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Engineering the revolution? Imagining the role of new digital technologies in infrastructure work futures

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Abstract

Contemporary imaginations of the impact of new digital technologies (NDTS) are dominated by utopian visions of a 'revolution' in productivity and efficiency, contrasted with dystopian views of declines of work and human skills, and distrust of artificial intelligence's efficacy. This article explores imaginations of digital futures in the infrastructure sector through case study research of a global engineering organisation. Drawing on a practice approach, a typology is generated from interviews with engineers and managers to reveal that three broad imaginations compete within the organisation: technodeterminism; technoscepticism; and human-centric, all with utopian and dystopian variants. Clear relationships exist between the diverse imaginary positions taken by employees with their different roles, biographies and levels of the organisational agency. Those with relatively higher levels of agency tended towards technocentric utopianism while those with lower levels of agency displayed a resolutely dystopian version. Conversely, while the outward-facing image of the organisation promotes a utopian imagination of a technologically driven future, those with the very highest levels of the organisational

agency remain technosceptic. This means that real change is slow. However, an encouraging manifesto for the future is suggested by those who are innovating NDTS to reimagine alternative infrastructure futures through improved human-centric social outcomes.

KEYWORDS

dystopia, engineering, human-centric, infrastructure, new digital technologies, sociotechnical imaginaries, technodeterminism, technoscepticism, utopia, work futures

INTRODUCTION

Predicting the impact of new digital technologies (NDTs) and, in particular, artificial intelligence (AI) on the future of work, jobs and careers is a preoccupation currently uniting academics, policymakers and industry strategists alike (e.g., Boyd & Holton, 2018; Dellot et al., 2019; Mckinsey, 2020; Spencer, 2018), not least due to high profile 'failures' in the management of the impact of Covid-19 on society (Peach, 2020). Within sociotechnical studies (STS), how best to conceptualise the complex relations between workers, the 'new' new technologies (Howcraft & Taylor, 2014) and work futures is undergoing a resurgence of theoretical interest (e.g., Aroles et al., 2019; Spencer, 2017; Thompson & Briken, 2017), but rather less academic attention is being given to empirical investigations of 'the Fourth Industrial Revolution' (Schwab, 2016) as this is unfolding on the ground (Lloyd & Payne, 2019). At the same time, just how human-NDT relations will play out in everyday, material practice is a topic dominating debates in both policy circles tasked with advancing 'smart' delivery (Kispeter, 2019), and industrial and professional contexts where rapid advancements in new technologies herald potentially dramatic sectoral transformations (Nania et al., 2019). Developing an effective, practical 'digital strategy' for the future is perceived by both national economies and individual organisations as the route to, at least, remaining economically productive and sustainable and, at best, achieving desired outcomes and a distinctive and competitive edge (DCMS, 2017).

Two broad themes govern policy and business scenarios of work futures, as well as the broader public imagination (Holtgrewe, 2014; Spencer, 2018). On the one hand, it is argued, a new utopia dawns, NDTs relieve us from the routine and tedious monotony of work to augur a 'revolution' of increased leisure, health, and wellbeing (Brynjolfsson & McAfee, 2014). AI in particular is positioned as an engine of positive economic and social transformation, whereby wealth will be more evenly distributed and social inequality reduced (Bastani, 2019; Mason, 2015). On the other, more dystopian hand, there is fear of loss of the 'human', either through a wholesale destruction of jobs for both unskilled workers and skilled professionals by robotics and AI replacing their roles (Ford, 2015; World Economic Forum, 2017); or through deskilling, whereby digital technologies may 'cream off' the intellectual and creative elements of work, leaving humans to perform more menial tasks, or those requiring emotional skills (Head, 2014; Susskind & Susskind, 2015). While seemingly oppositional, both -topias converge through their underlying ontologies of 'technological determinism', wherein technology is

assumed to have linear and predictable impacts on society (Dafoe, 2015). In contrast, STS stresses the contingent and undetermined complexities of all the factors involved in any consideration of the impact of NDTs. These include, at the very least, social relations, culture, politics, ethical and legal issues, identities, health and lifestyle, and work and career aspirations (Boyd and Holton, 2018; Selin, 2008). The uncertain nature of the human/nonhuman relationship across these realms means there is no predictable path or outcome which will result (Baldry, 2011; Howcraft & Taylor, 2014; Tegmark, 2017).

How are organisations and professions negotiating this complexity of 'sociotechnical imaginaries' (Jasanoff & Kim, 2016) in their future planning? Our aim in this paper is to contribute to this broad question sociologically, through new case study research conducted with civil engineers in a global infrastructure corporation. Infrastructure makes an interesting context here, as it is simultaneously attracted to, and ripe for, development through NDTs, recognising the advantages to productivity which technologies such as AI, building information modelling (BIM), visuals and robotics could deliver to its practices. At the same time, as the strategy manager at our case study organisation, *InfraTech*,[1] confirmed, the sector is notoriously slow—and even resistant—to digitalisation in comparison with others, such as health and manufacturing (Argawal et al., 2016). Our objective was to contribute to understanding this conundrum, by exploring perceptions of the role of technology in infrastructure futures held by managers and employees, and the subject positions they took within the larger discursive context. Drawing together Jasanoff and Kim's (2016) notion of sociotechnical imaginaries with a practice approach to focus on what engineers are saying and doing (Nicolini, 2012), we generate a typology of 'homogeneous types' of imaginaries of practices. Our empirical analysis reveals how 'futures are incredibly contested, saturated with conflicting social interests' (Urry, 2016, p. 3). Nuanced differences were found between 'utopian' convictions of far-reaching economic and/or social benefits and 'dystopian' fears of risk, loss of skills and professional identities. This distinction in imaginations of the future is explained by the amount of agency held in the present, produced through the interplay of people's organisational roles with sociological features including identity, age and career stage. Our findings reveal how those with the most power and agency, the management executive, posited claims of wholesale change through NDTs as overblown. Uncomfortable with any destabilization of the status quo, scepticism prevails. The dominance of a techno-scepticism imaginary held at the senior level helps to explain the slow pace of technological change not only within Infratech but the civil engineering profession, as well as the infrastructure sector more generally.

At the same time, the management team are very aware that technoscepticism is not an image compatible with a forward looking, innovative organisation. As such, high profile is given to those with influence over the organisation's digital capabilities and strategy, typically senior technologists and early career 'techie' engineers. These employees have the digital skills and role agency to imagine technology in utopian and more 'revolutionary', technodeterminist, terms. As holders of this imaginary progress through the organisational hierarchy and gain higher levels of agency for change, it is likely that alternative rhetorics around NDTs will become consolidated as material practice. This picture is fractured further, however, by alternative imaginaries which recognise how the outcomes of sociotechnical relations are co-constituted and negotiable (Edwards & Ramirez, 2016). This position enables more 'human-centric' visions of the future, wherein NDTs are strategically 'engineered' as mechanisms through which infrastructure can more effectively tackle profound social and environmental challenges. Espoused by a nonhierarchical mix of engineers 'hobbying' digital innovations in

their own time and/or working on projects which afford more creative freedom, new forms of agency are emerging to reimagine infrastructure futures as improved social outcomes.

CONCEPTUALISING THE DIGITAL TRANSFORMATION OF WORK

The relationship between technology and its effects has been debated extensively in STS, primarily with the aim of developing more critical approaches than technological determinism to understand the role of technology in the shaping of socioeconomic relations and futures (Howcraft & Taylor, 2014; Lloyd & Payne, 2019). Technological determinism is critiqued as blind to the possibility of human agency, through its central tenet that new, complex systems of digitalisation, information and communication are innately revolutionary and will generate comprehensive social change in a prescribed manner (Dafoe, 2015, p. 1052). While some fear this means a dystopian dehumanisation of work, skills and creativity, many assume that change will be productive, not only to the economy, workplaces and occupations but also to the shape of society and politics (Ford, 2015). This more utopian discourse

> 'Persists in the action taken and justifications given by many actors: it persists in analysts' use of it to make sense of the introduction of technology in a variety of settings; it persists in manifold theoretical and abstract accounts of the relationship between the technical and the social; it persists in the responses of policy makers and politicians to challenges about the need for or appropriateness of new technologies; and it persists in the reactions we all experience when confronted with new machines and new ways of doing things'. (Wyatt, 2008, p. 167)

The dominance of technological determinism, particularly its 'utopian' variants, in social, political and economic thinking means that it operates as a sociotechnical imaginary: a 'collectively held and performed vision[s] of [a] desirable future[s], animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology' (Jasanoff & Kim, 2016, p. 19). Sociotechnical imaginaries are more powerful than mere ideas: they are 'collective, durable and *capable of being performed*; yet they are also temporally situated and culturally particular' (ibid:19, our italics). They also, therefore, have material consequences, as produced through performances, social arrangements, organisational strategies and even the 'hard stuff' of infrastructures such as roads, power plants and transport systems (Jasanoff & Kim, 2016, p. 22; Selin, 2008). A key sociological question of imaginaries is, therefore, 'out of the many ways it is imagined, organised, materialized and distributed' (Urry, 2016, p. 17), which—or whose—future holds power over others.

While powerful in many work and policy contexts, the transformationalist spin of technological determinism is by no means the only imaginary at play. It competes with other imaginaries, which can be positioned on a 'continuum' (Dafoe, 2015) of human agency, from 'hard' determinism at one end, through to 'soft' constructivism at the other (Leonardi & Barley, 2010), while also having utopian and dystopian variants. To aid understanding, this plethora can be clustered into three broad approaches, as we capture in the following typology.

This matrix produces a range of imaginaries, such as the more conservative 'techno scepticism' (Tegmark, 2017). This holds the claims of technological determinism to be highly exaggerated: AI, robots and digital technologies to the nature of work will undoubtedly take

over some routine tasks, but more dramatic changes will not happen for a very long time, if ever. Creating and adopting NDTs is risky and time-consuming, such that advancements such as general AI—machines capable of understanding the world as well as any human—remain distant dreams. More positively, the fact that people gain multiple benefits from work, not only economic but also in terms of mental health, creativity and social relationships, means 'good work', rather than the 'end of work' (Granter, 2009), should be prioritised (Taylor, 2017; Thompson & Briken, 2017), not abandoned.

At the 'soft' end, social constructionist approaches hold that change emerges through ongoing social action and relations, in which people have the agency to respond to, negotiate, resist or modify technology's constraints and affordances, as well as each other (Howcraft & Taylor, 2014; Leonardi & Barley, 2010). Technologies are thus conceptualised as 'relational artifacts': more than mere tools, but constitutive of social life, both shaping and being shaped by human culture (Wajcmann, 2006). While technology is a 'social product whose uses and direction of development reflect the priorities of the holders of social and economic power both in society and in the workplace' (Baldry, 2011, pp. 175:1), how it is actually operationalized (or not) *in practice* is produced through the responses, motivations and resistances of individual users. An example here is 'human-centric technology' (Bryson & Theodorou, 2019), which holds that indelibly intertwined alongside technological developments must be continuous debate about their social and political consequences. The unpredictable consequences of technology, the ways in which 'objects and materials often bite back at us' (Nicolini, 2012, p. 8), and the ability to use technologies with consequences for harm, mean that individuals, beyond governments and organisations, must and do question and assert control of technology, to ensure it is built and designed judiciously for the public good. To paraphrase Berners-Lee (2019), this approach argues that, collectively, we exert the agency to oversee technological futures in terms of development, use and consequences.

The recognition that technology use is a social practice involving individual agency highlights how technological practices in the present have the capacity to produce a diverse range of different futures, both imaginatively and materially (Stein, 2008). Shove (2005) argues that to understand how practices emerge and, crucially, how they might change, we need to see how practices are combinations of three elements: Materials (objects, infrastructures, tools, technologies, or 'stuff'), Meanings (underlying values and understandings, motivational knowledge or 'image') and Competences (background knowledge, multiple forms of understanding and practical knowledge, or 'skills'). Practices evolve or change 'naturally', or can, in theory at least, be actively changed to fit a new vision of the future. If changes in practices are to happen, however, all three elements need to be addressed. In the context of infrastructure design, this means that if the aim is to enhance the take-up of NDTs, staff not only need to be given the stuff (computers with the necessary processing power and software) and the skills required (e.g., training in BIM), but also accept an 'image' of, for example, BIM, as superior in terms of design, accuracy, cost- and time-saving, and so forth. Personal identities intersect here, such that meanings are framed in complex relations with, for example, our gender, age and professional background. In this way, workplace practice change can trigger nostalgia for the perceived loss of identities formed through 'traditional' stuff and skills. Consequently, practice change may be resisted (Nye, 2007).

Changes in practice, therefore, involve elements of both risk and trust. The concept of risk, particularly in technical assessments, has grown in usage over the last 20 years but is largely understood in negative terms: as leading to an undesirable outcome in the future. Luhmann (1993) argues that the growth in the traction of risk is because the decisions of individuals or

organisations, not least those in the infrastructure sector, can be identified as the root cause of disasters, and it is, therefore, demanded that their decisions obviate danger, or they be charged to account. People may therefore be risk-averse and unwilling to change practice for fear of negative consequences. The concept of risk has also gained in importance because society's dependence on decision-making and strategic planning for the future has increased: risk now dominates ideas about the future (Lupton, 2013).

Trust is a tool to reduce the complexities of risk and enable people to act (Beitat, 2015). Trust plays a significant role in systems such as the infrastructure industry, as a mechanism to foster cooperation in highly specialised, complex and fragmented delivery environments. Past and present experiences of risk and trust, and our own senses of agency to impact on these through our practices, underpin our imaginaries of the future. With the development of digitisation in the infrastructure sector, there must now also be trust in the technology as well as its people and organisations.

DIGITISING THE INFRASTRUCTURE SECTOR

The infrastructure sector is a broad church, including all those assets necessary to enable society to function effectively: energy, transport, water, waste and, increasingly, digital. It is the sector's role, and the job of the civil engineers it employs, to construct, maintain and improve these aspects of the physical environment, which include *inter alia* bridges, tunnels, roads, railways, airports, buildings and cables. Both within the United Kingdom and globally, the infrastructure industry is often perceived by governments and the sector itself as facing critical challenges (Balfour Beatty, 2019). The sector is marked by very low levels of productivity growth, averaging at 1% for the last 20 years (Argawal et al., 2016). It remains resolutely low-tech with minimal levels of automation and thus, in contrast to other industries which have successfully harnessed technological advances to improve and reshape their products and services, infrastructure is perceived as 'lagging behind' technologically. Large projects typically take 20% longer to finish than scheduled and can be up to 80% over budget (Argawal et al., 2016). Operating at 'wafer thin' profit margins, and suffering from an 'old-fashioned' image, the industry struggles to attract skills (Balfour Beatty, 2019).

As an industry 'ripe for disruption' (Argawal et al., 2016, p. 2), policy analysts have positioned technology as the catalyst for change. NDTs are emerging to reimagine infrastructure projects, such as, for example, Elon Musk's infamous 'boring tunnel'. Higher definition surveying, geolocation and visuals tools and next generation five-dimensional (5D) BIM are among those seen to have the potential to address skill shortages by changing the outdated image of the industry. The Internet of Things also has the capacity to improve health and safety and communication on site and improve collaboration through moving engineers from paper to cloud-based sharing of information.

Against this background, our case study research was conducted in 2019 in the central London headquarters of *InfraTech*, a large, global engineering and development consultancy with over 16,000 employees working on projects all over the world. While their key strengths are in the traditional areas of energy, water and transport, a key part of the business is in social development: global health and education. Our key informant, a member of the 'Strategy Team', explained to us that, to cover this wide range of expertise, over the last few years InfraTech has been highly active in undertaking technological analysis, horizon scanning and scenario setting, and developing a digital strategy for their future engagement with NDT.

Several staff members are involved in UK Government-led working parties and consultations on digital futures in infrastructure such as digital twins. Together with others across the sector, Infratech overtly positions technology as having the potential to solve problems of low productivity growth and profit margins and improve other challenges such as widening public consultation. More specifically, InfraTech are keen to place themselves as being at the forefront of digital innovation and creative technological excellence in civil engineering. The most widely used technology is BIM, 'a digital tool and organisational process used to represent buildings in 3D digital models and databases and to facilitate coordination and communication within building projects' (Neff et al., 2010, p. 558). Engineers are being encouraged to move away from traditional, 2D paper-based drawings and multiple face-to-face meetings with different expert teams, to design and collaborate virtually through developments in BIM and online communication tools. However, at the same time, InfraTech was also becoming sensitive to the fact that change is slow, and high levels of anxiety are emerging amongst their staff, as well as in the engineering profession generally, about technology and the future. Some engineers are becoming increasingly concerned that their jobs could/would be replaced by AI and advanced forms of BIM. We had been invited to contribute to an investigation of these concerns.

METHODS

To enable in-depth understanding of everyday work practices (O'Reilly, 2012), we conducted an ethnography in InfraTech's central London headquarters in the first 3 months of 2019. Author B was based here full-time for three months, working alongside engineers on a daily basis, while Author A spent time in the organisation on a part-time basis. During this time, 49 semi-structured interviews were conducted with senior management and engineers, as well as those involved in digital delivery and strategy. For contextual background, we also interviewed staff in human resources, training and the law team, as well as stakeholders external to the organisation, such as clients, a skills agency and an engineering professional association. Reflecting the gender distribution in engineering (Engineering UK, 2018), our sample consisted of $n = 39$ men and $n = 10$ women.

Interviews were held face to face, or via Skype with staff in other UK or international offices in the United States, the Middle East and Australia. Participants were asked about current technology use and what they perceived the barriers, challenges and opportunities are in relation to this. We then moved on to 'the future', inviting participants to imagine the future of the sector, their profession, the organisation and their own careers in relation to NDTs. In addition, we attended a workshop with early-career engineers to brainstorm ideas on 'the digital future', as well as the Annual General Meeting, where this topic was also addressed. We were given complete access to the organisational intranet to read policy documents, organisational news and chats.

Interviews were recorded and professionally transcribed and, together with our ethnographic fieldnotes, submitted to close textual and thematic analysis through NVivo and manually. We first coded the data according to key concepts relating to the practice approach: skills/competences, materials/stuff and meanings/image, both in relation to the present and to the future. While discussion crossed conceptual boundaries, we used the concept of *Competences* to capture discussions of skills, training, work tasks and perceptions of ability to use technologies such as 2D drawings, 3D technology such as BIM, geographic information systems (GIS) and virtual reality (VR), AI and 3D printing. The concept of *Materials* was used creatively,

to encompass 'stuff' such as computing hardware and relevant industry standard software packages such as Revit and AECOsim, as well as NDTs mentioned above. In addition, as all these materials require detailed navigation through complex commercial and legal issues which affect the design and use of data, we included discussions of these under this heading. Although these issues are intangible, they are a very material part of the landscape of the industry and frame—and possibly curtail—some of the more innovative aspects of infrastructure's digital future. *Meanings* incorporated discussions of how work, work identities, work practices and work cultures of the engineering profession and wider industry may change due to increased digitalisation.

Building on this and inspired by the theoretical literature on diverse sociotechnical imaginaries, we were also interested to tease out the positions people took in relation to these through their talk and practice. We thus coded our data a second time, to identify patterns of meaning across the data set: recurring and common themes in participants' language when talking about NDT practice change and the future. While our participants demonstrated diversity in the range of their imaginaries, our initial typology (Figure 1) provided a valuable 'conceptual-empirical' tool by which to start to analyze the variations in respondents' positions and what these meant in practice in the specific context of InfraTech. We thereby formulated a second typological matrix (Figure 2) to distil and classify the findings of our research. To acknowledge that there was some overlap and slippage in how people expressed their sociotechnical imaginaries, each imaginary is conceptualised as a broad continuum of attitudes from dystopianism to utopianism. As such, the matrix is intended to be illustrative, not exhaustive: An overarching frame to represent the diversity of imaginaries and practices in combination with the theoretical knowledge (Nind & Lewthwaite, 2020). As well as being a valuable 'descriptive tool' (Bailey, 1994, p. 12), we felt the typology might also be useful as a thinking tool for InfraTech's own strategic planning.

FINDINGS

Constructing the typological matrix revealed systemic patterns and relationships between the sociotechnical imaginaries and *InfraTech*'s organisational structure (Figure 2). Our analysis revealed intersections between roles and imaginaries, with those located in similar functions often sharing broad visions of the future. The perceived impact of NDTS on the competences, materials and meanings of different roles helps to explain this coherence, as well as the amount of agency held to negotiate such change. Sociological features such as professional background,

	Approach	Dystopian	Utopian
'Hard' ↕	Technological Determinism	**Dehumanisation** through loss of jobs/deskilling	**Revolutionary** transformation of systems and lifestyles
↕	Techno-sceptic	**Conservative** 'business as usual': work will not fundamentally change	**Good work:** important for health and wellbeing
'Soft'	Human-centric	**Justice:** control needed to ensure tech for public good and to eliminate bias	**Social impact:** new opportunities for tackling social inequalities

FIGURE 1 Typological matrix of sociotechnical imaginaries

Sociotechnical Imaginery	Competences	Materials	Meanings	Role in organization
Techno-Determinism	**Dystopian:** Loss of skills Risk of failure	**Dystopian**: Loss of traditional artefacts e.g. 2D drawings	**Dystopian**: Loss of the human Loss of professional identity	**Infrastructure project managers and 'on project' engineers** Low levels of individual and organizational agency
	Utopian: Exciting new skills Redefining the profession: data analysis	**Utopian:** New, advanced technological affordances Industry disruption Innovations in asset management	**Utopian:** New opportunities for economic efficiency	**Early career 'techies'** **Digital delivery managers** **Hobbyists:** High levels of individual agency Divisional-level agency
Techno-Scepticism	**Dystopian**: Lack of confidence and understanding and access to or time for training Pressure to get on with the job	**Dystopian:** Complexity of legal and commercial landscape Lack of appetite for change by clients	**Dystopian:** Affection for tradition Distrust of technology Risk aversion	**Senior Management :** High levels of individual and organizational agency
	Utopian: Systemic approach to training needed to reap any benefits	**Utopian:** Government legislation for technological deliverables necessary for change	**Utopian:** Effective management of organizational cultural change	**Middle Management :** Lower levels of individual and divisional-level organizational agency
Human Centricism	**Dystopian:** Need to think about long term consequences e.g., data trusts; data ethics	**Dystopian:** Data security Data protection	**Dystopian:** Resistance might lead to loss of beneficial social outcomes: Tech prioritized over people	**Digital delivery managers:** High levels of individual agency Divisional-level agency
	Utopian: Release from routine/time-consuming tasks open space to develop new skills in data analysis and social science	**Utopian:** Open-source data and tools	**Utopian:** Greater transparency for citizens New possibilities for social outcomes	**Development and Environmental project managers:** High levels of individual agency Divisional-level agency

FIGURE 2 Typology of InfraTech's sociotechnical imagineries

career trajectories and the social structural homogeneity to be found at different levels of responsibility within the organisation are also influential. While most demonstrated consistency in their broader sociotechnical imaginery positioning, within this there was variation between participants, with some articulating *either* a utopian *or* a dystopian version, while others held a mix of both.

Particularly striking was how, in spite of the organisation's public rhetoric about the utopian future that NDTs will deliver to the sector in the future, our analysis exposed that many of those in the most senior roles held a technosceptic imaginary of 'no change'. Vacillation was found within this positioning on the dystopia–utopia spectrum, with some senior managers shifting between the two within the same interview. Furthermore, technoscepticism did not stop at this level: it also dominated across middle management. With this imaginary pervading the upper structural levels of power and organisational agency, it is unsurprising that technological change is not fast paced within the sector.

From our other interviews across the organisation, we found that those who did express technodeterminism, especially the more utopian versions which the organisation ostensibly supported, were in less senior positions within the organisation. As such, they had lower levels of organisational agency to facilitate wholescale change although, as we will go on to demonstrate, relatively high levels of individual agency over their own work. Those whose views reflected technodeterminist dystopianism tended to be located at the bottom of the power/agency structure, in roles driven by client demand and tight budgets. Those who held human-centric positions, of both dystopian and utopian persuasions, expressed higher levels of agency, seeing their roles within the organisation as enablers of change. We now turn to discuss these findings in more detail.

Technodeterminism

The new interfaces opening up between engineering and technology are providing seemingly unbounded motivation for the future for some members of InfraTech, who reflected a 'utopian' version of technodeterminism in their imagination of engineering futures as completely digitally-driven and, therefore, inevitably much improved. Devotees to this imaginery consisted predominantly of young men in their 20s and 30s, with either a high-tech engineering bent or a computer science background. These were joined by some more senior managers from highly technical backgrounds in their 50s with specific responsibility for digital delivery. For example, Nick, Senior Digital Manager, in his 40s opined: *The boundary between technology and engineering- that's where the best place in engineering is right now!*

The technodeterminist utopian imaginery occupied an important symbolic role within the organisation. A sizeable cohort of computer scientists had recently been recruited to join a new, high profile, project team established within InfraTech for 'digital innovation and enterprise'; their very existence seen to prove the organisation's commitment to NDTs. The team are afforded a high degree of individual agency to plan their own work, and spend their time 'innovating' with tech, pitching new ideas directly to senior management. Some brought their laptops into our interviews, eager to demonstrate their latest digital invention.

Utopian technodeterminism also appealed to those with an engineering background who were clearly inspired by NDT materials at the vanguard, such as the new affordances of VR, GIS, 3D printing and modular building. The unsystematic approach to skills training within InfraTech was leading to some learning how to use this new software, and even dabble at the frontiers of digital technologies, in their own time. As David, an architectural engineer in his early 30s explained, *I'm a bit of an anomaly because I've actually trained myself through YouTube!* Small teams are forming to disrupt traditional working practices, and real developments in timesaving are meaning that some tasks previously requiring months now only take days or even minutes. We heard of one team who dedicated their focus to automating the design of a water pumping station, leading to a dramatic reduction in the time taken from 3 weeks to just 15 s:

> That was a pilot project just to see what we could do with it, and we, basically, were told that we had absolutely knocked it out of the park! It went beyond all expectations. And what that essentially did was that opened up a lot of people's eyes at a high level, they went: 'Oh, blimey, gosh, this BIM thing and this technology thing, it's got legs, hasn't it?'. (Andy, Senior Engineering Technology Consultant, 30s)

Successes such as these are given high profile, used in marketing and branding to demonstrate InfraTech's technological savviness. A seminar we attended on 'the future' revealed that some see infrastructure as an industry ripe for disruption: 'Big Tech' giants such as Google, Facebook, Uber or Tesla, with track-records for acquisition, may perceive infrastructure's comparatively low-profit margins as of high potential for new market entrants:

> Construction-tech is the new hot potato in the venture world, because it's a different ball game. It's the newest in-thing, getting a lot of funding all over, especially in Silicon Valley and other places: because the industry's got sluggish productivity, this is seen as very ripe. (Taposh, Digital Senior Analyst, 30s)

Radical potential was also seen to exist for data to revolutionise the way assets are created and managed, and for more economic value to be derived from existing assets. New opportunities are presented through connecting different datasets together in new ways to generate insights about how physical assets are performing, and hence how they could be improved to create economic or environmental efficiencies and enhance national productivity. New possibilities were also seen to be offered through the open sourcing of data, allowing not only large infrastructure organisations but other budding developers to share knowledge and skills. In sum, from a technodeterminist utopian position, with technology as the driver, the future of infrastructure is bright.

In marked contrast, there are those in the organisation whose imaginary of the future is bleak. Some engineers expressed real concern at the perceived ability of NDTs to replace the traditional skills of engineering practice, and demonstrated deep reluctance to undertake re-training in 3D skills when 2D had served them well for many years, if not decades. Often those in mid- or late-career working on traditional infrastructure projects such as railways and highways, bridges and tunnels, losing skills they held dear to reskill provoked a clear sense of anxiety. Exposure to testing and assessment means, potentially, risk of failure:

> It's an anxiety and if you're past the point in your career where you're going up, maybe you're levelling off or even going down in terms of your progressions, that brings pressure. A lot of people are avoiding it, saying, 'Oh, it doesn't work' or, 'I haven't got the right software' or, 'Oh, it's not as good' or 'This is too stressful, I fear for my job'. Apparently, somebody went on leave due to stress. That's the most extreme example. (Jack, Projects Director, 50s)

Geographical location was also positioned as significant to enthusiasm for technological engagement. Different regional offices were seen to have very different digital cultures, perhaps a reflection of the challenge of uniting multiple fragmented sites and projects under one strategic vision with lean resources. Some were derided as being 'little empires', 'stuck in the dark age' and 'technologically backward':

> You walk into some offices, mentioning no names, and it's like going back in time. Big tables, drawings everywhere, these people do not want to give up their paper without a fight! (Alistair, Project Director, 50s)

> Some people scattered up and down still have a 'traditional' view of the role of an engineer. That traditional mentality cascades down to not releasing budgets and investments needed to keep us on top of the curve. (George, Digital Designer, 30s)

The situation can be compounded by a lack of appetite for more digital solutions by some clients. As one engineer explained: *'if a client doesn't want to drive it digitally, it's quite difficult'*. There is large variance in clients' material demands with some, such as the UK government, increasingly requiring digital deliverables (BSI, 2016), while others still demanding 2D 'drawings':

> It might be that we've used some intelligent tool to produce those drawings, but it's still the drawings that are the contractual deliverable, so that's exactly the same as 25, 50 years ago. We're just using technology to make it slightly more efficient, but it's not a wholesale change, it's very behind the times. (John, Divisional Digital Delivery Manager, 50s)

NDTs can create further anxiety within an already risky decision-making landscape. Perceiving low levels of ability to maintain the status of traditional skills in the future, the only means by which these engineers may demonstrate agency is by resistance through negativity and/or non-compliance, or through absence such as sick leave. This individualised resistance reflects a broad acceptance that NDTS are a significant shaper of the future, but that there is very little they can do to change this. The technodeterminist dystopian discourse of the 'loss of the human' resonated through the accounts of these older participants. Memories of earlier career stages were recalled with affection and pride. 2D, whether on paper or screen, was conceptualised as a 'craft', and the skills needed in producing high-quality drawings and accurate calculations are clearly integral to some engineers' sense of identity. These stories make it clear that there is a lot at stake here: the future is not just about changing the way things are organised or done, but also about changing engineers' identities, work practices and cultures, senses of self-worth and achievement, the shape of careers and the redistribution of status and power.

Technoscepticism

> Who's in charge of construction and infrastructure? Forty-eight to fifty-year-old white men, like me, not confident with technology. People like me have created a dam. We make decisions, and we don't invest... because we don't understand it. (Nigel, National Skills Agency, 40s)

Senior management at InfraTech is dominated by white men in late middle age who trained as civil engineers years ago. Their own competences with NDTs are low but, as these skills are not required in their day-to-day work of leading the business, little interest is expressed in personal upskilling at this stage of their careers. Further, the daily pressures of delivering the organisation's strategic vision 'to make a difference' through their infrastructure and development projects while, at the same time, maximising profit, means that, in spite of the rhetoric, allocating resources for a wide (and expensive) rollout of digital upskilling is not positioned as an immediate organisational priority either.

This reluctance to upskill was bolstered through an underlying attachment to the 'pencil and paper'/'chalk and talk' types of skills in which they were trained. Many were proud of civil engineering as a profession, not least the form in which they had been trained. They clearly enjoy their current practice of face-to-face 'hands-on' leadership, although that this is economically and environmentally costly due to the frequency of international trips. A *technosceptic dystopianism* towards the future was reflected through rebuttal of any suggestion that this would, or should, be replaced by communication technologies and practice change. Reluctance for any destabilization of the status quo was strengthened further by a concern that the 'techies' are myopic, privileging technology over people, which is the 'heart of the business' (Gary, Strategy Manager). Many commented that they disliked the way technological discourses reduce real people to the abstract concept of 'humans', worrying that, if technology leads decision-making, the 'civic core' that has

traditionally characterised the engineering profession may be lost. While clearly aware of some of the utopian possibilities of NDTs, these are distanced to some abstract time in the future. The consolidation of power and agency within the senior management team mean that, while they remain in positions of governance, their imaginary of the future as being fundamentally similar to what exists at present, remains the reality.

A rung below them in the organisational hierarchy, middle managers also projected a predominantly technosceptic imaginary of the future. Our practice approach helped to reveal the range of factors that feed into their dystopian belief that technological change is unlikely soon. While this level possesses lower levels of individual and organisational agency than senior management, they are in roles which carry large amounts of regional responsibility for the delivery of large-scale projects. This helps to explain the fact that that risk aversion is endemic when it comes to adopting anything new within the sector, as Andy, a Senior Engineering Technology Consultant, explained:

> As soon as you introduce a little bit of technology, that takes that calculation away and it becomes almost like a black box... where you input things and then a calculation comes out at the end. There is an element of distrust in that.

Fear of being sued by external actors or even other contractual stakeholders was felt acutely and can deter innovation:

> [the] industry is really quite litigious. Every single day you're making a decision that could go wrong. It is really hard to go, 'Oh I'll just do something new', because it could end your career or cost the company millions. So, staying with what you know tends to be the safe zone that is—what you've built your career on. (Jenny, Practice Leader)

As well as admitting to risk aversion themselves, middle managers were also often identified by others within the organisation as a critical barrier to transformative technological change. However, here it was their age, career stage and lack of technological skills which were cited as key reasons for their technosceptic dystopianism:

> The 'sticky middle'... the ones who are just old enough to not quite get it, who have not been doing it on a day-to-day basis, so they find the concepts a little more tricky. They are absolutely driven to manage the business in a particular way, given the structure of the business and the framework that we work within, and the KPIs that we work to. So, it is difficult for them to get the opportunity to change, and it is difficult for them to see how to change, because they are not hands-on enough with some of this stuff. Also, they are just traditionalists as well. (Jamie, the Head of Digital Design)

> It's the same as everywhere, it's the older engineers that say, 'I did Channel Tunnel this way 30 years ago and why should I change? That project was quite successful'. ...yeah, but you delivered that with a team of 5,000 people! You can do the same job now with a team of 400 people in terms of the design office side. (Conor, Digital Delivery Leader)

Older age, combined with a career forged through client-facing and management and roles, can mean a lack of exposure and familiarity with NDTS. However, while it was indeed the case that adherents to technoscepticm were 'older' (50 and above), it is important not to automatically conflate reluctance for technology with age and/or life stage. Some older engineers we talked to were clearly embracing the new opportunities presented by digital developments with real enthusiasm, enjoying adapting their skills in new directions.

The position of middle managers can be further explained by deeply embedded structural factors within the sector over which they have little control. Significant here is the relationship between access to training and length of projects: Whereas longer-term projects of, for example, several years, might release some time and funding for upskilling, the pressures of delivering multiple shorter-term projects to lean time frames and budgets leavers little space or opportunity for new skills development. NDT training for engineers of all levels is often therefore a case of luck, of being assigned to the right project:

> It's quite a hard industry we are in. There is a lot of pressure: 'just get the next job out' and sort of 'rats on the treadmill'. The margins are low, the training budgets are very low, everyone works really, really hard. There's not a lot of time for learning, not much funding or structure towards wider thinking. But realistically, it's a false economy. (Mark, Divisional Manager, late 40s)

However, a more utopianist glimmer was expressed through a few of the middle managers' hopes that a far more concerted and professional approach to organisational training would inevitably become seen as necessary:

> It's not just something you can pick up after looking on Google in a couple of hours! You need more people who actually do this kind of stuff for a living and can build big reliable software systems that thousands of people can interact with. (Mike, Senior Engineer, 30s)

Those directly involved in training argued that with more effective management of the organisation's training policy, gains in skills and capacity could result.

A combination of their roles as managers responsible for the 'bottom line', unfamiliarity with NDTS due to age and career background, and work practices within the sector as it is currently structured contribute to the dominant sociotechnical imaginary held within Infra-Tech management being technosceptic dystopianism. As this group holds the highest levels of agency for organisational change, it is unlikely that fundamental technological change will happen until the current executive team have been replaced by the younger cohort, preferring different imaginaries, who are currently moving up through the organisation.

Human-centricism

The promises of technology to release us from routine and time-consuming tasks offer a utopian vision of the future to some. This, it is imagined, will open new spaces and exciting opportunities to focus on the social and environmental outcomes of projects, challenging social inequalities and carbon emission levels. A 'human-centric' imaginery was largely displayed by engineers working in functions such as sustainability, development and social impact

evaluation, who had a degree of autonomy in designing their own projects. At the same time, as these were often not 'big bucks' projects in terms of winning fees, their position of influence within the organisation was more marginal. However, acquiring power was not necessarily their driver: Their utopian imaginaries were constructed through the identity of the socially impactful engineer. Many explained they had chosen the profession, and the organisation, because they wanted to make a positive difference to society. This, for them, is the real purpose of engineering, and being better able to centralise this in the future is a clear motivation:

> I guess lots of engineers are like that, really want to make the world a better place, I know it sounds a bit idealistic and a bit too broad, but I think that engineers look to do that in many different ways. I see in digital transformation an opportunity to bring about a bigger better change in the industry. It's seeing that this really is an opportunity. (Mike, Technical Director, 50s)

> By making sense of the SDGs [the United Nation's Sustainable Development Goals] locally, it's possible to address them in projects. Any infrastructure project has impacts. I think about development of metros, or the value of properties around a new station - it skyrockets. We need to understand all these impacts as well, the first mile, the last mile, how you reach the station. There's a lot of health and wellbeing, there are inequality aspects. As a consultancy, you are going to be chosen for the best solutions whether the client is governmental or private. Better solutions—not just technically or financially—ones that make everybody happier. (Luca, Sustainability Director, 40s)

For engineers occupying this position, the revolutionary potential of NDTs is a valuable resource which must be carefully, and responsibly, 'engineered' to maximise social and environmental outcomes. Some recognised that shifting the focus from technical and design decisions to evaluating social impact and designing new methods to make a positive difference to societies through infrastructure will require different sets of skills:

> Engineering doesn't exist now without a level of a sociology or economics. Those three disciplines are more closely together now than they ever have been and will only get closer. (Graham, Divisional Manager, 50s)

> Particular disciplines [are] very dominant, but that is changing over time. The optimist in me says that's the natural evolution of the profession, you start to see new job opportunities that attract a different type of person from a different background with a different degree. Instead of only employing chartered engineers, it might be good to have a social anthropologist for certain projects. If it works well, you think, 'We need another one of those!' What rails against that is inertia: If all you have is a hammer, everything looks like a nail! (Bill, Global Practice Leader, 40s)

Human-centricism intersected with a sense of personal agency. These engineers were looking forward to acquiring broader skills sets and combining their engineering skills with those from the social sciences. New possibilities were also seen to be offered through the open sourcing of data, and human-centric utopians were excited by the democratisation of access to this. However, this utopianism was countered by others who were concerned with more

dystopian issues of technology's potential for social harm. Caution was expressed by some engineers that while NDTs undoubtedly offer real opportunities, care and responsibility needs to be taken so as not to ignore 'the people side' in imaginations of the future:

> Bringing new technology is easy: you press a few buttons, make sure you've got the hardware in. But *people*, that is the area I feel is most neglected when companies go through this kind of transition. (George, Digital Designer, 30s)

In short, to avoid dystopia, the future we wish for needs to be carefully planned and managed, and this was seen to be important at a range of scales. At a sector level, it was recognised that the new possibilities for open data and data sharing across the industry and beyond also raise important issues of data security and the protection of personal data: *How do we keep our data secure? I don't think we've even begun to think about that* Andrew, one of the Senior Strategy Team admitted. Commercial and legal issues will require detailed navigation and may affect the design and use of data, as well as the ability of the sector to move forward both digitally and ethically, as Chun, one of the young digital innovators explained:

> On the one hand there's pushes for transparency, citizen data science... And, then at the same time, people saying, 'But, we have to value our data', and by that we mean economically value our data... those two things feel like opposite ends of the spectrum. How do we get beyond that point?

At the organisational level, concern was expressed at InfraTech's unsystematic approach to training and upskilling, and the structural inequalities being generated by leaving training to individual 'hobbying'. Without an open, transparent and equitable strategy for digital upskilling, pre-existing inequalities in terms of opportunity, time and ability may become more deeply entrenched in the future, as Christine, Head of Training, observed:

> It's not necessarily fair or easy for employees to do that, you know, try having six kids and cope with a job like this, good luck with that and then be a community contributor as well, ha!

In spite of these concerns, many we spoke to expressed real commitment to InfraTech's identity as a socially impactful organisation, which prioritises beneficial social outcomes as well as economic viability within its infrastructure projects. To this end, some were uneasy that the slow take-up of NDTs within InfraTech might lead to a wider human cost:

> I just hope that we don't end up being too cautious and miss the opportunity, and then find that somebody else has gone and done it, and maybe somebody kind of worse than us. (Mike, Technical Director, 50s)

CONCLUDING DISCUSSION

This paper explores engineers' imaginations of the impact of NDTs on their profession and the infrastructure industry in the year before the Covid-19 pandemic, which triggered a wholescale shift in the centrality of online tools for all occupations. Our typology of sociotechnical

imaginaries has provided a useful conceptual tool to categorise the diverse positions occupied by different engineers at InfraTech at this time, and what this may mean in terms of motivations to shift to and design new work practices for the future. From our empirical analysis, we are able to identify reasons for the slow take-up of NDTs within InfraTech, but also that the organisation, and civil engineering as a profession, are at an interesting—if not critical—moment to exert agency over the design of its future relationships with NDTs. Three key conclusions can be drawn in this regard:

First, drawing on STS and practice theory, we highlight the importance of agency in shaping engineers' imaginaries of infrastructure futures. Our findings demonstrated the nuanced relationships between imaginery with personal features such as identity, age, competences and career, organisational features such as role, responsibilities and working practices, and sector-wide factors such as risk, profit margins and professional conventions. These combine to contribute to both individual and organisational agency. Thus, while there was no simple or automatic mapping of, for example, age or role onto an allegiance to a particular imaginery, our typology reveals patterns within the diversity of the engineers' positions in relation to agency. We do not see these imaginery/agency relations as inevitable or essential but produced through the culture/power relations of InfraTech at the time of our research. Agency was produced both discursively, in terms of the meanings and status attached to technological competences, and materially, through the allocation of resources. Our conceptual approach allows us to capture and interrogate this range of complex outcomes at InfraTech but also makes a contribution to current understandings of work futures in infrastructure and civil engineering as a profession as well as, perhaps, the wider digital economy.

Second, our findings reveal the consequences of different imaginaries for Infratech. The dominance of technoscepticism within management levels means that those with the most power and agency to effect transformative change are reluctant to allocate the resources necessary for this to happen. A fundamental disbelief in technology's ability to replace traditional work practices and what they saw as distinctive to civil engineering as a profession, feeds into a piecemeal approach to skills training, which not only fails to provide the breadth and pace required to upskill the workforce but embeds inequalities in access to skills of high value. A key reason for technoscepticism is the risk-aversion endemic to the industry. This is perhaps understandable: the consequences of error can be mass fatalities, as the 2018 Genoa Bridge collapse demonstrated so graphically. It can be impossible to ‘beta-test’ NDTs in infrastructure, and so relying on ‘tried and tested’ practices are viewed as the safe way forward. However, others across the organisation maintain that NDTs and AI help to minimise human error, and that the role of management should be to provide the trust and sense of direction that is now needed for change.

Furthermore, the ways in which technodeterminist utopianism is given high symbolic value within the organisation demonstrates, somewhat contradictorily, a recognition that technoscepticism is not an appropriate imaginary by which to frame the organisation and its future to the outside world. The recruitment of a new, fast-growing cohort of young ‘techie’ engineers and computer scientists, selected for their innovative technical and entrepreneurial skills, often wrapped up with no small degree of machismo, suggests new forms of knowledge and capital are emerging, by which to yield agency and challenge traditional structures (Mancini & Perry, 2014) for the future. At the same time, that this team is dominated by young white men reflects a gendered and racialised stability in workplace power and agency. Lack of diversity within those that design NDTs can leads to ‘techno-chauvinist’ systems of inequality and discrimination (Broussard, 2019). And, as Broussard (2019) argues, understanding the limits

and problems of technology design enables more informed choices about what we should be doing with technology to make the world a better place for everyone.

Our final point, therefore, is to suggest a manifesto for the future. Technological determinist utopians argue it is simply a matter of time before the 'old guard' retire and disappear, and the new cadre of highly technologically skilled engineers and computer scientists gain agency to transform the sector. However, the existence of multiple imaginaries raise possibilities of other, more dynamic and as yet unimagined visions of the future. On the one hand, the diversity of positions may not be so easily or swiftly reconciled, even representing a site of ongoing conflict and resistance. On the other hand, the call for 'tech for good' resonated through the interviews, and the awareness that the 'revolution' within the profession needs to be carefully and responsibly 'engineered' to maximise social outcomes, lends some hope that the future of infrastructure will include human-centric utopianism. Yet good intentions are not necessarily enough to ensure design processes and practices which do not, even if inadvertently, reproduce inequalities (Costanza-Chock, 2020). Now is the time for engineers of all sociotechnical imaginaries to collaborate and develop the principles to lay the foundations of trust in infrastructure's technological future.

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DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

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ENDNOTE

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