles drive the method of scenario creation used within this study: first, a focus on non-technological innovation to foreground the social aspects of implementing robotic systems in construction supply chains; second, plausible storytelling to acknowledge uncertainty and explore sociotechnical configurations with those 'at the coalface' of implementation; and third, to facilitate dynamic social interaction through the use of visual imagery.

Co-constructed stories with emotive plotlines help to reposition foresight to incorporate socio-technical change and broaden the capacity for imagination and creativity. This creates opportunities for alternatives to prescribed and predetermined scenarios. Incorporating visual imagery within the story-making process can help to encourage engagement in the scenario itself rather than focus attention on how to reach predestined futures.

4. METHOD

The method builds on foresight exercises commonly used with the field of futures studies to create stories of alternative futures. But rather than trying to predict futures as logical projections from present circumstances—with implied pathways to reach them—the intention is to create a series of alternative characterisations of the future. The goal for doing so is to provide an arena in which to imagine and explore alternative—and sometimes radical—sociotechnical configurations of the sector. In addition, and perhaps more importantly, the goal is to challenge normative assumptions of how robotics may become entrenched in the industry.

The research involved three participatory workshops with a total of 20 participants and 10 in-depth qualitative interviews (Table 1), which occurred over six months. The project's industrial partner, Artemis Consulting, was heavily involved in the research design and participant recruitment. Artemis Consulting is a development and improvement consultancy that specialises in driving manufacturing productivity using new technologies. The company has a large client portfolio of businesses in the south-west of the UK and an extensive knowledge of technological and organisational challenges relating to the uptake of robotics and automation. The research team worked closely with the managing director of Artemis Consulting to recruit appropriate participants, facilitate the workshops and tailor the research design as the scenarios evolved.

In order to recruit participants for the initial workshop, Artemis Consulting sent an information sheet and invitation to potential participants. These were selected from their client portfolio in terms of the size of the company, whether they were part of construction supply chains, and if they had experience or interest in adopting robotics. This initial sampling strategy was subsequently widened for the following workshops to include actors in the broader supply-chain. Having a large proportion of SMEs in the initial sampling strategy allowed scenarios to be developed where SMEs were foregrounded in long-term technological transitions. The remaining participants were recruited by publicising the project through Artemis's day-to-day workshops and through events organised by the study's funders. Participants included seven SME manufacturing and fabrication organisations (selected from Artemis's client portfolio), one industry membership organisation providing training and continuing professional development services to the industry, one independent research and technology organisation, one large contractor involved in research and development (R&D), and one SME robotic system supplier. These sampling strategies allowed SMEs to be brought to the forefront of the scenarios whilst acknowledging that changes would occur across the sector.

PARTICIPANT	SPECIALISM	PRIOR EXPERIENCE WITH ROBOTICS
Artemis Consulting (industrial partner)	Business development and improvement	Involvement in an Innovate-UK (IUK) project exploring reconfigurable robotic systems in the supply chain
SME1	Balustrades, staircases, bracketry	Previously explored the reconfigurable robotics in their firm
SME2	Fabrication and welding, 3D computer-aided design (CAD)	Used to work for Artemis Consulting and is involved in an IUK project exploring flying factories
SME3	Building access solutions, door locking systems	Limited
SME4	Doors, locking systems, ironmongery	Limited
SME5	Offsite modular housing systems	Some
SME6	Thermoplastic mouldings and assemblies	Limited
RTO	Research, development and training: robotics, offsite, digital technologies	Consistently involved in projects involving robotics
T1	Contractor: project development and construction	Involved in research and development (R&D) into robotics in the construction industry
SME7	Robotic technology and solutions provider	Involved in R&D into robotics in the construction industry

Table 1: Interview participants

Note: RTO = research and technology organisation; SME = small and medium-sized enterprise; T1 = tier 1 contractor.

4.1 CONDUCTING THE WORKSHOPS AND INTERVIEWS

The participatory workshops were designed to encourage participants to share reflections with all participants. This was achieved by sharing the fragmentary sketches of the scenarios beforehand, having a maximum of seven participants in the workshops, exhibiting the scenarios, and including a combination of open and closed questions.

Potential futures were presented almost as an exhibition, and participants to the process moved in and around them. This helped participants to contemplate potential interconnectivities between the artefacts within the scenarios. Two members of the research team led the workshops. They began by encouraging introductions from all participants. Each scenario was subsequently presented by the research team through an explanation of the scenarios, and subsequently sharing a collection of illustrations and descriptors to help convey the key themes and issues raised in the workshop. Once each scenario was presented, overall thoughts about the scenarios were prompted before participants were asked to comment on what aspects of each scenario were realistic or unrealistic, how they would expect their organisation to change, and what broader changes to the industry they would expect if the scenarios occurred. Within the workshop participants moved between project, firm and industry levels discussing the nuances of each scenario and sharing knowledge and experience to add to them.

Participants from the workshops were invited for interview to extend their insights on the scenarios, and to provide fine-grained detail on how their company would operate in these scenarios. For example, what organisational change would be needed to adapt to an industry in which the participant's company was part of an SME collective, or if they worked with an industry characterised by tier 1 contractors. Interviews were structured around the scenarios and lasted between one and two hours.

Despite the exploratory and short-term nature of this research, there were limitations. The research commenced at the beginning of the first round of Covid-19 restrictions put in place in the UK in March 2020, leading to the original research design to be reconsidered. Rather than face-to-face workshops and interviews, interviews and workshops—and meetings between the research team—occurred online. Conducting participatory workshops online was a new experience for the researchers, but they drew on recent experience of teaching and conducting meetings online to ensure participants engaged with the scenarios.

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5. FINDINGS

The scenarios are presented in the following section with examples of the types of artefacts used to convey each scenario, as well as those that were created from the ideas and insights from the participants. Taking on board the importance of 'how stories are told' (Bowman *et al.* 2013), each of the four sections begins with a 'final' synopsis of the scenario co-created through ideas and insights from the participants as they engaged with the artefacts. Examples of the artefacts used and the conversations they prompted are described using excerpts from interview transcripts along with observations. Along with the scenarios themselves, the artefacts progressed in their embellishment throughout the research project.

For each scenario there is one final synopsis (Boxes 1–4) and visual image (Figures 2, 4, 6 and 8) of the future depicted. The final images are a collage of the multiple narratives emerging from the workshop and interviews. Not every artefact is described due to space restrictions here. The artefacts and participant responses that follow were chosen due to being particularly illustrative of how storytelling aided the scenario building process.

5.1 SCENARIO 1: THE END OF THE MULTI-TIERED SUPPLY CHAIN

Box 1: Scenario 1 synopsis

A focus on vertical integration …

Large contractors have bought up parts of the supply chain and control end-to-end production of buildings and infrastructure. The tiered systems of construction have been replaced by five companies—the Mega 5—which employ the entire construction and manufacturing industry in the UK, resulting in the end of the multi-tiered system. Standardised product platforms and design templates needed for automation/robotics led the Mega 5 to bring design, construction and manufacturing in-house.

The Mega-5 operate in the form of a cartel whereby each company focuses on particular sectors of the industry—residential, commercial, heavy civil, industrial and environmental—ensuring profits for each company. Each of the Mega-5 is focused on providing a consistent approach to delivering its sector-specific projects.

The workforce remains relatively diverse and holds on to traditional construction roles with the combined knowledge and experience of the parent company and newly acquired SMEs, but automation skills begin to develop as planning and design functions become standardised with each company.

The initial sketch of a future industry in the midst of an ongoing aggressive tier 1 acquisition strategy was presented to the participants as the headline story on a faux newspaper (Figure 1), alongside a pared-back version of the 'final' synopsis (Box 1). The provocation of a robotic workforce and the vertical integration of the industry into five huge oligopolistic competitors, which these two artefacts help to convey, prompted substantive debate about the fate of SMEs. Initial responses to the proposal were proportional to its outrageousness, many with a catastrophising undertone suggesting the eventual obsolescence of SMEs—the emotive response the scenario intended to provoke:

> Response 4: It's likely that if purchased we would either exist as a divisional site/office or be swallowed up into a larger regional centre. Many of our hand-skilled workforce would not find employment in this new scenario—more than half of the workforce. We may exist on a purely consultative/project management basis with no manufacturing capability.

> Response 6: A loss of SMEs unable to provide the high-tech systems of design and manufacturing services that the Mega 5 would expect. SMEs that did survive would have to offer much more specialist products and services.

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Construction's "Mega 5" make their final acquisition

One of construction's "Mega 5" - Cronus Corp - is getting its second acquisition-fuelled jolt of the past few weeks. The company made the announcement on Friday that it is acquiring 30-year old SME Demeter-Fabrications for £27.5 million.

The acquisition of Demeter Fabrications comes exactly one month after Cronus Corp announced plans to acquire Hestia Steel, another SME manufacturing firm, for £36 million in November (the deal closed today). Together, the two acquisitions mean South East-based Cronus Corp has paid £63.5 million in a month. Acquiring Demeter and Hestia, both based in the NW, pours some fuel on the fire of Cronus's strategy under CEO Peter Dennis to focus on end-to-end automation of the construction process as its top priority …

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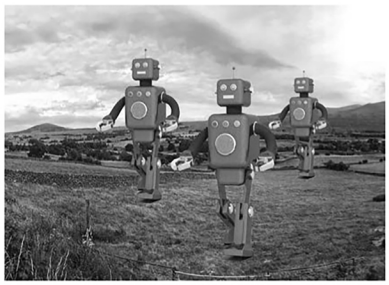

Cronus Corp workforce clock in for the 24/7 three-week construction of Monsterat mega hospital in Penrith, Cumbria

Figure 1: Scenario 1: *Global Daily* faux headline.

In the process of consolidating participant responses to the fragmentary sketches, the obsolescence of SMEs provoked participants to think about the role of SMEs in future scenarios within the workshop. As illustrated in response 4, participants added how the Mega 5 would require regional divisions if this scenario took hold. There was consensus around the unlikelihood of SMEs becoming obsolete in this future, but what it prompted was a discussion about the distinctiveness of SMEs and how their business models and organisational structures might need to change to operate in a vertically integrated industry. The workshop included in-depth discussions regarding whether SMEs could work as divisional sites in the Mega 5; would focus on bespoke projects (not deemed high volume enough for automation); or balance the retention of traditional skills whilst benefiting from increased automation.

Several adaptations to the scenario emerged to take the distinctive characteristics of SMEs forward into the final collage of the future. The example that follows describes the co-construction, or co-creation, of one of these adaptations: communication channels and regional offices.

In reflecting on the value propositions related to the organisational structures associated with SMEs (*e.g.* 'agile', innovative), SME2 raised the point of how networks of communication may change and have implications on project-level innovation. In their words:

> if the SMEs sat within one of those large five organisations, then that would potentially in a way slow down innovation.

For SME2, then, one of the key implications of a vertically integrated industry would be that the ability to finish bespoke projects quickly would be hindered. In referring to a project that another participant mentioned earlier in the workshop, SME2 stated how 'I guess it's like SME1 did that project in three weeks'. SME1 subsequently continued the conversation adding how the project rested on quick decision-making between two members on the project and stated how he was not sure whether such communication channels would exist when working within a large corporation.

This prompted the participants to explore how the Mega corporations would need regional offices and how 'changes, discussions, contracts, *etc.* would have to go in through those regional offices'. SME2 continued his point regarding how communication channels relate to regionality:

> A conversation between two people rather than a [regional office], I don't know, submit a document into a department within a huge corporation to get, then, a review of that document. That same decision-making process [currently] happens between two individuals.

Figure 2 captures the detachment from the shop floor that the participants believe a vertically integrated supply chain would create. The image illustrates an indicative narrative of the scenario's hierarchical nature involving groups of middle management making top-down decisions. Display cabinets are filled with the same awards to demonstrate each of the Mega 5's supremacy in each sector of the industry and raise questions as to the future role and relationship with SMEs.

Figure 2: Scenario 1: Tier 1 oligopolies.

5.2 SCENARIO 2: SOFTWARE VENDORS AND ORIGINAL EQUIPMENT MANUFACTURERS DOMINATE

Incumbent firms have lost out to new market entrants …

Software and robotic development corporations dominate the construction industry. Software vendors have acquired all the assets and knowledge they require to deliver a fully automated design, manufacture and construction process.

Construction Robotics Inc. is a robotic firm specialising in automation. Designed by robots for robots, manufacturing in mega-factories ensures that Construction Robotics can secure the availability of buildings within five working days. The company offer various robotics-as-a-service options, such as 'click & deliver' whereby clients specify buildings based on a sliding scale of alternatives from a defined set of styles. Modular elements are subsequently manufactured and delivered either to regional distribution hubs for collection or directly to site.

PropTech and AI have automated the planning and design stages, and diversity within the workforce has been thinned out, except for specialist quality control roles. Customers also have the option to buy add-on packages and upgrade their service to 'click & construct' where Construction Robotics draws on the expertise of its subsidiary partners. The robotic-led design and automated manufacturing lines eliminate the possibility of human error and delay in supply.

Box 2: Scenario 2 synopsis

The second scenario positioned software vendors and original equipment manufacturers (OEMs) as the dominant player in an automated 'click and deliver/construct' supply chain. A mock-up of the software and OEM company website (Figure 3) was used to illustrate multiple aspects of the scenario, including partnerships, terms and conditions, tiered packages of services, and customer reviews. The scenario mirrored much of the utopian rhetoric of Construction 4.0 to present a fully integrated industry with a 'neoliberalism on steroids' nuanced resolution to issues around ownership and employment space (both barriers to SME robotic uptake). Participants felt this to be a 'more likely shift than Scenario 1'—likely due in part to familiarity with industry discourse around modular construction. But in contrast to scenario 1's responses, that focused on business relationships, responses to scenario 2 tended to focus on operational realities surrounding business model adaptations involving workforce and value streams, as the responses below illustrate:

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Response 1: We would have to set up as a supplier of modular parts to the construction industry. This would require a different set of skills from our workforce and not all current employees would want to switch to production-type work.

Response 2: The majority of our work is currently installed on city and town centre sites where the opportunity to install modular type works is not feasible (even the modular work that we have and are currently involved with has a large amount of specialist engineering required in order to overcome constraints in site).

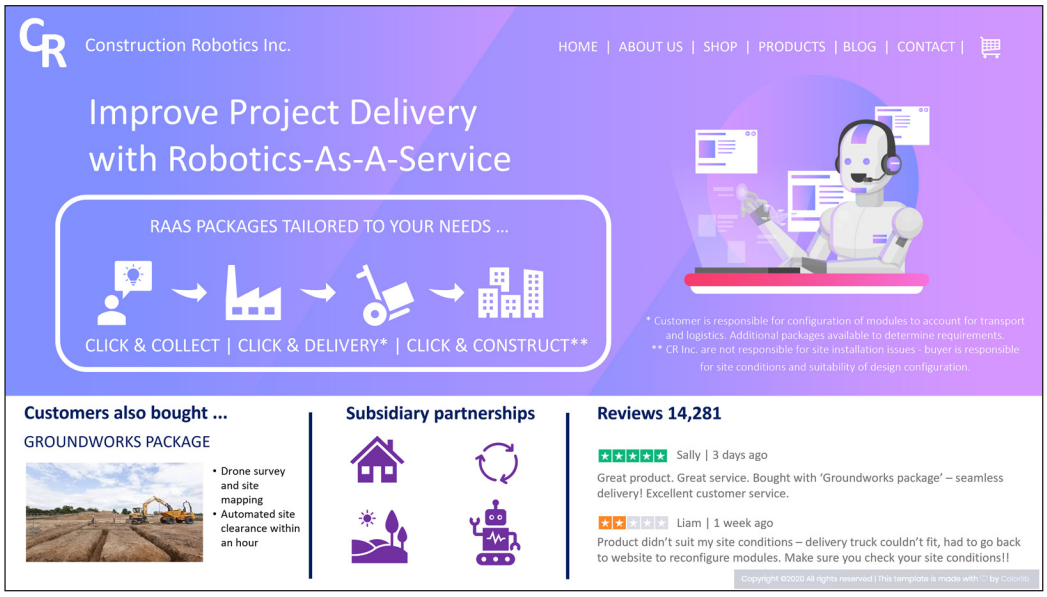

Figure 3: Construction Robotics Inc. company website.

In the workshop participants discussed how SMEs would adapt to provide high-tech systems of design and manufacturing, and how development opportunities might change in this scenario. For many of the participating SMEs, there was a mix of refurbishment/retrofit and new-build work which requires thinking through past, present and future approaches to the built environment. This is exemplified in the following quotation from the participant from SME4:

> you need to have a [business] model that overlays both the here and now, what would the, be the new state, but also the current state, which is many, many years of a building being around that you need to cover.

Whether a future dominated by software vendors and OEMs would be compatible to the vast amount of work refurbishing and retrofitting existing building stock became a talking point. In one workshop, the participant from SME4—whose organisation specialised in the manufacture of doors—added to the discussion with the point that implications would vary between SMEs depending on how much of their work involves existing building stock or new build:

> if I may just jump in, we've got probably different markets. One is we're doing a refurbish market, which obviously is not a greenfield, so you're starting from what's been built maybe 30 years ago, and the, we're a bespoke manufacturer, and the reason we're bespoke is because every single storey and every single opening and every single door, for instance, or hospital, is a different size. There's no standardisation across time at all. If you're starting up a complete new site and you was using robotics and you'd be able to digitise and, *etc.* maybe you'll get some repeatability then.

The discussion continued to explore how the benefits of working in the industrial landscape of scenario 2 depended upon the extent that their value streams could adapt to repeatability and the diversity of sectors in which SMEs worked. As the participant continued to describe, there is very little uniformity of sizes over time and sectors, providing examples such as how walls for hospitals or museums can be three times the thickness of schools built at the same time.

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The bifurcation of value streams into bespoke and repeatable then led on to the logistical aspects of doing so. Participants highlighted interconnected issues relating to the time taken to retrieve information and working around a contractor's costing exercises. This pushed the conversation toward the role of storage and order fulfilment networks to balance this:

> even if we, through robotics we could probably reduce our cost, but it wouldn't really reduce the lead time to give you the Amazon type thing, unless you have some kind of stock.

Figure 4 was used within the workshops to evoke SME thought and feeling as to the industrial scale of scenario 3. In the summary image, blankets of prefabricated homes reach the horizon to encourage participants to think about the impact of standardisation on development type. In turn, participants described the potential changes to their business models and the broader changes that would need to occur to support this, such as order fulfilment networks as described above.

Figure 4: Scenario 2: Software vendors and original equipment manufacturers (OEMs) dominate.

5.3 SCENARIO 3: REGIONAL NETWORKS OF SMALL AND MEDIUM-SIZED ENTERPRISE COLLECTIVES

Box 3: Scenario 3 synopsis

Equitable sharing of risk and reward supports collaboration…

The construction industry is dominated by networks of SMEs. Through shared rental of robotic systems, SMEs in the case study can adjust their organisations to benefit from robotic systems with less substantial upfront capital costs. In the scenario, SMEs pay an annual fee and are allocated a share of the robot's time. The time periods are determined democratically by the overall collective. The collectives distribute risk and reward through shared rental of robotic systems.

Within a cooperatively owned manufacturing hub, reconfigurable robotic systems are scheduled to move between organisations in order to aid batch runs when needed and to allow employees to focus on bespoke aspects of particular projects. Where SMEs were previously unable to capitalise on robotic collectives allow organisations to diversify their portfolios whilst maintaining repeat work.

Diversifying portfolios allows expertise to flourish, which in turn encourages new generations into the industry. Entrepreneurship competencies are fostered through apprenticeships in close collaboration with colleges and universities. The advantage of SMEs having autonomy over what they choose to standardise means that the existing building stock is maintained through retrofit.

In scenario 3, SMEs were positioned as the dominant player around which the future vision of the industry was configured. Inspired by previous research into SME robotic adoption where

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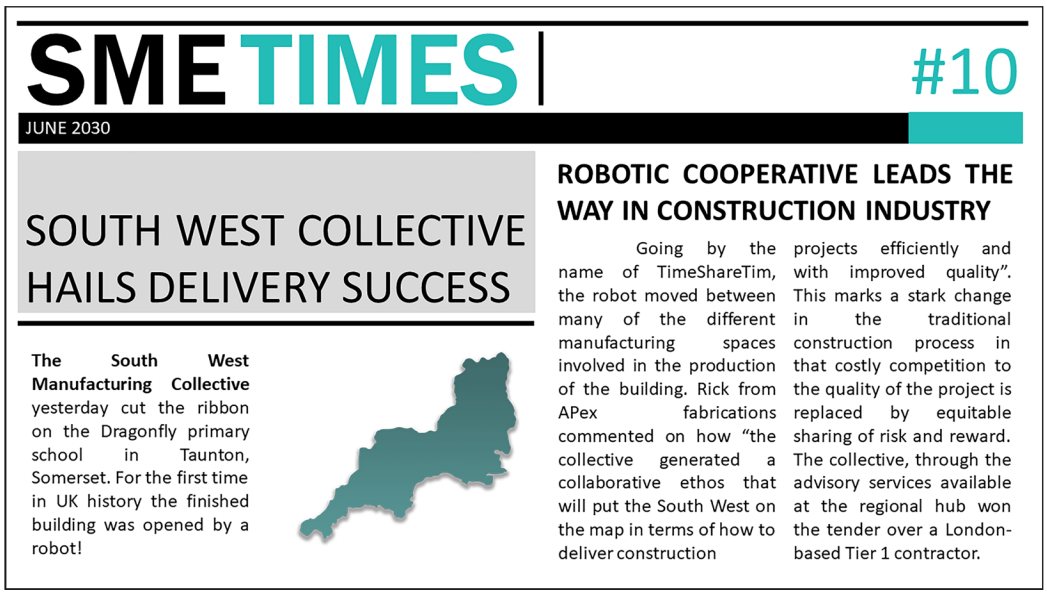
employment space and capital expenditure revealed to be significant barriers to uptake, a sketch of the synopsis above was presented to participants alongside an industry news article portraying a flagship case study of robotic cooperative success (Figure 5).



SME TIMES | #10

JUNE 2030

SOUTH WEST COLLECTIVE HAILS DELIVERY SUCCESS

The South West Manufacturing Collective yesterday cut the ribbon on the Dragonfly primary school in Taunton, Somerset. For the first time in UK history the finished building was opened by a robot!

ROBOTIC COOPERATIVE LEADS THE WAY IN CONSTRUCTION INDUSTRY

Going by the name of TimeShareTim, the robot moved between many of the different manufacturing spaces involved in the production of the building. Rick from APex fabrications commented on how "the collective generated a collaborative ethos that will put the South West on the map in terms of how to deliver construction projects efficiently and with improved quality". This marks a stark change in the traditional construction process in that costly competition to the quality of the project is replaced by equitable sharing of risk and reward. The collective, through the advisory services available at the regional hub won the tender over a London-based Tier 1 contractor.

Figure 5: Scenario 3: *SME Times* faux headline.

As with all the scenarios, participants engaged with scenario 3 by unpacking the future artefacts presented through their organisation's experience. Responses to the initial fragmentary sketches and discussions in the workshop pointed toward how this scenario offered flexibility for SMEs, whilst with the flexibility also came organisational challenges. This is summed up in the following response:

> This would be the most flexible of the scenarios and possibly most realistic for the industry to transform to however we have found the most challenging thing to be the setting up and management of such collaborations.

For participants, SMEs would be able to capitalise on the repeatability that robotics offers with the reduced risk of training existing staff or recruiting new staff. A response to the Google form question, 'What aspects of the scenario are realistic and unrealistic?' also articulates the attraction of sharing and/or renting the robotic systems, and only partially changing their value streams to retain the bespoke work in which they had come to specialise.

> Robotics is a big investment in cash and resources. It requires businesses to completely re-evaluate their manufacturing processes and supply chains. Specialist staff either have to be trained or new staff appointed. All of these issues could be averted in using 'shared' robotic & automation systems. This scenario is definitely a realistic approach that would enable SME's to 'test the water' and get confidence in using and working with robotics. I see nothing unrealistic or problematic in this proposal.

The advantage of partial adoption of robotic systems was furthered in the workshops where participants explored how working within such a landscape could pan out for SMEs. The productions director from SME1 viewed the potential participation in a regional network of SME collectives 'almost like a subcontractor', which could help with projects involving a lot of repetitive work:

> when we hit peak periods or we have a particular job where there's a lot of repetitive work, this would be an option we would have up our sleeve maybe to subcontract this out to a central depot somewhere.

Discussion in the workshops was also directed toward the running and maintenance of the facility whereby potential challenges included: working with a variety of materials would require cleanliness and housekeeping strategies; capacity planning would need to be organised centrally;

what would minimum and maximum batch sizes be; and whether it may be more beneficial to take a flying factory approach in which the robotic system would travel to different sites/manufacturing facilities. The following quotation attends to the importance of non-productive time in between jobs and ensuring this time does not outweigh the potential savings a robotic system could bring.

> We're not making thousands of widgets at a time, so the speed of programming that robot is paramount. If it's going to take a day to program that robot for a job that's going to only take the robot two days to make, then it's just not on. So it's the speed of the programming and setting up and rejigging. That's the secret behind it.

Discussions in the workshops often centred on potential solutions to challenges specific to the scenarios and the industry more broadly. In terms of the latter, the participants often agreed how the regional facilities would provide an opportunity to experiment with robotic systems, and give them, in the words of one participant:

> the actual confidence to say, right, yes, this is working for us, the time's come for us to actually invest in our own robotic system within the company.

The plausibility of a robotic cooperative opened up a more in-depth conversation around what it would take to balance the tension between risk and reward involved in the adoption of new technology.

As the dominant player in scenario 3, SMEs, the work they do and the environment they operate in is very much at the centre of the summary image shown in Figure 6. Varying types of building, product and material components running through multiple configurations of robotic systems within a factory are used to represent the autonomy SMEs would have in this scenario. A demand management dashboard proposes one model of operating in a cooperative environment to prompt discussion around the actualities of how this could work.

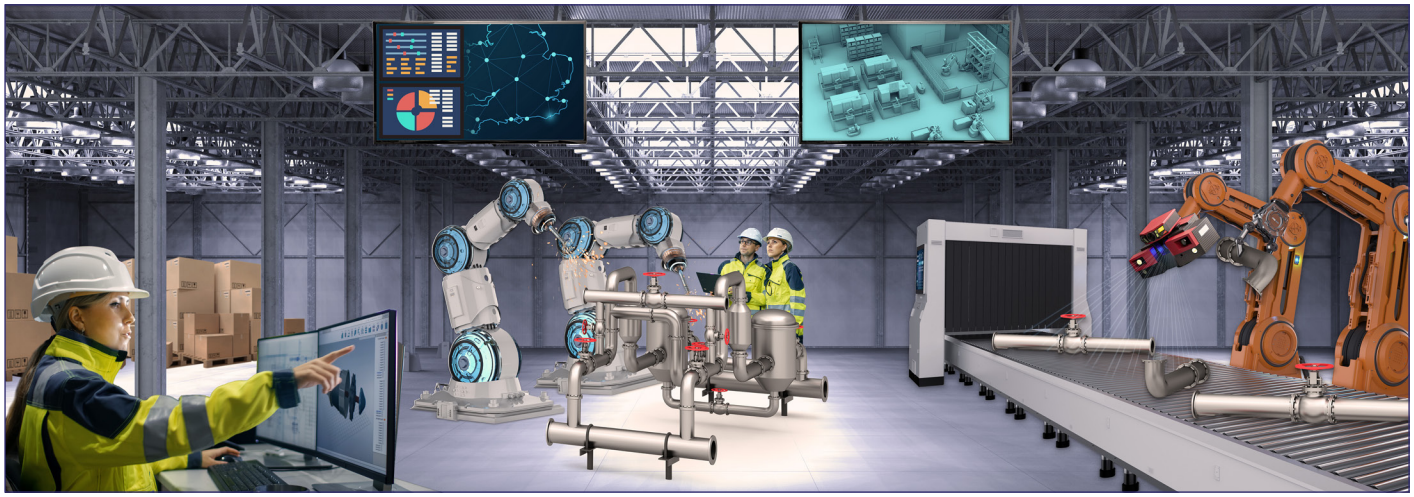


Figure 6: Scenario 3: Regional networks of small and medium-sized enterprise (SME) collectives.

5.4 SCENARIO 4: GOVERNMENT EXPROPRIATES FACTORIES AND MANUFACTURING

Box 4: Scenario 4 synopsis

Publicly funded projects finally deliver …

Following the failure of various reform agendas over the years, the 'blighted' industry is now seen as a major impediment to economic survival post Covid-19. The news is awash with the nationalisation of the construction industry. Under the terms of the Construction Act 2030, factories and machinery have been nationalised and handed over to the National Construction Board to distribute robotics and automation throughout the UK construction industry supply chain to deliver the scale of regional development required to meet the needs of the nation.

Subsidies and employment systems, such as apprenticeships, have been introduced to support skill development for the new types of construction professionals required in the automated construction supply chain.

Partnerships between publicly funded services, such as universities and infrastructure, ensure that the capital benefit generated by automation and robotisation is used to maintain the level of innovation required to improve employment conditions and job alternatives.

Scenario 4 placed the government in the position of dominant player in a radical future of a construction industry nationalised. Images of an apprentice scheme, news bulletin and factory expropriation notice brought a propagandistic feel to the scenario (Figure 7), evoking a strong reaction—primarily around disbelief and absurdity at the idea. For example, respondents in the survey commented 'It'll never happen!' and:

> Politicians and Civil Servants can 'talk the talk' but SME's and the country need people who can 'walk the walk'. Politicians in charge of construction and robotics would be a recipe for disaster!

As intended, these artefacts swung the discussion to the implications of a state-led industry. Whilst initial reactions were dismissive of the idea, it did prompt meaningful debate around the role of regulation in innovation and participants shared their experience and frustration with existing contractual relationships. Questions around how the relationship between policy and industry could be improved not necessarily to nationalise, but to change the way in which policy supports the uptake of robots for SMEs, were discussed in the workshop. One theme that emerged in conversation in the workshop around setting the standard and pace of innovation is exemplified below.

Drawing on their experience as a supplier to one of the Nightingale Hospitals, the participant from SME1 described the potential benefits of working on a project with fewer vested interests in the design and construction process. These were related to the mediating 'red tape' role the architect holds that, in their experience, slows projects down. As the participant goes on to describe:

> we turned around 140 tonne of steelwork in three weeks from, what, initial design to installation. It was done safely. It was done in accordance with all the rules and regulations, but we just cut out a lot of the red tape. So that was a very, very efficient job. [...] It was just a, more of a common-sense approach between us and the main contractor.

SME3 echoed these sentiments and furthered the conversation with his own experience of how contracts have changed over the course of his career, and the role government could play in shaping the mindset of the industry toward one of achieving a common goal in the shortest period of time if it were to 'set the standard and the pace that we move forward on the projects':

> In the past when you had a traditional contract and the architects were more involved in it, there was decisions being made at one point. Now that you've got to a point where you've got design and build, there's lots of vested interests in achieving probably more profitability than the end result, and it just, I think it just gets in the way.

Notably, in this scenario there was little direct discussion around the uptake of robotics as compared with the previous three scenarios. The use of visual images in this scenario further broadened the consideration of impacts to the role of policy and government support by making a relational link to SMEs' personal experience of present challenges. These insights, in combination with insights from the previous scenarios, provide a more compelling story of the potential project-, firm- and industry-level consequences of sociotechnical change.

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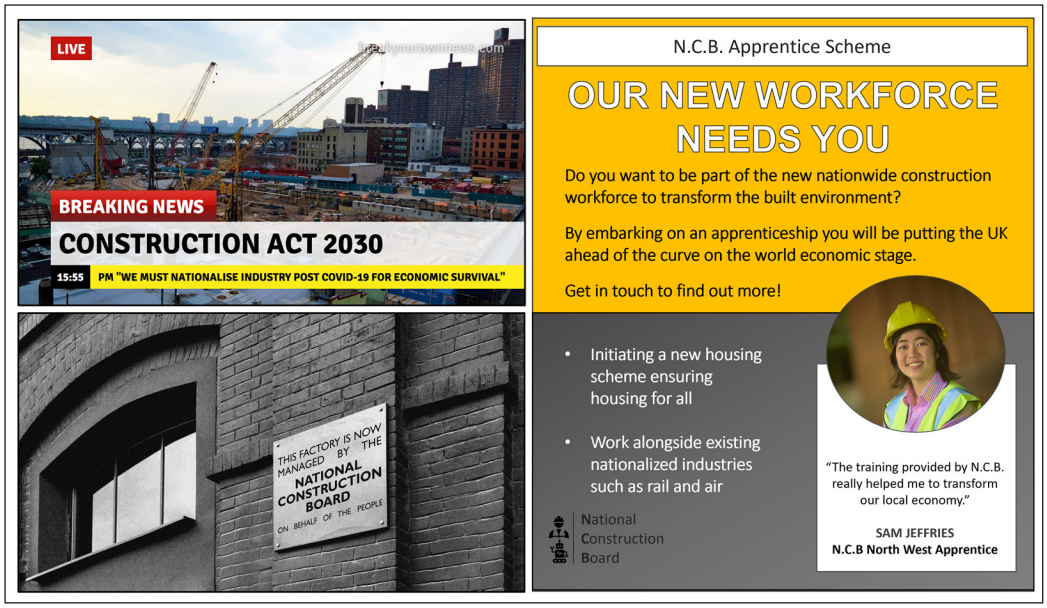

Figure 7: Scenario 4: Faux bulletins.

Figure 8 demonstrates the broader implications of governments expropriating factories and manufacturing. Cutting the ribbon of a high-speed rail system is provided as an example of how publicly funded projects may be delivered. The image as a summary of the scenario shows close connections between state-owned institutions such as apprenticeship colleges, factories, and colleges that could be possible with a national construction board.

Figure 8: Scenario 4: Government expropriates factories and manufacturing.

6. DISCUSSION AND CONCLUSIONS

Trajectorial technological predictions are ill-equipped to do much more than provide a critique of present circumstances (Harty *et al.* 2007). The aim of the present paper has been to present an alternative approach to construction foresight better positioned to explore the impacts of technology on organisations, supply chains relationships and business models. This was done by positioning the approach to speculation away from trajectorial technological predictions. Instead, the approach looks at the implications of different futures with those at the operational level.

This paper has explored what the future of work might look like when robotic systems are embedded into organisational features of the SMEs, and in doing so, it attempted to explore how the industry may be constituted differently if robotics and automation became more widespread. This has revealed how there are many more complex stories to tell and many more futures to articulate than probabilistic approaches to scenario development can deliver. Likewise, the linear

continuation of past and present inherent in normative approaches to scenario development narrows the range of 'plausible' futures imagined, presenting a false sense of certainty.

All the scenarios were 'under discussion' by participants. None was completely rejected, and all were explored through participants' operational experience. For example, the importance of communication channels in previous projects was used to think through how the sector might operate differently under different scenarios. As shown, futures are value-laden and the distinctive characteristics of SMEs and more specifically the value streams being reproduced by firms, informed how they explored multiple futures.

Participants 'at the coalface' (Chan & Cooper 2010) brought to the scenarios examples of existing ways of working: the relationship between repeatability and bespoke, ways in which policy currently supports and could better support the uptake of robots for SMEs, and communication across the supply chain. Such examples prompted adaptations to the scenario to take the distinctive characteristics of SMEs into the final collage of the future scenarios (which themselves were created to provoke rather than prescribe).

Framing the scenarios to include transient artefacts of the future helped to provide a conceptual space for multiple futures to be explored (Selkrik *et al.* 2018) and allowed the future thinking inherent in the participants' strategies to be explored further as it was shared with other participants in the process of co-creation. This allowed imagination already present (Morgan 1993) to be explored further as it was discussed by participants in the workshops.

It was shown that speculating beyond technology means acknowledging uncertainty and broadening capacity for imagination and creativity. With a focus on strong plots and challenging the status quo the ability to draw out complex stories is improved (Czarniawska & Rhodes 2006; Eidinow & Ramirez 2016). Furthermore, when objects and images, as well as narratives are used, these encourage imagination and creativity as a means to reformulate problems and challenge assumptions surrounding sociotechnical futures.

In responding to artefacts of the future, complexities were foregrounded and/or played down to highlight where issues, such power relations, are manifestly expressed. Organisational stories drawn on allowed different plotlines to emerge, which in turn helped to build scenarios. In these, one can begin to see new plotlines emerging and different areas for problematisation from an organisational point of view. These raise questions about the ways in which the sector could be rearranged.

A foresight approach based on storytelling created a more explicit connection between project-, firm- and industry-level characteristics. This was not forced, as in there was no prescription to the structure of the workshop discussion. Participants exchanged experience and built upon ideas with one another using the scenarios and visual images as the conceptual space to explore the implications of robotics and automation. Perhaps most significantly, the approach provided an arena in which businesses—which would not normally come together to discuss such things—could reflect on and share their organisational experience. It is a foresight approach very much centred around reciprocal knowledge exchange and the co-construction of 'good' stories as suggested by Wilkinson & Ramirez (2010). The whole that can be made up from the stories and what it can say about the state of things currently is a useful starting point from which to understand how sociotechnical futures might be reconfigured. This can help to reformulate problems and challenge assumptions—contrary to trajectorial predictions of technology dominant in construction foresight—for decision-makers to reflect on.

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AUTHOR CONTRIBUTIONS

All authors made substantial contributions to the conception and design of the work, contributed to its drafting, revising it critically for important intellectual content and provided final approval of the version to be published.

COMPETING INTERESTS

The authors have no competing interests to declare.

ETHICAL CONSENT

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