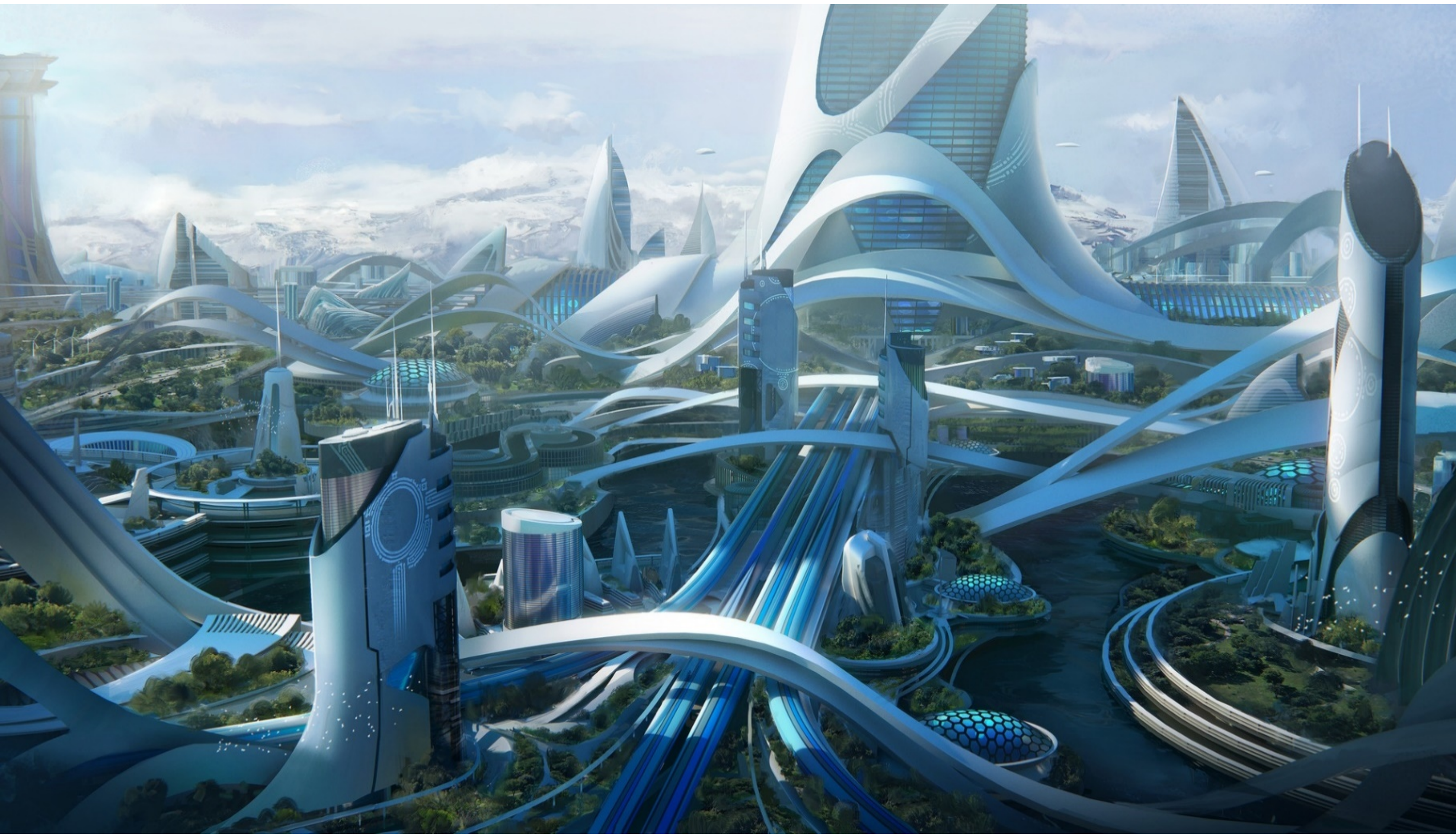
Built Environment Futures



Paper 2: Facilities Management

In Association

Foreword

At Robertson our vision for the future is to 'assure a sustainable future'. By this we mean we will work to ensure profitable growth which builds on a strong customer focus, consistent and predictable construction delivery, investment in our people, partnership with our suppliers, and adoption of new technology.

To ensure we were 'future-proofing' our business and operational strategy we identified a need to have a look further ahead to 5, 10 and 20 years down the line to understand how our customers and markets are likely to change. This in turn allows us to consider the impact or opportunity for our businesses and respond accordingly.

We were pleased to find willing collaborators in this endeavour in Autodesk, Scottish Enterprise and the Construction Scotland Innovation Centre, all of whom helped fund this work. We commissioned Glasgow Caledonian University to carry out a series of three research papers looking at the Construction, Facilities Management and Infrastructure Markets. The views expressed in the papers are those of Dr Michael Tong and his team of researchers, but they have been guided by the steering group of partners. We are also grateful to Autodesk for sharing with us the time of some of their global experts.

Since the reports were commissioned, we have experienced the unprecedented circumstances of the COVID-19 pandemic which has changed the built environment sector overnight, accelerating the use of digital tools and reconfirming the importance of front-line Facilities Management staff. Although business challenges have changed in the short-term, the risks and opportunities the reports highlight are still relevant. Some, such as the desire to become more resilient through a net zero carbon economy and by using digital technology have come closer, whilst others may have become less relevant or are likely to move on a slower timescale. Nevertheless, we value the insight and challenge they bring to our business.

However, whilst we take time to consider how these inform our strategy and business models, we are keen to share this insight with the wider built environment. We hope you enjoy reading the papers and that they stimulate conversations in your organisations and with your partners about the opportunities they present for our sector.

Elliot Robertson
CEO Robertson Group

Contents

Figures

Tables

Executive summary

Facilities Management (FM) is at the beginning of a digital revolution which is shifting the sector away from a traditional operational cost centred approach to one which is more strategic and focused on added value for the client. This requires FM providers to embrace innovation both in terms of the planning and adoption of new digital technology within the facilities and in terms of the management processes which it enables. The digital world is already revolutionising the way FM is delivered and it is clear that providers who do not embrace this will be left behind requiring an integration between the physical and the virtual environments. This will not only impact our building management systems, it will also affect the way people use buildings and the nature of the working environment. Delivering better building performance for sustainability through FM can only be achieved if the FM sector has the right knowledge, skills and most importantly culture to embrace this revolution for their clients as future competitive advantage will depend on this.

This report starts from the position that digital technology is evolving faster than FM practice is able to embrace it and operationalise its potential. This represents an exciting future over the next 5, 10 and 20 years but requires the FM sector to start embracing its potential now. The challenge facing FM is that it is widely seen as a sector servicing the built environment, historically playing a minor role in the design and construction decisions taken within new builds and with decisions often being taken on a largely operational level on behalf of clients rather than focusing at the strategic level where real value can be added for clients. The 4th industrial revolution provides this capability and FM needs to be at the heart of building design, construction and operation.

This report responds to calls within a series of government, professional body and industry reports which have called for FM to embrace the 4th industrial revolution and importantly to realise its strategic role for clients. This will have significant implications for FM providers and whilst this report does not seek to provide definitive answers, through an extensive literature review, interviews with three senior experts working in the field and the guidance of the Steering Group, this report seeks to expose decision makers to the latest thinking and trends to ensure that they can ask the right questions now and in the next 5, 10 and 20 years. The report examines nine key themes which we believe will have the most impact on the FM sector. These themes emerge strongly from the literature, but through interviews with three senior experts in the field and the guidance of the Steering Group these were contextualised and framed for this report around an interpretation for the FM sector of the World Economic Forum's three future scenarios (*Building a Virtual World, A People-centred World*, and *A Green World*).

Building in a Virtual World shows us that Artificial Intelligence and Machine Learning is with us now, and needs FM providers to embrace the potential for improving building performance, FM productivity and in the connection of workflows and BIM. Digital Twins and Robotics are identified as the future over the next 5, 10 and 20 years with the potential to revolutionise FM provision in terms of service delivery and labour requirements. A key strategic partnership for FM providers will be working with software and technology providers.

People-centred World takes the view that as we embrace Industry 4.0, FM needs to remember that its core focus is the end user i.e. those using and working in the facilities. The dependency of the workforce on the physical environment is going to decrease with home working never being easier, and the

Coronavirus outbreak has only reinforced the potential of a virtual workforce and service provision across all sectors. In the future work spaces require to be dynamic and interactive experiences supported by high quality technology to enable engagement with those within and out with the office. Social distancing in the short term requires service providers to rethink their offering with online provision, which longer term will change the nature of their facilities requirements (i.e. Higher Education). FM need to work with clients and designers to make sure that workspaces are future proofed with evolving space and technology requirements, with those able to add value for their clients achieving competitive advantage. In addition, FM providers need to address technology to help address a labour shortage for unskilled labour accelerated by Brexit and to focus on upskilling staff to be able to embrace the digital world.

A *Green World* acknowledges that FM needs to focus on Sustainability and Climate Change and aid clients to meet their obligations with a focus in the short to medium term on net zero carbon within building performance and its lifecycle, as well as the need to move towards increasingly the circular economy. Building energy management, systems efficiency and workplace management are all linked to this scenario, and key to enabling this is for FM to embrace the potential of Smart Cities which is more than just technology and is about the connectivity of buildings, districts and communities.

The digital revolution is with us, and for FM providers the need is to embrace it, innovate and be prepared to offer clients added value by focusing more at the strategic level rather than the traditional operational. The recent Covid-19 outbreak will undoubtedly accelerate our reliance on digital technology and virtual environments representing marked changes in the way FM is delivered. Changes to facility spatial design and creating an environment where workforces can engage from other locations in a productive and collaborative way is being implemented and is having a significant impact across all sectors from schools, hospitals, retail and offices. It is clear that successful FM providers will be those who have sought competitive advantage by being innovative, dynamic and more strategic in their engagement with the digital future and its implications for their clients.

1. Introduction

This report reflects the framework established in the Construction and Infrastructure papers and explores the future for the FM sector over the next 5, 10, and 20 years. This is a fast changing sector due to the importance of digitalisation and the potential it provides for data capture, storage and management with an emphasis placed on the ability for shared and integrated service provision. This will have significant ramifications for the nature of the service offered by FM providers moving from a traditional operational cost centred approach to one which is more strategic and focused on valued added for the client. It is harder to visualise the long term implications of these changes for this sector, but it is apparent that the short and medium terms will require FM service providers to be innovative and able to embrace change in their provision as the sector changes and embraces the potential of a digital and virtual world. A shift that is driven by changes in society (demographics and behaviour) and the economy, advances in technology and the growing importance of sustainability.

The digital work will have significant implications for our buildings as working environments as practices change and office environments become more flexible, but also in terms of the efficiencies and environmental performance of their operation. The importance is also emphasised on the need for FM providers to focus increasingly on sustainability and to deliver this across the building lifecycle through advances in technology but also through the advantages for efficiency savings offered by digital innovations. This report will consider the implications of this around three future scenarios, which are identified as the three dominant drivers for the future of FM:

Building a Virtual World – In this World, FM is digital and automated. New and more advanced technologies, the increasing usage of autonomous Robotics, Internet of Things, Artificial Intelligence, Machine Learning and improved data collection, storage, mining and analysis, shape the development of the FM and services industry. This is altering how services are managed; how end-users interact with service providers; how, when, and where people work, redefining the workplace; and, how real estate and facilities are used.

A People-centred World – FM is a people-based business. FM are proactive in transforming the organisations they provide the services to, into one that embraces a true service mind-set by putting the end-user first and living the organisation's values. The new way of working and the importance of well-being and productivity is changing the role of FM, from asset provision to service provision. There is an ageing FM workforce which lacks the right skills to embrace digital innovation, and a gap in the frontline workforce and new-young talent in the FM discipline.

A Green World – The sustainability agenda is a business imperative, driven by ambitious targets set by the Governments for energy efficiency, waste management, resource utilisation and carbon foot printing. Sustainable expectations and targets are of high importance to customers, both corporate customers and individual building users. Automation and technology are an essential element of the Green World as they help to protect scarce resources and minimise environmental damage.

These three drivers are not mutually exclusive forces which will shape tomorrow's FM practice, but they highlight the position of FM as an integral part of a long-term perspective, underlining the connection that FM has with the other stages of the building life cycle. We are already experiencing their transformative roles in the reorganisation of labour markets, the way business is delivered across all sectors and this is having significant implications for FM.

There is a recognition that as businesses respond to changing demands that there is a need to balance limited budgets and resources with the requirement to operate and maintain the building portfolio across its lifecycle. Yet, it is challenging to visualise the long term implications of the future scenarios presented throughout this report (e.g. greater energy efficiency, lower costs for consumers, reduction of total life cycle costs, business efficiency and sustainability, etc.), but it is apparent that the short and medium terms will require FM service providers to be more innovative in order to embrace change.

'Whereas buildings change slowly, FM cannot afford to'

2. About the research

This report investigates the future of FM around the three future scenarios – Building a Virtual World, People-centred World and Green World. These emerged following a review of the literature and discussions with three leaders in estates and facilities management with experience at managing healthcare and high level education facilities. The wider Steering Group which guides this research has provided important insight into shaping the scope and direction of the final report.

Nine themes have been also identified and investigated further through a review of scientific evidence (using several databases and further consultation of relevant journals), as well as a review of grey literature including policy documents, professional body reports, organisational and expert publications. Although the themes identified for this report can be argued to have some influence on all potential scenarios, the research team have categorised them into the most relevant scenario.

In addition to grouping the nine identified themes using the three future scenarios, Table 1 provides an indication of the impact that each theme has on digital transformation in the next 5, 10 and 20 years. Furthermore, each theme has a provisional assessment of its position in the innovation portfolio/pipeline for a FM organisation. The impact on digital transformation for each theme is assessed either High (H), Medium (M) or Low (L). Having said this, it is important to note that the impact that technological change will have on FM will depend, partly, on how the profession and the broader facilities services industry responds to the opportunities and challenges presented by emerging digital technologies, which will only be realised if FMs have the right skills and knowledge.[1]

Each of the nine identified themes is introduced with a table that provides a summary of the key trends of theme, along with an indicative timeline of its application and its potential impact to a facilities management organisation.

The later stages of the research have coincided with the Coronavirus outbreak and the lockdown, with dramatic ramifications for FM providers and the need to reflect on what a future may look like with social distancing and increased home working, but also what this means for the future for the services offered by clients.

2.1. Research approach and limitations

This research presents some limitations. A key difference to observe when compared to the construction phase is that the digital transformation remains an emerging area of knowledge very much in its infancy within FM. This was identified by RICS (2018)[2] and has been also confirmed by the research team. There is limited availability of scientific evidence of the future of FM and many of the references used in this report are from white papers and research studies conducted by private companies and professional bodies.

Although the report identifies the impact on digital transformation in 5, 10 and 20 years' time, this has been mostly based on the research team's judgment, the reflections of three leading estate and facilities managers informed by the direction set by the Steering Group. The literature demonstrates that there is uncertainty of how fast digital solutions will penetrate markets and how quickly societies will adopt new technologies, making prediction further into the future a difficult task.

3. Future scenario A: Building a virtual world

Theme 1: Artificial Intelligence/Machine Learning
Theme 2: Connected workflows
Theme 3: BIM
Theme 4: Digital Twins
Theme 5: Robotics

3.1. Theme 1: Artificial Intelligence and Machine Learning

Key Trends	Timeline	Impact
Key Trend 1: Artificial Intelligence and Machine Learning – Artificial Intelligence (AI) is the broader concept of machines being able to carry out tasks in a way that we would consider "smart". It is also the area that has led to the development of Machine Learning. AI is already playing an important role in automating workflows This technology is essential in a smart building, and many of the new and future FM applications combine this technology with Internet of Things (IoT) sensors and Building Data Analytics (BDA). AI and Machine Learning is with us now and will continue to evolve with benefits for improving building performance and FM productivity.	**Now (0- 5 years)**	**High**

Automatic controls in buildings are nothing new, but the new generation of Artificial Intelligence (AI) and Machine Learning applications offers a step change in capability. AI is when a machine performs a task that human beings find interesting, useful and difficult to do. The current wave of AI works by using computer models to simulate intelligent behaviour. Machine learning and cognitive computing complements AI. Machine Learning is any program that improves its performance through experience rather than explicit programming; whereas, cognitive computing simulates, specifically, the perception and reasoning aspects of human intelligence (natural –language processing, speech and vision).[3]

	Case 1	Case 2	Case 3
ML	Recognizes faces	Predicts equipment breakdown	Predicts the likelihood of disease
AI	Infers you are upset	Schedules a repair	Finds a new treatment

	Case 4	Case 5	Case 6
ML	Clusters documents by similarity	Learns to recognize obvious defects	Predicts the performance of a system
AI	Sorts documents by priority	Infers hidden defects	Designs a system to meet performance goals

A system is AI if, for example, machine learning algorithms infer a customer's need and recommend a solution. Figure 1 provides some examples of the relationship between terms like AI and Machine Learning.

Figure 1: Relationship between terms like AI and Machine Learning.[3]

Voice activated virtual (or personal) assistants, such as Amazon's Alexa and Apple's Siri, are also some examples of how AI is being applied in everyday situations.[1]

It is useful to think of three levels of AI:[5]

- Assisted intelligence, widely available today, improves what people and organisations are already doing. A simple example, prevalent in cars today, is the GPS navigation programme that offers directions to drivers and adjusts to road conditions.

- Augmented intelligence, emerging today, helps people and organisations to do things they could not otherwise do. An example of this is car sharing businesses (e.g. real-time data analysis provides driving advice. The car is fully configured for the client before they set off on their trip).

- Autonomous intelligence, being developed for the future, establishes machines that act on their own. An example of this will be self-driving vehicles, when they come into widespread use.

There are many ways in which facility-related services are likely to be affected by AI. Although some examples are provided below, it is important to note that this technology is essential in a smart building (see Section 3.2.1), and many of the new and future applications will combine AI and Machine Learning with IoT sensors and BDA. An example of this are the new systems that can contribute to cleaning services by recognising poor hygiene habits such as spillages in a corridor. These are then caught on camera and sent to the administrators via a mobile alert allowing for cleaning to be actioned. Healthcare estates will benefit specifically from this, with systems able to combine AI intelligence algorithm analysis with IoT technology to search camera footage for different "risk management" areas. This technology will be able to identify eight types of misbehaviour including smoking and playing on mobile phones, and recognise four positive habits such as regular hand washing and disinfecting the kitchen.[6] Another example is the possibility of monitoring who is not washing their hands and then sending them a polite private SMS or email to prompt them.[7] This presents potential as part of mitigation measures to prevent for example spread of Coronavirus.

AI is also playing an important role in automating workflows with an AI building management system able to automatically allocate tasks. The system analyses data and allocate task based on proximity, skill set, priority, etc.[1] For example, if a plumbing repair is needed, the office manager can log onto an online platform to report the incident. From there, the process is automatic. A call goes out to an approved vendor to make the repair, eliminating paper orders and manual steps, such as locating an approved plumbing contractor with immediate availability. The automated process has the potential to add value by capturing data that was never tracked in paper-based systems. Using GPS data, the system can for example tell when the technician arrived and left the site. The system can also determine if the invoice price conforms to the contract price, and using benchmarking data can show whether the cost of the repair is out of line with area averages. With digitised services, there is transparency throughout the process, allowing everyone to see what stage the request is in and when it is completed.[4]

3.2. Theme 2: Connected Workflows

Key Trends	Timeline	Impact
Key Trend 1: Internet of Things, Big Data Analytics and Smart Buildings – Building Data Analytics (BDA) increases in the use of BIM and other technology tools has generated large amounts of both structured and unstructured data. The goal is to fully utilise this data by employing Machine Learning algorithms to provide predictive analytics to help us make better decisions in real time. In an FM setup, Internet 0f Things (IoT) typically involves installing meters, sensors, systems and devices that measure the actual behaviour of assets, equipment and components, and interact with other systems to create a data pipeline. IoT together with BDA allow for predictive instead of reactive maintenance, improve space management and gain an improved understanding of how a facility is being used and interacted with by its occupiers, amongst others. A smart building is any structure that uses automated processes to automatically control the building's operations including heating, ventilation, air conditioning, lighting, security and other systems. The most fundamental feature of a smart building is that the core systems within it are linked. This technology is evolving quicker than the practice is able to implement, providing already the potential for improvement now.	**Now (0- 5 years)**	**High**
Key Trend 2: Blockchain – Blockchain provides transparency in data handling, traceability of all transactions and ease of collaboration between qualifying parties. Blockchain technology is currently at its peak of inflated expectation and it is expected to be ready for adoption in 5 to 10 years.	**Next (5-10 years)**	**High**
Key Trend 3: Social Media – Social Media can be valuable for FM providers in understanding how effectively facilities are managed from the point of view of the users, and actively manage their brands to protect their reputations.	**Now (0- 5 years)**	**Medium**

3.2.1. Key Trend 1: Internet of Things, Big Data Analytics and Smart Buildings

It is important to recognise that data in the FM sector can be both structured and unstructured. Both types of data play a necessary part of FM with structured data normally referred in building information models, but a typical facility maintenance project also generates additional volumes of unstructured data, captured in photos, graphics, videos, and scanned documents, etc. Building management systems (BMS) increasingly seek to integrate different data systems for example computer-aided facility management (CAFM) systems for the evaluation of an organisation's operational efficiency and performance, BIM containing spatial information, as well as a variety of sensors and controllable devices such as heating, ventilation, air conditioning (HVAC), security systems. BMS's are not new and were first patented in 1996 providing data gathering and processing for FM. The emerging ability to integrate data and processing within BMS has seen a questioning of conventional BMS's with isolated communication protocols and static rules unable to respond to real-time building conditions, as the data processing technique is primarily based on a SQL database or even spreadsheets statistics, which is inefficient, resource demanding, and costly and not intended for analytics. This requires changes in the way data is gathered and managed, and currently it is clear the technology is moving faster than FM practice, presenting significant potential for improvement in the short, medium and longer time horizons. An example of this can be seen in building services which is improving by developing more accurate contextualisation of data using recent IoT and BDA technologies, which are capable of integrating dynamic control strategies and new efficient and effective algorithms to deal with large influx of data, hold the promise of improved system reliability, greater energy efficiency and lower costs for consumers.[8]

Internet of Things – IoT is a network of physical devices and objects embedded with electronics, software, sensors and network connectivity which enable these devices to produce, exchange and consume data with minimal human involvement. [9] In simple words, IoT is a system of machines or objects that can collect data and communicate with one another; a means of collecting and sending big data.[10]

In an FM setup, IoT typically involves installing meters, sensors, systems and devices that measure the actual behaviour of assets, equipment and components, and interact with other systems to create a data pipeline.[11] IoT offers the possibility to understand in real-time what is happening throughout every aspect and component of a building and its operation and can provide valuable contextualised data for analytics.[10] These trends not only allow for the integration of different pieces of building equipment, systems and data sources, but also enable the conversion of the massive amounts of big data relating to building operations (data that surpasses the processing capability of traditional database systems), into actionable information through the use of analytics. IoT enables every aspect of building performance. The number of devices that are fitted with interfaces for remote management and status reporting will be higher as this technology becomes more cost effective.[12]

The 'golden egg' for FM with regard to IoT is the attainment of predictive instead of reactive maintenance to reduce downtime of assets and aid efficient labour management, amongst other benefits. It can also be used for example to improve space management and gain an improved understanding of how a facility is being used and interacted with by its occupiers.[10]

Big Data Analytics – Big data are datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse.[13] As stated earlier, big data is generated by collecting a wide variety of data both structured (e.g. in a database or spreadsheet) and unstructured (images, videos, emails, transaction data etc.) from different systems to produce actionable knowledge.[14] The goal is to fully utilise this data by employing machine learning algorithms to provide predictive analytics to help us make better decisions in real time. By looking for patterns in datasets, relationships between things are identified (in some cases things that were not previously considered to be related to each other) in order to provide new insights, make predictions and enable better decisions.[1]

BDA is seen as presenting major opportunities to generate value for a wide variety of safety and maintenance operations, addressing issues such as energy savings, reduction of total life cycle costs, business efficiency and sustainability. BDA delivers the information needed to make informed decisions about the future, such as asset replacement trend analysis, benchmarking cost, workplace future demand prediction, complex acquisition and disposal modelling or risk and control learning among others.[12]

Smart Buildings – Smart buildings are leading to the next generation BMS, where operational systems are automatically regulated and controlled, space utilisation is managed flexibly, and technology is used to create a comfortable, healthy and productive working environment. At the heart of any smart building system is data; specifically, connected data. All buildings contain systems, technology and sensors that generate data, including BMS, utility meters, security access systems, weather monitoring stations, air-quality sensors, CCTV networks and a whole range of other meters, monitors and sensors. The more data it can collect and analyse, the greater the benefits it can deliver.

In a typical building, these systems operate discretely from each other, producing data in isolation on a specific aspect of building performance or operation. BMS collect data from a range of sensors and use that data to control assets according to pre-determined protocols, such as temperature, pressure or humidity settings. The systems can only collect data from sensors to which they are connected, and can only enable or disable assets according to pre-programmed criteria. Such systems cannot really be described as smart. But now, manufacturers of assets, such as chillers and boilers, are creating increasingly intelligent products that produce a rich array of data about the condition and performance of the asset. This data is transmitted to the cloud where it is easy to access and analyse. So much of this readily available data is currently being unused by conventional BMS technology.[15]

To create a smart building, all of this data needs to be connected on a single software platform, so that it can be analysed to create meaningful insights. Here, software-based analytics, Machine Learning and AI based programming can be applied to extract value from that data. This analysis enables to gain a detailed understanding of the relationships between different activities and systems in the building, and the external factors affecting it. The greater control enabled by this solution also means that assets will be better managed and maintained, and likely to last longer. Data from building assets can be combined easily with external data such as information on weather conditions to improve control and optimisation.

For example, Smart Buildings, Building Energy Management Systems (BEMS) to control lighting, refrigeration, security, heating, ventilation and air conditioning systems. All systems may have the ability to link together through an internal protocol (IP) network, instead of operating these systems as standalone entities, and regulate the performance of a building's critical plant systems as it does today. Integrating these systems through an internet protocol network allows building managers to efficiently manage them with one console as opposed to several and to gather data about building performance and energy usage. As a result, dramatic savings could be achieved by reducing business operating costs through delivering a leaner, cleaner and more exciting environment.[11]

By 2025, every asset/device will have a unique identity and fully integrated into a networked smart building. Smart buildings that adopt open architecture design standards can adopt new capabilities as additional hardware is added to the overall BMS infrastructure[16]. In the medium and long terms, the potential exists for buildings to be linked through smart data through centralised data management systems and shared with different agencies and stakeholders at all scales from individual building, estate, neighbourhood, city, national and even global levels.

3.2.2. Applications in FM

Engineering and maintenance

The use of IoT in combination with powerful analytics software enable organisations to develop automated fault detection and diagnostics (FDD) methods, that allows for predictive maintenance rather than reactive maintenance solutions and support smarter decision making.

According to a report produced by PWC[17] preventive maintenance is classified as:

- Level 1 Visual inspections: periodic physical inspections; conclusions are based solely on inspector's expertise.
- Level 2 Instrument inspections: periodic inspections; conclusions are based on a combination of inspector's expertise and instrument read-outs.
- Level 3 Real-time condition monitoring: continuous real-time monitoring of assets, with alerts given based on pre-established rules or critical levels.
- Level 4: Continuous real-time monitoring of assets, with alerts sent based on predictive techniques, such as regression analysis. It is about predicting future failures in assets and ultimately prescribing the most effective preventive measure by applying advanced analytic techniques on big data about technical condition, usage, environment, maintenance history, similar equipment elsewhere and in fact anything that may correlate with the performance of an asset.

Traditional approaches to asset and maintenance management involves slow response times, disruptive site visits and costly periods of downtime. They are based on established programmes, with servicing and maintenance scheduled at predetermined intervals. Yet, real-time condition monitoring provides automatic alerts. Here the sensors from each piece of equipment alert to real-time issues based on pre-established rules or critical levels, but this only get FMs to a certain level of reliability; a level where there is still a large number of unforeseeable and inexplicable failures. By applying advance data analytics (Preventive maintenance - Level 4) these failures can be tackled, allowing FMs to ensure maintenance and servicing interventions are timed appropriately and efficiently, scheduling improved maintenance plans that are predictive and reliability-based (e.g. rather than simply changing air filters every month, they can be changed when the data indicates it is necessary). The rapid advance made in AI, in particular Machine Learning, will allow assets self-monitored and communicate with each other, thus assets in a system can warn other assets that they are going to fail and stop the process before it extends to the entire system. These measures will lead to increased asset performance and life through optimised asset operation.[11]

Preventive maintenance (Level 4) is still at its early stage of its life cycle, making it difficult to find many suitable reference cases and to quantify the expected returns. One example is Sitche*, that identified in a pilot study conducted with a single, but critical filter, annual savings of around 60,000 euros for that filter alone; while the sensors and model development only cost a fraction of that.[17] Anecdotal evidence from systems analytics providers suggests reductions in maintenance costs of 20-30% are possible, although as yet there is little independent research to support this.[18]

Case study: Predictive maintenance - A large FM company, in partnership with academia, developed a pilot project where data collection for the condition-based maintenance (CBM) (vibration, temperature, humidity, energy and operational data) comes from a sensor-enabled platform. The main focus was placed on vibration analysis, since the vibration levels can provide an indication of condition as well as the differentiation of normal acceptable variations from harmful levels. The CBM detected faults to 48% of the assets and increased asset operational life by up to 75%. The comprehensive technical feasibility and business case identified potential savings in excess of £790,000 over the remaining duration of the concession period (16 years) and various operational benefits such as: mitigation of unplanned failure risk; increased asset life; and, enhanced analysis and reporting relating to asset maintenance and operations.

The initial use of BDA has been restricted to its longer length FM contracts (i.e. private finance initiative FM contracts). As such, the company has been able to achieve pockets of excellence by rolling out small trials and funding. These innovative pilot projects have demonstrated value for its customers' pilot projects. The CBM/vibration monitoring approach is able to detect symptoms and to uncover the causes of faults in pumps, bearings, gearboxes etc. up to a year in advance of the part becoming a problem. For instance, if the desired functionality is to grease a bearing, analytics data could exactly specify the quantity of greasing required to avoid over or under greasing components. By being able to detect component faults in advance, the company can schedule maintenance activities around production schedules and avoid causing disruptive downtime. This preventative approach effectively eliminates the servicing or routine interventions, typical of reactive maintenance programmes and ensures improved machine availability. Asset performance data is regularly presented as a series of dashboards available for the relevant stakeholders; data on these dashboards are tailored to the interests and overall goals of parties involved.

As a result of these BDA and digitalisation initiatives, the company has been able to achieve wide-ranging benefits, which include: informed decision making, better transparency with customers, evidence of engineering compliance, enhanced productivity in workflow management, improved stock management, develop targeted as well as flexible information management, achieve better route planning for jobs, precisely record the time taken to complete a particular job improve tender pricing accuracy, achieve better functionality for older buildings, and better resource management.[11]

---

[*] Sitche offers site services at Chemelot, which is a site for the chemical industry in Limburg (the Netherlands), as well asset management and manufacturing services for 22 factories located at Chemelot.

Health and Safety and Compliance

Digitalisation simplifies and extends the compliance function of FM. The FM team is responsible for ensuring that what goes on in and around the building complies with government regulations and that all work is done in accordance with relevant fire, safety, and zoning codes. In the world of paper-based processes, compliance has been a labour-intensive and costly process. It has also been prone to human errors and gaps. Moving compliance online has made an enormous difference, not only making compliance more accurate and efficient, but also creating greater transparency for management. Systems can automatically track when required inspections are due and capture data about the results[4]: however, digitalisation is taken this a step further. For example:

The continuous monitoring and recording of asset information is possible through sensors and prediction engines that provide evidence of the legal engineering compliance of assets.

- Using unique identifiers, an employee or contractor can prove that they have the right permits and training to perform work on a facility. These checks can be conducted instantly using beacons and smart tags.
- Digitalisation can also assist with the evacuation of buildings. Occupancy sensors provide data on user presence. Emergency crews utilise live occupancy sensor feeds to identify if, where, and how many people are in danger areas during an incident, and guide authorities to them and help them find their way to the nearest emergency exit.
- Sensors can also identify risks in environmental elements such as a drop-in air quality or noise pollution, which help increase the building users' wellbeing and productivity. Within chemical or mechanical engineering, plants sensors are placed on all staff so that all areas of the plant where staff are operating have full environmental sensor coverage as well as enabling early warning alerts in that area.

Catering

Case study: The Netherlands division of global facilities services provider ISS launched in 2017 a new IoT driven catering app for smartphones, Order@ISS, which allows customers to order food and beverages, pay on their phones, and pick up their order at their convenience. The app also gives users easy access to daily specials and reduces waiting times in cafés and restaurants. Through the use of smart sensors at customer sites and the data gathered through the catering app, ISS Netherlands is able to identify peak times during the day and adjust its catering service accordingly. The behavioural data has also helps ISS deliver an increasingly personalised experience for each customer, ensuring catering in the workplace can adjust to individual food and beverage preferences and promote special offers at the right times.

Space Management

IoT enables data to be gathered regarding how and when every space in a building is used thereby facilitating evidence-based decisions regarding space usage. By providing better space management the FM profession can identify opportunities to release space, avoid allocating additional space where it is not needed or/and reduce energy consumption. The latter can be regulated based on occupancy and provide real-time usage and efficiencies. The monitoring of occupancy also extends to better asset and facilities management. By knowing which areas have seen increased usage we can better schedule cleaning and maintenance activities.[10]

Workplace Management

FM service providers will benefit from technology in measuring the end user's behaviour, needs and satisfaction levels. From reserving conference rooms to adjusting lighting and temperature preferences, digital FM provides building users with new levels of space personalisation and efficiency, often from the convenience of a mobile app. The data derived from these preferences can then be used to continue to enhance and optimise the space, increasing employee productivity through fewer facility "distractions" and improving overall happiness.[15]

Some applications of the digitalisation of the workplace include:[15] (also see Section 4.2.2)

- *Sensor controlled heating, ventilation and air conditioning (HVAC)* – Digitalisation allows the conditioning/heating switched on at the optimum time based on the first booking in a meeting room to ensure the desired temperature is reached with minimal energy wastage.
- *Environmental and occupancy sensors* – Workplace environments automatically adjusted to a user's personal preferences. For example, an employee books a meeting room and the booking and building system adjust the environmental elements such as light and temperature to the known personal preferences.
- *Sensors on resources* **-** Rooms, desks, parking spaces, providing real-time data on space usage and availability. For example, staff can view hot desk and meeting room availability throughout the building from a reception kiosk or mobile app. Users can also search for the nearest available meeting room relative to their location or the location of their colleagues.
- *Personalised workspace based on sensor data* - Staff member chooses a work area based on preferences of natural light, climate, noise pollution and population density, based on other bookings and real-time occupancy data.
- *Advances in GPS technology* - This is already helping to improve 'wayfinding' around unfamiliar buildings. However, new devices such as smart glasses or smart contact lenses, which are now being developed, could take this a step further (e.g. wayfinding information, details of forthcoming meetings and a whole host of other useful information and reminders could be displayed directly and privately to the user on these devices).

Cleaning

Digitalisation in cleaning means more than simply connecting machines via the Internet. It refers to the connectivity between processes and technology which is designed to make processes more efficient. Robotics together with IoT platforms and BDA have a significant place in tomorrow's cleaning world and they will change the industry for the better over the next coming years, bringing numerous opportunities in commercial cleaning. There is a view that cleaning standards will rise, and cleaners' working conditions will improve as they start to work smarter, not harder.

IoT platform is already enabling data to be gathered regarding how and when every space in a building is used. Cleaners using state of the art mobile devices to record the areas cleaned, by scanning QR codes or tags, are already commonplace. The IoT can also be used with sensor or beacon technology to provide footfall monitoring, enabling improvements in the way the demand led cleaning is delivered. By knowing which areas have seen increased usage allows better schedule cleaning and maintenance activities. Some applications that enables this, include:

- Sensors on bins/containers that provide real-time data on bin/container capacity to help schedule collection and cleaning rotas.
- Sensors that indicates which resources have been used and associated volumes. For example, on a Friday occupancy data indicates that only a 1/3 of the meeting rooms are used and therefore may need cleaning. The room signage and FM mobile app indicates whether the room needs to be cleaned or not. This allows to identify exactly what areas need cleaning, and allows the client to pay for what has been serviced, a more on-demand approach.

Automatic chemical dosing systems are also becoming more common and these can improve operator safety by taking human error out of the equation, besides the risk of spillage that comes with 'glu-glu' methods of dosing (a solution that is too strong could be hazardous to the cleaner's health, while a solution that is too weak might be ineffective at removing dirt and germs from surfaces). In a healthcare environment, this might impact on the health and safety of patients.[19] Another possibility is the digitalisation of cleaning trolleys. This could be applied for example to monitor how much cleaning chemicals are being used as the cleaner works their way around the building. Data would be gathered on how much is being used, whether the correct dosage is being used, and analyse trends. In his view this could lead to more targeted training, and a reduction in costs.[7]

Case study: Sodexo have been successful in recent years in implementing sensored supplies holders and embedded wireless multi-sensors to measure occupancy as well as the room climate of almost every space type: work-desks, meeting rooms, bathrooms, hallways. Then, they provided their cleaning teams with tablets that allowed them to understand foot traffic to monitor when refills such as soap and paper products were needed, and to control and clean rooms only when it required their attention. Also, open workspaces were noted as available for day-time cleaning. By empowering their employees with this technology they realised the following benefits for their client:

- Reduced cleaning hours by 15%.
- Reduced non-essential cleaning rounds by 30%.
- This change has allowed bathrooms, toilets and office environments to be kept clean and functional 99% of the time which increases the productivity of their client's employees.
- Increased quality, efficiency and customer satisfaction.
- Reduced cleaning intervals by 24%.
- Cleaning teams have been able to redeploy to be more visible within the client environments and to spend more time on other important duties.

Energy and Sustainability

Digitalisation is already playing a significant role to help FM improve energy efficiency. Smart building technology already allows to optimise the performance of energy-consuming systems and eliminate wasted energy. By gathering and analysing data from assets, plant and equipment, it can be seen whether building assets are working as required, as well as to identify anomalies and take appropriate action. By enabling the implementation of targeted measures, such as improving controls, modifying equipment set-points and adjusting timings, smart buildings help to significantly improve efficiency, reduce consumption and lower energy costs. For example, by linking lighting to daylight sensors, electric lights can be dimmed automatically when there is sufficient natural light. In a similar way, blinds can automatically be raised or lowered to regulate temperature.

More advanced energy-management systems can observe complex usage patterns and tailor energy usage precisely for particular occupants. There are also on-demand temperature and lighting apps that office workers can download to their mobile devices. This enables temperature and lighting control in an individual office or zone, rather than an entire floor; therefore, contributing to energy savings as well as giving employees a sense of control over their environment.[4] This is significant in environments such as healthcare facilities that face the need to do more with less. Their operating costs continue to rise, while budgets decline. Rising healthcare costs put added pressure on hospitals to reduce their expenses. Energy efficiency is a hidden opportunity to help health facilities reduce operating costs and improve their financial health.

Case Study: ENGIE is an energy and services provider (achieved a revenue of €60.6 billion in 2018) that provides facilities and energy management services to the Park and is the operational arm of the LLDC Park Operations and Venues team. ENGIE installed smart building technology which extracts data from the BMS at the London Aquatics Centre and the Copper Box Arena. Data points collected include energy consumption, temperature, air pressure, humidity, valve positions and a host of other variables. The data is sent to ENGIE's smart buildings analytics platform, C3NTINEL. The insight and analysis provided through C3NTINEL enables the FM team to investigate any potential faults. The team are often able to identify and fix an issue before it would even have been detected in the past. The level of detail provided means that an appropriate engineer can be sent straight to the scene, equipped with accurate information about the nature of the fault.

Once the fault has been fixed, data from C3NTINEL can be used to verify that the intervention has been successful. C3NTINEL effectively acts as an early warning system, enabling facilities management resources to be deployed efficiently and accurately, saving time and cost for LLDC.

Data is also used by energy managers to identify and propose potential projects for long-term energy and cost savings. For example, when data from the Copper Box Arena suggested that air handling units (AHU) weren't operating efficiently, ENGIE's energy-management specialists were able to design a strategy for AHU operation, which included installing additional temperature sensors. This resulted in a 49.5% reduction in cooling requirements and a 43.3% reduction in electricity consumption during the summer months.[20]

3.2.3. Key Trend 2: Blockchain

Blockchain is a peer-to-peer distributed digital ledger that records data which is accessible and shared by multiple qualifying parties. It is the underlying technology of Bitcoin and other cryptocurrencies. Technically, blockchain – as the name suggests – is a chain of blocks of information. Blockchain offers immutability and security. Immutable would mean that transactions cannot be undone once they are captured on the blockchain, which reduces risks of fraud, abuse and manipulation of transactions. In terms of security, it is deemed to be more secured than the traditional system because cryptography is used in blockchain to protect the blocks, reducing the possibility for external parties to corrupt or modify previously saved transaction records.

Blockchain can assist in ensuring efficiency in the built environment and resolving the transparency and accountability challenge. Its adoption will give companies an edge over others in that projects are more transparent, each product life cycle stage can be tracked, and all parties involved has access to a collaborative platform. Since FM involves issuance of contracts and agreements, smart contracts can be deployed to provides a transparent and faster way to make transactions since they can be automated in blockchain network. Blockchain enables near to real-time settlement of all recorded transactions, allows for the debugging of potential conflicts and fraud prevention, and helps to reduce risks.[21] There is also a role for blockchain when BIM is used, to manage information on who did what and when and thus provide a basis for any legal arguments that might occur.

Some of the advantages of blockchain for FM identified by IFMA[22] include:

- Streamlining processes and lowering cost through the reduction or elimination of manual operations. This could be adapted to just about any process such as preventive maintenance, work orders or environmental health and safety planning and would provide major benefits over systems now in use.
- Make data collected by the IoT sensors more secure, reducing the opportunities for the data to be stolen and other security risks.
- Enables facilities to quickly and easily track all space changes and provides a good picture of how the space across different geographic areas. By establishing and unchangeable history of ‘adds and moves’, it will create the ability for FMs to review what changes have been most effective. This prevents costly mistakes and lost or unproductive time.
- Blockchain’s immutability also lends itself to the application of proof-of-process for compliance. For example, Blockchain could be used to keep track of every step required by regulatory entities, allowing them to verify compliance quicker, improving the quality, accuracy and confidence in the process.

Blockchain technology is currently at its peak of inflated expectation and it is expected to be ready for adoption in 5 to 10 years.[21] According to IFMA, it makes sense to start evaluating the possibilities now and invest some time and energy in looking at ways this technology can be enabled.

3.2.4. Key Trend 3: Social Media

In a conference held by Workplace Futures in 2016 – FM: Agent of Change[12] – one of the speakers mentioned social media as a disruptive technology that will contribute to change the way FM is approached. Social Media can be very valuable for FM providers in understanding how effectively facilities are managed from the point of view of the users, and actively manage their brands to protect their reputations.

Data shows that social media is the number one way that younger generations – Millennials and Gen Z – use to communicate. They find it easier to interact with the companies using Twitter, Facebook and Instagram to look for information, comment or complain. FM providers that are in social media are able to track these systems to get feedback on their own performance, understand what their facilities are getting right and wrong (e.g. monitoring tweets to food retailers will unearth many complaints about the state of stores). Social media will further refine the facility management program, especially as it relates to facility condition and maintenance, and also produce opportunities to up-sell extra services on the basis of protecting a brand.[12]

According to a speaker in the Higher Education Facilities Forum held in 2018, “the risk of not using social media could be even greater than the benefit of using it”. In higher education facilities, people are using social media to talk about the performance in facilities and how the campus looks. Students are using it to Tweet or Instagram their first gut reaction of their campuses, so facility managers need to intercept that feedback to know what people are saying about the services, engaging in a two-way conversation”.

3.3. Theme 3: Building Information Modelling (BIM)

Key Trends	Timeline	Impact
Key Trend 1: BIM as a FM Tool – While BIM has been widely adopted within the design and construction phase, its adoption within the operation and maintenance phase is still limited. The expectation is that it will not be until the new generation of FMs (who are the digital native), when BIM will be really seen as a FM tool.	**Next (5-10 years)**	**High**

3.3.1. Key Trend 1: BIM as a FM Tool

Most of the attention of BIM relates to new builds, but BIM is becoming increasingly relevant for existing buildings. In the view of some experts the operational phase of BIM has not been embraced yet, or difficulty has been found in its adoption and therefore does not achieve its potential benefits. Lack of understanding plays a big part in how BIM is viewed and adopted within FM; the benefits it can bring to the team and wider organisation are underplayed compared to the perceived effort and potential expense of implementing it. Understanding of an education in BIM is central to reducing this barrier.

It is acknowledged within the literature that some of the benefits of BIM for the operation and maintenance phase include, increase efficiency in maintaining assets, improve decision making on asset replacement, the ability to plan and model operational maintenance activities and workflows in a virtual environment, improved space management processes and space utilisation, more efficient use of energy, more economical refurbishment, improved management of whole life costing, and improved communication and marketing opportunities.

BIM has capacity to work together with IoT sensors for the purposes of space usage, energy control or facilitate maintenance. Sensors provide information on current and predict future asset condition and facility use, whereas BIM is the bedrock of building information. For example, BIM models help to identify areas/assets where to localise the sensors, thus FMs will be able to know when an asset needs to be serviced/replaced and see exactly what component it is and where it is located in 3D, achieving savings in maintenance. Sensors have not been strongly linked yet to BIM models, but it will become a common place.[23]

In the view of the Director of Business Development at SWGNordic: “for those without BIM Model, Reality Capture, the method of capturing information to create 3D models, is becoming more readily available and can utilise different methodology, from mobile camera to 3D laser scanning equipment. The resulting Point Cloud is used to create a BIM Model and the Point Cloud can also be used as an important information source for details that are not digitalised in the BIM Model”.

One step further is the idea of integrating robot-assisted cleaning into BIM. This consists in increasing integration of sensor systems, data analysis and automation holds even more potential. A robot generates a 3D model of building, which is the starting point for the development of cleaning workflows. Questions such as which machines are to be deployed and how many, where charging should be located or which floor coverings can be cleaned specially efficiently and in an environmentally friendly way, can be answered in advance and taken account of in the building robot.

There is also the belief that CAFM and BIM are very closely linked and will become even more integrated and so with sensors. For example, a sensor can predict a small change in temperature that is indicative of breakdown in an asset sending an alert to the CAFM systems to despatch an engineer. When BIM is integrated with CAFM, the engineer can see, through the CAFM software, exactly where the asset is located as well as parts and materials required.

Although there is a potential for BIM to have a future for FM, experts have highlighted some barriers such as the lack of FM software vendors who are able to provide a good level of BIM integration and the lack of IT skills. The expectation is that it will not be until the new generation of FMs, who are the digital native, when BIM will be really seen as a FM tool.[23]

3.4. Theme 4: Digital Twin enabled asset management

Key Trends	Timeline	Impact
Key Trend 1: Digital Twin – This is in the infancy. Some of the technology linked to Industry 4.0 is embryonic but FM providers need to embrace this now to be competitive and to work with clients to ensure they are not left behind.	**Next (5-10 years)**	**High**

3.4.1. Key Trend 1: Digital Twin

Digital twin (DT) although widely promoted, it is still in its infancy. When well developed, DT will play a significant role in infrastructure planning and enable better asset maintenance using predictive data analytics, better asset tracking, more efficient use and management of equipment, and will achieve energy savings. In the view of Arup, the digital twin concept is limited by our imagination, rather than by our technology. In the not too distant future, an ecosystem of digital twins communicating across boundaries will be envisaged, sharing data and learning from each other to form meaningful collaborations and solve global challenges.[24]

DT is a digital model, which is a dynamic representation of a physical asset or a system and mimics its real-world behaviours, and it is built on data. The representation may provide information about its current design, state, condition and its history, and can also share this data, with defined levels of access. The DT technology relies on being able to integrate data from different sources including IoT, AI, ML and existing software analytics with required data to create a dynamic digital platform that updates as-is conditions following the physical asset (As-is conditions express the design of the assets, state, current condition, work orders, operational information records, FM professional in charge, up-to-date maintenance information, status, etc.).[25]

The real power of the DT, however, arises from its machine learning capabilities. To reasonably predict asset failure or to detect opportunities for optimisation, a data-driven approach will require a large amount of data collected over a long period of time. By running simulations on the model, the digital twin can generate 100,000 times more data than can be provided by the sensors alone. In this way, the digital twin becomes smarter much more quickly than the unaided physical building ever would.

Furthermore, a DT simulation can interpolate many more virtual sensors than would ever exist in reality, thereby filling the information gaps which could not be gleaned from the sensor data alone. Beyond even this advantage, the DT will already understand the relation between these points, whereas discovering this relation solely from real-time building data would be extremely challenging, due to the many non-linear and dynamic physical responses characteristic of the built environment.[24] Currently research is being conducted to integrate the asset data with the 3D BIM model, ensuring that the DT adheres to common data standards and is interoperable.

Case study: VINCI Facilities offers the "Digital Twin" solution that displays the full set of relevant data needed to manage a building's facilities efficiently. The company equips the building with DT tool and interfaced with the VINCI Facilities computer assisted management system. On a typical system, a technician may receive an alert which reads "Fan broken, Office 14, Building 3". What seems like a clear message is actually very ambiguous: What type of fan is it? What parts are required? Where exactly is the fan located? Using the digital twin for the building, a vast amount of information can be accessed by the technician before they reach the job. When there is an incident, the technician receives an incident report containing a photograph of the place where the failure occurred, taken by the customer who reported it. Based on this photo, the DT will locate the office and display it in an environment similar to Google Street View. A virtual inspection can be carried out showing the exact type of fan, the most recent maintenance report, a video tutorial and an exact nomenclature. The correct tools can then be prepared to carry out the job. The technician is given an accurate photo of the location as well as the most efficient route to take to reach the job. All of this combined reduces the time spent working out what is required and keeping the actual maintenance time to a minimum. For business units, the DT has the advantage of reducing their dependence on local and personal familiarity with the spaces. The solution is particularly suitable for existing buildings that are not equipped with BIM (the building information modelling system designed prior to construction). It is more than an indoor "Street View". It is a navigation tool but also a very intuitive way to access building documentation.

3.5. Theme 5: Robotics

Key Trends	Timeline	Impact
Key Trend 1: Robots – Robots have already shown applications for FM in cleaning, pottering, security and visitor management in different settings, and this will increase. This technology is in its infancy but has already showed significant benefits for reducing labour requirements. We need to start planning now, but this will become a common place in the next 5-10 years.	**Next (5-10 years)**	**High**
Key Trend 2: Drones – Drone technology will become more common. Sensor innovation has yet to fully transform drone capabilities. Drones will need to be appropriately managed to ensure they can be safely integrated into the skies.	**Now (0-5 years)**	**High**

3.5.1. Key Trend 1: Robots

The use of sensor technologies is opening up new robot applications for performing some of the tasks of FM such as cleaning (see Section 3.2.2), pottering, security and visitor management. Automated receptionists are already a reality. According to a report published by CBRE[26], using robots to meet and greet, taking visitors to rooms and helping them with travel information is already a reality. A pilot study using a humanoid robot in the role of receptionist and concierge was conducted by JLL in 2016 at its Sydney office. Working as part of a fully automated visitor management solution, the robot (JiLL) greet and supported staff and visitors with a range of front-of-house tasks, including check-in for meetings, providing directions, contacting hosts and recording and reporting technology or building maintenance issues. It works in conjunction with a tablet-based visitor management system, and has in-built facial recognition software to enable her to respond differently to team members than to external visitors.

Robots have shown many applications for FM in a healthcare environment, and this will increase. They are already entering specific environments like hospitals where Automatic Guided Vehicles transport food, linen and hospital stores in a safe, hygienic and efficient way. This has shown to bring a marked reduction in crowdedness in hospital corridors by nurses and relatives of patients, improving efficiency and productivity of nurses who are no longer engaged in the porter services.[27] This also adds energy savings as robots can deliver 'out of hours', when buildings and grounds are empty. This is already achieving light, heating or cooling savings because when robots need to 'see' they can carry their own lights and sensors.[26] In relation to cleaning, for example Sodexo Healthcare launched in 2016 a team of germ-zapping robots to help prevent the spread of healthcare-associated infection in hospitals.

Robots are also increasingly being deployed for waste management in light of the increasing tonnage of waste generation. An example of this, it is the smart bins which have been available in the market for a few years. A smart bin is a robotic trashcan designed with the ability to identify the waste that should be thrown away from the waste that should be recycled. They system is equipped with IoT sensors and AI technology. The sensors on these trashcans measure the waste levels of the garbage thrown inside them and send this data, via intermediate servers, to the main disposal system for processing. The system categorises the data into the type of garbage, the quantity of each type of garbage, and the respective waste disposal method. This entire system can also refine itself over time by studying historical records to improve its efficiency.

Case study: Smart bins at Colorado State University

The smart bins are high-tech, solar enabled, connected trash and recycling receptacles that through wireless technology, communicate directly with the facility mangers to inform when they are full and ready to be emptied. The bins know when to compact trash – and compact it themselves – to make room for more, and can hold up to five times the amount of trash and recycled items than regular bins. These smart trash and recycle receptacles enable just-in-time collection, saving valuable labour, time and fuel, while ensuring there are no overflow issues on campus. By implementing this technology, they have seen a reduction of 80% in the number of trips FM makes to empty trash and recycling bins. This means better time management and fewer vehicle trips across campus, which leads to a safer and quieter campus experience, lower greenhouse gas emissions, fewer trashcans in the landfill, as well as freeing up time for their team to perform other valuable tasks.

3.5.2. Key Trend 2: Drones

Drone technology, also known as unmanned aerial vehicles (UAV), will also become more common. The benefits of using the UAVs include quick access, low cost, and the ability to document asset conditions in an automated fashion. With the aid of remote controlled cameras mounted on the drone, it can transmit images of building structures, machinery on a rooftop, and general condition of roofs. As this technology evolves, it will allow to provide infrared and X-ray images which can be used to identify structural issues or dangerous leaks in an environment which is potentially unsafe for humans to reach.[28] Drones can gather visual data through cameras, thermal data through infrared cameras, and position data through Lidar (Lidar is a remote sensing method that uses light in the form of a pulsed laser to measure distance.). But, any sensor could be mounted to a drone. For buildings, those might include humidity sensors, carbon dioxide sensors, or pressure sensors. The management of drones for FM sit under the category 'Unmanned Traffic Management'. A number of measures are proposed in Section 5 of the consultation document produced by the UK Department of Transport[29] in 2018, and the aim is to bring them into force as part of a Drones Bill, but this will not be happening until this year at the earliest.

4. Future scenario B: A People-Centred World

Theme 6: FM Workforce
Theme 7: End-User of Services

4.1. Theme 6: FM Workforce

Key Trends	Timeline	Impact
Key Trend 1: Brexit – The FM Workforce is already going through change, but over the next five years onwards is going to require to evolve as political changes linked to leaving the EU will have implications for labour availability.	**Next (5-10 years)**	**High**
Key Trend 2: Demographics and skills development – The demographics linked to an aging population are the basis for many of the problems linked to the skills shortage. Training to the existing workforce will be required to ensuring they have the right digital skills to facilitate the convergence of people, place and process for business, as well, re-training and the development of new skills for older workers.	**Now (0-5 years)**	**Medium**
Key Trend 3: Workforce competition – FM providers need to think about their recruitment strategies. Having a working-life balance is becoming a priority in the agendas of the new generations (who are the early adopters of digital), and they look for employers who offer flexible working hours and treat them fairly in terms of pay, development and conditions.	**Next (5-10 years)**	**Low**
Key Trend 4: Robot-Human collaboration – As processes are transformed by the automation of individual activities, people will perform activities that are complementary to the work that machines do. FM providers need to think about how automation and robots can help to reduce the reliance on labour.	**Next (5-10 years)**	**High**

4.1.1. Key Trend 1: Brexit

The FM sector is extremely labour intensive. The workforce in the main carries out repetitive tasks to ensure the smooth operation of all kinds of facilities across all sectors of industry, commerce, education, health and social care. FM is already experiencing a workforce gap and this will increase in the years ahead, especially with Brexit.

Over the last two decades' labour from the EU has become a significant proportion of the FM workforce. In 2015, 2.4 million people, born in the EU were working in the UK with up to 24% of the FM workforce is coming from the EU, with the London-based workforce reaching as much as 34% of total FM workforce. With the end of the Brexit transition phase in 2021 restrictions may be placed on this level of labour from the EU and to ensure the sustainability of the sector recruitment will need to focus on the UK and non-EU nationals. EEA nationals work across the skills spectrum of the FM sector, from highly skilled business leaders, through managerial positions, down to the lower skilled, but not less valued, positions. Soft FM will be especially affected by reduced access to EEA nationals as this is the part of the industry that tends to employ higher numbers of EEA nationals. With a new immigration policy from UK Government not being available, but with the Freedom of Movement likely to end, the FM sector will have a particular problem in the short term with filling entry level roles which are often used as a stepping stone by EEA nationals. Added to this, there is the fact that the UK unemployment levels already being at a low accessing labour from the domestic market may be problematic. This can be for both skilled and non-skilled labour. For example, in hard FM, building services engineering roles are failing to attract UK school leavers and job seekers, roles consequently filled by EEA nationals. The wider societal impact of the loss of access to EEA nationals should not be underestimated, given many of these people work as front-line workers in public sector areas like healthcare.[30] This situation is fluid and needs to be monitored due to the Coronavirus and the downturn in the economy which will follow.

Three scenarios are speculated in the literature to deal with this issue:

- A return to more directly-employed labour (the UK government's attitude towards the self-employed is evidence of a major change here).
- If the statistics are to be believed, at least in part, one possibility is that it could be seen a new wave of foreign direct investment especially from the US and China as new trade deals are concluded.[31]
- An end to cheaper labour in general construction firms will have to consider alternative means and construction methods, some of which are bound to involve greater degrees of off-site prefabrication and on-site mechanisation and automation.

4.1.2. Key Trend 2: Demographics and Skills Development

The demographic changes associated with the aging population represents a wider societal challenge reflected in the way we use buildings and for the labour market. For example, for every four people of working age per elderly person in 2015 there will be just two by 2050.[32] FM needs to reflect the changing pattern of our demographics for both facility users and the availability and age profile of the FM workforce. This is a common problem across Europe, with the decline in the working age population being particularly acute. In order to address this shortfall, governments have already implemented policies that allow greater participation of women and elderly themselves. For example, in the UK older workers will work for longer, due to the increase in the statutory pension age and the fact there is no maximum retirement age. This, together with a lack of applicants with the right aptitude and motivation, is leading to a skills gap that is necessary to address through training, but also requires for FM to embrace innovation in technology to overcome the problem.

Training to the existing workforce will be required to ensuring they have the right digital skills (see also section 4.1.3) to facilitate the convergence of people, place and process for business. This is also important as emerging digital technologies bring with them additional risks around data security and ethics. Add to this, re-training and the development of new skills for older workers will be critical, besides the financial incentives this also brings. There is a joint role here for government and business to develop the lifelong learning that can help people to acquire new skills throughout their working lives, including for example mentoring so that older people can learn digital skills from their younger colleagues, or opened training and apprenticeships that are normally the preserve of younger recruits.

4.1.3. Key Trend 3: Workforce Competition

As mention above, there is an overall shortage of a human workforce and lack of skills gap, something that FM is already experiencing. In particular, for the FM industry, there is a mismatch between the traditional engineering education and the skills required to develop analytics-driven building operation and maintenance strategies. Multiple new roles are required to mediate between statisticians, business managers and IT specialists, which require domain knowledge in building systems and services, indoor environmental quality, and occupant comfort. Moreover, the role holders are expected to demonstrate skills in:

- applied statistics and probability,
- data mining and machine learning,
- computer programming,
- data visualisation, and
- sensors and communication protocols among others.

In the study conducted on the challenges associated with the implementation of big data in FM in the UK, the authors confirmed that the industry experiences difficulties in finding research personnel with even a small subset of these skills.[35] The competition for critical skills will become more intense in the coming years.[5] Yet, science and technological skills are needed for the future, but in the view of PWC, human skills like creativity, leadership and empathy will be also in demand.

Wellbeing is becoming high in the agendas of the businesses and organisations, especially with the nature of work changing where sourcing the right talent is vital. Some four million baby boomers are reaching retirement age every year. Generation Y or Millennials, born between 1981 and 2000 are currently making up half of the global workforce, and tech-savvy, connected, urban and educated, and they are already disrupting the world of business and the race is on to recruit and keep them.[26] These are the early adopters of digital the first true technology-dependent cohort. They will be key in helping businesses to navigate the changes of FM, but importantly, this generation is becoming more demanding on what they want to see from their employers. Previous generations learned to keep silent about the change they wanted but millennials are vocalising the change they want. Having a working-life balance is becoming a priority in their agendas and they look for employers who offer flexible working hours, and treat them fairly in terms of pay, development and conditions.

"Global research shows that millennials do not feel bound to a single employer, with 90% planning to stay no longer that 5 years. This means companies need to work much harder to retain these people".[36]

4.1.4. Key Trend 4: Robot-Human Collaboration

The entire business processes will change, and jobs performed by people redefined.[37] As processes are transformed by the automation of individual activities, people will perform activities that are complementary to the work that machines do.[38] FM role in such working environments is likely to be less about enabling people in the workplace and more about enabling and supporting automated business critical processes. For example, they may find they are spending less time managing people and more time overseeing automated systems/business critical process, both physical (e.g. robots, drones and autonomous vehicles) and virtual.[1] FM will become a group of technological analysts providing outcomes based on information technology and customer analytics, specialising in procurement of just in time predictive maintenance and compliance. Facilities managers will be collecting data on activities and systems performance that can be analysed to inform better decision making. In an automated world we will still need human workers. Whether this is working to develop technology, alongside it – or in narrow, very specialist or very human types of employment – the places automation simply cannot compete in yet.[5]

4.2. Theme 7: End-User of Services

Key Trends	Timeline	Impact
Key Trend 1: The new workplace – The recognition that the needs of the building users are changing with the emergence of digital working environments, sees office spaces become increasingly focused on flexible environments which promote collaboration and promote socialisation amongst colleagues. Recognising that staff will spend more time working outside the office will mean that less floor space is required, but that the space needs to be serviced with high quality digital technology and to provide more than a workstation but a dynamic and interactive experience. This is happening now in relation to office space design, but is going to be increasingly the focus for all sectors (e.g. healthcare, education and in the commercial and public sector office environments).	**Now (0-5 years)**	**High**
Key Trend 2: User's wellbeing and productivity – FM is shifting the focus towards user experience. FM will no longer simply be servicing the building; rather, FM providers will be directly involved in providing environments that demonstrably improve the working lives of their occupants, improving their performance and wellbeing, and helping those individuals become more successful.	**Next (5-10 years)**	**High**

4.2.1 Key Trend 1: The New Workplace

The way business and public sector organisations are working is changing. As it was predicted by ISS World Services in 2011, new workplace practices have been adopted to foster more efficient collaboration, knowledge-sharing, flexibility, speed, innovation and productivity.[33] We have seen for the last few years an increase in the use of communication technologies to avoid face-to-face meetings and supporting homeworking infrastructure, and further expansion and evolution of non-conventional configurations, such as hot-desking, or activity hubs approaches.[48] This move from the traditional workplace will become even greater in the coming years. For example, highly-serviced hubs will replace office acreage to support mobile knowledge workers when they need to interact physically with their co-workers and managers. The traditional workplace is becoming the alternative workplace, which is a combination of non-traditional work practices, settings and locations that supplement or replace traditional offices. At the same time, the more process driven elements of work are falling to artificial intelligence. The companies of the future will be leaner and more dispersed allowing their employees to focus more narrowly on value creation.[16]

The future of work will also alter the way corporate real estate is thought about, holding both opportunities and challenges for those designing hard and soft facilities management services. Perhaps the most notable change is the move from asset provision to service provision.[31] In order to achieve this, FM industry needs to engage with architects, office designers and the construction industry to a much higher degree to ensure that buildings designs enable flexible and productive workspaces that are easy to maintain and managed. It also requires a more collaborative way of working with the IT and HR departments to be able to help the company create a seamless electronic work environment that provides the same experience whether workers are sitting at a desk in the headquarters or working from home office hundreds of miles away. With cloud-based applications, desktop video and video conferencing facilities in the office, workers have access to all the tools they need to do their jobs in or out of the office. They can collaborate, attend meetings, participate, contribute, and engage wherever they are. FM is playing an important role in making this vision of the virtual workplace a reality.[16]

Case Study: In 2019 the Lab University of Applied Sciences (LAB) in Finland opened their new campus in Lahti (www.lab.fi/en) providing a modern learning environment which is built retrofitting a former furniture factory premises. The new campus consolidated the university on one site releasing a number of smaller campuses scattered around the city and mixes old and new buildings providing a unique and inspiring setting for learning and working. Incorporating the latest technology for learning and teaching, the campus provides fluid and flexible spaces, with no staff member having their own office but who are able to operate within a variety of different hot desk working environments reflecting contrasts between spaces for quiet and more interaction. The campus provides other facilities such as spaces for sleeping and relaxation, sauna, bookable meeting rooms of varying sizes, virtual meeting rooms, coffee shops and canteens, sports centre, travel hub, cycle storage and showers. All staff have a locker, fitted with charging point and can take their laptop to any part of the campus and work through the high speed Wi-Fi. The expectation is that with more staff spending a higher proportion of their working week at home or off campus, and then there is less space required for individual offices. However, when they are on campus the design seeks to provide high quality flexible spaces designed to promote collaboration. From a student's perspective they are presented with a modern and interactive campus which is fun to be on, has a high quality virtual campus which can be accessed from anywhere and where the floor space is focused more on their learning experience through quality class rooms and lab spaces. The design of the campus is changing the way both staff and students interact, collaborate and responds the more flexible way they use space and respects the increase in working from home whilst enhancing the on campus experience. This provides big changes for FM with greater emphasis on combining the digital and physical environment, with the building also extending its opening hours to reflect changing demands of its users. Examples can be seen in the Wi-Fi throughout campus, the live online room booking system, movement censored lighting and swipe card access to different parts of the building. The campus is now a hub for socialisation as much as it is for work for both staff and students.

4.2.2. Key Trend 2: User's Wellbeing and Productivity

FM is shifting the focus towards user experience.[39] It will become an even more people-based business than it already is, with both employees and customers being imbued with the organisation's values and ambitions. Hence, service management in FM will no longer simply be servicing the building; rather, FM

Education:

Recent statistics have shown that air quality can have a significant impact on our cognitive performance, even causing reduction in education levels. According to new research, air pollution is already affecting younger generations, particularly in schools with test scores decreasing in older, more polluted schools. The class environment needs to achieve the desired level of satisfaction and comfort for the students, in order to encourage and sustain students' motivation for continuous learning.

Healthcare:

In healthcare facilities, patient satisfaction is paramount and will only grow in importance as providers offer patients more choice. Through IoT, there will be new opportunities to build patient loyalty, which ultimately leads to better patient outcomes — a main driver for hospitals around the world. IoT puts a measure of control into the hands of patients through solutions such as mobile patient room control applications. For example, by using an app installed on their smartphone, patients can create their own optimal healing environment through individual control over their room temperature, lighting and window blinds rather than calling on nurses to perform these basic tasks.

Digitalisation as an enabler of the workplace management – IoT sensor technology, BDA, AI and a biophilic design approach, together, enable the well-being of the occupants to be improved by monitoring and adjusting the indoor environment in real-time to better meet their needs.

The environment can be easily adapted to the preferences of the occupants by continuously monitoring the temperature and humidity of the space. Instead of having constant disputes about the temperature being too high or too low, clustered areas can be created that fit the requirements of the occupants. Air quality can be monitored and altered to ensure the health and well-being of the employees. Air-quality sensors are now being developed that can detect minute particulates in the air, as well as pollen, engine emissions and other pollutants like chemical composition. Data like this could be used to provide better data for decisions on air-filtration and better control of extraction systems, as well as to inform occupant behaviour, such as when and where to open windows. Improving air quality in a building can have a significant impact on employee well-being and happiness. For example, working in a hot, stuffy room where CO^2 levels are high causes tiredness, reduces concentration and inhibits productivity. By monitoring CO^2 levels in real time and connecting this data to air-exchange system controls, smart buildings can ensure rooms are always fresh and comfortable. Displaying air-quality data on a prominent dashboard in any building, whether an office, a manufacturing plant or a fitness centre, can help to inspire and motivate individuals and make them feel better about their environment.[15] Furthermore, connecting this data to room booking systems or space utilisation data enables room conditions to be adjusted according to the number of occupants and the nature of the work being carried out. All this can be further enhanced by providing the occupants with suggestions on how to improve their health and well-being by monitoring their habits, such as how many hours they are active and how long they have been sitting at their desk.[10]

Mitie's Connected Workspace

Mitie is a UK's facilities management organisation, with a £2bn annual turnover and employing 54,000 people.

Mitie's Connected Workspace embraces digital transformation, technology expertise and systems integration to deliver a better workspace – improving the performance of the buildings they operate and the wellbeing and productivity of the people within them.

Connected Workspace consists of a platform analytics where data from buildings, processes, systems and people is collected. This is supported by a Data Science team and engineers within a Remote Monitoring Operations Centre, responsible for providing powerful building analytics and management support to customer workspaces. They process the data in real time to identify inefficiencies, detect trends, forecast potential issues, and propose solutions to improve overall workplace efficiency. Previously untapped data streams are constantly reviewed by a suite of pre-defined and machine learning algorithms that automatically assess the efficiency and performance of the building's assets and working environments. This platform is designed to be able to include seamlessly new facilities management applications and portals; it is flexible, able to be tailored to any customer and is completely scalable, as well as, be established as a new build or retrofit. It also uses the last API standards to be seamlessly linked to any existing non-Mitie applications, portals, sensors or devices already use by the client. According to Mitie, Connected Workspace is enabling existing FM services through the following activities:

Catering	queue management; space optimisation; waste reduction; workspace design and consultancy
Cleaning	demand led cleaning; service optimisation; smart washroom management.
Security	demand-led security; remote monitoring & control; risk management; smart video analytics.
Workspace management	comfort and wellbeing management; employee engagement; flexible workspace management; space optimisation.
Engineering and maintenance	asset performance optimisation; compliance management; predictive and demand-led maintenance.
Energy and sustainability	air pollution monitoring; energy management; energy procurement.

Mitie's connected workspace has been able to:

- Reduce Fujitsu's security cost by 30% (2017)
- Increase the productivity for Red Bull Racing of at least 5% and a 3.4% per annum reduction in energy costs (2018)
- Achieve a reduction in the energy consumption of 91.77GWh per annum by a High street banking group (2018)

5. Future scenario C: A Green World

Theme 8: Sustainability and Climate Change
Theme 9: Smart Cities

5.1. Theme 8: Sustainability and Climate Change

Key Trends	Timeline	Impact
Key Trend 1: Sustainability and Climate Change – Net Zero Carbon within a buildings lifecycle is emerging as a consideration now, but will increase in its focus in the next 5-10 years with FM providers needing to focus on monitoring of building performance, installation and maintenance of renewable energy systems, and the key focus on reducing energy use through efficiency measures. This is linked to the wider transition towards sustainability with FM providers needing to enable their estates for the circular economy, focusing particularly on waste management. Now the focus is on waste segregation to prioritise recycling, but the next stage needs to look at reuse and ultimately in the future finding alternatives to avoid waste. This results in a need for focus on energy management, systems efficiency and workplace management.	**Next (5-10 years)**	**High**

5.1.1. Key Trend 1: Sustainability and Climate Change

The pressures for action on climate change have increased further during 2019 and the release of the Committee for Climate Change's report on a net zero system provides a 'proof of concept' scenario. The UK Government has set a target to reach net zero greenhouse gas emissions by 2050 (Scotland by 2045), with also ambitious interim targets which include achieving a 75% reduction of greenhouse gas emissions by 2030.

According to a recently study produced by the Infrastructure Commissioning for Scotland[41], infrastructure is a long-term asset, with 80% of the Scottish current systems likely to still be in use in 2050, which makes the optimal management of those existing assets essential. Transport and heat emissions combined contribute the majority of CO^2 emissions in Scotland and are a key focus for UK Government in its planning to achieve a NZC target.

The UK framework sets out the pathway to achieving net zero carbon buildings in the construction as well as operation (in-use energy consumption), recognising that the indirect embodied carbon emissions associated with the manufacture of construction materials can be responsible for as much as 50% of a building's emissions across its entire lifetime.

The net zero carbon buildings framework sets out definitions and principles around two approaches to net zero carbon, which are of equal importance (Figure 3).

The focus at the moment at the operational phase is on energy, but reporting and offsetting processes for whole life carbon will be developed and introduced in the next coming years to take account of all building lifecycle stages. This will build on the current framework principles addressing construction impacts at practical completion and operational energy impacts in-use, but will also likely require annual reporting and offsetting of embodied carbon impacts from maintenance, repair and refurbishment on an annual basis.

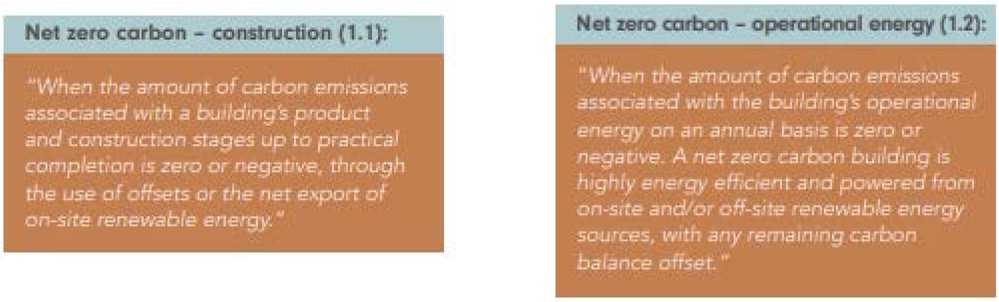


Figure 2: Definitions of net zero carbon for construction and operational energy.[42]

The following figure (Figure 4) outlines the principles which should be followed to demonstrate alignment with net zero carbon through the lifecycle of a building.

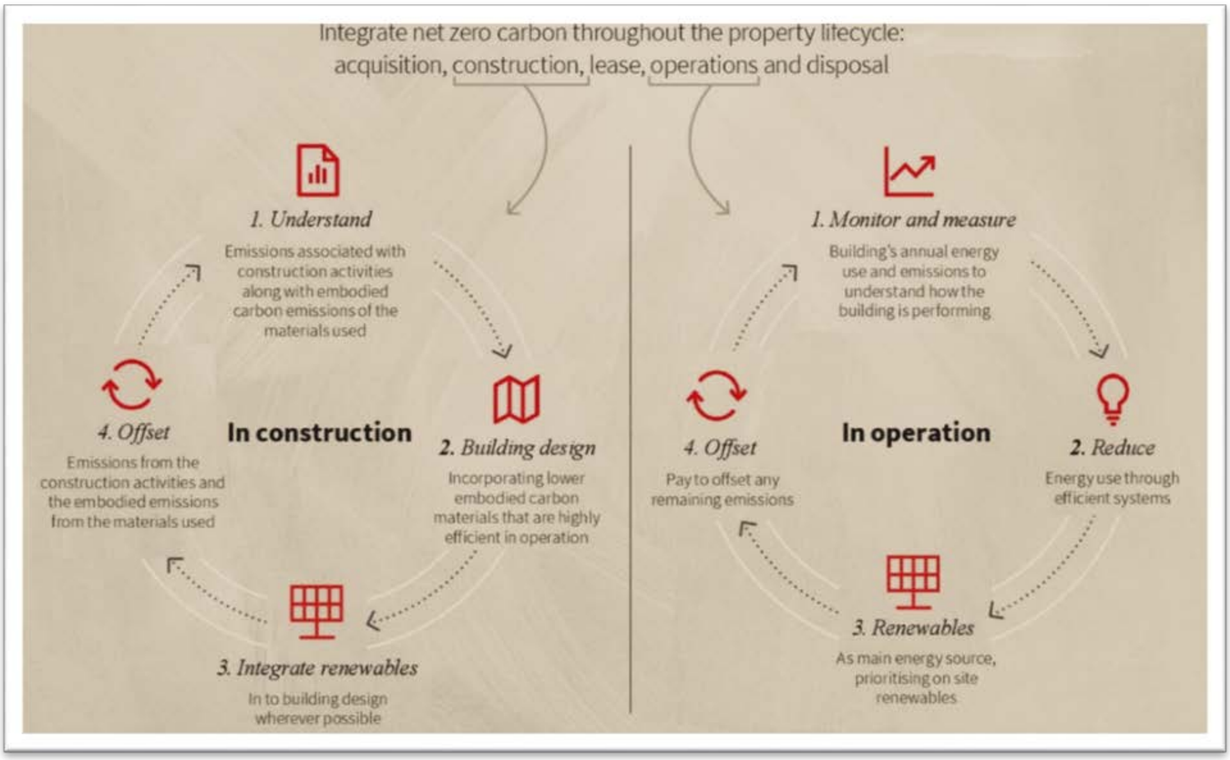


Figure 3*:* Net Zero Carbon throughout the property lifecycle

With growing concern about climate change and increasing pressure to reduce carbon emissions, businesses are putting zero-carbon targets at the top of the agenda. But making the transition to carbon neutrality is a complex process, affecting all aspects of an organisation's operations and activities. In some cities, clean air zones have been established, which impact the activities of businesses within those zones. Local authorities across the UK have also declared climate emergencies, with the introduction of targeted plans to reduce carbon emissions in their districts.

Despite the legal requirements, businesses face pressure from their own shareholders too, as well as customers and the wider public. Employees expect their employers to minimise their environmental impact, and people increasingly value businesses that demonstrate a commitment to caring for the planet. All of which means that carbon-reduction policies could even impact an organisation's ability to attract and recruit the best young talent. Pressure for climate action comes from supply chains too.

Globally, businesses want to work with suppliers and partners who share their principles. Businesses that fail to take action on carbon reduction are likely to find it difficult to participate in the increasingly connected and environmentally conscious supply chains of the future.

At the basic level, this will mean switching to renewable power sources and moving away for the use of fossil fuels in buildings, like natural gas for heating. The challenge will be retrofitting older buildings, as this may require updating traditional energy systems, as well as changing internal layouts and facades. But, with only a maximum of two refurbishment cycles between now and 2050 there is limited opportunity to implement these changes; early action is needed to carefully evaluate the most cost-effective route to transition existing assets to zero carbon. Developers aiming for net zero carbon in construction should design the building to enable net zero carbon for operational energy, and where possible this should be achieved annually in-use.[42]

Climate change is having an impact on the world, and companies need to adapt to the changing environment. However, in the view of ENGIE, many businesses lack the knowledge and expertise required to implement effective carbon-reduction strategies and are focused on their core business.

Adding to the net zero carbon, there are other environmental sustainable issues that also are becoming high in the governments and organisations agendas and have an impact on how FM operates such as the use of resources and waste. Scotland targets is to reduce by 2025 total waste arising in Scotland by 15% against 2011 levels, reduce food waste by 33% against 2013 levels, recycle 70% of remaining waste and send no more than 5% of remaining waste to landfill.

5.1.2. Implications for FM

The journey towards net zero carbon and sustainability is expected to support the growth of the FM, as clients look to have more support in these areas.[43] FM must be committed to net zero carbon by working with clients on their sustainability and net zero journeys. This means that FM will need to put more effort on sustainability criteria into maintaining and repairing physical fabric of the site, obtaining resources, minimising and disposing responsibly waste, in order to reduce energy demand.[44]

FM services providers will have the opportunity to expand their business by taking responsibility for reducing energy demand and consumption through:

- Energy management – Implementing smart energy/building management systems. Improvements include conducting an energy audit, managing occupant behaviour, managing ‘peak loads’, adjusting HVAC temperature set points, achieving ISO 50001 accreditation.
- Systems efficiency – Increasing the energy efficiency of the building systems. Improvements include highly energy efficient building systems – HVAC, lighting, vertical transport (elevators and escalators), etc.
- Workplace management - The physical wellbeing of building occupants should be considered alongside energy reductions. These include considerations around indoor air quality, daylight and overheating.

Being able to demonstrate the contribution to net zero carbon in terms of in-use energy performance is, in the view of the UKGBC[42], moving the industry towards 'performance contracts' that are based on achieving specified outcomes. A verified net zero carbon building is one that is based on in-use, rather than modelled energy performance. In this way, net zero carbon should not simply represent a label, but a process which demonstrates that a building's performance is being maintained at net zero carbon. The move towards in-use performance will see a wholesale.

The inclusion of facility managers in the design teams from the very beginning is also significant. When developers aim for net zero carbon in construction they need to also design the building to enable net zero carbon for operational energy. This also applies to the retrofit and construction modifications of the buildings. In the case of smart buildings, the involvement of a facility manager in the design team is a critical necessity. Thereby, the facility manager not only represents the interest of the investor (the future owner), but also of the future occupants. If the facility manager just takes over the already completed construction, he/she only has a very limited range of possibilities to influence the efficiency of the building costs during its lifecycle. [45]

As mention in Section 3.2.2, technology plays an important role in energy management and achieving efficiency, however it is important to bear in mind that technology is important as an enabler, but not a solution itself. As an Energy Expert at Upstream Sustainability Services commented: "technology alone is not enough. What we also need is better energy services that exploit the potential of big data and new analytical approaches to enable more agile, efficient and evidence-based decision-making to help prioritise investment, implement practical solution and ultimately reduce climate impacts".[46]

In essence, technology will enable improved measurement and transparency, that it is becoming highly demanded in this environment. As far as possible, building emissions should be based on measurement rather than estimates and using the most accurate data available. Public disclosure of emissions should also provide transparency about how this information has been collected and the approach taken by a building to achieve net zero carbon.[42]

5.2. Theme 9: Smart Cities

Key Trends	Timeline	Impact
Key Trend 1: Smart Cities – Smart Cities provide a significant opportunity for enabling a lot of the themes within the Building in a Virtual World and People-centred World as well as enhancing the A Green World. It is more than just the use of technology, but is about connectivity between buildings, districts and seeking to build communities. This is applicable across all the time horizons and will have an impact in the next 5-10 years.	**Next (5-10 years)**	**High**

5.2.1. Key Trend 1: Smart Cities

A far bigger area of interest and more immediate concern is the smart city. The complexity of a modern city and the pressure it places on resources of all kinds – human, natural and spatial – suggests that support from intelligent machines might prove beneficial. Since so much of the world's population lives in cities and others continue to gravitate towards them means that threats and opportunities will occur in ever-increasing concentrations. [31] For our cities, to be smart translates into the following:

- driverless vehicles (including trains, trams, taxis and cars)
- drone deliveries
- automated health-check facilities
- virtual campuses for learning and entertainment
- law enforcement actroids (human seeking robots)
- Unmanned restaurants
- 24/7 surveillance

Smart Cities is more than just about the use of technology, it is also about connectivity between buildings; about the understanding of the space between buildings as social arenas that build communities and create connectivity between districts. Smart Cities mentality argues away from the individualistic approach of how buildings are used and focuses more on relationships between buildings, this introduces further complexity on how to maintain and manage FM services in buildings, neighbourhoods and city scales. The connectivity of buildings within a district is apparent particularly within the idea of Plus Energy Buildings (PEB). These buildings produce more energy than they consume and therefore supply energy back to the grid or to surrounding buildings. In this way, these building create a community of energy users. The issue is that energy users are not easy to predict as their behaviour is linked to function and use, and lifecycle assessment tools often do not reflect the impact of user's behaviour on energy load. Therefore, in order to develop areas that will be developed in sustainable ways, it will important for FM to understand their function and use, or how users wish to use the area. [47]

6. Challenges and opportunities

The three future scenarios bring many opportunities for FM providers to be innovative and competitive and offer many benefits to their clients, but this is also accompanied by some challenges and barriers that will increase the difficulty of their journey. A summary of the main challenges/barriers and opportunities/benefits are shown in Table 1.

7. Coronavirus pandemic and time horizon implications for FM

Since the first case of Coronavirus was confirmed in the UK at the end of January 2020 we have entered a period of societal uncertainty on an unprecedented scale and one which has significant short, medium and long term implications for the FM sector. The speed of this pandemic is such that when the research was commissioned this was not even considered as a likely theme, but it has gone on to represent the most significant challenge since World War 2 disrupting society and the nature of the economy which it serves. The lockdown which commenced on the 23rd of March 2020 and has had a number of impacts due to the restrictions on the freedom of movement, focus on those who can work from home to do so, and the emergence of social distancing of 2m with spatial implications on workspaces and users of

Table 1: Challenges/barriers and opportunities/benefits

Scenario	Challenges/Barriers	Opportunities/Benefits
Building in a Virtual World	• Lack of staff capability to support digital transformation • Skills gap in FM • Issues with legacy systems integration specially BDA which is restricted by systems and technologies that have not been designed to facilitate open access to data • Ethical and security challenges associated with the use of IoT, robotics and automation technologies • Establishing a clear business case for funding • Clients are risk averse • Cost of developing and engineering automation technologies	• Offers greater transparency to clients around their buildings' performance • Promotes engineering and statutory compliance and the availability of evidence to justify decision making and refine business processes • Lower costs for clients - reduction of total life cycle costs • Cost savings through space management (energy efficiency, better schedule cleaning and maintenance activities) • Enhanced productivity in workflow management • More accurate and timely reporting/monitoring • Enhance efficiency (e.g. optimising use of energy) • Increase asset performance and life through optimised asset operation; improving well-being an enhanced productivity in workflow management • Enhance organisational profile and greater competitiveness
A People-centred World	• Skills gap of FM to partake in the design of the buildings • Resistance to new workplace patterns • Failure of clients to invest in a physical environment which supports the virtual environment for workforce and service delivery	• Reinvent the FM provider business models, engage with the clients and reinvent the end-user experience • Deliver more value through services enhancement, workplace innovation and technology enablement • Improve customer satisfaction, comfort and air quality • Reduce complaints • Improvements to health and well-being, recruitment and retention of staff
A Green World	• Cost of renewable generation technology, more energy-efficient equipment and other carbon-free assets • Resistance from clients and facility managers to embrace opportunities presented	• Government financial incentives for supporting green initiatives • Adopting sustainability principles enhances the image of the organisation • Business efficiency and sustainability • Achieve compliance

buildings and services in all sectors. During lockdown the FM sector has had to evolve to enable a safe place is provided for those key workers requiring to still go into their work place and that compliance with social distancing measures and the implications for hygiene through cleaning and sanitising surfaces. This requires a redesign of workstations, and clear instructions for building users to ensure that they are aware and comply with the government's advice. Facilities also need to be managed by FM staff despite the lockdown and this requires to be considered for security and general cleaning and maintenance. Healthcare providers have been required to operationalise their service with a view to providing capacity to cope with the anticipated pressure on beds and intensive care. This has required rapid redesign and reallocation of hospital spaces, with emergency provision for large new hospitals in exhibition centres like the SECC in Scotland and the EXCEL Centre in London. FM providers have been critical to this transition, ensuring that building services are provided and equipment is sourced and provided, and that cleaning and maintenance teams are available and trained.

Education providers are split into schools, and higher and further education institutions. For the school sector, schools in lockdown have been largely closed with focus on online support for parents and pupils. Schools need to plan how they are to be able to reopen to pupils whilst aligning with social distancing measures, and this requires FM providers to work with local authorities and private providers to modify the internal and external environments to ensure that this can be achieved in line with government advice. Higher and further education providers have closed campuses to students and staff, with staff working from home to delivering lectures and support for students online. This requires considerable investment in digital technology and capacity from the institution. For the academic session 2020/21, there are questions as to the ability of campuses to be able to accommodate students and align for social distancing measures with planning going on for online delivery of academic programmes. FM require to consider innovative solutions to help the sector align with the social distancing measures if an on campus experience is to be enjoyed by the students. However, if this is not possible the increase reliance on online tuition is going to have long term ramifications for how universities and colleges are designed with less reliance being on attended lectures and the need to gather on campus. The potential exists for education providers to look increasingly at smaller campuses, with less focus on students and more on environments to support research and enterprise. This would have significant implications on the design of education buildings and the implications for FM.

For office environments, the transition to virtual work places is significant and the lockdown and resulting slow transition out of it will result in organisations being virtually enabled to deliver their services with a workforce largely at home. The likelihood is that as social distancing and a reluctance of commuters to use the transport network in rush hour continues, that home working will become a stronger part of the future working environment. It will provide confidence to staff and employers, and therefore require a rethink of how facilities are spaced and equipped. This will only strengthen the changes which are being seen Theme 7 Key trend 1 where the work place becomes more about providing an interactive environment which is supported by high quality digital technology, but provides a positive, dynamic and collaborative experience for those when they are on site. The Coronavirus pandemic will have ramifications for the economy for many years, and this will reduce the finance available to support growth. This will have clients looking for added value from their facilities and to justify investment for FM. There is a clear need for providers to embrace the innovations stemming from the digital revolution and to position themselves as a strategic partner of their client.

8. Conclusions

This report reflects the same framework as established in the Construction and Infrastructure reports and provides three future scenarios and themes which were identified following a literature review and consultation with three senior FM professionals working in the Healthcare sector in Scotland. The three scenarios are *Building a Virtual World*, *A People-centred World* and *A Green World*. The second and third scenarios have been amended to reflect the FM context.

In the first scenario, *Building in a Virtual World,* five themes were identified: Artificial Intelligence/ Machine Learning; Connected Workflows; BIM; Digital Twin; and Robotics. Research into these themes reflects that the technology is evolving quicker than the practice is able to implement. Similar to the Construction paper, this scenario is very much for the now and requires FM providers to look at incorporating the available technology within their facilities and processes with a view to improving performance. AI and Machine Learning is with us **now** and will continue to evolve with benefits for improving building performance and FM productivity, with Connected Workflows and BIM whilst being underutilised, providing already the potential for improvement **now**. Digital Twins and Robotics are where the **next** (5-10 years) and **future** (10-20 years) time horizons will focus. These are in the infancy but already show significant benefits for reducing labour requirements. Some of the technology linked to Industry 4.0 is embryonic but FM providers need to embrace this **now** to be competitive and to work with clients to ensure they are not left behind. Future proofing technology and practice is going to be a big part of such an evolving field, so having a view to the **next** and **future** time horizons is going to be important for FM providers to remain current and competitive, so an emphasis on research and working with software and technology providers is going to be important.

The second scenario, *People-centred World*, examined the themes of FM Workforce and End-User of Services. This contrasts to the scenario within the Construction and Infrastructure reports as it reflects the importance of people within the context of FM whether that be the labour who provide the FM service or the user of the building who experiences it. The FM Workforce is already going through change, but over the **next** (5-10 years) and **future** (10-20 years) time-horizons is going to require to evolve as political changes linked to leaving the EU will have implications for labour availability, and the demographics linked to an aging population will be the basis for problems linked to the already skills shortage (**now**). FM providers need to think about their recruitment strategies, skills development of existing labour and importantly how automation and robots can help to reduce the reliance on labour. These are issues for the **now**, **next** and **future** time-horizons. Aligned with this, recognition that the needs of the building users are changing with the emergence of digital working environments, sees office spaces become increasingly focused on flexible environments which promote collaboration and promote socialisation amongst colleagues. Recognising that staff will spend more time working outside the office will mean that less floor space is required, but that the space needs to be serviced with high quality digital technology and to provide more than a workstation but a dynamic and interactive experience. This is happening **now** in relation to office space design, but is going to be increasingly the focus for all sectors (e.g. healthcare, education and in the commercial and public sector office environments). Working with designers to ensure that workspaces are future proofed for evolving space and technology requirements is going to be important.

The final scenario, *A Green World,* examined the themes of Sustainability and Climate Change and Smart Cities. Similar to the Construction and Infrastructure reports this scenario needs to be considered at all three time horizons given the pressing nature of the climate emergency and the key trends highlighted areas of focus that could be implemented today. The move towards net zero carbon within a buildings lifecycle is emerging as a consideration **now**, but will increase in its focus in the **next** 5-10 years with FM providers needing to focus on monitoring of building performance, installation and maintenance of renewable energy systems, and the key focus on reducing energy use through efficiency measures. This is linked to the wider transition towards sustainability with FM providers needing to enable their estates for the circular economy, focusing particularly on waste management. **Now** the focus in on waste segregation to prioritise recycling, but the **next** stage need to look at reuse and ultimately in the **future** finding alternatives to avoid waste. This results in a need for focus on energy management, systems efficiency and workplace management. Smart Cities provide a significant opportunity for enabling a lot of the themes within the Building in a Virtual World and People-centred World as well as enhancing the A Green World. It is more than just the use of technology, but is about connectivity between buildings, districts and seeking to build communities. This is applicable across all the time horizons and will have an impact in the next 5-10 years.

These scenarios are not mutually independent and their evolution is very much driven by each other. Cross cutting to these will be the implications which will emerge from the Coronavirus pandemic through the short term impact of the lockdown, the medium terms transition whilst respecting social distancing and in the long term the impact this will have on the workplace and service provision from increased confidence in home working. Potentially significant ramifications for the nature of FM into the future, but only enhances the need to align with the digital revolution with providers needing to become strategic partners of their clients facilitating the physical and virtual environments.

Finally, the scenarios and themes emerging in this report have been identified through a literature review but also through consultation with experts who are senior within FM for the Healthcare Estate in Scotland. Their views have informed both the development of the themes but also they have provided reflection on the time-horizons and what the priorities for an FM provider should moving forward.

This themed paper has provided an essential overview of the identified key themes in Facilities Management. The approach used in this paper, along with the chosen research methodology will be applied in the supporting papers for Construction and Infrastructure.

Glossary

API (**application programming interface) –** is a set of programming code that queries data, parses responses, and sends instructions between one software platform and another. In simple words, it is a software intermediary that allows two applications to talk to each other.

Algorithm – a process or set of rules that computers follow when carrying out calculations or other problem-solving operations

Automation - doing things without human assistance, usually with a view to doing them better in some way e.g. quicker, cheaper, more consistently or more safely.

Beacon technology – a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems.

Biophilic design – is a concept used within the building industry to increase occupant connectivity to the natural environment through the use of direct nature, indirect nature, and space and place conditions. Biophilic design emphasises human adaptations to the natural world that over evolutionary time have proven instrumental in advancing people's health, fitness, and wellbeing.

BMS (building management system) - a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems.

CAFM (computer-aided facilities management) – software that assists with the planning, management, monitoring and reporting of FM activities. It usually involves some combination of computer aided design (CAD) and relational database software.

Data mining – looking for patterns (correlations and relationships) in large datasets using statistical and machine learning techniques. Examples of data mining include retailers using information about their customers and their shopping habits to help inform marketing and sales strategies.

Internet protocol – is the method of protocol by which data is sent from one computer to another on the Internet. Each computer (known as a host) on the Internet has at least one IP address that uniquely identifies it from all other computers on the Internet.

Fault detection and diagnostics – is the process of uncovering errors in physical systems while attempting to identify the source of the problem. It identifies anomalies in the performance of critical equipment such as boilers, chillers, motors, elevators, pumps, exhaust fans, etc.

SQL (structured query language) – is a standard language for accessing and manipulating databases. It is used to communicate with a database, inserting, searching, updating and deleting database records. SQL can do lots of other operations including optimizing and maintenance of databases.

References

[1] BIFM (2018) Embracing technology to move FM forward.
[2.] Workplace futures (2018) FM: adding value.
[3] Overton (2018) Artificial Intelligence. 1st edition. O'Reilly Media, Inc.
[4] JLL (2016) Reinventing facilities management for the digital world (White Paper).
[5] PWC (2018) Workforce of the future: The competing forces shaping 2030.
[6] European Cleaning Journal (2019) Artificial intelligence captures unhygienic practices in Chinese kitchens.
[7] European Cleaning Journal (2018) Smarter Facilities Management.
[8] Konanahalli, A., Marinelli, M. and Oyedele, L., 2020. Drivers and challenges associated with the implementation of big data within UK facilities management sector: an exploratory factor analysis approach. IEEE Transactions on Engineering Management.
[9] Rose, K. Eldridg, S. Chapin, L. (2015) The Internet of Things: An overview understanding the issues and challenges of a more connected world. Internet Society.
[10] IWFM (2018) Internet of Things for Facilities Management.
[11] RICS (2018) Big data: A new revolution in the UK facilities management sector.
[12] Workplace Futures (2016) FM: Agent of Change.
[13] Manyika, J. Chui, M, Brown, B., Bughin, J., Dobbs, R., Roxburgh, C. and Byers, A. (2011) Big Data: the next frontier for innovation, competition and productivity, Report for the McKinsey Global Institute.
[14] Bernan, J.J. (2013) Principles of Big Data Preparing, Sharing, and Analysing Complex Information. Waltham: Elsevier.
[15] ENGIE (2020) The Future of Smart Buildings.
[16] JLL (2016) Workspace, reworked. Ride the wave of tech driven change.
[17] PWC (2017) Predictive Maintenance 4.0 Predict the unpredictable.
[18] ARUP (2019) FM 2.0 Re-imagining Facility Management for the Digital Age.
[19] European Cleaning Journal (2016) Cleaning in the Digital World.
[20] ENGIE (2018) Case study: Queen Elizabeth Olympic Park venuew (online). Available at: https://www.engie.co.uk/wp-content/uploads/2018/12/lldc-case-study.pdf (Accessed 12/04/20)
[21] Shi, P. and Tay, J., 2019. Blockchain for Facilities Management.
[22] IFMA (2018) The Past and Future of Blockchain in FM (in FMJ magazine).
[23] SWG (2019) The Future is BIM (in Facilities Show).
[24] Arup (2019) Digital Twin – Towards a meaningful framework.
[25] Lu, Q., Xie, X., Heaton, J., Parlikad, A.K. and Schooling, J. (2019) From BIM Towards Digital Twin: Strategy and Future Development for Smart Asset Management. In International Workshop on Service Orientation in Holonic and Multi-Agent Manufacturing (pp. 392-404). Springer, Cham.
[26] CBRE (2017) Top trends in facilities management.
[27] Outsourced Client Solutions (2016) Rise of the robots - how increased automation in facilities management is benefitting businesses.
[28] Bobby (2017) Drones and the emergence of unmanned asset management.
[29] Department of Transport (2018) Taking flight: the future of drones in the UK.
[30] BIFM (2017) Migration policy for the FM sector Post-Brexit.
[31] RICS (2017) Artificial Intelligence: what is means for the built environment.
[32] UN Population Division, World Population Prospects 2015.
[33] ISS Wold Services (2011) ISS 2020 Vision – Scenarios for the future of the Global Facility Management Industry.
[34] BIFM (2018) Briefing paper: FM and the future world of work.
[35] Konanahalli, A., Marinelli, M., & Oyedele, L. (2020). Drivers and challenges associated with the implementation of big data within UK facilities management sector: an exploratory factor analysis approach. IEEE Transactions on Engineering Management.
[36] Workplace Futures (2016) FM: Agent of Change.
[37] RICS (2017) The Impact of Emerging Technologies on the Surveying Profession.
[38] McKinsey Global Institute (2017) A future that works: automation, employment, and productivity.
[39] ISS World Services (2018) ISS 2020 Vision – Future of Service Management.
[40] Moritz, S. (2014) Design for Services, Keynote, Service Experience Summit.
[41] Infrastructure Commissioning for Scotland (2020) Part A: context and key drivers.
[42] UKGBC (2019) Net Zero Carbon Buildings: A Framework Definition.
[43] Workplace Future (2019) Surviving FM.
[44] Halim, A.I.A., Sarpin, N., Kasim, N.B. and Zainal, R.B. (2017) Capability challenges of facility management personnel toward sustainability agenda. In AIP Conference Proceedings, 1891 (1), AIP Publishing LLC.
[45] Pašek, J. & Sojková, V. (2018) Facility management of smart buildings. International Review of Applied Sciences and Engineering, 9.
[46] JLL (2019) Transforming real estate: our views.
[47] Lindkvist, C., Temeljotov-Salaj, A., Collins, D., & Bjørberg, S. (2019, October). Defining a niche for Facilities Management in Smart Cities. In IOP Conference Series: Earth and Environmental Science, 352, 1.
[48] Croner-I (2018) Future FM — new directions and new talents?

Report Authors

Dr Michael Tong *Principal Investigator*

Department of Construction & Surveying, Glasgow Caledonian University

Dr Craig Thomson *Reader,* Glasgow Caledonian University

Dr Laura Rodriguez Labajos *Research Assistant*, Glasgow Caledonian University

Steering Group

Shona Dunsmore Robertson Group

James Gall Autodesk

Brenda Joyce Construction Scotland Innovation Centre

Clare Reid Robertson Group

Margaret Watson Scottish Enterprise

Michael Wescourt Autodesk

Scott Wilson Robertson Group