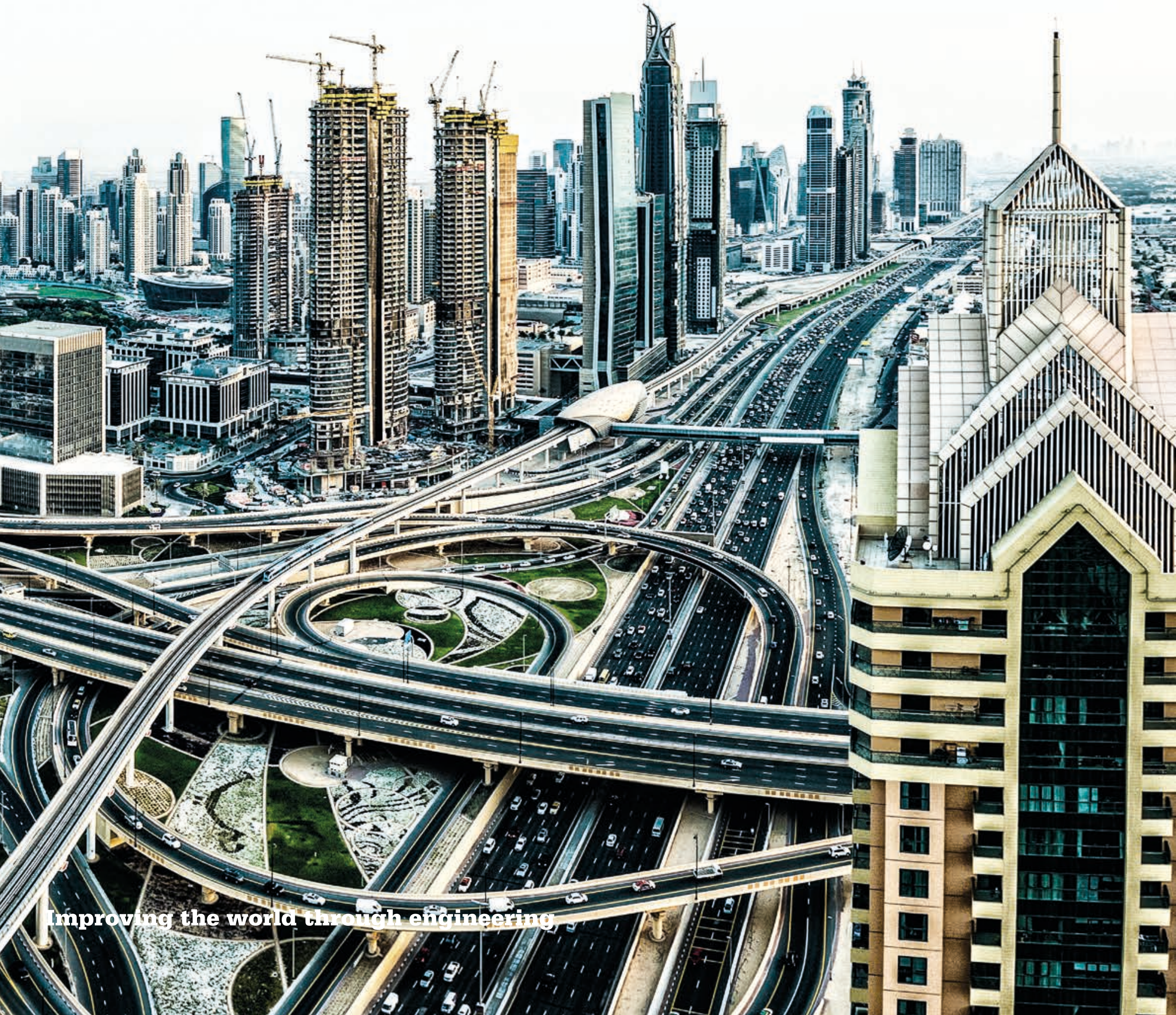
SMART CITIES: TECHNOLOGY FRIEND OR FOE?

Institution of MECHANICAL ENGINEERS



Improving the world through engineering

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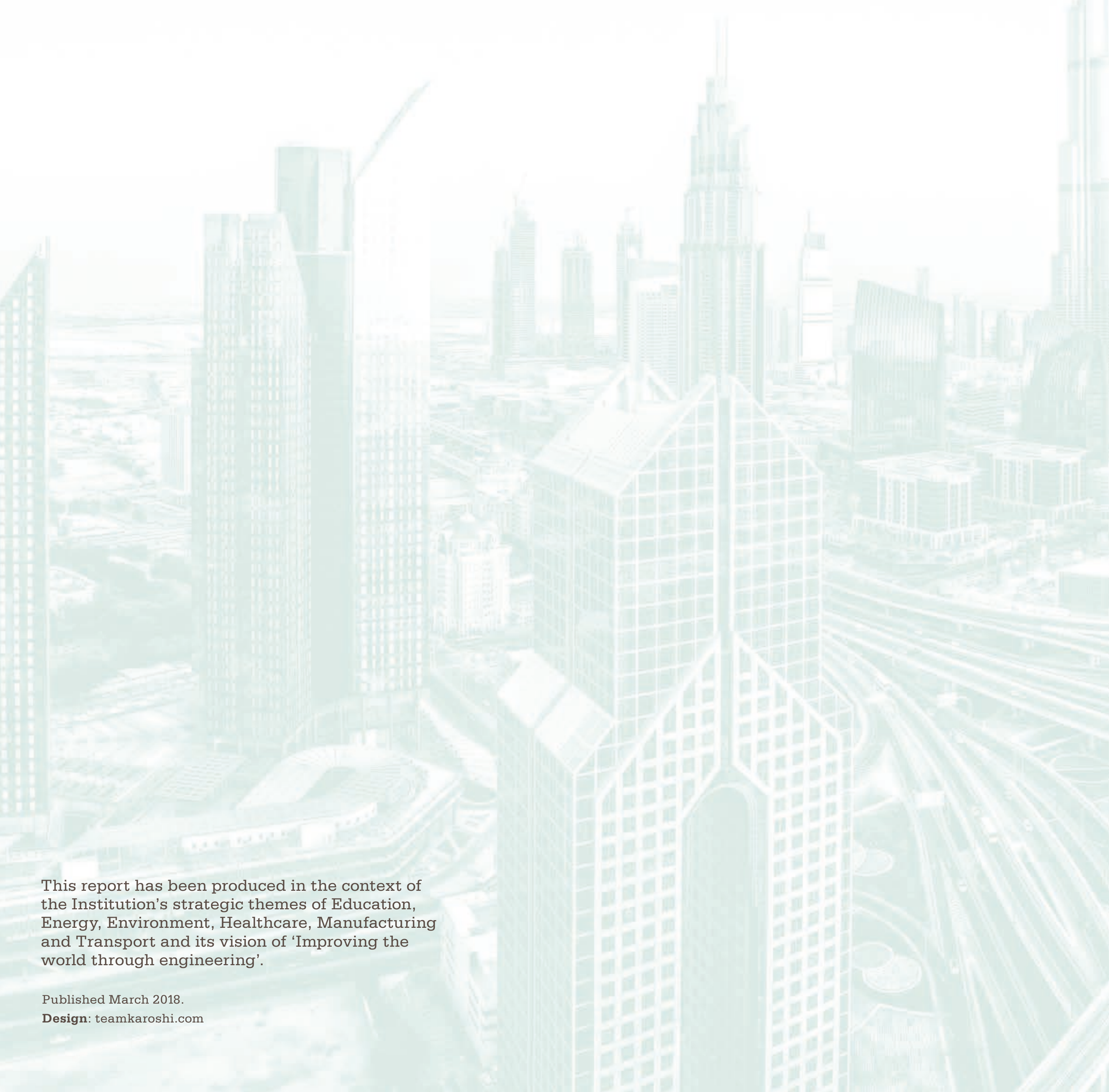
If the power goes off, even for a very short time, the disruption could be widespread and have far reaching economic and social consequences.



This report has been produced in the context of the Institution’s strategic themes of Education, Energy, Environment, Healthcare, Manufacturing and Transport and its vision of ‘Improving the world through engineering’.

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CONTENTS

EXECUTIVE SUMMARY

THE OPPORTUNITIES

Urbanisation is a principal characteristic of modern human life. Given the prospect of a world dominated by megacities and vast sprawling urban conurbations, much is at stake. Climate change, natural resource depletion and the impacts of ecological and environmental degradation all need to be addressed. It is therefore ever more important to ensure that cities are fair, safe, socially cohesive and humane places to live.

Digital technology and connectivity have a role to play in optimising the benefits of city living. However, this report clearly shows that much needs to change in the approach of technology companies, governments and city authorities if this role is to be successfully realised. There needs to be far less focus on projects and pilots that provide cities with Internet of Things 'bling' for self-promotion. Instead, more attention must be paid to seriously engaging with people's very real concerns about the use of technology in the cities in which they live.

Fundamentally, in the UK people have not been particularly concerned with the idea of 'smart cities' or the 'smart' technology application. In many ways, digital technology is seen as a 'business as usual' that should quite rightly be undertaken when it makes good economic and business sense. What does matter to people, however, are issues such as equality of access, loss of skills, future jobs, social interaction, data ownership, privacy, freedom of choice and value for hard-earned money, as well as a sense of place, community and purpose.

THE CHALLENGES

Today's culture seems to be competitively positioning city against city in a race to be smart city leaders. This culture is reinforced by UK Government smart city related programmes that encourage competition for access to the limited public funding available. What results are 'islands of success' that are inequitable and unsustainable. What is needed is more collaborative working, with increased connectivity of cities to each other and their nearby rural communities.

No city can be considered 'smart' if it does not ensure equality of access to services for all its people, particularly those who are digitally unconnected. In the UK, 13% of people are not connected to the internet. A parallel mix of digital and non-digital access to services must be designed and maintained. More attention needs to be paid to ensuring that opportunities for traditional human modes of face-to-face, person-to-person communication remain during the digital transformation. Social cohesiveness relies on shared physical space for gathering, socialising, collaborating, and experiencing and sharing the arts. Digital integration must be less about efficiency and cost benefit and more about enhancing lives in ways that are genuinely meaningful to people and their sense of purpose.

Productive work and the attendant need for knowledge, skills, experience and recognition are core to a sense of purpose. Technology has already enabled a move towards higher levels of independent working, and the emergence of a 'gig' economy. The trends of automation, robotisation and artificial intelligence are set to continue. There is therefore a need for a fundamental change in the nature and character of education, training and skills development to keep pace. In short, a radical repurposing of the nation's educators and trainers must be urgently considered.

A key part of the success of smart city initiatives, however, is privacy of data and personal space. Failing to understand and engage in people's concerns in this area has been shown to lead to a backlash that can terminate digital integration projects and programmes. Of particular significance is the use of data to provide unconsented insights into people's daily living and building occupancy patterns, as well as the possibility of using smart city monitoring systems as surveillance and tracking tools. People still feel they have a right 'to be let alone' and to exercise their freedom of choice.

Most importantly, the foundation of a digital future is electricity. Cities are already large consumers of power (about 76% of world production[1]) and the shift to increased digital integration will grow this demand further. It will also increase the requirement for an absolute 24/7 reliability of supply in cities 365 days a year. The need for new levels of resilience and reliability must be recognised and, in particular, the cyber security challenges faced. There needs to be higher standards, better regulations and best practice guidance. If the power goes off, even for a very short time, the resulting economic and social impact could be substantial. Ultimately we must ensure that basic services, such as power, water and sanitation, will continue to function, albeit at a reduced level, at all times.

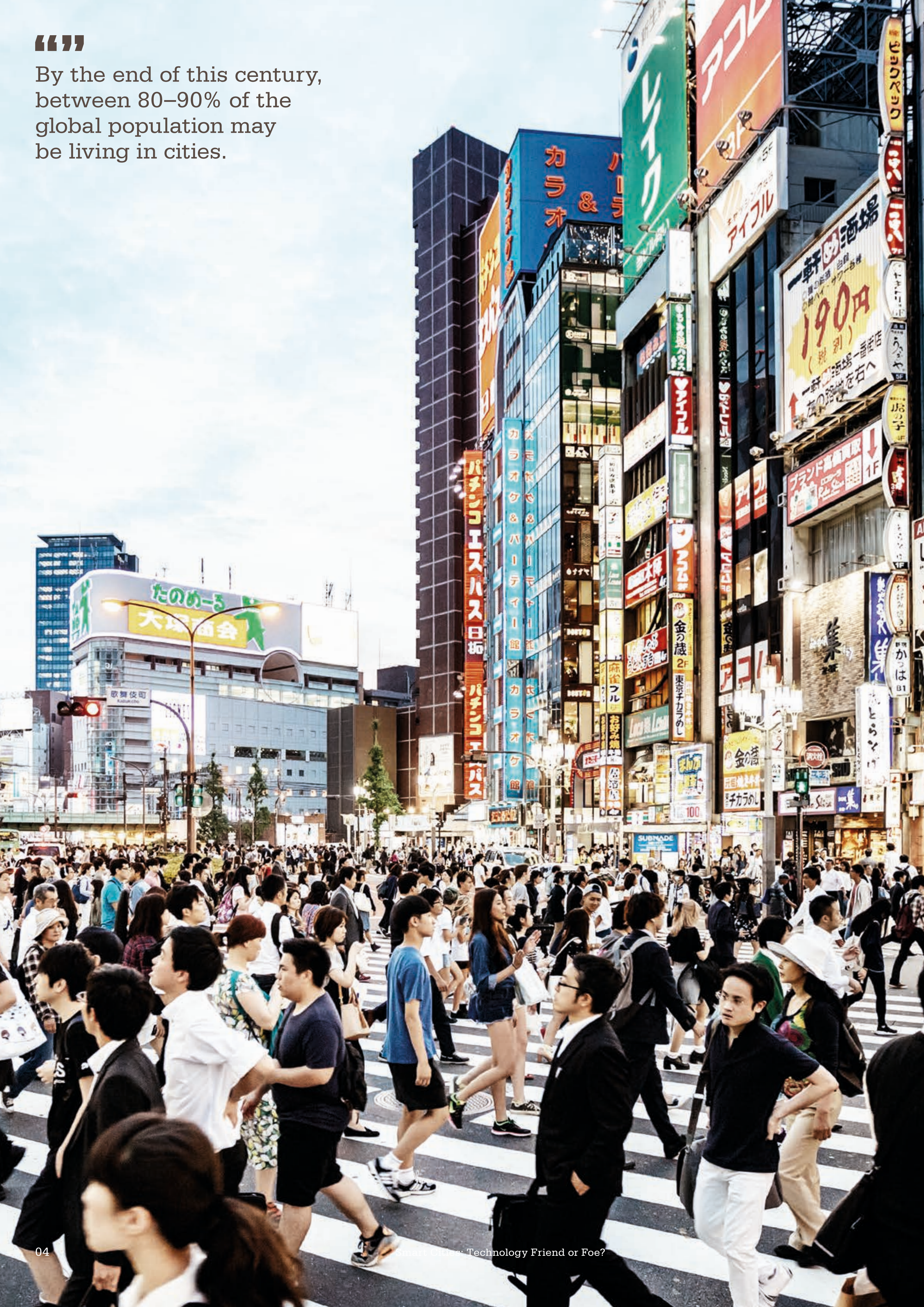
SUMMARY RECOMMENDATIONS

The Institution of Mechanical Engineers recommends the three priority areas for action in the short term are:

1. **UK Government includes the electricity system requirements of digitally integrated smart cities, in terms of both demand and reliability, in the planning of pathways to the nation's future power infrastructure.**
2. **City authorities focus more on collaborative working and sharing smart city learning across networks of cities, and engage with people's concerns regarding equality of access.**
3. **The education profession acknowledges the new skill sets needed for living and working in a digitally-enabled urbanised society, and radically reconfigures education and training to be fit for purpose in a 21st-century smart city future.**

See page 33 for detailed recommendations.

By the end of this century, between 80–90% of the global population may be living in cities.



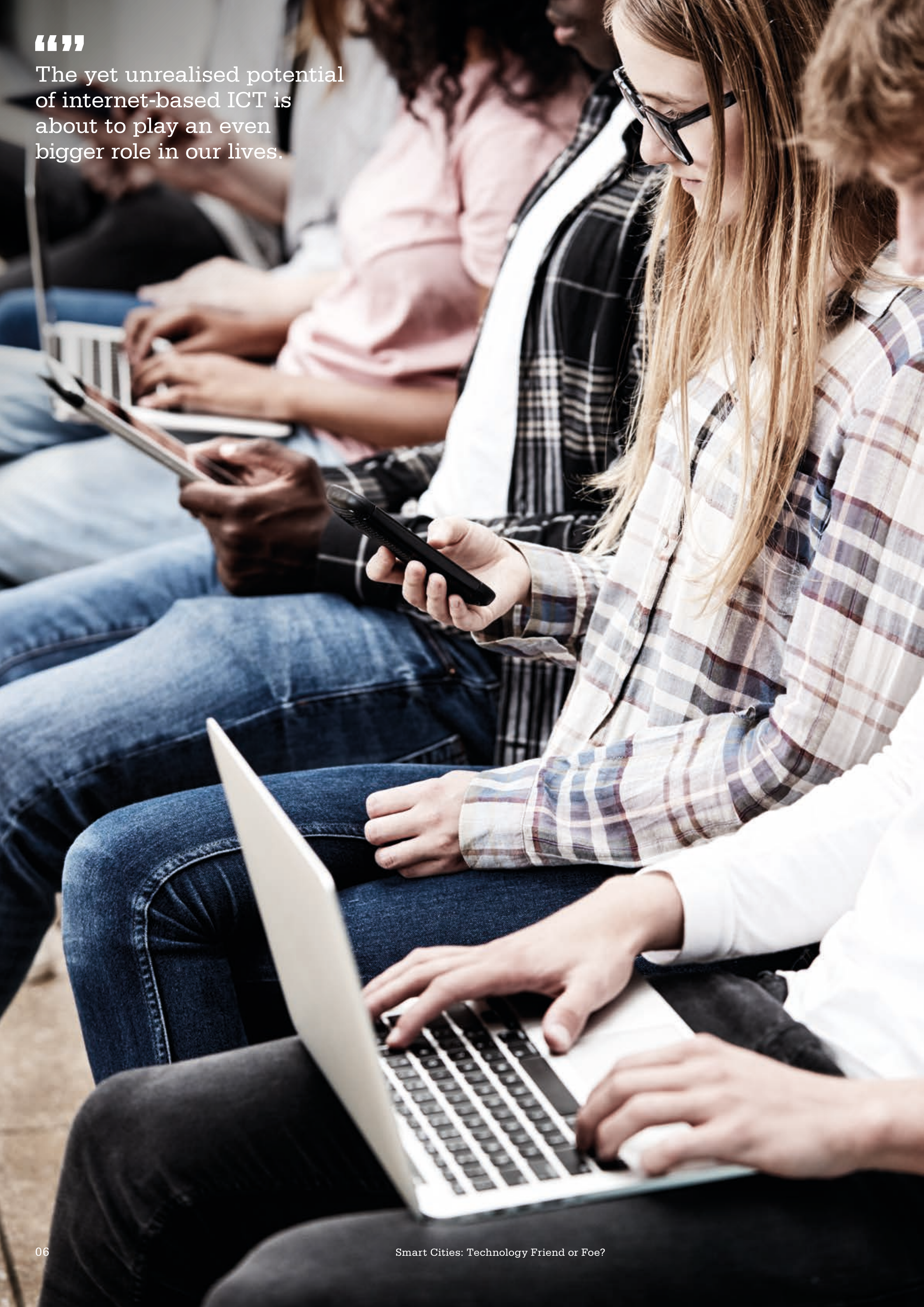
OUR FUTURE AS URBANITES

The population of the world is growing at an unprecedented rate, and as it does so people are heading to the cities to live. Urbanisation, the process by which more and more people leave the countryside to move into urban settlements, has been gathering pace since the end of the Second World War, and it shows no sign of slowing down. Today, about 54% of the 7.3 billion humans on the planet live in an urban setting, and as global population rises to an estimated 9.5 billion by 2050, the proportion of urban dwellers is projected to increase to 66%[2]. It is conceivable that by the end of the century humans will be almost entirely an urban species, with urbanites making up 80–90% of the world's population.

Rapid urbanisation, sprawling cities and vast urban conurbations in contemporary times conjure up images of the industrialising and developing economies of Delhi, Shanghai, Dhaka, Hong Kong, Singapore and many other Eastern cities. Indeed, urban development in these countries has been substantial and continues to be so. Singapore, a nation with 100% of its people living in the city, is in many ways an ultimate prototype for a possible urban human future.

Across Asia, and in Africa too, the large-scale migration of people from rural to urban environments is set to continue in the coming decades, with 90% of the additional 2.5 billion urban residents by 2050 expected to be located on those two continents alone[2]. Today, however, one of the most urbanised geographical regions in the world is Europe. The UK, for example, is currently 82% urban, with a projected growth to 89% by 2050 when the nation's population is anticipated to reach 73 million people. This continued urban expansion will place significant pressure on the ageing engineered infrastructure of UK's cities, such as transport, energy, water and sewage systems, much of which is centuries old and in need of constant maintenance, repair, partial renewal and expansion. By contrast, in the rapidly developing economies of Asia and Africa, the opposite challenge is apparent, with the need to build large amounts of engineered urban infrastructure from scratch. Infrastructure that will need to be fit for purpose to meet the demands of continued rural-urban migration in the decades ahead.

Cities have held a compelling attraction for humans over many millennia and as well as satisfying, through proximity, a fundamental psychological need for communication and sociability[3], they bring distinct practical benefits too. For example, modern urbanisation typically enhances opportunities for jobs, education, entrepreneurship, innovation and trade that in turn lead to prosperity, wealth and GDP growth. However, alongside these positive attributes many challenges are presented too, including access to affordable housing, overcrowding, social inequity, racial and ethnic tension, alienation, crime, transport congestion, pollution and severe pressure on infrastructure and services. If most of the human population on the planet are going to end up living in cities, how can society, and engineers in particular, help ensure that the benefits are optimised and fairly distributed in future urban environments, both in the UK and elsewhere, and the challenges tackled effectively?



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The yet unrealised potential of internet-based ICT is about to play an even bigger role in our lives.

TECHNOLOGY: THE URBANITE'S FRIEND?

Technology is for many people synonymous with information & communications technology (ICT), in particular the internet-connected smartphones, tablets, laptops, televisions and other electronic gadgetry that have become a core component in contemporary modern life. Indeed, so widespread has been the uptake of these devices in recent years, that it is hard to recall a time when they were not so much a part of our lives, or the names of the technology companies that provide them so prevalent. However, such is the as yet unrealised potential of internet-based ICT, that it is about to play an even bigger role in our lives.

In addition to using personal technology to access information and communicate with people across the globe, it is also already possible to connect with devices and sensors in homes via the internet[4]. The most obvious examples are the smart meter used to monitor domestic electricity consumption, or a webcam installed for security measures. In the near future however, the range of domestic systems and appliances that people will be able to access and control remotely in this way is expected to increase substantially[5] to cover, for example, items such as smart fridges and smart heating or cooling systems, as well as equipment to enable remote healthcare monitoring of less-able family members. The communication between these 'things' and personal technology will increasingly become a two-way process, with domestic appliances and home systems letting owners know of changes in status, sending reminders and providing news of opportunities to reduce costs or improve appliance performance[6]. In a further step, these things will communicate with each other automatically to optimise the performance and cost efficiency of the home in its entirety, turning machines on and off and adjusting their controls to suit an owner's personal preferences and the availability of low-price utility tariffs. Connecting all these things together, as well as with their owners, via the internet is known as the 'Internet of Things' (IoT)[4].

Technology companies want to go beyond the domestic home with the IoT. They want to use tens of billions of devices, sensors and cameras attached to engineered infrastructure, linked to computers via the internet, to do much the same for entire cities[4]. By connecting city-wide energy, water, waste and transport systems together, as well as to the systems operators and the people that live in the city, they say they can deliver the benefits of urbanisation while simultaneously tackling the problems of urban living, such as congestion, pollution, crime and social care. Many companies, governments and industry experts call this use of the IoT in an urban setting a 'smart city'[7]. The key selling points promoted by advocates of technology-enabled smart city are an increase in the efficiency of the services provided by city authorities, reductions in city operating costs, economic growth and enhanced well-being for the people who live in them. The big question however, is whether the use of technology in this way will help urbanites maximise the benefits of living together in cities, or will introduce new problems which present a set of additional challenges that prove just as difficult, if not even more difficult, to tackle. This report sets out to explore the answer to this question and to consider how engineers can help make sure digital technology is used to improve cities for everybody, and not make them worse places for people to live in.

SMART CITIES: CURRENT PROJECTS

The images invoked by the term ‘smart city’ have a compelling attraction to mayors and city authorities around the world. In recent years there has been an almost weekly stream of announcements declaring cities as ‘smart’, or on the way to being smart, by one definition or another. On every continent there are now dozens of initiatives taking place, many of which involve some degree of integration of digital technology with engineered infrastructure and city services. These range in character from genuinely new activities to a corralling together of existing projects or programmes under a new promotional banner. Almost all are, however, pilot or demonstration-scale trials of ideas. Across the globe there is no single recognisable example of a fully completed and operational smart city by any definition. Nonetheless, among the hundreds of initiatives, there are cities and national programmes that can be highlighted as examples of the different approaches being taken.

Barcelona is widely regarded as an evolutionary leader in developing and implementing, in the broadest sense, the digitally based smart city concept. The city has been through several iterative phases in a journey that has taken the idea from a technology ‘push’ starting point to a more socially minded, people-oriented version with an inclusive and participatory character[8].

On the other side of the world, Singapore can be singled out through its ‘Smart Nation’ programme[9] as the global leader of a digitally pervasive, data-intense, monitor and control version of the smart city. Likewise, the Arabian city of Dubai, in its mission to have the happiest citizens on Earth[10], is taking a technology- and data-intense approach with control at its core. However, Dubai has an additional high-profile futuristic dimension of pilotless air taxis[11], autonomous delivery drones[12], driverless cars[13], unmanned security patrol vehicles[14] and robotic police officers[15]. In a somewhat less futuristic and more locally interpretable version, India has begun implementing a national ‘Smart Cities Mission’[16] that aims to deliver 100 smart cities. In this programme, projects vary from large-scale digitally enabled city control centres located in the major urban conurbations[17], to the provision of basic physical infrastructure such as clean water, sanitation and power systems in relatively small urban settlements[16,18].

These and many other projects around the world, illustrate the diversity apparent in smart city thinking and perceptions of how such a city should be defined and implemented. However, despite the variety of approaches and the lack of a single model or blueprint, it is clear that the smart city name tag is popular and everybody wants one.

IOT AND THE SMART CITY

From an engineering perspective, the concept behind the Internet of Things is not new. The use of a computer network to connect sensors and control systems on machines with operators located remotely in control centres, is something engineers have been doing for many years. Indeed, since the mid-1960s, computer-based supervisory control and data acquisition (known as SCADA) systems[19] have been a core tool used by engineers for the efficient operation of industrial plant such as power stations, oil refineries, gas processing facilities, chemical works and car factories. Over the years these systems have evolved from isolated networks of sensors and controllers, connected to dedicated early versions of micro-computers, to today's sophisticated internet-connected versions that fully utilise open networks and cloud computing. What is new for engineers however, is the extensive use of ICT at very large scale to rapidly acquire enormous amounts of data and run cities of people living their lives, rather than industrial plants composed of machines processing liquids, gases and solid materials to manufacture products.

The idea of connecting large numbers of sensors, devices and computers together throughout an urban landscape via the internet, to gather data for use in increasing the performance efficiency of a city, was conceived in the 1990s[20]. Since then it has continued to gain increasing interest from technology companies and governments under the smart cities banner. Today about 20% of IoT projects globally are focused on this area of application (about 47% of these are in Europe, 31% in the Americas and 15% in Asia-Pacific)[21]. Often quoted examples of the types of technology application that might characterise a smart city include: street lights that turn on/off as pedestrians approach and report their faults automatically; waste bins that let local authorities know when they are full and need emptying; parking bay sensors that can let car drivers know that they are available; and traffic lights co-ordinated with live congestion data. Bringing a substantial number of such applications together in a city, each of which has thousands of sensors and devices associated with it (estimates of 15,000+ connected devices per 100,000 people[22]), requires an extension of the IoT concept to another order of magnitude and has led to the widespread adoption among technologists of the term 'Massive Internet of Things' (MIoT).

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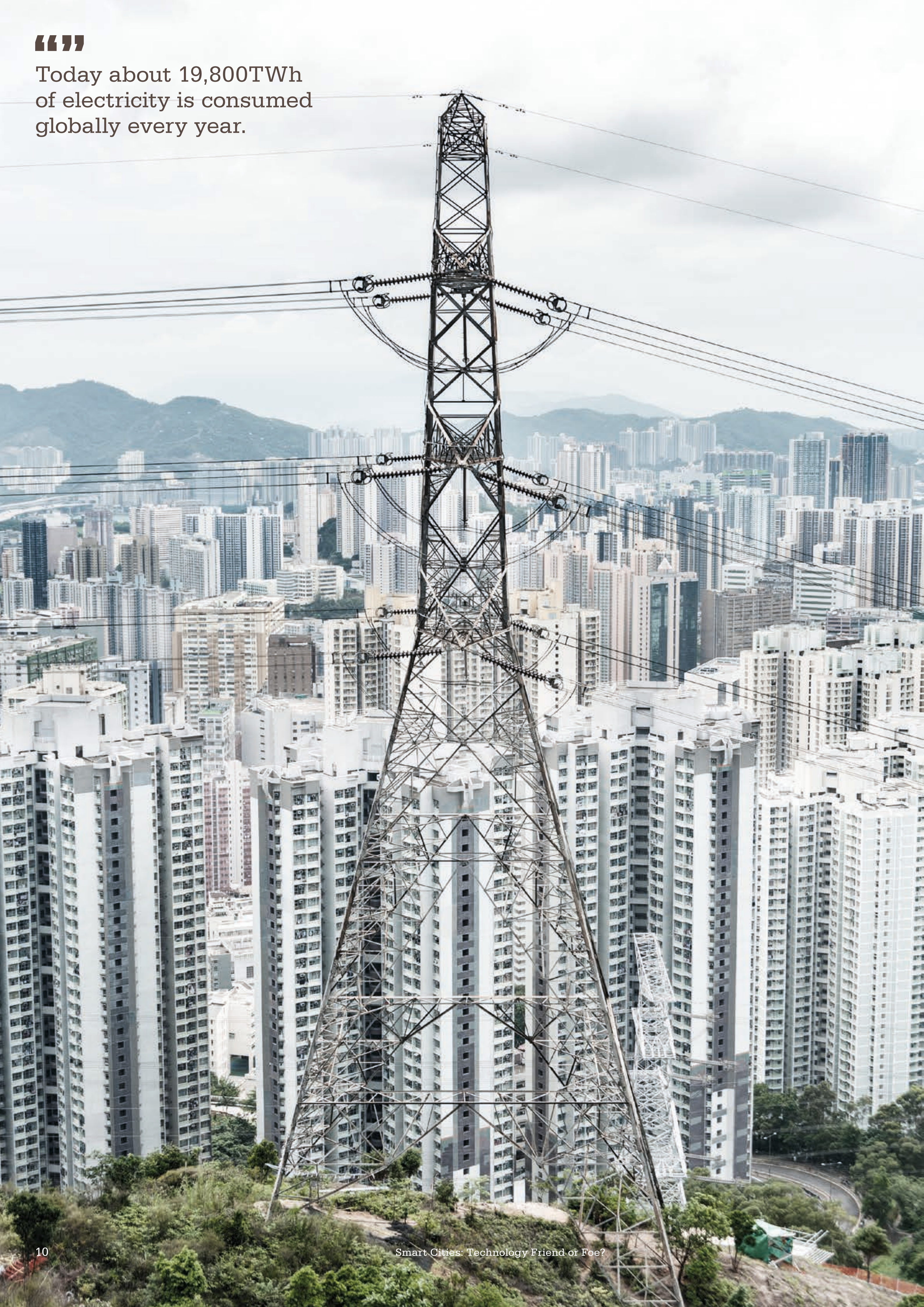
Today about 19,800TWh of electricity is consumed globally every year.



ELECTRICITY: NOTHING 'SMART' HAPPENS WITHOUT IT

Since the pioneering work in the late 19th century by engineers such as Thomas Edison, Nikola Telsa, Werner von Siemens and George Westinghouse to successfully harness the power of electricity, it has become ubiquitous in homes, businesses and industrial premises worldwide. Today about 19,800TWh of electricity is consumed globally every year.[23] About 1.5% of that total, or 304TWh, is the power consumption in the UK[24]. This is projected to potentially double by 2050, as the UK further electrifies domestic homes, commercial premises, industrial sectors and infrastructure to help meet its decarbonisation obligations[25,26], and may conceivably exceed that value if the MIoT is realised to the extent envisioned in the next 20 to 30 years.

It is predicted that by 2020 alone, just two years into the future, global networks will be handling 40,000EB of data, up from 130EB in 2005[27], a factor of 300 times greater. It is important to recognise that the devices, sensors, computers, networks and power-hungry data centres fuelling this explosive growth will be reliant entirely on the availability of electrical power to function. For example, city-wide utilisation of the MIoT, as envisaged in the technologist's notion of the smart city, will require the provision of substantial amounts of additional data handling and storing capability, and in this regard data centres illustrate the scale of the electricity challenge ahead. The world's eight million data centres currently use about 3% of global power production, as much as 50% of which is for cooling provision. To meet increasing data volumes in the near term, it is estimated that approximately 600,000 new centres are currently being added to the global network[28]. Future new facilities will, however, be very different from the large out-of-town centres built during the past decade and run by companies such as Google, Facebook and Amazon. In order to reduce connection latency and deliver the response speed necessary for many mission-critical applications (eg autonomous transport systems and smart drones), they will instead be smaller and co-located with systems and sub-systems throughout the urban landscape. Even with anticipated improvements in the thermal performance of IT equipment and cooling system energy efficiency, this co-location approach will put a substantial additional demand on city power systems.

Today, the entire ICT infrastructure of the world is estimated to account for about 10% of global energy consumption[29] and as IoT and MIoT adoption grows, alongside a broad range of other ICT applications, so too will the sector's electricity demand. The Institution of Mechanical Engineers recognises the scale of this challenge and is concerned that to date the impact of the ICT sector, and in particular the deployment of the IoT and MIoT in the context of smart cities, has not been included in UK Government's planning of pathways to the nation's power infrastructure for 2050[25,26]. However, digital technology of all types, and the IT infrastructure that supports it, are not only power-demanding, they also depend on 24/7 reliability 365 days a year. The worldwide disruption to British Airways flights and UK airport operations that resulted from a short interruption of the power supply to the airline's computer system in May 2017[30], illustrates the latter point clearly. This new demand will require not just increases in the amount of electricity generated and distributed, but also a new level of system resilience and reliability. In the UK city of the future, if the power goes off, even for a very short time, the disruption could be widespread and have far-reaching economic and social consequences.

In the UK, the connections between digital technology and energy are beginning to be addressed by the local Distribution Network Operators (DNOs). To create an environment where new energy generation from community projects, housing and businesses can be shared, bought and sold, the DNOs are becoming Distribution System Operators (DSOs). This means they are trialling new systems and software that enable communities to manage their energy generation and use bitcoin technologies for buying and selling, directly reducing the importance of the energy companies. In return, the energy companies are responding by using increased visibility and real-time feedback of systems operation to handle greater complexity, closer running to margins, and better decision-making. Overall, digital technology is clearly an enabler of engineering integration and systems thinking, that is of benefit to a wide section of society.

ELECTRICITY: THE TOOL OF CHOICE FOR A CONTEMPORARY SIEGE?

Although city-wide integration of digital technology with engineered infrastructure offers the possibility of efficiency gains in the delivery of city services, it also opens up potential vulnerabilities that might be exploited by people with malicious or criminal intent. In this regard, connecting millions of electrically powered devices and sensors together via the internet, potentially creates a myriad of exposed entry points to critical infrastructure systems, the exploitation of which can impact on normal operations and significantly disrupt city services. A 2016 internet scan carried out by global cloud security company Trend Micro Inc, revealed that about 178 million IoT devices were exposed in US cities alone[31]. Earlier investigations[32,33] with a specific focus on the industrial control systems (ICS) and the supervisory control and data acquisition (SCADA) environments used extensively in the engineering-based sectors of transport, energy and water treatment, suggested that the archaic security measures often embedded in these systems made them particularly vulnerable to cyber attacks when connected to the internet.

Such weaknesses provide a potential opportunity for hackers to disrupt entire urban systems, through personal malice, as state-sponsored warfare, or as an act of terrorism or criminal activity intent on extracting a ransom for restoring system operation. The last mentioned was the case in the recent (June 2017) Petya-based ransomware attack that shut down the Port of Los Angeles' largest terminal, along with disrupting operations at ports in Rotterdam, New York and New Jersey[34]. Globally, cyber attacks on critical infrastructure are on the increase. In 2015 the USA recorded nearly 300 incidents compared to about 200 in 2012[35] and worldwide about 17% of industrial computers protected by the Kaspersky Security Network were estimated to be attacked in July 2016, increasing to nearly 25% in November the same year[36]. A 2017 survey of nearly 1,000 IT professionals[37] from across the globe found that over 60% were worried about IoT connected sensors/devices in their domain, while an earlier 2016 study[38] of US IT professionals working in state or local government revealed that over 80% were concerned that a cyber attack on critical city infrastructure could cause a threat to public safety (88%) and/or physical damage (81%).

If the electricity went off across a fully integrated smart city, there would soon be no communications, no transport, no security surveillance, no heating, no cooling, no lights, no water, no trading in a cashless world and, in a very short space of time, no food. The chaos and looting that resulted in Texas and Florida in the aftermath of Hurricanes Harvey and Irma in late summer 2017[39,40] provide a small pointer to the answer. In the smart city vision, electricity is the foundation of everything, and the reality is that today energy companies globally experience about 66 million cyber security events annually, which is 25% more than typical in other industries, and about 90% of published vulnerabilities are medium to high risk[41]. In the USA, according to the Department of Homeland Security, the energy sector is subject to more cyber attacks than any other industry, and in a 2016 survey, 83% of the sector's security professionals said that they were not confident that the organisations they worked for had the ability to detect all cyber attacks[42].

When targeting electricity infrastructure, hackers can exploit vulnerabilities in digital technology to interfere with the communications signals of advanced energy management controls (eg to introduce fake power demand requests or block genuine ones). These disrupt the operation of power generation equipment, thereby creating system instability. Such actions can lead to problems with power distribution, and in extreme cases force temporary outages that potentially inflict economic and social impacts as well as physical damage on power systems. As early as 2003 a nuclear power plant in Ohio, USA was disabled by hackers in an industrial control systems (ICS) attack[33]. More recently, in December 2015 the Ukraine suffered the first (publicly acknowledged) cyber-attack that resulted in a grid outage[43]. In the latter incident 30 electricity substations were disconnected, leaving nearly a quarter of a million homes without power in the middle of winter. The possibility of extending such an attack to cover portions of a city, or ultimately an entire city-wide electricity network, offers the prospect of a modern-day version of a medieval siege.

Given that power companies worldwide are subjected to large numbers of cyber attacks, one area of concern identified by the Institution of Mechanical Engineers is the potential vulnerabilities that could be created through the growing trend towards distributed community-based energy systems[44,45,46]. Although a desirable and sensible shift from a physical resilience and sustainability point of view[47], this transformation in city energy infrastructure might unwittingly increase the opportunity for hackers to launch damaging cyber attacks. Typically, these localised systems will be composed of a range of engineered energy facilities, for example combined heat and power plants, solar and/or wind power generators and energy storage devices, all of which will be connected to consumers via a smart micro-grid[48]. This in turn is connected to a city-wide grid for energy trading with neighbouring communities and possibly wider through a national grid[49]. The integration of digital technology will be essential to the operation of this type of local community-based system. A substantial part of the associated cyber security challenge will be ensuring that the devices, sensors and systems installed at the community level are correctly configured and protected and, once operational, continuously updated and upgraded as new security threats emerge. Other areas of challenge will include maintaining up-to-date information on the apps deployed as well as fully understanding the risks they introduce; managing the ongoing security of mobile devices in the community and the networks they utilise; understanding that the applications and services in the cloud potentially create vulnerabilities and require added security precautions; and ensuring a capability to provide a cost-effective response to any emerging threats or breaches.

In a world where large, well-resourced companies and city authorities struggle to keep smart systems protected, and artificial intelligence (AI) is likely to be adopted by hackers to create smarter, autonomous malware[50], these types of community level scheme, which by their nature have limited resources, will likely become weak points for entry and city-wide attacks. As with the application of digital technology with engineered infrastructure more broadly, it is important for the UK Government to anticipate this potential challenge and to take a lead on developing the standards, regulations and best practice guidance necessary for community energy project teams to deal with the associated threats to cyber security.

Although the temptation for city authorities to fully automate infrastructure control systems will be high, the Institution of Mechanical Engineers recommends maintaining an ability to function safely and provide basic services such as energy, water, sanitation, policing and emergency medical care effectively, albeit with reduced efficiency, in the event of compromised digital technology.

TECHNOLOGY AND CITIES: WHAT REALLY MATTERS?

The engineered infrastructure of cities is largely taken for granted by most people on a day-to-day basis, unless of course it is not functioning properly. Indeed, the expectation is, quite rightly, that local authorities and governments working together with engineers will deliver reliable and efficiently performing systems that deliver the best achievable value for money with minimum disruption and pollution. It is also expected that infrastructure will be upgraded and further optimised over time, as new demands emerge and advances are made in engineering methods, techniques and products. This includes, where it makes economic sense to do so, integrating the most up-to-date digital technology available. The emergence to some extent of the technology-enabled smart city is thus largely taken as a given, and perhaps it should therefore not come as a surprise that discussing the idea is of little interest to most people. A recent UK survey by the Institution of Engineering and Technology (IET)[51] underlined this lack of engagement in that it found that only 18% of people interviewed (or fewer than one in five) had heard of the term 'smart city' and that the level of interest in the use of digital technology was very low. For example, a mere 8% saw value in autonomous or electric vehicles that could be hired or ordered from a smartphone; similarly only 15% were interested in up-to-the-minute travel information delivered to their smartphones; and just 29% of respondents thought intelligent street lighting useful.

Although the IET survey suggests that the digitisation of city infrastructure and services may be perceived by most people as relatively mundane, and to some extent 'business as usual', there are a number of sensitive personal implications to be considered by everybody in the face of this inevitable advance in technology use. In this regard, what actually matters to people is not the devices and related infrastructure performance benefits that technology advocates push in the promotion of smart cities, but the more personal human issues of equality of access, skills and jobs, social interaction, a sense of community, data ownership and security, privacy, freedom of choice and value for hard-earned money. Indeed, a recent UK survey by Ipsos MORI[52] revealed that among these concerns, equality of access to services (for people, for communities and for cities) and avoidance of a loss of basic skills are of primary importance to people in terms of what they want from UK cities of the future. In recognition of the fact that the era of widespread integration of digital technology with city services is dawning rapidly, and that engineers are at the sharp end of implementation as technical custodians of city-wide engineered infrastructure, these are the important issues considered in this report. The aim is to improve the world through engineering and to help make future cities fairer, safer and more humane places to live in privacy, with dignity and freedom of choice.

CITIES OF THE FUTURE: UNREALISED AMBITIONS

Building a fully digitally integrated smart city of the future from scratch, is a compellingly attractive idea to those with a technological mindset. For example, in South Korea, 35 miles from Seoul and close to the nation's Incheon International Airport, on 1,500 acres of land reclaimed from the sea sits Songdo IBD[53]. A development which began life in the late 1980s as a vision of a purpose-built futuristic city, Songdo's goal was to be a leading cutting-edge international business hub[54]. To realise this urban dream, a city design based on digital connectivity and competitiveness was conceived, integrating the latest technology with the city's engineered physical infrastructure. Innovations included a city-wide underground waste management system, taking rubbish direct from homes and businesses to processing point, state-of-the-art environmentally sustainable buildings and smart street lighting, among many more. But despite construction beginning in 2001 at an estimated cost of US$35 billion, and 70% of the project being completed, the desired world-class international businesses and their high-quality employees did not largely come. Instead 99% of the city's properties are sold to Koreans[54], primarily families attracted not by the global business potential, but by a city with 40% open public space and walkable traffic-free journeys. Of an anticipated population of about 250,000 – mostly professionals, just 36,000 – mostly commuters, currently live in Songdo IBD. It is clearly a failure by its own success criterion of being an international hub for cleantech innovation.

Another ghost town, this time a 'green' one, stands about 4,000 miles to the west of Songdo in the sands of the Arabian desert near Abu Dhabi – Masdar City[55], a 5% built testament to the failure of an early 21st-century dream of a sustainable, zero-carbon mixed-use urban landscape of the future. Construction of the planned 2.3 square miles city began in 2008 with the goal of creating a global hub and showcase for the emerging clean technology industry.

Originally estimated to take eight years to complete at a cost of US$22 billion, the finish date has been pushed back to 2030 and the vision has now largely been abandoned. Today, of the anticipated 50,000 people population, and 40,000 commuters, just 300 students live in the city on the campus of the purpose-built Masdar Institute of Science & Technology, joined daily by a few thousand travelling workers. Largely isolated, the city suffers from the same lack of physical connectivity with neighbouring settlements and communities as its Asian counterpart to the East.

Yet despite these two high-profile failures and many more around the world, the irresistible belief that such a city can be created, and that others simply got it wrong, persists. The latest to chase the dream is Sidewalk Labs, a subsidiary of Google (now Alphabet), which plans to build a city from the 'internet up' at district scale[56], possibly on a 12-acre waterfront development site in Toronto, Canada[57]. The idea underpinning this attempt is the creation of a new 'public realm', facilitated by ubiquitous digital connectivity built into the fabric of the city and quality of life enhancement through people's use of the data generated therein[58]. The engineering infrastructure focus of this proposed 'living laboratory' will be on innovative housing and real estate, transport, sustainable energy provision and environmental sustainability. The question is of course whether this latest smart city dream will lead to a radically different and more fully inclusive implementation, or simply create another technology-driven pilot largely occupied by a technical elite.

Why do these technological dreams of utopian future cities consistently fail to realise their visions? The answer to this question is undoubtedly complex and involves issues of culture, philosophy, geography, history and social science. It is however clear, that the technocratic purveyors of these visions need to learn from past failures in urban development, and address what fundamentally matters to people and communities.

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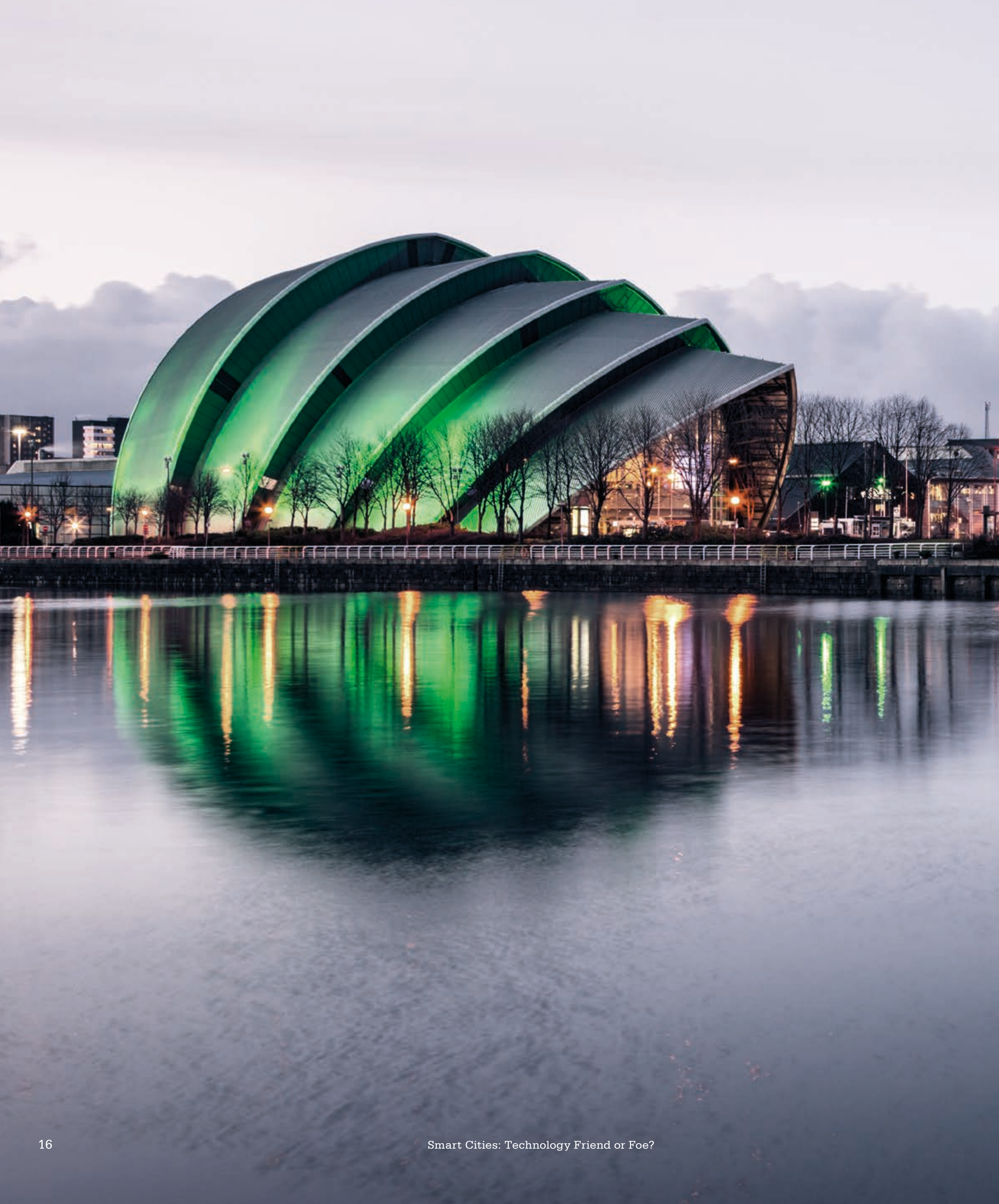
Unlike Glasgow, winner of the Future Cities Demonstrator competition, nearly half of UK city authorities do not have a clear smart city ambition.



CITY WINNERS AND CITY LOSERS

The majority of ideas and technology applications proposed as smart city solutions do not currently have a robust economic model or business case for their long-term viability. They are often also seen in isolation from their rural hinterland. Also, the various demonstrator or pilot initiatives that are under way around the world rely largely on a technology 'push', including providing sponsorship monies or in-kind collaboration for implementation, and/or public funding from central government and/or city authorities. Indeed, without public funding, very little 'smart city' activity would be happening as financing of such projects is regarded by the sectors involved as the most significant barrier to progress[59].

In the UK, smart city programmes are largely supported by various government departments, often in collaboration with the national research councils and/or city authorities, through public monies awarded via divisive national competitions that create city winners and city losers. It is therefore appropriate to ask: 'Does this make good and effective use of public money?' and 'Is it what people want?' This is particularly pertinent in the context of the austerity measures being taken nationally and locally across the nation, and when there is no clear compelling business case yet developed for the majority of smart city applications anywhere in the world.

In the ten 'Principles Underpinning Integration' distilled from the 2016 Ipsos MORI work[52], equality of access was the number one principle people wanted applied in relation to future UK cities. There are two dimensions to this: equality of access by people, particularly in relation to poorer people, to the services that smart city initiatives will deliver; and equality of access by cities to the technology, funding and benefits of smart city initiatives taking place across the nation. Regarding the latter, people specifically did not want to see large inequalities between future cities or communities within future cities. The competitive nature of the UK smart city landscape, in terms of both public funding models and city authority culture (as reflected in the competitive branding and positioning of cities as smart cities and smart city leaders), is directly at odds with this principle. In addition to Government clearly needing to review its funding model in the light of these findings, the Institution of Mechanical Engineers suggests that the UK needs to establish a network of cities approach to policy and funding, as opposed to the current culture of encouraging 'islands of success' that are inequitable, and in the long run, unsustainable. What is needed is a focus on sharing of digital integration knowledge, learning and experience between cities, as well as physical connectedness between communities in close proximity to one another. Scotland is potentially showing some leadership in this regard, with all seven of the country's cities forming the Scottish Cities Alliance to work together on expanding their smart city capabilities. In the UK it should not be necessary for people to have to move from one place to another in order to benefit from digital technology integration in the urban landscape.

UK SMART CITY PROGRAMMES

Since the late 1990s, technology thought leaders, industry visionaries, technology companies and sector-related academics have enthusiastically promoted the idea of the smart city around the world. Today there are hundreds of related initiatives either planned or under way[21]. In the UK, the dominant activity taking place is the nation's 'flagship' Future Cities Demonstrator competition project[60], which was launched in 2012. In the first phase of this initiative, 30 UK city authorities entered a competition in which they were granted £50,000 each to develop proposals for second-phase funding of innovative schemes that could significantly improve their city's performance. As a result, in 2013 Glasgow was announced as the outright winner to receive £24m from central Government for implementation of the city's submitted proposal, which largely focused on a comprehensive integration of city services and delivery of a data-driven operations centre. Additionally, as runners-up in the competition, London, Bristol and Peterborough were each awarded £3m grants to enable them to take forward some components of their proposals.

Beyond the flagship competition, just under a half (33 cities) of UK city authorities with urban populations of over 100,000 have a clear smart city ambition and/or related activities taking place[61]. In general, of the various initiatives being pursued, the majority are focused on engineering infrastructure projects related to smart energy and waste management and smart transport, or connectivity projects such as superfast broadband roll-out, with less emphasis on city governance or social sustainability. Many of these initiatives are funded through other sources of competitive grants from central Government, including UK broadband initiatives, or ad hoc partnerships of city authorities, universities, private sector companies and NGOs accessing a range of funding pots[62].

The latter includes significant monies provided by the EU in project grants from the Horizon 2020 and other programmes. Examples of activities[62] include: in Manchester the EU-funded Triangulum project and City Verve, which won a £10m competition prize from the (then) Department for Culture, Media & Sport; in Milton Keynes the MK:Smart project led by the Open University, which received an £8m grant from the Higher Education Funding Council for England (HEFCE); in Bristol, the Bristol is Open initiative, which was awarded £5.3m from Government's Super Connected Cities programme.

The predominance of public funding awarded through competitions is clear.

IT'S NOT ALL ABOUT EFFICIENCY AND PRODUCTIVITY

Much of the focus of city authorities, technology companies and engineers involved in the digitisation of urban infrastructure is on the efficiency and productivity gains that are anticipated. However, the work carried out by Ipsos MORI[52] indicated that the integration of digital technology should not be just about those two aspects alone. Indeed, there was strong support among those who participated for the social, arts and cultural dimensions of living in a city to be taken into account in such integration, regardless of the fact that the economic benefits will not be clear. In essence, the call was for a more human approach to be taken in smart city initiatives and an expression of a desire for a positive sense of place in UK city environments.

The deeply entrenched human need for face-to-face, people-to-people communication is well known[3,63], so the Ipsos MORI finding that people value traditional forms of interaction above online communications should not come as a surprise. However, with the push towards greater digitisation of infrastructure and public services in cities across the UK, there is a risk of stifling traditional, more sociable ways of communicating and interacting that underpin people's wellbeing. The concern is that an increasing shift to technological approaches could lead to less meaningful exchanges and a degradation of social skills, as well as potentially an increase in the incidence of mental illness[63]. It should also be recognised that a move to greater physical separation in society might undermine one of the core characteristics and human benefits of urbanisation – coming together in close proximity to form communities for socialising, social belonging and collaborating to achieve shared common goals[3]. This core human characteristic presents in human environmental psychology as a person's perception or sense of a place and includes place attachment and place meaning[64]. The former reflects the bond between people and places, and the latter the symbolic meanings people ascribe to places.

Projects that recognise this fundamental need and strive to deliver digital integration that supports online interaction as complementary to, and not a complete replacement for, face-to-face communications, and to establish thriving sustainable communities, will be more likely to succeed. It is important for technologists, engineers and city bureaucrats to remember that cities are primarily about people, and not about things.

THE OFFLINE SMART CITY

No city can be considered 'smart' if it ignores the interests of poorer, marginalised and vulnerable groups in society, along with communities that have been traditionally excluded from participation. However, in many cases around the world, city visions for digital integration do not include such groups of people and instead focus on improving access to services for those who have the financial means to own the necessary technology and be digitally connected. Indeed, the digital divide between those who have internet connectivity and those who don't is considerable. For example, in India 68% of the nation's population are not connected to the internet, and in China the figure is 47%[65]. Even in the UK, 13% of people are not connected, with the figure reducing to 7% (625,300 people) in London.

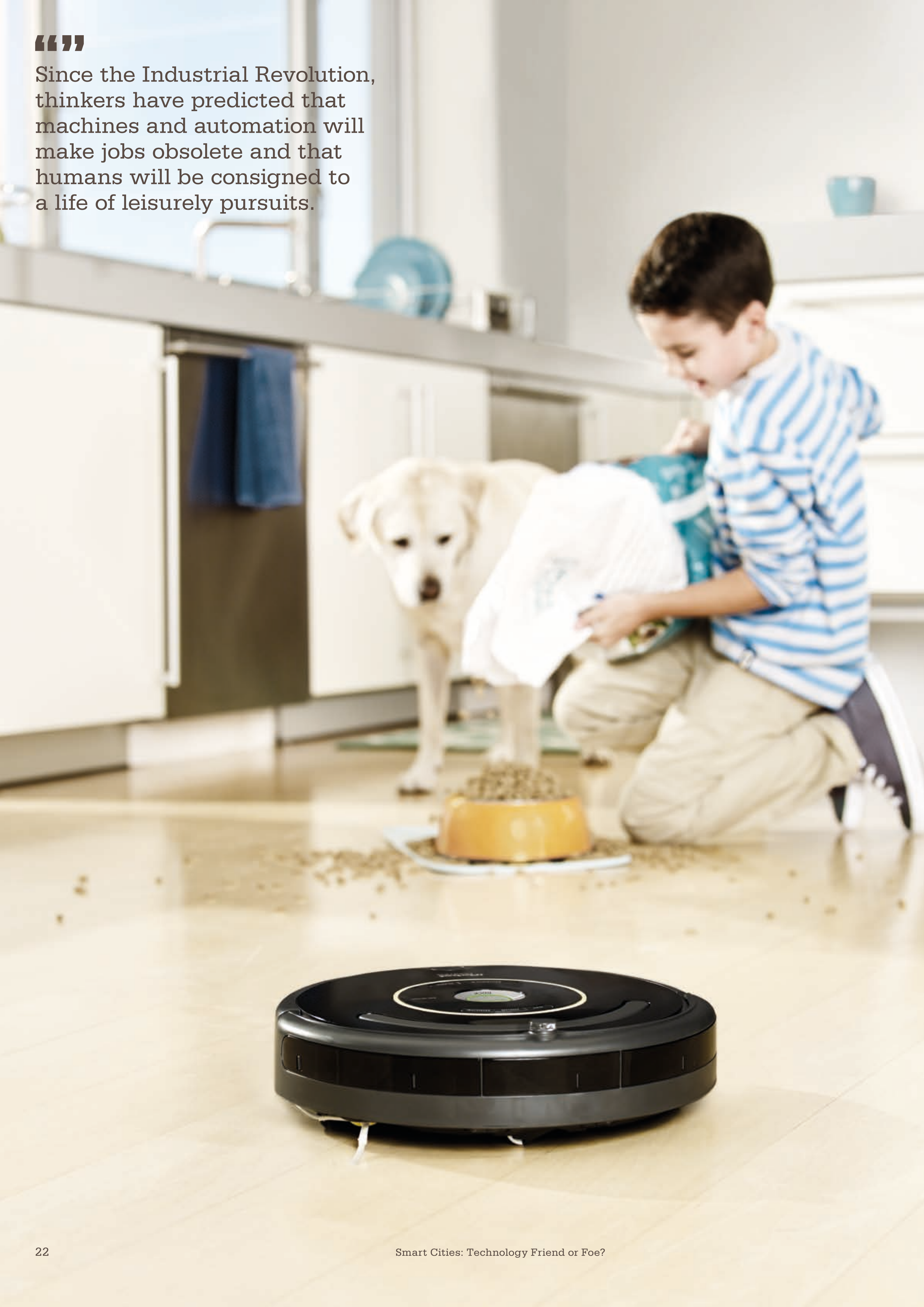
The reality is that people living in cities who are affluent enough to have the latest smartphone technology and instant digital connectivity, as well as the skills and available time, can gain benefits from participation in digitised infrastructure and services. For example, in the US city of Boston, the municipality introduced an app called Street Bump[66] which enables users to report damage (such as potholes) in road infrastructure for repair scheduling. However, upon implementation, the city engineering department noticed that only repairs in the neighbourhoods of young, relatively wealthy people were being notified[67]. Their response was to reintroduce, in parallel to the digital-based service, previous non-digital methods of damage notification as well as observational patrols in disadvantaged neighbourhoods. In this way, a fairer utilisation of road repair resources was achieved across the city. The lesson to be learned here is that in the digitisation of engineered infrastructure it may be necessary to offer a parallel mix of digital and traditional non-digital access, if equality of access to service is to be achieved. Local and national government decision-makers and policy-makers, as well as engineers, need to understand that digital technology can help as part of an engineered service provision solution, but in the context of equality of access it cannot necessarily be the total and only solution.

Another equality of access issue to be considered and addressed, is that of individuals deciding not to participate with digitally integrated city services. For example, there is an emerging trend of providing 'free' public Wi-Fi across cities, but this has some serious privacy implications, in that users are typically required to provide some personal data to access the service. Thus what initially appears to be a good idea to facilitate participation of economically disadvantaged groups, can, if people don't feel comfortable with providing the data, become a privacy threat[67]. This is by no means a unique case; there are many other examples where the same problematic thinking applies of forcing people to enter themselves into a dataset before they can gain access to a service, and excluding them from equal participation in that service if they choose not to consent to providing that data. It is therefore important that engineers and city authorities do not think about digital solutions in technical isolation, but instead in the context of broader societal issues including those of choice and privacy.

INDIA AND THE DIGITAL DIVIDE

India, with 1.3 billion people, the world's second most populous nation behind China, is urbanising at a rapid pace and coincidentally has a large-scale, well-established and successful IT sector. Indeed it has for the past few decades been the 'go to' destination for outsourcing of software development and IT services to the engineering and technology industry across the globe[68]. If there is one place where technology-enabled smart cities might be expected to emerge, to improve the planning, building and efficient running of urban infrastructure and services, it would therefore be here. But the size and worldwide reputation of the Indian IT sector, employing about 10 million people and accounting for about 67% of the global IT outsourcing market[68], mask the reality of a nation where nearly 70% of the overall population and 31% of urban citizens are not online[65]. Such is the scale of the digital divide in India, that it raises questions about the prospects for the digital aspirations of the government's high-profile Smart Cities Mission[16], beyond delivering limited benefits to a relatively small, largely middle class, technical elite.

Indeed, serious concerns have been expressed[69] that the ambitious five-year programme will potentially increase the nation's inequality gap, with further disempowerment of the urban poor, unconnected and IT-illiterate, impacting on their human rights and effectively discriminating against them. Many of India's over 4,000 urban areas lack even the most basic ability to deliver affordable housing, clean water, adequate sanitation, access to electricity and accessible public transport for all their people. In a country with such a substantial deficit in engineered infrastructure, it might be smarter and more inclusive to focus on delivering physical improvements to urban living for the nation's entire urban population, rather than selecting 100 cities capable of developing the most popular proposals, often with over-emphasis on technology that will benefit only a privileged few.



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Since the Industrial Revolution, thinkers have predicted that machines and automation will make jobs obsolete and that humans will be consigned to a life of leisurely pursuits.

PART OF THE SMART CITY MACHINE: LOSING SKILLS

New ideas for making people's lives easier, safer and more fulfilling through digital technology in cities and homes, seem to emerge on an almost daily basis. From intelligent street lighting, waste bins, bus stops and driverless vehicles through to smart home heating, refrigerators, cookers and even wallpaper that 'listens' to vulnerable relatives, the possibilities appear endless. However, although the technologists and engineers conceptualising these effort-saving smart applications do so with the best of intentions, there is a degree of unease about them in the minds of those who they believe they are helping. Indeed, in the 2016 Ipsos MORI work[52] deskilling by technology was the second most prevalently expressed concern regarding future UK cities.

Skills are defined as 'the ability to do something well'[70], and a 'practised ability'[71]. In the context of digital integration for smart cities, fears of deskilling fall into two categories: the skills used in the workplace and those used in everyday life, particularly the home. In the case of the workplace there is a fundamental and obvious direct question about what technological skills will be needed to produce and maintain a digitally integrated smart city, which has been considered exhaustively by others[72,73]. In addition to this, there are important tangential ones about the impact of technology on the types of job that will be available in future smart cities, and how this changes the requirements today for learning and training. The latter is also a key question for everyday life skills, and this leads to a need to understand what skills will be essential to live in a future smart city.

In everyday life, concerns about the widespread use of digital technology in homes and public spaces centre on a fear of skills degradation and no longer being able to do the things that are currently perceived as an essential part of daily human life[52]. For example, smart fridges which automatically order products that are running low from online retailers, smart cookers that require little or no culinary skills, and autonomous vehicles that do not need driving, are all examples of effort and time-saving convenience technologies that can be seen as leading to the degradation of what are considered by many to be life skills.

In the extreme incarnation of this trend, the perceived danger is that people end up simply becoming components in a highly efficient and 'convenient' digitally run city – a city in which the spontaneity, alternative possibilities and human interactions that make urban life so interesting, will have disappeared. The challenge for governments and city authorities is to recognise, understand and address these concerns and deliver digital integration projects that leave space for sudden impulses, choice and face-to-face interaction. In the home, this challenge sits with the consumer in negotiation with technology companies through the medium of the marketplace.

Living in a digitally enabled smart city of the future will require the development of skills for the use of smart devices and interaction with a largely virtual world for accessing city services. Such skills are already widely adopted and honed by the UK's younger generation, as is evident in school classrooms across the country, where children from early years to final years use internet-connected tablets, smartphones and touchscreen gadgets effortlessly to access knowledge, learn, prepare and deliver work assignments. But in what could be regarded as a small glimpse of a smart city future, there is evidence that this ubiquitous use of digital technology is in some cases arresting the development of life skills such as fine motor skills, dexterity and social interaction, through a form of sensory deprivation[74]. The emergence of this observation into an evolutionary trend may require changes in learning and training that develop, and effectively preserve, these traditional life skills in a balanced approach that ensures humans can function both in and out of the digital smart city world.

Beyond everyday life, human skills, their development and use, are intimately bound in modern post-industrial economies such as the UK, with a deeply held notion of employment, work and productive activity as a core characteristic of societal participation[75]. In this context, it is important to ask what skills will be needed for the workplace, as city infrastructure becomes increasingly integrated with digital technology. In particular, which of these skills should UK Government and city authorities be encouraging the nation's educators and trainers to nurture for the future? In a contemporary framing of these questions, the answers depend on projections and forecasts for what types of job, and other forms of work, might be available for people to do in UK cities in the coming decades.

WORK... ISN'T THERE AN APP FOR THAT?

Since the early days of the first British Industrial Revolution, thinkers and commentators have been predicting that machines and automation will make jobs obsolete and that humans will be consigned to a life of leisurely pursuits[75,76]. However, although there have been radical changes over the past 200 years in the types of work that people undertake to earn an income, the future of a world 'free of work' has to date not been realised. Indeed, in overall terms, in nations that have experienced the full transition from agricultural-based societies to post-industrial economies, the proportion of employment to population has remained roughly steady and actually increased during the 20th century[76]. This suggests that as new inventions and technical innovations become established, those work activities that become obsolete are replaced by others that did not previously exist, or radically modified versions of those that did. In contemporary France for example, a 2011 study[77] of the impact since 1995 of the internet on employment, found that 1.2 million new jobs had been created while about 500,000 had been destroyed, thus resulting in a net gain of about 700,000 (or 2.4 new jobs for each lost job). The era of a largely leisured human society where there is an app to replace work, is still likely to be a long way off into the future, if at all.

Despite this historical perspective on wave after wave of technical innovation, many commentators today suggest that things will be different this time, with the development and deployment of advanced robotics, AI, the IoT and MIoT. To explore this thesis, McKinsey Global Institute took a task-based approach to undertake research into the technical potential of automating jobs in the 46 countries across the globe that represent about 80% of the global workforce[78]. Of the 820 occupations considered (embracing 2,000 contemporary work activities) the proportion that, based on current technological capabilities, could be fully (100%) automated was found overall to be less than 5%, though for the middle-skill categories that share could rise to 15–20%. However, in broad agreement with another similar study by PwC[79], in just over a third of the job roles considered in the research, more than 60% of the work tasks could be automated, reducing to 30% for about two thirds of the roles considered. These partially automatable jobs included a diverse range of occupations across the skill set spectrum, not just administrative or factory-based roles, and imply that although few jobs will completely disappear, many will experience radical change and about 30% of the UK workforce will face significant disruption.

However, when considering the potential of digital automation, it is important to recognise that a technical capability to automate does not necessarily imply that the automation will actually take place. In reality, economic factors such as the availability of capital, operational costs and the potential risk of disruption to current production, would be considered in establishing a commercially viable business case for the change to be implemented. Nevertheless, these findings suggest an increased use of automation to some degree in the global workforce in the coming decades, and that this change will be more likely in an advanced post-industrial economy such as that of the UK. Of course the social and political challenge is that the people employed in the jobs who do become redundant, or partially redundant, might not necessarily be those gaining employment in the newly created jobs, largely because of changes to the skill sets required. The latter issue, and the cyclical unemployment that results, needs careful consideration by national government and city authorities in terms of education and skills provision, as well as overall employment policy. Indeed, the accelerated pace of change associated with digital integration may require radical policy interventions and workable frameworks to be developed by government to control and mitigate urban impacts. At UK national level this might, for example, include focusing public funding and support for automation, AI and robotics R&D, as well as subsequent deployment of applications, in areas of known skills shortages and jobs people do not want to do. For city authorities, immigration-style quotas could possibly be developed and implemented to control the number and type of automation and robotics applications entering a city, as well as to ensure that those that are adopted align with overall strategic economic and social goals.

FLEXIBLE, INDEPENDENT AND WORKING IN THE CITY

For the majority of people across the globe, paid employment of one form or another is still, and will clearly be for some time to come, their primary source of income. However, within the mature post-industrial economies of the UK, USA and much of Europe, there has been in recent years a growing trend across many sectors, including those based on engineering, of a shift away from the traditional employment model of a permanent '9–5' corporate job, towards different approaches to earning income through paid work[80,81,82]. In parallel with this societal change, and in response to a wide range of economic and socio-political pressures, including globalisation and widespread rapid urbanisation, cities have also been changing their role within nation states. In this regard, rather than city authorities being largely focused on performing their traditional primary function of managing resources for the efficient operation of engineered infrastructure and public services, the trend is for them to have a broad range of objectives related to attracting investment, growing the local economy, creating jobs and positioning and promoting themselves on a competitive global stage of cities. Re-energised in this way, cities have regained their role as key centres of employment and once again become fertile ground for innovation, both technical and societal. With both trends in play, as well as the widespread adoption of the internet, Wi-Fi and digital technologies in the cities of post-industrial economies, have come new ways of working in city environments.

In corporate organisations, digitisation has opened up new opportunities for flexible working, collaboration and productivity increases. For employees in the UK, a flexible working aspect to corporate life is now of primary importance to the majority of current workers (57%) and, as suggested by a 2014 survey[82] this is likely to continue, with 92% of 16- to 36-year-olds identifying flexibility as a top priority when selecting a future workplace. This digitally enabled shift in corporate working culture and practice has, in addition to changing the way in which employees work, led to innovation in the way workers external to organisations are engaged. For example, in recent years there has been a proliferation of new digital platforms, such as TalMix and PeoplePerHour, that are used by companies to access skilled talent for consultancy assignments, and in 2016 PwC created its own corporate portal, Talent Exchange, for sourcing external consultants.

The emergence of digital platforms for connecting workers to sources of work and vice versa, combined with a cultural shift in society to preferences for more flexible working arrangements, has led to the beginnings of a transformation in the employment landscape of UK cities. As a result, new forms of independent and semi-independent working outside corporate employers have appeared, and this shift is set to accelerate in the decades ahead.

In the UK, about 4.6 million workers are classified as self-employed[83], which represents 11% of the working age (16–64) population, but this figure does not include those independent workers who are supplementing their income from other sources (such as students, retirees and traditional employees seeking extra income). Estimates of the latter group vary from 0.8 million to 5.8 million[84]. Although many independent workers have maintained a high level of autonomy, as well as benefited from the flexible modes of working that digital technologies and worldwide connectivity enable (such as for example self-employed home-based professional consultants working in the engineering, legal, medical and creative sectors), a relatively new but growing proportion are dependent on an emerging set of digital platforms to source work tasks in what has become known as the 'gig economy[81]. These platforms, which include MyBuilder, Task Rabbit, Uber and Deliveroo, currently account for about 15% of independent work globally, and their characteristics of scale, efficiency and ease of use make them well suited to city environments, where customer and worker densities are high. Indeed, London leads the UK in the use of digital platforms for obtaining independent work, with 27% of the nation's gig workers based in the capital compared with 13% of all UK employees[81].

In a 2017 survey by the RSA[81] it was found that over half of the people participating in the UK's gig economy are providing professional, creative or administrative services (including consultant engineers, freelance graphic designers, legal advisers, bloggers), about a third (33%) are offering skilled manual or personal services such as plumbers, electricians and cleaners, and the remaining 16% are taking on driving or delivery tasks. Although the first two categories clearly map more traditional forms of digitally engaged self-employment, in the case of the latter this represents a recently emerging group who are growing rapidly in size and scope. These new gig workers have been attracted into independent working by the creation of digital platforms with relatively low barriers to entry, compared with those previously servicing the needs of professionals and skilled manual workers, and their offering of low-skilled (and low-paid) tasks, such as running errands and delivering goods.

The growing popularity of gig working and the revolution it promises in urban working life present significant challenges in the UK relating to education, skills and training needs that must to be addressed. In general, the nation's gig economy workforce of 1.1 million people are young (34% of participants are aged 16–30 and 86% below 55) and, with one in four people aged 16–30 expressing an interest in trying it in future, this transformation in the way people work is likely to continue[81]. Additionally, given that the UK has one of the world's largest cohorts working in this way, it is incumbent upon UK Government and city authorities to consider the education, training and reskilling needs of this growing group of workers.

It has been difficult for education systems in post-industrial economies, including that of the UK, to keep pace with the changes occurring in the contemporary workplace and broader society at large. In a recent survey[84] covering nine countries, 40% of employers cited a lack of relevant skills as the principal reason for their unfilled job vacancies at entry level, and 60% said graduates were not adequately prepared for the workplace in areas as fundamental as communication, team working and even punctuality. In addition to curriculum deficits within the education system itself, this might in part be due to a move in contemporary society towards study preferences for more academic as opposed to vocational subjects. Gaps were also identified in skills related to science, technology, engineering and mathematics (STEM), many of which have previously been highlighted in various reports from the Institution of Mechanical Engineers[85,86,87].

Finding solutions to current skills needs has proved challenging, and as the digitisation of city infrastructure, services and forms of employment gathers pace, the degree of complexity of how best to prepare young people for the world of work promises to increase substantially. For example, given that 33% of those people who say that they would consider gig work are degree-educated[81], what is the UK higher education system doing to prepare graduates for a lifetime of work in the gig economy, if indeed this should be their role at all? How will vocational training in cities adjust to the replacement, or partial replacement, of a wide range of current jobs across all skill levels as a result of automation, as well as prepare people for those that will emerge as a result? How should schools respond to the challenge of ensuring basic education for a world where life in cities is largely digitised, and how will UK Government assist people outside the education and training system, because of age or choice, to reskill where necessary? Bigger questions are also raised about the future of educators and trainers as private or public sector players, and whether they should be educating for a life of constant change, rather than attempting to maintain the status quo[88], and nurturing skills for the workplace of the past[89].

To consider these questions, the Institution of Mechanical Engineers proposes that a multidisciplinary commission of enquiry be established, that brings relevant professional bodies together with the education and training community, to consider how best UK Government can address the skills needs of the gig economy and a future city workplace with increased levels of digitally enabled automation. This commission will need to examine a broad base of evidence and, importantly, be prepared to recommend radical structural changes to a national system established nearly 200 years ago to meet the needs of an emerging industrial society[89] – a system that is potentially no longer fit for purpose in a post-industrial, digitised urban world.

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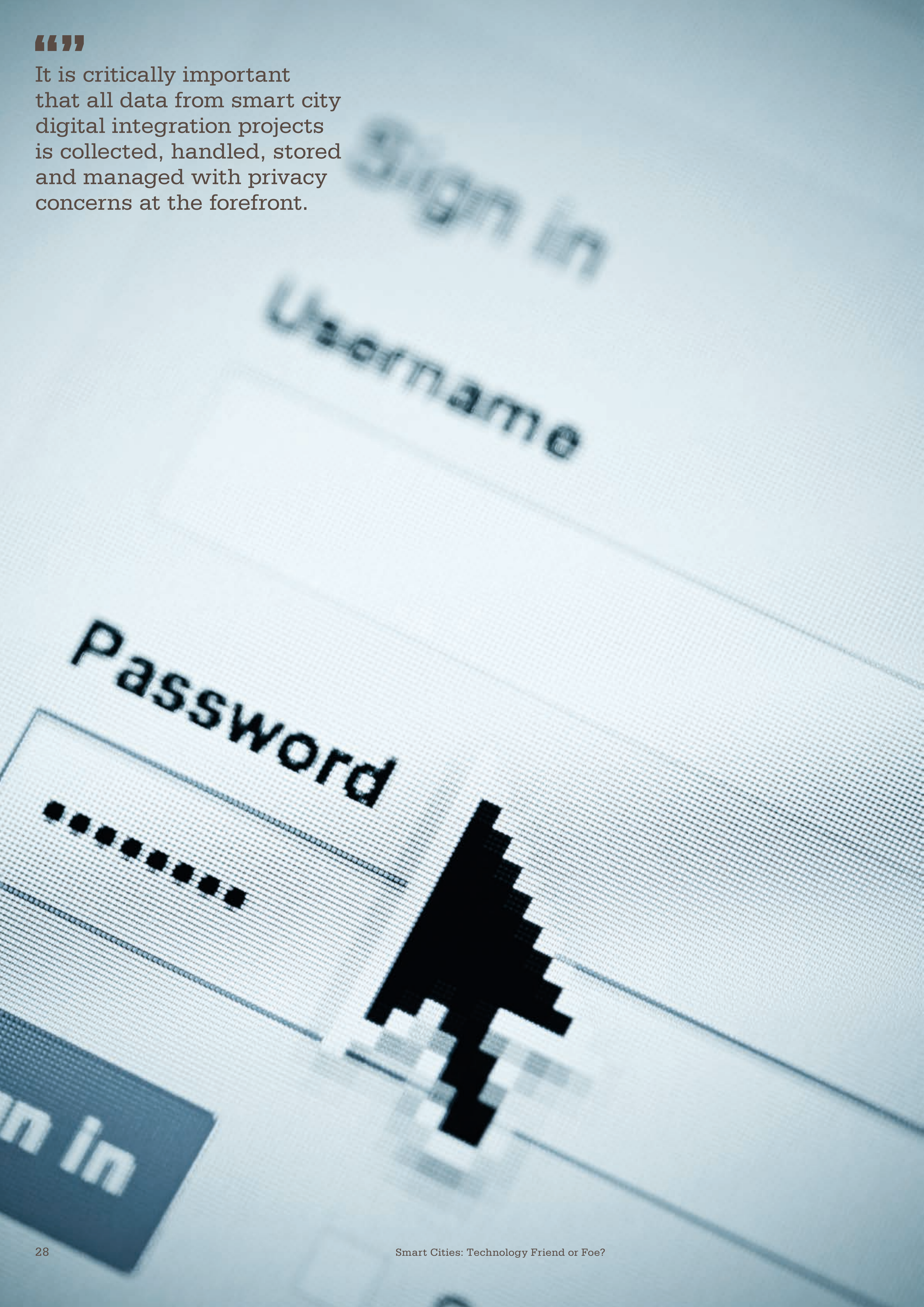
It is critically important that all data from smart city digital integration projects is collected, handled, stored and managed with privacy concerns at the forefront.



PRIVACY IS PARAMOUNT

City authorities have been collecting data and information on people and their activities, as well as on the performance of engineered infrastructure, for millennia to learn how to improve efficiency and exercise control. From an engineering perspective, what will make the digitally enabled future of data gathering in smart cities different, will be both the speed and scale of the data acquisition, as well as the complexity of the analysis that will be possible. This potential step change in character raises new challenges in the area of personal privacy that need to be addressed. Failure to do so, experience suggests, could cause the most laudable and well-intended digital integration projects to fail as a result of widespread public backlash, possibly before they even begin.

Privacy of personal data and personal space are, from an individual person's point of view, potentially the single most important factor to get right on the journey to the digitally enabled smart city. It is also, coincidently, the most difficult element to get right, and the history of the digitisation of public and private services is littered with failures resulting from the inadequate handling of this highly sensitive, complex area[90,91,92]. The use of the IoT and MIoT for monitoring and controlling engineered infrastructure city-wide will involve the gathering of physical measurements, images, videos, audio and written information as data from millions of devices and sensors; much of this acquisition potentially taking place without the knowledge of individuals, effectively forcing people's participation. It is therefore critically important that all data from smart city digital integration projects, of whatever type, is collected, handled, stored and managed with privacy concerns at the forefront[93,94].

On the face of it, much of the information gathered from the devices and sensors used with city infrastructure will, from an engineer's perspective, appear to be benign with regards to privacy (for example temperatures, electricity usage, light and sound levels). Some will, on the other hand, be more clearly sensitive, such as vehicle registrations in traffic management systems, vehicle parking locations and electronic tagging at public transport access points. In the case of the latter examples, these might obviously be processed to provide unconsented insights into people's daily living and their building occupancy patterns. Less obviously, however, if gathered at the large scale of the MIoT, combined with other data, and analysed using sophisticated computer technology, even the apparently more benign data could help yield similar unwelcome insights[94].

FREEDOM TO IGNORE BIG BROTHER'S NUDGE

Smart cities are fundamentally about control. The notion behind the integration of digital technology with a city's infrastructure, is that today's rapidly expanding urban landscapes have become so large and complex they are no longer as efficient as they once were, when they were smaller and more manageable. The idea is to take control of the physical and human variables that are difficult to handle because of this new scale. In the implementation of the idea it is important for city authorities to be aware that although the monitoring systems to be used will be designed with the best of intentions, for the control of specific variables in achieving efficient city performance, they could ultimately be commandeered for other uses and may become something more sinister in the wrong hands[95].

Concerns in this area largely arise from two categories of monitoring activity associated with digital technology integration:

- Direct monitoring activity involving cameras and audio sensors (including CCTV, facial recognition systems and audio monitors) used for applications such as traffic management, building security, flood control, noise pollution abatement;
- Indirect monitoring activity involving collection and analysis of large amounts of proxy data (including locational information collected through smartphone (MAC) address acquisition, points of access to city services use, ID card access to services such as street bins) used for service scheduling, targeting and improvement.

From these monitoring sources, if sufficient controls and safeguards are not put in place by city authorities, it could potentially be possible to locate and/or identify individuals without their consent and for surveillance and/or tracking to be undertaken[94]. For example, what began as a traffic management or flood control system could be used instead for surveillance, tracking and people control. Such a repurposing recently took place in Rio de Janeiro, Brazil, where digital technology integrated with engineering infrastructure for rainfall prediction, landslide warning and flood response management is now used for surveillance and control of people[95,96]. Indeed, the project's former high-tech operations centre, which receives data from over 30 urban agencies, has become a command centre for real-time tracking of activity across the city. The pervasiveness of the repurposed digital technology was summed up by the city's former mayor, Eduardo Paes, 'The operation centre allows us to have people looking into every corner of the city, 24 hours a day, seven days a week.'[95]

The origins of the modern notion of privacy, as embodied for example in contemporary legally binding documents such as the EU Charter of Fundamental Rights, can be traced back to the 1890s, when Warren and Brandeis noted what US Judge Cooley called the right 'to be let alone'[97]. In contemporary society, the ubiquitous and pervasive nature of digital technology makes being let alone challenging, and the move to integration with engineered infrastructure in smart city projects has the potential to exacerbate the scale of this challenge. In the recent Ipsos MORI work[52] on what people want from UK cities in 2040, a strong preference was expressed for the allowance of freedom of choice. The issue raised was not that data and technology might be applied to encourage good behaviour, through the use of the nudge[98], but that people wanted the right to ignore the nudge if they so wish, without fear of penalty or sanctions. Essentially, they want to maintain the right to be let alone. Whereas younger people had hitherto been more relaxed about sharing their personal data, there are now signs that the latest generation of teenagers are resisting online exposure and are better equipped to protect their privacy. It is therefore important that UK city authorities and engineers consider carefully the implications for the freedom dimension of privacy concerns when designing and implementing digital smart city projects.

SINGAPORE: A MODEL TO FOLLOW?

Singapore is widely recognised as one of the world's leaders on smart cities, in terms of both its vision for the future of the city and the progress it has made to date. As a city-state nation of about 5.6 million people covering a land area of 719.1km^2, Singapore has a scale and culture amenable to the pervasive city-wide deployment of internet-based digital technology. With an unofficial but widely adopted slogan of 'Everyone, everything, everywhere, all the time', the government's flagship Smart Nation initiative[9,99] has, however, the potential to turn Singapore into the most intensely surveyed, tracked and controlled city on the planet.

Begun in November 2014, Smart Nation programmes have already delivered more than a dozen apps, for functions as wide-ranging as reporting municipal issues to selecting optimum transport options and personal health and diet tracking, as well as a Smart Living pilot[100] which includes real-time monitoring of domestic energy and water usage, toilet usage, senior citizen activity and whether household appliances have been left on when nobody is at home[101,102]. The city authorities have also built a powerful centralised virtual platform for Singapore that acts as a real-time 'digital twin' and enables monitoring of how the city is performing at any given time[103]. Plans for future deeper penetration of digital monitoring technology into the life of the city include, for example, a wider deployment of the Smart Living concept in Singapore's public housing (which accounts for about 80% of the nation's homes), the implementation of a cashless society through wearable devices, and the creation of a Smart Nation Sensor Platform to gather and share data between agencies across Singapore[104]. There are even ideas for the deployment of microphone-embedded wallpaper for monitoring senior citizens and to facilitate calls for help in emergencies[105].

Despite the personally intrusive nature of many of these applications of digital technology, in general the people of Singapore appear to be culturally comfortable with the Smart Nation programmes and accepting of the dimensions of direct and indirect control that result[99]. This appears to be partly due to a combination of a high level of faith in the nation's government and a deeply entrenched historical precedence of acceptance of limits on behaviour in return for a more efficient state. To Singaporeans, in the five decades since gaining independence in 1965, this combination has served the country well, at least economically. Singapore today offers a small glimpse into a possible future outcome of smart city initiatives across the world, a future that might be characterised by some as the realisation of an Orwellian Big Brother dystopia. Is this a model for the UK cities of the future?

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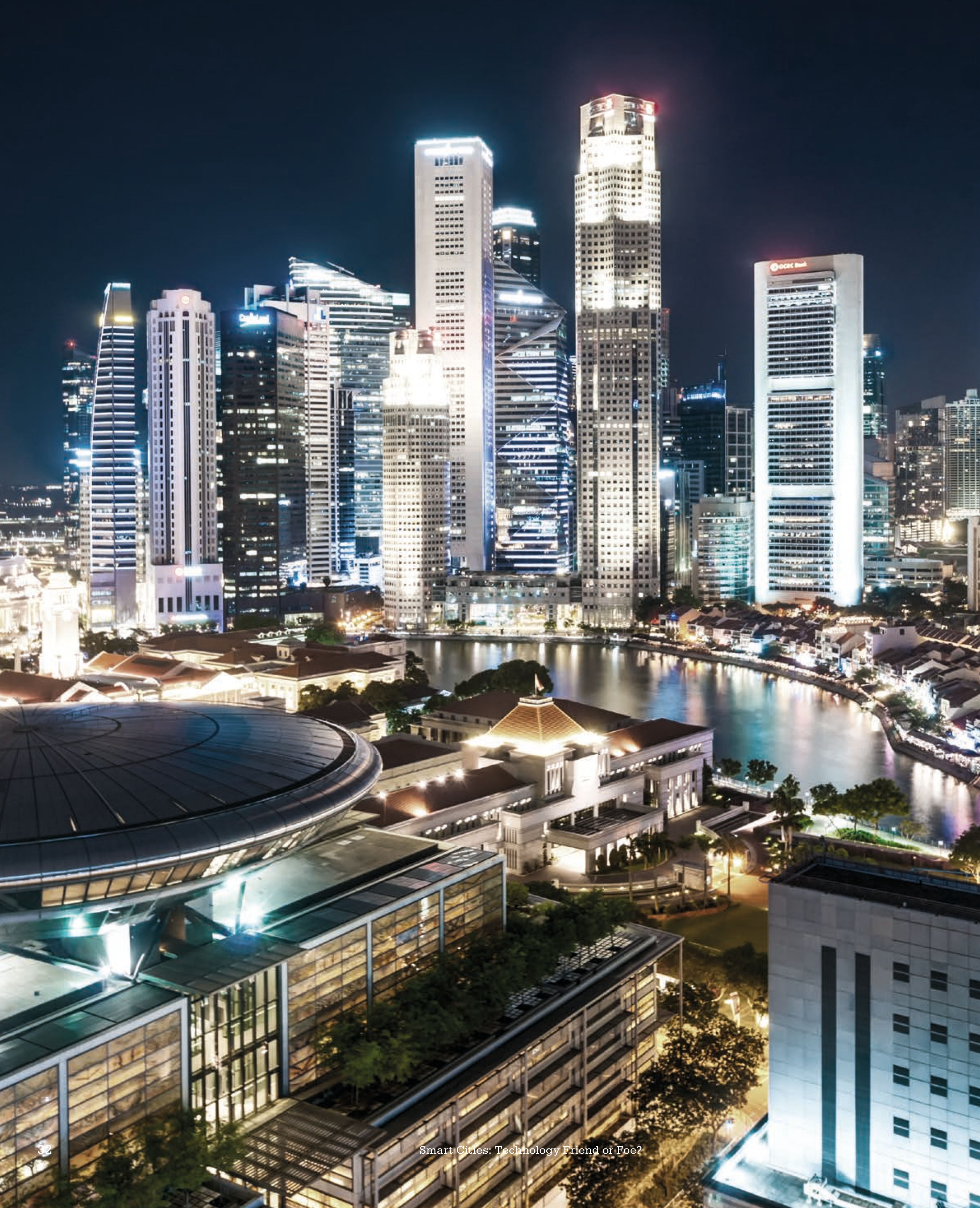
Singapore is widely recognised as one of the world’s leaders on smart cities.



RECOMMENDATIONS

The Institution of Mechanical Engineers recommends the three priority areas for action in the short term are:

1. UK Government includes the electricity system requirements of digitally integrated smart cities, in terms of both demand and reliability, in the planning of pathways to the nation's future power infrastructure. The continued adoption of internet-connected digital technology in UK cities for the monitoring and control of engineered infrastructure, makes city services increasingly dependent on electrical power. Not only does this potentially lead to a substantial increase in the scale of power demand in cities, particularly with the anticipated use of the Internet of Things (IoT) and Massive Internet of Things (MIoT), but it also creates a requirement for 24/7 reliability of supply in cities 365 days a year. In future UK cities, even relatively short interruptions to supply will potentially lead to substantial economic and social impacts. Government must absolutely ensure that as well as meeting demand, the electricity supply to future UK cities is highly resilient to uncertain external physical shocks and cyber security threats, as well as to normal operational faults and breakdowns.

2. City authorities focus more on collaborative working and sharing smart city learning across networks of cities, and engage with people's concerns regarding equality of access. Today's culture of cities competitively positioning themselves against one another for smart city status, and for access to public funding for smart city initiatives, is against people's overwhelming desire for equality of access across the UK to the benefits of digital integration. Instead, UK city authorities need to pay more attention to working together in city networks to share smart city knowledge, learning and experience, as well as creating stronger physical connectedness with each other and nearby communities. UK engineered infrastructure and city services should integrate digital technology only when it makes credible economic, business or social sense to so, and such projects must take into account people's concerns, as raised in this report, about the use of technology in the cities in which they live.

3. The education profession acknowledges the new skill sets needed for living and working in a digitally-enabled urbanised society, and radically reconfigures education and training to be fit for purpose in a 21st–century smart city future. Substantive shifts are already taking place in the character of life and paid employment in UK cities as a result of digitisation. Further integration of digital technology into engineered city infrastructure and city services will likely increase the pace of this transformation, bringing into sharp focus the need to address people's concerns regarding the degradation of life skills and acquisition of skills to meet the requirements of future jobs. The UK education community needs to recognise these changes and concerns and work with the engineering profession, as well as relevant others, to consider a radical repurposing of education, training and skills development in the UK to ensure fitness for purpose in a 21st-century digitally enabled urban world.

CONTRIBUTORS

- Dr Jenifer Baxter
- Rupert Blackstone, Energy Environment & Sustainability Group, Institution of Mechanical Engineers
- Tom Brookes, Palo Alto Networks
- Dr Colin Brown
- Kelsey Finch, Future of Privacy Forum (Washington DC, USA)
- Peter Finegold
- Dr Tim Fox, Process Industries Division, Institution of Mechanical Engineers
- Dr Helen Meese
- Peter Hall, Palo Alto Networks
- Aaron Miller, Palo Alto Networks
- Philippa Oldham

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REFERENCES

1 IIASA, Global Energy Assessment (GEA) – Toward a Sustainable Future. (International Institute for Applied Systems Analysis, Laxenburg, Austria, 2012)

2 United Nations, World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352). (United Nations, Department of Economic and Social Affairs, Population Division, New York, 2014)

3 Fox, T., Pope, M. and Ellis, E.C., Engineering the Anthropocene: Scalable Social Networks and Resilience Building in Human Evolutionary Timescales. The Anthropocene Review, November 24, 2017, DOI: 10.1 177/2053019617742415.

4 Cambridge Consultants, Review of latest developments in the internet of Things. Ofcom contract number 1636 (MC370). (Cambridge Consultants Ltd, England, 2017)

5 https://www.cnbc.com/2016/01/06/ces-smart-homes-of-the-future.html

6 http://smarthome.reviewed.com/features/10-tech-products-that-will-save-you-money-on-your-utility-bills

7 BSI, Smart Cities – Vocabulary. BSI Publication (PAS 180:2014). (British Standards Institution, United Kingdom, 2014)

8 http://www.alphr.com/technology/1006261/how-one-european-smart-city-is-giving-power-back-to-its-citizens

9 https://www.smartnation.sg/

10 https://motherboard.vice.com/en_us/article/7xza9d/dubai-smart-cities-interview

11 https://www.smartrailworld.com/urban-mobility-goes-airborne-as-dubai-set-to-trial-pilotless-self-driving-air-taxis-this-year-video

12 https://www.khaleejtimes.com/business/local/delivery-this-dubai-company-will-use-drones-to-do-if-for-you

13 https://www.alaraby.co.uk/english/society/2016/4/26/dubai-announces-plans-for-driverless-cars-by-2030

14 http://mashable.com/2017/06/29/dubai-police-self-driving-bot/#1b6v0H4_uaqz

15 http://mashable.com/2017/05/24/robocop-dubai-robot-police/#9RGTmIhPumq2

16 https://www.india.gov.in/spotlight/smart-cities-mission-step-towards-smart-india

17 https://economictimes.indiatimes.com/news/politics-and-nation/smart-cities-take-shape-two-years-after-launch-of-modis-flagship-mission/articleshow/60075719.cms

18 http://www.lemonde.fr/smart-cities/article/2017/05/29/in-india-extremely-ambitious-urban-projects-run-by-managers_5135634_4811534.html

19 http://www.transmission-line.net/2011/05/history-of-scada-supervisory-control.html

20 https://theurbantechnologist.com/2016/02/01/why-smart-cities-still-arent-working-for-us-after-20-years-and-how-we-can-fix-them/

21 https://iot-analytics.com/top-10-iot-project-application-areas-q3-2016/

22 https://gowlingwlg.com/en/united-kingdom/insights-resources/what-do-data-centres-need-to-provide-to-enable-smart-cities-

23 IEA, Key World Energy Statistics 2016. (International Energy Agency, Paris, 2016)

24 BEIS, Digest of UK Energy Statistics (DUKES) 2017, Chapter 5: Electricity. (Department for Business, Energy & Industrial Strategy, UK Government, London, 2017)

25 HM Government, 2050 Pathways Analysis. (Department of Energy & Climate Change, UK Government, 2010)

26 DECC, Electricity System: Assessment of Future Challenges – Annex. (Department of Energy & Climate Change, UK Government, 2012)

27 https://www.emc.com/collateral/analyst-reports/idc-the-digital-universe-in-2020.pdf

28 https://www.newswire.com/news/new-green-data-center-technology-win-accolades

29 http://marshall.org/energy-policy/the-cloud-begins-with-coal/

30 http://www.bbc.co.uk/news/uk-40069865

31 Huq, N, Hilt, S and Hellberg, N, US Cities Exposed. (Trend Micro Inc., Irving, USA, 2017)

32 Wilhoit, K, Who's Really Attacking Your ICS Equipment? (Trend Micro Inc, Cupertino, California, USA, 2013)

33 Wilhoit, K, The SCADA That Didn't Cry Wolf. (Trend Micro Inc, Cupertino, California, USA, 2013)

34 http://www.presstelegram.com/2017/06/27/cyberattack-shutdown-of-la-port-terminal-sparks-security-worries/

35 https://www.nytimes.com/2016/04/07/us/politics/homeland-security-dept-struggles-to-hire-staff-to-combat-cyberattacks.html

36 https://ics-cert.kaspersky.com/reports/2017/03/28/threat-landscape-for-industrial-automation-systems-in-the-second-half-of-2016/#2l3

37 AlienVault, Cloud & IoT; Or, how I learned to stop worrying about security & Love Innovation. RSA 2017 Survey Report. (AlienVault, San Mateo, California, USA, 2017)

38 http://www.smartdatacollective.com/smart-cities-future-innovation-or-intrusion/

39 http://www.telegraph.co.uk/news/2017/08/30/houston-imposes-curfew-amid-reports-looting-hurricane-harvey/

40 http://abcnews.go.com/US/florida-police-report-looting-hurricane-irma-battered-state/story?id=49769726

41 IBM, Critical energy infrastructure targeted by cyber-attacks. Infographic available at https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=SE912363USEN&Best

42 http://www.atimes.com/article/blockchains-can-counter-cyber-threats-energy-security/

43 https://www.nytimes.com/2016/03/01/us/politics/utilities-cautioned-about-potential-for-a-cyberattack-after-ukraines.html

44 https://en.wikipedia.org/wiki/Microgeneration

45 https://www.gov.uk/guidance/community-energy

46 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/274746/20140108_Community_Energy_Modelling_FinalReportJan.pdf

47 https://www.americanprogress.org/issues/green/reports/2016/07/13/141118/girding-the-u-s-electric-grid-with-community-energy-storage/

48 https://en.wikipedia.org/wiki/Microgrid

49 https://www.fastcompany.com/3058201/this-new-york-project-fuses-energy-microgrids-with-blockchain-technology

50 http://www.darkreading.com/threat-intelligence/artificial-intelligence-cybersecurity-friend-or-foe-/a/d-id/1328838

51 IET, Smart Cities. Time to involve the people? (Institution of Engineering and Technology, London, 2016)

52 Ipsos MORI, Future Cities Dialogue: Report for Innovate UK and Sciencewise. (Ipsos MORI Social Research Institute, London, 2017)

53 http://songdoibd.com/

54 http://www.npr.org/sections/parallels/2015/10/01/444749534/a-south-korean-city-designed-for-the-future-takes-on-a-life-of-its-own

55 https://www.theguardian.com/environment/2016/feb/16/masdars-zero-carbon-dream-could-become-worlds-first-green-ghost-town

56 https://medium.com/sidewalk-talk/reimagining-cities-from-the-internet-up-5923d6be63ba

57 https://www.curbed.com/2017/5/9/15592598/sidewalk-labs-smart-city-urban-planning-google

58 http://statescoop.com/google-wants-to-build-a-city

59 Black & Veatch, 2017 Strategic Directions: Smart City/Smart Utility Report. (Black & Veatch, Kansas City, USA, 2017)

60 Innovate UK, Future Cities UK: Investing in better places to live, work and play. (Technology Strategy Board, Swindon, 2015)

61 Caprotti, F and Cowley, R, Smart Cities UK 2016. (King's College London, London, 2016)

62 Caprotti, F, et al, Smart-Eco Cities in the UK: Trends and City Profiles 2016. (University of Exeter, Exeter, 2016)

63 http://theweek.com/articles/689527/hightech-cities-future-utterly-lonely

64 https://www.thenatureofcities.com/2016/05/26/sense-of-place/

65 HIS Market and WBA, The Urban Unconnected. White Paper. (HIS Market and Wireless Broadband Alliance, 2017)

66 https://www.boston.gov/departments/innovation-and-technology/apps#streetbump

67 Stockholm Internet Forum 2017: Access and human rights in the smart city. Video recording (2017). Available at https://www.youtube.com/watch?v=oKnRG2ZcDhU

68 https://www.ibef.org/industry/information-technology-india.aspx

69 HLRN, India's Smart Cities Mission: Smart for Whom? Cities for Whom? – A Human Rights and Social Justice Analysis of Smart City Proposals. (Housing and Land Rights Network, New Delhi, 2017)

70 https://en.oxforddictionaries.com/definition/skill

71 http://dictionary.cambridge.org/dictionary/english/skill

72 https://www.techrepublic.com/article/16-tech-jobs-that-will-be-needed-for-the-future-of-smart-cities/

73 http://www.constructionweekonline.com/article-37236-exploring-smart-skills-required-for-smart-cities/

74 PE, Robots, leave these kids alone! Professional Engineering, September 2017, p29. (2017)

75 https://www.theatlantic.com/magazine/archive/2015/07/world-without-work/395294/

76 Autor, DH, Why Are There Still So Many Jobs? The History and Future of Workplace Automation. Journal of Economic Perspectives, 29(3), pp3-30. (2015)

77 McKinsey, Impact d'internet sur l'économie française: Comment internet transforme notre pays. (McKinsey & Company, 2011)

78 McKinsey Global Institute, A Future That Works: Automation, Employment, And Productivity. (McKinsey & Company, 2017)

79 PwC, UK Economic Outlook. (Price Waterhouse Coopers LLP, London, 2017)

80 McKinsey Global Institute, Independent Work: Choice, Necessity, And The Gig Economy. (McKinsey & Company, 2016)

81 RSA, Good Gigs: A fairer future for the UK's gig economy. (Royal Society for the encouragement of Arts, Manufactures and Commerce, London, 2017)

82 UKCES, The Future of Work: Jobs and Skills in 2030. (UK Commission for Employment and Skills, 2014)83 ONS, Trends in self-employment in the UK: 2001 to 2015. (Office for National Statistics, Newport, 2016)

83 ONS, Trends in self-employment in the UK: 2001 to 2015. (Office of National Statistics, Newport, 2016)

84 McKinsey Global Institute, Technology, Jobs, And The Future Of Work: Briefing Note. (McKinsey & Company, 2017)

85 IMechE, Science in Schools, Education Policy Statement. (Institution of Mechanical Engineers, London, 2010)

86 IMechE, Engineering Skills for the UK Industrial Economy, Education Policy Statement. (Institution of Mechanical Engineers, London, 2013)

87 IMechE, Big Ideas: The Future of Engineering in Schools. (Institution of Mechanical Engineers, London, 2016)

88 https://www.inc.com/greg-satell/a-20th-century-education-system-wont-prepare-our-kids-for-a-21st-century-world.html

89 https://www.theguardian.com/commentisfree/2017/feb/15/robots-schools-teaching-children-redundant-testing-learn-future

90 Bulger, M, McCormick, P and Pitcan, M, The Legacy of Inbloom, Working Paper 02.02.2017. (Data & Society Research Institute, New York, 2017)

91 Belanche-Gracia, D et al, Determinants of multiservice smartcard success for smart cities development: A study based on citizens' privacy and security perceptions. Government Information Quarterly, 32(2), pp154–163. (2015)

92 van Zoonen, L, Privacy concerns in smart cities. Government Information Quarterly 33, pp472-480. (2016)

93 https://fpf.org/2017/03/31/shedding-light-smart-city-privacy/

94 Finch, K and Tene, O, Welcome to the Metropticon: Protecting privacy in a hyperconnected town. Fordham Urban Law Journal 41, pp1581 – 1615 (2015)

95 https://www.theguardian.com/cities/2014/dec/17/truth-smart-city-destroy-democracy-urban-thinkers-buzzphrase

96 http://securitymiddleeast.com/2015/10/09/smart-cities-a-smarter-operations-centre-for-rio/

97 Warren, DS and Brandeis, LD, The Right to Privacy. Harvard Law Review, IV(5). (1890)

98 http://www.waterwise.org.uk/pages/nudge-theory.html

99 https://www.citylab.com/life/2017/04/singapore-city-of-sensors/523392/?utm_source=nl__link6_050417

100 http://www.hdb.gov.sg/cs/infoweb/press-release/yuhua-the-first-existing-hdb-estate-to-go-smart

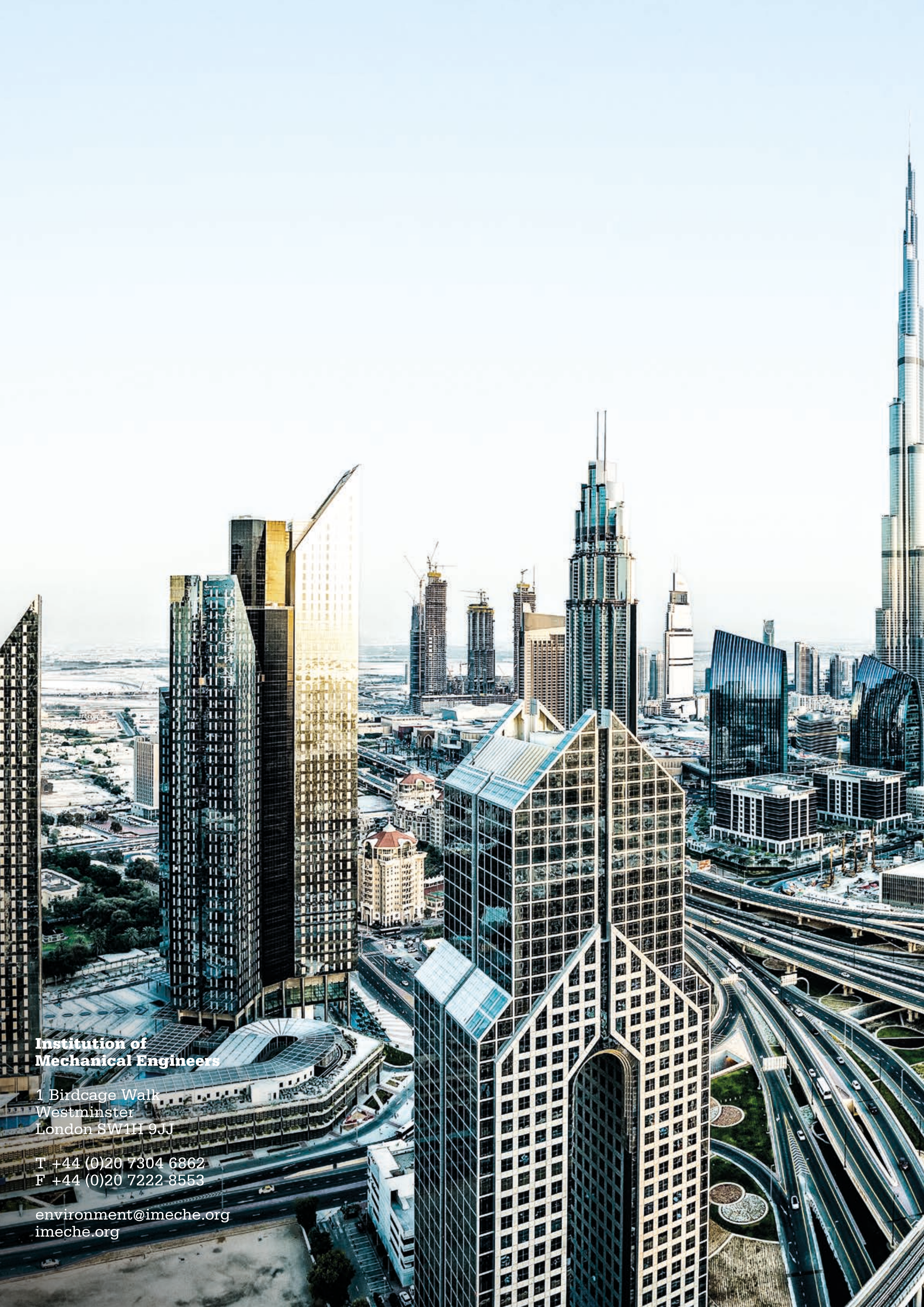
101 https://www.wsj.com/articles/singapore-is-taking-the-smart-city-to-a-whole-new-level-1461550026

102 https://www.smartnation.sg/initiatives/Living/smart-homes-tech-enabled-solutions-for-homes-in-singapore-1

103 https://www.digitaltrends.com/home/virtual-singapore-project-mapping-out-entire-city-in-3d/

104 https://www.tech.gov.sg/Programmes-Partnerships/Programmes-Partnerships/Initiatives/Smart-Nation-Sensor-Platform

105 https://www.digitaltrends.com/home/smart-wallpaper-will-be-embedded-with-microphones-sensors/



Institution of Mechanical Engineers

1 Birdcage Walk
Westminster
London SW1H 9JJ

T +44 (0)20 7304 6862
F +44 (0)20 7222 8553

environment@imeche.org
imeche.org