



Technical Report

ISO/TR 41016

Facility management — Overview of available technologies

*Facility management — Vue d'ensemble des technologies
disponibles*

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CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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This document was prepared by Technical Committee ISO/TC 267, *Facility management*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 348, *Facility management*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document provides facility managers, their teams and stakeholders an overview of available facility management (FM) technologies. Only by understanding technology's diverse, evolving potential can the facility manager community make best use of its scope, efficiencies and benefits to support its everyday operations.

The long-term benefits of FM technology are not only commercial or budgetary, relating to hard or soft services, safety or environmental objectives, or achieving process change; they will contribute to achieving the United Nation's Sustainable Development Goals (SDGs). As a component of the ISO 41000 family of standards, integrated technology also offers significant potential value by providing input to their core business strategy roadmap. It will allow facility managers to fully understand and deploy the power of technology as a business productivity enabler, to improve on their capabilities and system capacities. Those that take advantage and embrace technology will be better able to shape the vision of an enhanced, digitalised FM experience.

Globally, the FM industry continues to adapt by advancing thought leadership and creating innovative, operational digital frameworks. Applied effectively, frameworks that are designed to foster international best practices will enhance the productivity of the FM workforce and enable each FM sector keep pace with digital advancements and transformation campaigns.

Further education on achievable goals is needed, as well as a shared common vocabulary and a collective understanding. Digital FM (DFM) is the interface between FM and technology. It presents an ideal opportunity for transformation, enhancing workforce skillsets, improving asset owners' awareness and service delivery performance capabilities, by further automating the built environment and connecting all stakeholders.

FM has become a globally recognized discipline, in which challenges are faced, be they technology-related, involving safety or environmental protection, or even from pandemics or budget constraints. It is important to note that facility management is a people-centric sector. As devices become more tech-capable, these resources need to be able to work in buildings that are categorized as SMART (specific, measurable, achievable, realistic and time-related). From the PC to the internet, smartphones to energy management, the public has high expectations from technology and its everyday use. Well-managed facilities and carefully applied technology enable facility occupants to work effectively and safely, in a constantly changing digital environment. Facility managers need to be an integral part of this digital transformation.

Adoption of the Internet of Things (IoT), together with Building Information Modelling (BIM), the use of 5G telecoms, new software products and applications for 3D to 7D management of the life cycle of buildings (including their design, construction, operations and maintenance), is not a single change management programme. This document gives insight into the means by which technology can be more understood and better incorporated, a key part of a business strategy.

Facility management — Overview of available technologies

1 Scope

This document provides an overview of the available facility management (FM) technologies. This document is applicable to facility managers, their teams and their stakeholders. It aligns specifically with ISO/TR 41013, the ISO 19650 series and the ISO 41000 family of standards as part of an integrated framework to achieve FM best practice.

This document outlines various long-term benefits and enhanced value that can be derived progressively by the operators, occupants and owners of facilities, worldwide, via the effective application of technology. This document includes, defines and categorises systems, equipment, methodologies and software applications that are available.

This framework defines how facility managers can understand and integrate digital practice and technologies in the built environment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 41011, *Facility management — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 41011 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Scope of facility management technology

4.1 Facility management technology

A digital ecosystem is a distributed, adaptive, open socio-technical system with properties of self-organization, scalability and sustainability inspired from natural ecosystems. Digital ecosystem models are informed by knowledge of natural ecosystems, especially for aspects related to competition and collaboration among diverse entities.

There has been a significant increase in the introduction of innovative technologies used within the built environment. These technologies are often a key enabler to achieve better outcomes that were previously unimaginable due to legacy work practices and other human factor constraints. As the cost of storage per Mb of data has diminished progressively, the volume of data needing to be stored securely has increased, almost exponentially.

Technology is becoming an intrinsic part of this industry through realized opportunities, competitive differentiators and in response to market demands for cost efficiencies. Technological equipment and

operating applications, like smart devices and building management system (BMS) sensors, continues to decrease in price, and the positive impact of these advanced technologies has expanded exponentially.

One such example is the real-time engagement with facility owners, building occupants and service providers, to enhance the user experience via smartphone applications and cloud-based data storage. Other potential benefits to users include improved safety and security, better wayfinding and communications, enhanced service response and key performance indicators (KPIs). Additionally, communications and information flow are streamlined through technologies such as digital signage, touchless kiosks, geofencing and push notifications. Although this document focuses on such technologies, it is not meant to be an information, communication and technology (ICT) centric document. It is designed to bridge technical knowledge and process gaps with FM operations.

4.2 Impact of application on facility management business goals

Technology touches almost every aspect of an FM practice. Increased access to information and data empowers better planning of many FM activities. Sensors and other devices can provide real-time feedback for improved decision-making, helping to speed up responses. Foot traffic, congestion and people-movements can be analysed in real-time with increasing levels of automation.

Universal foundational elements include preferences for finding and using evidence in FM, the acquisition of data, and drawing evidence from data; this is the external validation process. The internal validity of data, also foundational, is comparable to quality assurance (QA). The data collated and stored is of known and consistent origin, validated in form and value, complete (or with known omissions), and uncorrupted. From this verifiable position, data are usually selected by the FM exponent from a variety of sources.

The impact of technology on FM provides a foundation for numerous additional benefits, including more target-based resource efficiency, optimizing the life and usability of assets streamlined facility operations, and improving the quality and reliability of outcomes. The use of technology can assist in mitigating risks.

4.3 Golden thread initiative

In 2017 in West London, the Grenfell Tower fire spread rapidly upwards through the entire building due to its flammable exterior cladding. Reference [9] suggested the implementation of a “golden thread of information”. This golden thread, in its association with the built environment, provides information about the building and the steps required to ensure the safety of the building and the people in the present and the future [10].

The term has grown in its potential application to the built environment into one which applies not just to building safety but to whole life value and user experience. There are several international activities already underway looking to further extend this concept into existing information models and digital environments.

4.4 Asset and facility management applications

Applications and systems that provide functionality to cover all asset management (AM) and FM life cycle processes and related data include those providing functionality such as incident logging, work order management, asset management, corrective and preventive maintenance, material, contract, vendor, project and financial management.

4.5 Interfacing

Back-office systems such as computer maintenance management systems (CMMS) and computer aided facility management (CAFM) rely on and maintain valuable historical data required to generate any report or KPI understanding. Some are promoted as being a complete software solution for all instances and activities. However, there are three types of interfaces that are usually considered when formulating an FM technology strategy and action plan: input, output and visualization (see [Table 1](#)).

Table 1 — Types of interfaces for consideration when planning

Interface type	Description
Input related interfaces	Input related interfaces allow systems to online or batch receive information for further processing. Such interfaces include BMS system, IoT devices, mobile devices / applications collecting information from the field.
Output related interfaces	Output related interfaces provide silos of FM and AM information to BI and artificial intelligence (AI) related tools for further analysis and decision-making. Output related interfaces are also required to synchronize CMMS/CAFM systems with back office financial and human resources systems such as enterprise resource planning (ERP) systems.
Visualization interfaces	Visualization interfaces are required to project FM and AM data to computer aided design and mapping systems such as GIS, 2D architectural designs, energy sustainability management systems and BIM models.

4.6 Optimization systems

These are the digital systems that allow transformation of raw data and transactions into FM and AM knowledge. Examples of these systems include AI, BI, prediction analysis, capital planning and energy management systems, amongst others.

4.7 Facility management technology drivers

For a facility manager to achieve the optimal outcome from using technology, there is a need for clarity, communication and collaboration with technology providers in facility management consulting services. It is challenging for a facility manager to have an in-depth working knowledge of every aspect of the facilities they manage. It is therefore of critical importance to know the right questions to ask when evaluating or selecting a technological solution to ensure it will achieve its intended outcome. The compelling reasons for adopting such technology is the increase in likelihood of adoption when facility managers can identify and communicate relevant drivers (see [Table 2](#)).

Table 2 — Selection of technology-based drivers of change

Technology-based driver of change	Description
Health and safety	From wellbeing to building safety, technologies afford new ways to bring enhanced insight and support across the function's life cycle.
Commercial pressures	COVID-based, adversely-impacted commercial activities have meant, for many developers, building owners and business operators, a three-year reduction in revenues, additions to operating costs and lowering of profits that need to be redressed. This can be achieved by various means including raising productivity per resource, savings in utility cost outlay and enhanced competitiveness through business process efficiencies. Implementing technology can offer opportunities for each solution.
Data capture	Data capture is not a technology, per se, but an ongoing process which can be applied throughout various technologies.
Digital transition	Increasing digital integration from design, engineering and construction (DEC) through FM operations and maintenance (O&M).
Commercial competitiveness	By implementing new processes, systems, infrastructure, protocols and raising training standards, organizations can demonstrate recognizable international qualifications (e.g. the ISO 41001 family of standards), building sustainability status (e.g. LEED platinum) and resource-based certifications and qualifications (e.g. certified FM qualifications).
Risk register	From a collated list of business continuity planning (BCP) criteria and disaster recovery planning (DRP) topics, identify what are the key issues that can impact an organization's ability to deal with potential built environment-related crises and identifiable risks.
Technology value	User stories and customer journeys are critical to assess the value of new technologies.

Table 2 (continued)

Technology-based driver of change	Description
Corporate social responsibility (CSR)	Many companies, by their articles of association, have a duty of care for the wellbeing of their employees and sections of the wider community. These responsibilities extend far beyond the workplace and boards are responding increasingly to the social and welfare needs of the less privileged. Recycling surplus ICT equipment to local schools is one proactive example.
Grids and networks	Practical or theoretical means of environmental sustainability and ways of limiting carbon emissions can help stimulate interest in and use of smart grids.
Global sustainability campaigns	Global sustainability campaigns provide growing international requirements to reduce carbon footprints and improve water utilization.

Table 3 lists some foundational questions for a facility manager considering a technology solution and the creation of a FM digital technology strategy (see 6.1). They are typically used to form the basis of a checklist.

Table 3 — Potential foundational questions

Reference	Foundational question
T3-Q1	What strategic outcomes and business requirements are the demand organization seeking, such as enhanced health outcomes, higher productivity, improved user satisfaction, raised space utilization efficiency, greater sustainability, workspace flexibility?
T3-Q2	How will any technology deployments perform and scale in the future?
T3-Q3	What qualitative and quantitative technology gap analysis has been performed and what are the key results?
T3-Q4	Are there technologies that can be retrofitted?
T3-Q5	Is the digital network infrastructure capacity suitable to support planned FM technologies and to address future anticipated demand?
T3-Q6	Will the network infrastructure capacity be sufficient to address future anticipated demand?
T3-Q7	What cyber security measures are required?
T3-Q8	What corporate, local, national and international communication protocols and naming conventions are used?
T3-Q9	How will return on investment (ROI) be calculated: financial versus unit of productivity versus user satisfaction?
T3-Q10	What special skills or maintenance will be required to enable ongoing use of the technology?
T3-Q11	What type of FM sustainable impacts are expected from technological breakthroughs?
T3-Q12	What ethical principles and values of the organization are to be considered?

5 Key concepts: Domains in facility management technology

5.1 Ontologies

An ontology is the philosophical study of a being in general, or what applies neutrally to everything that is real. How does this apply to technology in FM? Ontologies seek to classify and explain entities, specifically their relationships and conditions.

In FM and technology, this concept is applied to the different naming and classification categories, so that existing things (assets) can be assigned to orders (categories) and groupings (data sets), to better understand all of the information associated with FM asset data (especially from BIM) and how it relates with data sets, status conditions and system data field definition criteria.

Those ontologies applicable within the scope of this document can include international foundation classes (IFCs), construction operations building information exchange (COBIE), even operational naming, classifications and definitions. Each one offers differing features, benefits and interoperability issues around the common purposes of data-mapping and asset-labelling.

5.2 Conceptual landscape

The intersection between FM and technology (known variously as FMTech, FM Ecosystem, FM Digital Twins, Digital FM or DFM) has presented the biggest opportunity for change in the industry, enhancing workforce awareness and capacity while automating and connecting the built environment.

With the reach and scope of facility management teams around the world, the operational requirements in both a direct context as well as alignment with each demand organisation can cover so many different parts that it is inevitable to end up with a system of systems delivering everything from environment control, space availability, asset performance and user experience.

DFM uses data and technological systems to automate, optimize and integrate with FM, as outlined in [Table 4](#).

Table 4 — Digital facility management data and technological systems examples

Digital FM data	Example of a technological system
Sourcing and procurement	Dashboard data flows
Property and lease management	Asset database and life cycle costings
Relocation and space management	Auto-alert and reporting configurations
Handovers and commissioning	Reactive and preventive maintenance

Conceptually, digital FM comprises many related activities, but in principle, it can be broken down into these five classic main elements:

- what: technology ecology based on the as-is and to-be analysis to create strategy;
- where: place, space and asset definitions and methodologies;
- when: optimal start and delivery in the FM life cycle;
- why: performance outputs and key deliverables needed;
- who: the primary beneficiaries are those in the digital FM team.

These five elements are deployed to support the implementation of digital FM across various activities, dependent upon the maturity, capability and needs of each organization.

5.3 Foundation domain pillars

The digital FM model forms the foundational pillars (see [Table 5](#)) from a functional point of view. There are four such main pillars that build up this model, summarized in this subclause and included in the lower row of [Figure A.1](#), the digital ecosystem “Periodic Table” infographic in [Annex A](#). Not all technologies will fit every FM operation, either in respective need or in digital maturity. Therefore, taking short, medium and long term views that align to the ongoing FM strategy allows the FM operation to be built from a full list of potential enablers as given in [Table 5](#).

Table 5 — Four foundation pillars

Pillar	Description
Demand end point	This pillar represents anything physically present and active such as place (including its 3D geolocation, label, name and address), space (defined by the floor section label, occupant or owner, building story or elevation, square metre size or cubic meter volume) or asset (details ranging from maker's name, purchase price, equipment model, construction materials and age, to net book value, associated original equipment manufacturer manuals, warranty and data loss prevention criteria, spare parts, standard operating procedures, and risk assessment models).
Edge	Where the physical world crosses seamlessly over to the digital world to monitor, communicate and deliver some type of autonomous action. Decentralized technology – be it a building sensor, a security camera or an access control system – is unlike traditional centralized systems, where data is sent to a main server or cloud for processing, edge computing processes data on-site or near the data source. This real-time processing capability can enhance responsiveness, reduces latency and can offer improved security.
FM information model	Where the full life cycle of facility management has been captured and structured to deliver an optimal whole life experience - leveraging the vast human knowledge data domain of the built environment. For example, CMMS systems can instruct elevators how to respond and even predict human movements and lift lobby queues.
Virtual environment	Represents the entire digital ecosystem in either its virtual or digital form on the Cloud or on-premise. Use of virtual reality (VR) is a simulated experience that can be, by design, similar to or completely different from the real world. Although VR applications can vary from graphic-intense, sensory-input entertainment video games, radical adoption has seen military training roles and medical interventions achieve successful results, with doctors and patients sited in different continents. The global uptake in the use of audio-visual internet-based video conferencing from 2020 to 2022 has yet to reach its zenith but the educational and commercial benefits have been immense, worldwide. Intuitive, creative memes, avatars, animated GIFs and digital screen backgrounds are all available to an entire generation unphased by new features. Other distinct types of VR-style technology include augmented reality (AR) and mixed reality, sometimes referred to as extended reality (XR). VR headsets or high-resolution projectors can create ultra-realistic images, surround sounds and other sensory feedback that simulate a user's physical presence in a virtual environment. Pilots in the latest fifth-generation fighter jets are provided with such head-mounted displays. For FM resources, complex maintenance or repair procedures can be practiced in a VR domain beforehand when sites are inaccessible or high-risk. With the latest digital XR accessories, specialized tools can provide sensitivity or touch and resistance to movement, via haptic technology.

5.4 Operating environment

With the four foundational pillars listed in [Table 5](#), the operating environment (see [Table 6](#)) is intended to provide a resilient framework to inform, guide and integrate with all FM technologies of both today and tomorrow. The full “periodic table” model in [Annex A](#) illustrates how different technologies relate to one another and to the respective operational practice. This provides a foundational understanding of the entire FM ecosystem. Using this matrix, FM stakeholders plan and adopt an ongoing, digital transformation journey, that is aligned to support their facility and business needs.

5.5 Horizontal versus hierarchical structures

An organization's structure relates to its company or entity's hierarchy. It defines the concept of superiors and subordinates who collaborate to achieve specific goals. The organization's corporate culture and strategic objectives usually determine its structure and how it operates. Responsibilities are allocated according to the functions of the structure. Horizontal or flat structures operating with minimal management tiers are often found in small organizations. By delegating decision-making processes and awarding operating authority, productivity is enhanced, agility is commonplace and competence is expected.

Whatever the management structure or ontology in place to deploy FM-Tech via a framework process, international best practice is usually three-phased: as-is analysis, to-be planning, then implementation sequential process. The topics, activities and components of this ontology are therefore reviewed and categorized to support such a planning process. Each technology subject is represented by an “element”. In the example in [Figure 1](#), “Blockchain” is abbreviated to “BC”, represents [Table 6](#), Column 2 (transactions,

security and storage), and Element 3 from the transaction, security and storage group of the ecosystem landscape (reference code: BC, 2.3).

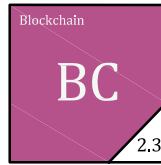


Figure 1 — Sample periodic table element

In [Clause 5](#), components of the full “periodic table” model are defined and explained. The fully arranged elements of this diverse, constantly adapting environment are shown in a graphical format in [Figure A.1](#). This illustrates how such technologies relate to one another and to which FM operational practice. This provides a foundational understanding of the entire, end-to-end horizontal ecosystem. Using this matrix, FM stakeholders plan and embrace an ongoing digital transformation journey aligned to support their own entity’s strategic needs. The core structure of [Table 6](#) is six rows, each one defining the respective column as contained in the “periodic table”.

The components of the operating environment have been identified as given in [Table 6](#).

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Table 6 — Identified components of the operating environment

Periodic table column	Ecosystem landscape vertical column heading	Description of the component
1	Grids and networks	The digital FM model is empowered by a variety of elements which are not typically consumed directly; those elements are required to animate or bring to life the digital FM requirement: they are represented by a variety of means for connectivity to digital grids and networks. Some are established terms in use for several decades, some are relatively new in concept.
2	Transactions, security and storage	From every bit of stored data to digital transactions and connections to all the security surrounding all of these needs. Cloud-based data storage facilities are becoming more common yet effective cyber security protocols and protective measures are paramount. From this hierarchy, a set of concepts and categories in a given subject area or domain are defined that show their properties and the relations between them.
3	Automation, monitoring and delivery	Sensors drive autonomous activity where the space, place or assets capture input and can control action output. The DFM captures digital states (using technology such as BIM photogrammetry or laser scanning) to capture reality and create base representations of buildings infrastructure and other assets. These can then be organized to align with human interpretation and ease of understanding; robotics are becoming more widely deployed, newly-adopted interfaces with the IoT are increasing in use.
4	Digital workplace	The digital workplace and generic FM environment capture digital states in methods that are organized to align with human interpretation and provide an ease of understanding: mobile dashboards and wearable devices are gaining wide acceptance. Data within a digital twin can be rendered into a virtual 3D graphical model, with complex tracking systems that mirror how human eyes capture images and ideas from the physical world.
5	Computer and data insight	Machines are capable of being trained to understand the enormous volumes of data (often known as big data) from the FM environment: this allows facility managers to understand and unlock the hidden potential of their FM environment, both physically and virtually. The learning processes for each software language reflect innovative coding and data insights.
6	Information models and frameworks	Machine learning will take what it learns from the models (algorithms, relationships, experiences and data) that people provide and programme. With such predictive programs, the life cycle management of assets is enhanced and, with multi-dimensional location and labelling of assets, users are provided with more means of accurate forecasting tools for operations and maintenance tasks, plus economic estimations.

5.6 Grids and networks (FMTech periodic table reference: column 1)

5.6.1 General

The electric power grid is radically evolving and transforming into the smart grid. The drivers behind the smart grid are to improve energy efficiency while driving resiliency and reliability. Energy management systems, often integrated with building automation systems, play an important role in the control of building energy usage. These integrated systems provide building managers and consumers alike with digital information on power consumption patterns to help them adopt more energy-efficient behaviours. The operational phase of a facility is its primary energy consumption period, so, cumulatively, across many districts and cities, it represents a major hindrance to the development of sustainable energy solutions in many countries.

5.6.2 Networks (FMTech periodic table reference: MbN, 1.1; LAN, 1.2; WAN, 1.3)

Networks have been a major player and have contributed to the whole process described in [5.6.1](#), as well as to the existence of the “smart grid”, “energy-efficient behaviour” and the advent of “SMART buildings”. They have helped energy management and micro-grids to be developed and improved in many territories. Recent

developments and pilot programs include data and power via a local area network, wide area network or wireless wide area network, long range wide area network, fibre optics, and other novel, radical technical options such as edge networking.

Grids and networks, more generally, can also carry more than just energy. Of late, data networks have fuelled much of the digital transformation process and support such things as mobile phones, robotics and IoT. This general ability for a network to carry and distribute various resources allows technology to reside in a greater collective, bringing more and more capability to the FM and, in turn, organizations.

With the array of emerging technologies and things like quantum computing, the grids, networks and communications present a new platform of possibility, creating a foundation for the FM stack to drive the very heart of our smart world, as shown in [Figure A.1](#) in [Annex A](#).

5.6.3 Utilities (FMTech periodic table reference: UTL, 1.4)

New generation energy management and utility systems leverage advanced analytics and communication technologies to offer consumers control features to drive actionable information, ensure ease of use, and ensure energy availability. Adequate energy quality in buildings and industrial companies have a large upside. Water supplies and waste extraction are key systems subject to discrete health and safety regulations.

Many electronic devices and automation systems in smart buildings and industrial production facilities are sensitive to voltage or frequency variations in the energy supply, often caused by unexpected sources. They can also cause faults themselves and feed them back into the supply system. Continuously recorded and evaluated measurements relevant to power quality help to detect issues early and offer the chance to correct failures.

Energy quality goes hand-in-hand with utility management. It refers to the quality of the supply voltage according to given criteria regarding its frequency, magnitude and wave form. The aspect of energy quality can be further classified into frequency quality (i.e. the fundamental frequency of the supply voltage), the voltage magnitude (i.e. its root-mean-square value) and the voltage wave form (i.e. the lack of distortions thereof). This issue has grown because installation has increased the nonlinear loads.

There has been a significant interest in achieving more efficient utilization of electrical power generation capabilities (especially sourced from local wind power, solar panel and other renewable sources) coupled with more sophisticated control of electrical loads by users. With a growing awareness of decarbonization and the cost impact of inefficient utilization of energy resources, electrical power consumers have become aware of the desirability of altering their usage patterns, as have facilities that consume significant volumes of water.

The concept of demand side management (DSM) is highly effective in countries with high energy and utility tariffs. Where local kilowatt per hour rates are subsidized or low, due to the availability of hydrocarbon and fossil fuels, the compelling reasons to adopt energy frugality is a harder campaign to pursue.

Energy management promotes sustainability while achieving savings on energy and operational spending. It encompasses real time meters for electricity, gas and water that can benefit several stakeholders including facility managers, retail and business tenants, residents and government organizations.

The operational phase of the building is a major consumer of energy, therefore energy consumption in buildings is a major contributor and hindrance to the development of sustainable energy solutions in many countries. For this reason, it is an important aspect for building energy conservation that high-efficiency operating conditions exist for building equipment through optimized control schemes. Utilities are controllable by micro-grids, designed as self-sufficient energy systems that serve a discrete geographic footprint. University campuses, a medical complex, a business park or a residential community, often using technologies such as power over ethernet (PoE), extremely low voltages, inverters and remote-monitored and controlled equipment, are all capable of reducing annual energy consumption by up to 30 %.

Renewable energy resources are being deployed on a large scale to meet the needs of increasing energy demand, mitigating environmental pollutants and increasing socio-economic benefits for sustainable development. The integration of such sources of energy distributed across the electrical grid opens the way for micro-grids.

5.7 Transactions, security and storage (FMTech periodic table reference: column 2)

5.7.1 General

For every action in the DFM environment, there is a transaction. For the whole digital ecosystem to both be trusted and relied upon, there needs to be confidence that the transaction will be captured, stored and maintained. Assurance that the security of these transactions will be complete, in all phases, locations and forms, is critical.

Historically, the generation, collection, transmission, security and storage of data to support building controls and monitoring systems, have proved cumbersome. With the introduction of these FM technologies over 25 years ago, specific interoperable protocol standards were not envisioned for the eventual integration with future IoT devices, ERP and BMS systems and related smart applications. With many of these legacy equipment controls and monitoring systems still in operation, the technology gap restricts the benefits of digital interoperability and building automation needed.

5.7.2 Biometrics (FMTech periodic table reference: Biom, 2.1)

Building on many years of advancement in biometrics, the advent of COVID-19 promoted the acceleration of the development of an enhanced range of touchless interfaces for facility access controls and of the installation of infrared motion-controlled valves in washing faucets and paper dispensers. Biometric controls migrated from fingerprint-registered devices to retinal scans and facial-recognition cameras. To mitigate the risk of multi-touched door handles, automatic motion sensor-controlled sliding doors were shown to be effective in mitigating the spread of the virus.

5.7.3 Cyber security (FMTech periodic table reference: CS, 2.2)

Cybersecurity is the practice of protecting computer systems and mobile devices, networks and servers, programs and digital transactions, electronic devices and sensors, infrastructure and data from cyber vulnerabilities or malicious attacks (also known as “hacks”). The countermeasures against such actions are known as information technology security or electronic information security. The goals of such measures include

- protecting sensitive and proprietary information,
- preventing extortion attempts, or
- interruptions to normal business processes or operations.

Implementing effective cybersecurity measures is particularly challenging because there are more devices than people and hackers are becoming more innovative and devious. A full regime of the cyber security resilience measures is available to FM departments, as shown in [Table 7](#).

Table 7 — Regime of cyber security measures available

Subject	Description
Application security	Application security keeps hardware and software threat-free.
Network security	Network security keeps a computer system secure from intruders, attackers or malware.
Operational security	Operational security controls how data are accessed, moved, stored and protected.
Training	Training provides an ongoing responsibility for all system users by educating them on preventing viruses from being introduced via infected USB drives or opening suspicious email attachments.
Physical security checks	Physical security checks are performed on a random and regular basis, to deter and detect individuals from misappropriating proprietary data and digital records.
Information security	Information security ensures data privacy and integrity, whether stored or during transmission.
DRP and BCP measures	DRP and BCP measures prioritize how an enterprise mitigates risk and plans, specifically for cyber-security threats and events.

The DFM landscape is incredibly data intensive so, data storage consideration is a crucial consideration within the digital environment. This is especially true when planning for disaster recovery, resilience and becomes even more important when enabling technologies for advanced analytics, artificial intelligence, or virtual, augmented and mixed reality.

From on-premise enterprise storage systems and hybrid cloud storage environments to off-premise private and virtual cloud environments, there are many types of data storage methods widely available. Every type of data storage has its positive and negative aspects. Choosing the right option varies for each organization and its business needs.

5.7.4 Blockchain (FMTech periodic table reference: BC, 2.3)

Digital transactions can be broadly defined as being either online or automated, and can take place between people and organizations without the use of paper. If a field engineer is assigned a task and completes this work, while adding details to the work order, this would consist of several digital transactions in one process. It makes the entire transaction faster, easier, more accurate and more convenient.

Technologies like Blockchain, which by design are resistant to modification of the data, can greatly assist in creating and maintaining data-protocol compliance and ultimate trust. Once recorded, the data in any given block cannot be altered retroactively without amending all subsequent blocks, which requires consensus of the network majority.

Although blockchain records are not unalterable, blockchains themselves can be considered secure by design and exemplify a distributed computing system. Decentralized consensus has therefore been claimed with a blockchain. A transaction is the smallest possible event on the blockchain. A thorough understanding of cybersecurity is necessary, whether inhouse or outsourced. Further information on how to manage information security is contained in ISO/IEC 27000.

5.7.5 Backup (FMTech periodic table reference: BU, 2.5)

Gone are the days of stacks of 1,5 MB floppy disks in desktop boxes, used to backup data from desktop PC applications. It is of more relevance to CAFM managers to ensure that all data set storages are backed up, whether they are static, mobile or cloud-based. A typical range of backup facilities includes provision for a range of data set instances (cloud or server-based in data centre):

- operational daily data set;
- mirror offsite operational daily data set storage;
- training data set for inductees and skills advancement;
- demonstration data set for potential clients and new users;

- upgrading, testing and build environment(s);
- archived and maintained entities.

5.7.6 Smart contracts (FMTech periodic table reference: SmC, 2.6)

For those new buildings that are being or have been designed with a series of digitalization goals, the common data environment (CDE) requires deliverables such as common internet data standards throughout the building's data systems. Contracts for service providers operating and maintaining the facility are most effective when inclusive of SMART terms and conditions that define the CDE in use.

One opportunity-cost benefit for hotel chain owners and operators during the COVID-19 pandemic was to close out floors or even whole buildings and implement refurbishment programmes, to address obsolete legacy systems and deploy CDE with much less disruption to occupants or revenue streams.

Systems integrators are taking on the challenge of centralizing data silos from BMS, with water recovery programmes, energy management systems and storing the output data on secure, cloud platforms. Other systems are being upgraded (e.g. converting from legacy 220 V or 110 V electrical distribution systems to ELV and inverter-based systems, for power, lighting and security).

5.8 Automation, monitoring and delivery (FMTech periodic table reference: column 3)

5.8.1 Robotics (FMTech periodic table reference: RBT, 3.1)

Adopting new techniques requires a modern mindset, enhanced skillsets, working in multiple tiers, from strategic planning to system integration and practical, O&M working practices. Building automation drives even deeper insights for facility managers in the forms of safety and security, operational efficiency, resiliency and maximizing the useful life of building assets. The real value of building automation is the promise of enabling facility managers to accomplish more with less, by relegating some of the more menial, repetitive, 24/7 mundane tasks, to free up time and resources.

The growing use of robotics is being researched to serve specific needs addressing repetitive, hazardous and potentially dangerous jobs that put people at risk.

5.8.2 Wearables (FMTech periodic table reference: Wbl, 3.3)

The fitness-associated wristbands that monitor vital personal health statistics of blood pressure and pulse rate have expanded in their digital capabilities. Wrist watches that displayed time are now SMART watches capable of linking to 5G telecoms devices via near field communications (NFC) and Bluetooth™ technology. They can be linked to IoT via Wi-Fi™ and thereby interface with many more capabilities: dynamic calendars, CAFM tasking and work order assignments, and facility alerts and alarms. The capabilities of wearables continue to expand, enhancing resource productivity and team efficiency.

5.8.3 Smart assets and digital experience monitoring (FMTech periodic table reference: Sma, 3.4; DEM, 3.5)

To implement digital transformation a SMART building project requires access to quality data and the trained resources and systems to deploy the processes and protocols needed to manage such data in a time and cost-effective model.

Poor quality data, badly handled, will very quickly threaten the success of a digital transformation process and cause stakeholders to lose confidence in such systems. The material condition, maintainability and life duration of assets are impacted rapidly if associated smart asset data are not kept accurate, updated and relevant. See ISO 19650-1 for information on the organization and digitization of information about buildings and civil engineering works, including BIM.

Measuring the accuracy and relevance of data are often best determined by periodic surveys of the end customers' digital experience, across a range of applications.

An information-overlap and a clear demarcation line exists within the ISO 19650 series, that addresses a different specialism focus and technology maturity level, that this document does not attempt to cross.

Information on technology breakthroughs and associated risks exists as professional body white papers, academic research journals, think tank periodic summaries, conference proceedings and technical books (available in hard, soft and audio versions). As AI and big data increase their global influence on FM operations, all built environment organizations need a harnessing plan as part of their overall strategy. Such a plan accommodates innovation and ensures that parallel developments are integrated, mutually supportive and generically productive and not a potential source of conflict.

The oft-quoted Fourth Industrial Revolution is reshaping each industry. FM exponents are working to acquire the skills to deploy the technology available. As the capacity and speed of ERP systems increase, year-on-year, so too does the volume of data and metadata needing to be processed, stored and analysed. Whatever the source of guidance and information, be it online or via training, there is a wealth of templates, protocols, frameworks and guidance documents to support the effective design and implementation of technology in FM.

5.9 Digital workplace (FMTech periodic table reference: column 4)

5.9.1 General

Applications, interfaces and experiences are able to make assets function “smarter”, particularly workplace environments. For a meaningful digital exchange to happen, information is generally conveyed through a visible application interface designed with the intent of a positive customer experience (CX) and end user experience (UX).

5.9.2 Virtual reality and assistants (FMTech periodic table reference: AR, 4.1; VR, 4.2; VA, 4.3; 3DA 4.4)

Innovative 3D modelling (via digital twins), VR and AR solutions have given facility managers new ways to visualize and experience their FM environments. These advanced technologies can provide the frameworks and opportunities to visualize, augment and simulate physical and functional FM data using methods, that until recently, were simply not available to those engaged in the FM industry.

An application interfaces with the screen-visible part of the program that enables end users to see their data and information. The design of a user interface, or “UI”, often determines the experience (ease of use and convenience), whether positive or negative, of an end user.

Visualization tools allow the 3D visual, virtual presentation of facility space or asset data through interrogatable dashboards of layered information. Visualization is all about taking large amounts of complex data and presenting it in a format for easy consumption. Augmentation is where the digital environment meets reality. These solutions allow the FM world to bring additional digital information into everyday lives and experience the built environment while enabling a deeper understanding, connection and awareness of data.

Simulation enables users to experience a facility, system or asset 3D visualization to experience conditions, situations and events in the virtual as-built environment. Virtual simulation is an ideal method to drive optimal operation and performance settings. The facility manager mitigates life cycle risk by understanding and preparing for future events and conditions by simulating circumstances that will impact the facility and its assets.

5.9.3 Smart workspaces

Smart workspaces in a pre-COVID-19 pandemic environment were usually optimized around dedicated workplaces, often in commercial offices, designed for optimal productivity and fitted with innovative Wi-Fi-based systems to support collaborative teamwork activities, based around a hierarchical management structure. Floor and furniture layouts were based traditionally on functional departments and pyramidal management models.

Advances in digital technology, the advent of hybrid and remote working practices, plus a strong focus on healthy environments and resource wellbeing, have resulted in modified workspaces, supported by far more mobile, interactive, online communities and subgroups.

5.9.4 Operational applications (FMTech periodic table reference: OA, 4.5)

Recent significant advancements in IoT controls and open standard protocols are driving the necessary interoperability and the automation between building systems, regardless of the building automation platforms in place. Examples of these enhancements in the operational FM environment include AI controls and metadata from autonomous-cleaning WC fittings and UV virus-zapping robots, surveillance drones, users' health monitoring and virus control.

Data assimilation and transmission protocols, like message queuing telemetry transport (MQTT) and advanced message queuing protocol (AMQP) are coming to the forefront, disrupting, and even replacing, older antiquated building monitoring and controls systems enabling smart automation technologies. Analysed BMS utility costs allow opportunities to save occupancy costs and reduce service charges.

Part of that user experience can be facilitated using another type of interface between applications. This data transfer is conducted through channels normally invisible to end users, termed application programming interfaces (API). Such communication channels, through predetermined routines and protocols, determine and regulate the data to be exchanged, how those data are transferred and in what format(s), as well as how frequently.

Some specific benefits gained by deploying digital solutions in FM include:

- competitive advantage via differentiation, raising performance-based FM standards;
- increased efficiency of 24/7 operations dependent on human alertness;
- agile processes that predict earlier, respond faster, reducing risks of FM asset failure;
- knowledge sharing between asset owner, managing agent and service provider;
- knowledge retention and availability, progressively improving FM work effectiveness.

5.10 Computer and data insights (FMTech periodic table reference: column 5)

5.10.1 General

The FM digital landscape can generate vast amounts of data that can become tremendously useful, when properly organized, to be analysed by human beings. It can provide facility managers with much greater visibility of key criteria, allowing them to make better decisions with the ability to greatly improve FM strategy, tactics and operations.

Insights from computers translate data into action for improved decision-making. Without such data-driven insights, FM data remains unused and undervalued. Not all data are in their ideal state when first created. They need to be recorded, mapped, processed and categorized ready for interpretation. Once the data has been normalized, the data can be interpreted for AI and machine learning (ML) to perform tasks like optimize building occupancy while assuring a building's heating, ventilation and air conditioning system is running as efficiently as possible to save energy.

Another example can be to increase the amount of outside air supplied to a building due to an increase in CO₂ levels detected within. Interpretation opens the door to the virtual FM digital assistants or chat bots to help continuously achieve a building's ideal state of performance.

5.10.2 Computer vision and learning types (FMTech periodic table reference: CV, 5.1; ML, 5.2; CC, 5.3; DL, 5.5)

Computer Vision (CV), ML, cognitive computing (CC), and deep learning (DL) are several of the examples of computer insights that are being developed in this exciting field. One of the more beneficial aspects of data

insights is the ability to analyse a building system's past, present and future performance to achieve optimal conditions.

One simple example of computer insight in action is when a building system's present state performance is contrasted against its original state to make predictions about how the system will perform over time. This is where the term "planned, predictive maintenance" (PPM) comes from. Yet, this is a methodology that is typically static by nature, whereas the more complex, condition-based maintenance (CBM) is dynamic by nature.

Prior to computer insights, most FM data remained in the brain of the facility manager. Computer insights deliver real-time information to a facility manager, allowing for better decision-making, improving efficiency while maximizing resources and saving cost.

5.10.3 Natural language processing (FMTech periodic table reference: NLP, 5.4)

Matching personnel training with professional development in system knowledge is critical to the success of any digital transformation. The digital FM team understanding of the technology goals allows them to be involved fully in the implementation journey. In order for facilities to be more efficient and for processes to achieve greater agility, training is planned strategically, scheduled operationally and delivered practically (either individually or in team / class batches, conducted online or in person). The language chosen in supporting training materials is of utmost importance to achieve maximum training effectiveness.

The adoption of "train the trainer" is a proven methodology to help control training costs per resource and also to ensure, in international work environments, that mixed local dialects and languages in the workforce do not inhibit the spread of required knowledge. The trainees are assessed per course, beforehand, during and post-delivery to measure the benefits and effectiveness achieved. If the information has been understood and assimilated accurately, then the language interface and data conversion processes are of good value.

As many workplaces operate in 24/7 shifts, a method for the system knowledge to be shared evenly between operatives and be accessible remotely by smart mobile devices is essential. It takes many months to form, induct and develop hard and soft FM cohorts, so personnel retention is crucial to overall performance delivery, service quality consistency and team cohesiveness.

5.10.4 Deep learning and neural networks (FMTech periodic table reference: DL, 5.5; NN, 5.6)

A major transformation of work practices for any FM team working with computer insights is in future forecasting. Examples include ordering parts from a materials supplier, ahead of a scheduled maintenance because computer insights can simulate and predict (with a high degree of confidence) a critical failure within a short period of time.

Another example is if there is a building fire to simulate optimal building evacuations and life-safety protocols that address footfall numbers, safest routes, alternative plans and risks forecast for muster points.

The power of computer insight is that each part of the function can work within an ecosystem to create integrated FM systems and solutions which will continue to operate with the whole works of FM. By involving all stakeholders via digital dashboards, accessing ERP systems' data and predictive AI analysis, the demand organization (especially) monitors FM safety, standards and resources deployed far more effectively, with less intrusion, more delegation, greater trust and improved visibility.

Neural network-based technology frameworks can therefore be relied on, increasingly, to enhance the dynamics of real partnering, improve outsourced service delivery models, reduce variability and raise the FM sector standards. Some examples of such supporting technology frameworks are:

- optical character recognition,
- speech recognition,
- photo and video manipulation,
- motion interpolation,
- image processing,

- image scaling,
- strategic planning,
- natural language processing, translation and chatterbots,
- robotics,
- facial recognition,
- handwriting recognition,
- photo tagging,
- virtual reality,
- computer vision,
- image restoration,
- photo colorization,
- nonlinear control,
- film restoration.

5.11 Information models and frameworks

5.11.1 General

Technology has forever altered how humankind plans, builds and manages facilities and infrastructure. It has enabled the capture, storage and use of data in FM in ways previously unimagined. More recently, with the rapid adoption and advancement of the latest technology, property developers, clients and service-provider organizations (and, most importantly, their leaders) have evolved and developed their common viewpoint to that of a creator, owner and user, of both refined and unrefined FM data and information; this is a quantum development step.

5.11.2 Building information modelling and location referencing (FMTech periodic table reference: BIM, 6.1; GIS, 6.2)

There are digital tools that allow FM users to monitor and control equipment and sensors within a specific area or facility. Examples include BIM and geographical information systems (GIS). Technology platforms continue to vastly improve the ways data is modelled and visualized. Creating highly accurate and comprehensive information insights will not just prevent facility management teams from drowning in data but also enable them to value-driven, data-rich information for decision-making.

The impact of BIM as an innovative process used in the built environment has been focused mainly on transforming building DEC practices. Significant quantifiable benefits, especially for major projects, have been derived via techniques such as clash detection, value engineering, cost management and others. These systems deliver measurable advantages in terms of achieving successful timelines, reduced commercial confrontation and enhanced collaborative teamwork and also the elimination of “snags” prior to crucial handover, testing and commissioning stages. Market surveys in the past 10 years have exposed the increased trend towards developing smart buildings.

The emphasis is frequently about how buildings actually work in the operations and maintenance phases of a building's life cycle, which can represent over 85 % of the life cycle costs of a modern, built asset. The introduction and importance of establishing a CDE allows authorized data users to view, extract and manipulate relevant data to provide a more seamless user experience. As more developers are encouraged, either by legislation, commercial advantages or competitive differentiator incentives to invest in the development of SMART buildings, the FM sector is under pressure to deploy service delivery models that can fulfill the digital potential of such premises.

5.11.3 Whole life management (FMTech periodic table reference: WL, 6.5)

Effective programme-planning and decision-making in relation to the whole life cycle of a built asset relies heavily on suitable and relevant data, information and knowledge being gathered, aggregated, organized and analysed to examine a known problem and determine a workable, cost-effective solution. Innovative tools and solutions, such as desktop and cloud-based business systems and content management systems, as well as recent innovations in IoT-related technologies allow organizations to achieve enterprise-wide knowledge capture and information sharing.

The result is greater visibility and access to a wide range of timely, relevant and accurate data that fundamentally improves collaboration to enable organizational decision-making during facility life cycle business practices. The types of information that an average FM professional creates, influences and uses range from the typical day-to-day (e.g. work orders and inventory information) to the contextual (e.g. standards, best practices and key performance indicators) and the more complex (e.g. condition assessments and supply chain management) as well as the sometimes formidable (e.g. cybersecurity, condition-based monitoring, energy modelling).

5.11.4 Health and safety, and well-being (FMTech periodic table reference: HS, 6.6; Well, 6.7)

Monitoring technology has become a critical function for facility managers. This includes filtering a wide array of information for example, for a single HSE priority issue of overseeing indoor environmental quality in the form of comfort, temperature, humidity, CO₂ and O₂ levels, air refresh rates, ambient noise, light levels, and energy management. Facility managers can monitor their facilities remotely from anywhere using IoT via a range of digital hand-held devices with dashboard visibility of essential data touchpoints, allowing faster, more accurate decisions.

Devices linked via IoT networks can be programmed to detect trends and alert thresholds that indicate potential failure or below-par performance. For example, did the demand control ventilation serving an indoor assembly space respond appropriately to rising CO₂ as people entered the auditorium for an event? IoT offers inexpensive procurement options but over-installation can lead to a plethora of surplus data, that is gathered, monitored and stored. A detailed implementation plan ensures that connectivity is useful and supports technology optimization.

5.12 Data-generating systems for re-commissioning and restoration

The restorative functionality of computer programmes, since they are all data driven, can also work in other instances to bridge gaps and perform functions that more traditional methods of information gathering, video recording systems and data storage facilities can be unable to deliver. Other, alternative options exist as listed in [Table 8](#).

Table 8 — Alternative data-generating methods available

Alternative method	Description
Recommissioning	Recommissioning is supported by technology when computer insight provides a way for the FM team to bring a building system back to its ideal or intended state especially after a period of time in suspension or being “mothballed”.
Restoration	Restoration is a different activity more often associated with reversing damage done to property or the impact of age on an asset. A computerized tomography scan (CT or CAT scan) uses computers and rotating X-ray machines to create cross-sectional images of an artefact or structure. TET PET and X-ray scans used typically in healthcare facilities need to have respective health and safety protocols established in order to protect equipment users and FM staff working in the property.
AI systems	AI systems can be programmed to interact within a “live” virtual BIM or digital twin model to transform a historical building back to its intended state in the 14 th Century, for example, using ML. ML is the study of computer algorithms that improve automatically through experience and by the analysis of data.
Light detection and ranging (LIDAR)	Large structures and building assets can be viewed using many different mediums from rendering a high-definition video capture through to LIDAR as an innovative remote sensing method that uses light in the form of a pulsed laser to measure ranges and scan objects structures and spaces very precisely. Programmable drones can be also targeted to survey premises from either exterior or interior flight paths. Within the field of 3D object scanning laser scanning combines controlled steering of laser beams with a laser rangefinder.

6 Business case benefits from technological applications in facility management

6.1 Facility management technological strategy

This technical framework outlines a high-level overview of the array of technologies that can be utilized within an organization. Certain technology stacks have interdependencies. FM teams and the demand organization have the freedom to determine the appropriate stack of technologies for their organizational needs, for their own roadmap. The standard approach to forming a FM technology strategy is outlined below:

- to understand the demand organization’s needs: identify potential areas of improvement;
- to form a strong coalition to determine the appropriate technology stack and approach;
- to build a business use case and prove the business value and ROI;
- from customer interviews, form user stories and customer journeys to measure value;
- to continuously evolve and evaluate the suitability of the chosen solutions;
- to develop plans (BCP and DRP) for unexpected challenges and contingent risks;
- to deploy a digital FM model that embraces an adaptive training concept for developing the digital wisdom in FM people.

6.2 Response to organizational needs

When approached from the perspective of ISO 41001 and ISO 41014, the FM technology strategy is positioned as a key component of the overall FM strategy. The latter is itself a component of the core business strategy. [Figure 2](#) outlines this principle, by placing the FM technology strategy in the context of the ISO 41001 model.

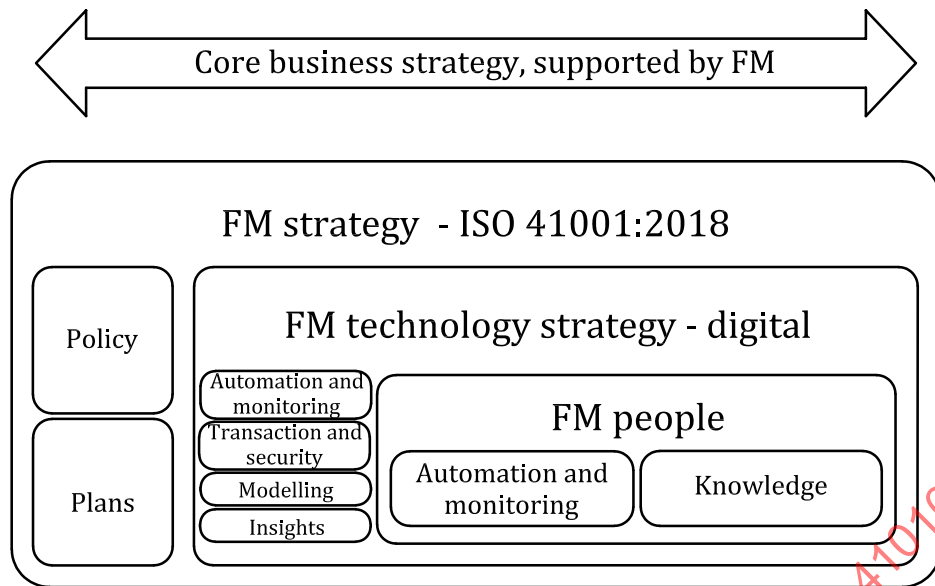


Figure 2 — Facility management technology strategy

An effective FM strategy aims to ensure alignment between FM requirements and the objectives, needs and constraints of an organization's core business (see ISO 41014). It is most important that the transformation goals of that organization are thoroughly examined, understood and documented prior to evaluating the technology stack and approach.

The classic As-Is and To-Be reviews provide comparative data and situational information that supports a detailed gap analysis report. From such a report, a stage and phase-based change management plan is developed. Typical demands and requirements as part of change management plan are:

- alerts and notifications,
- asset shutdown, outage and disposal,
- budgeting,
- contract management,
- data and functionality access rights,
- event management,
- invoicing,
- management,
- number and type of buildings,
- number of users required,
- project management,
- reporting templates and records,
- space management,
- asset life cycle realization,
- authorization,
- configuration,

- custodial,
- estimated number of incidents per day / month,
- help desk,
- leasing,
- monitoring, evaluation and control,
- number and type of assets,
- performance monitoring,
- quality management,
- sizing information,
- task library.

6.3 Formation of a guiding coalition

FM technologies can be often transformative in nature and, in turn, can have an impact beyond the FM organization. This can influence the demand organization's stakeholders and other business units such as, information technology and human resources. When creating and revising a FM technology strategy, it is typical to use a collaborative approach which encompasses input from all involved parties.

The facility manager can take a leadership position in forming an FM technology team to manage this process and gain collaborative input from parties, such as:

- demand organization top management;
- demand organization business units;
- service providers, sub-contractors and supply chain partners;
- end users.

Guidance and advice from industry specialists and service designers is generally sought when starting the FM digital transformation journey, from:

- internal IT experts;
- data scientists;
- systems integration service providers;
- network designers;
- technology OEM companies;
- digitalization consultants;
- FM technology experts, from a range of related sectors:
 - subject matter experts and FM consultants,
 - technology service and product specialists, and
 - specialist service providers.

6.4 Choice of technology

Once the strategic, tactical and operational needs of the organization are documented and the guiding coalition is formed, the appropriate technology stack can be determined.

Through an extensive iterative process, “elements” of the previously mentioned periodic table model can be combined into “molecules” to form more complex technology stacks that aim to resolve problems as required by the FM organization. The model below outlines how technology stacks can be combined visually. The “elements” used in this SMART building example of such a technology stack, as shown in [Figure 3](#), are: utilities (UTL), blockchain (BC), smart assets (SmA), BIM, ML and whole life (WL).

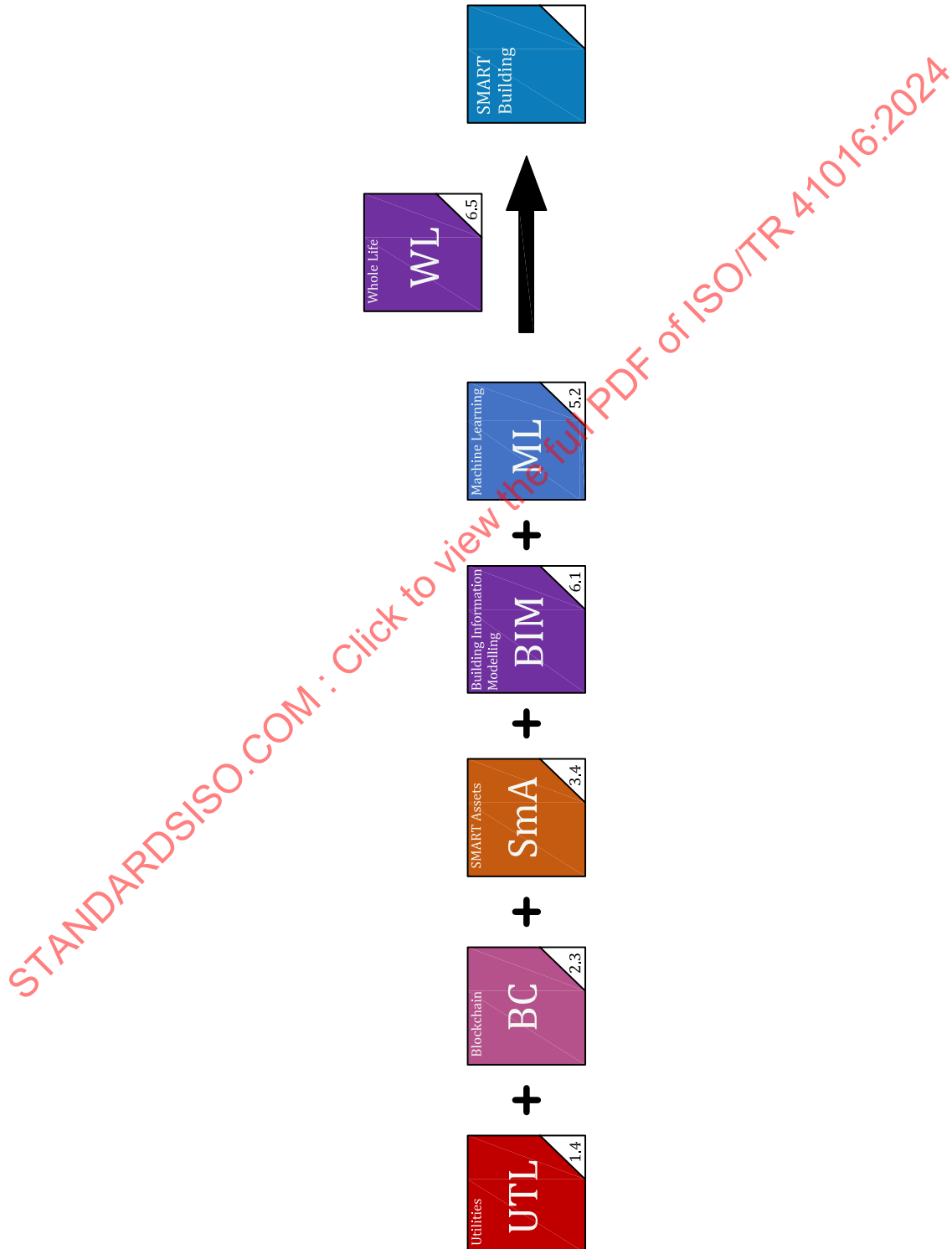


Figure 3 — Combination of elements from the periodic table to create technology stacks

Due to the broad number of potential technology offerings, it is likely that the procurement process selecting the right combination of FM technologies becomes challenging, which can cause delays in the overall project progress. An accurate user requirement document is essential for those in procurement and finance departments, or even senior management, who can be insufficiently knowledgeable to make effective product selections.

It is important, therefore, that the alignment and understanding of the demand organization and operation, the information needs, and the underlying technologies are collectively and independently considered. Some examples of considerations are given below.

- The facility manager stays close to the needs and wants of the demand organization, only adapting technologies where there is a proven use case to resolve issues or improve building experiences.
- The team takes an open, iterative, agile approach to testing and evaluating technology “molecule” combinations to find the appropriate fit for the organizational demands.
- The technology transformation team can require the expertise of specialists to augment existing team to ensure that any new technology or applications fit correctly and can be integrated within the overall landscape of FM digital solutions and approaches.

6.5 Creation of the business case and proof of return on investment

New technologies offer opportunities to revolutionize ways of working, upgrade supply chain structures and improve the overall quality of life. Consequently, a recurring cycle of continuous evaluation and development is imperative in the FM technology strategy management system.

Regular meetings between the FM technology team and relevant stakeholders can help to best utilize the deployed technologies and evaluate alternatives when new technological advancements have been made. Incentive schemes within organizations can help to broaden the range of innovation input sources that can potentially save costs, enhance efficiency, raise productivity or improve the workplace environment.

6.6 Agile project management

6.6.1 General

Agile project management is named after the publication of the Manifesto for Agile Software Development in 2001. Agile techniques started to develop as bespoke methodologies per industry. Essentially, they each represent an iterative approach to deliver a project throughout its life cycle.

As opposed to the traditional cascade or waterfall processes associated with property management or real estate processes, agile life cycles are made up of incremental steps that move progressively towards project completion. Iterative approaches are more commonly used by software developers to encourage speed of progress and flexibility of thoughts. Iteration's prime aim as a technique is to avoid a conventional, linear route and instead, gain benefits throughout the transformation process, rather than only at completion. Agile projects demonstrate core values and behaviours of trust, flexibility, empowerment and collaboration. These values cannot be ordered or expected, but rather nurtured and developed over time, with integrated, like-minded team members. Hence, the selection of project resources with such competences is critical to deploy agile as a project's methodology.

Further, agile does not define one specific methodology: it is more a framework of tools, structure, culture and discipline that by mixing planning with execution, allows a change management project or digitalization program to adjust its timeline, roadmap, milestones and goals while underway. The risks associated include maintaining a positive mindset amongst the project team despite any setbacks encountered. This team, made up of customer and client sponsor representatives, is embedded in multiple tiers as active project participants. Integrated reports with finance, procurement, human capital and governance departments are generated for best practice. A risk associated with agile as an innovative integration technique is that such stakeholder departments can be unable to work in intensive bursts for more than a few days, if their work cycle is monthly-based, for example.

6.6.2 Examples of agile methodologies

Agile methodologies that have gained credibility through worldwide success in the past 20 years Traditional approach would build a plan mapped out against a scripted timeline and where all detailed requirements are specified. Time elapses, often for months, pending progressive reviews and hierarchical approval of the plan and mobilization is seen as a logical, risk-averse eventual result. Agile methodologies start quickly, with a simple overarching goal, to be delivered in a relatively short period of time. Details are clarified as progress is achieved and project requirements become progressively defined.

[Tables 9](#) lists a selection of the 50+ differing agile techniques and methodologies available on the open technology-product market.

Table 9 — Useful agile methodologies to deploy FM technology

Non-commercial agile methodologies	Commercial agile methodologies ^a
agile fluency	Agile Business Analysis (AgileBA)
acceptance test driven development (ATDD)	Agile Digital Services (AgileDS)
agility scales	Agile Portfolio Management (AgilePfM)
agile modelling (AM)	Agile Project Management (AgilePM)
bimodal portfolio management (Bimodal PfM)	AgileSHIFT
design thinking	Behaviour-Driven Development (BDD)
experiment-driven development (EDD)	Continuous Integration / Deployment (CI/CD)
evidence-based portfolio management (E-B PfM)	DevOps (although a practice and philosophy, there are many commercial tools and platforms associated with DevOps)
feature-driven development (FDD)	Disciplined Agile (DA)
kanban (although the principle is open, there are commercial tools that have been developed around it)	Dynamic Systems Development Method (DSDM)
lean (a philosophy and method, but has inspired commercial tools and programs)	Holocracy
nexus	Large-Scale Scrum (LeSS)
open space agility (OSA)	Management of Portfolios (MoP)
praxis	PMI-Agile Certified Professional (PMI-ACP)
project half double	PRINCE2 Agile
rapid application development (RAD)	SAFe (Scaled Agile Framework Enterprise)
scaled agile lean development (scaled) test-driven development (tdd)	Scrum (or Sprint) (as a framework; while the Scrum Guide is open and free, training, tools, and certifications are commercial)
scrum of scrums	Scrumban
sociocracy	Spotify Model
standard for portfolio management (SfPfM)	XP (eXtreme Programming) (while the methods are open, training and consulting around XP can be commercial)
user experience design (UX design)	

^a These are example of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

6.7 Programmatic risk of being an early adopter

6.7.1 General

Emerging technology can change the relationship and expectations between FM businesses and their customers. Adopting new technology can bring with it specific associated risks and operational challenges.

Promoting innovation in FM and differentiating one's company from the competition can be sourced from creative processes, new products and adapted techniques; whatever the origin, some organizations pursue transformation earlier and quicker than others.

Such change as an "Early Adopter" is not without specific risks. The concept was that innovators, who comprise approximately 2,5 % of the population, are those who generate new ideas, inventions and concepts. The early adopters (an estimated further 13,5 % of the population) are those who then are the ones who first experiment and trial such ideas, ahead of those wider market members who follow behind.^[16]

6.7.2 Risk management

By reviewing and accepting greater risks, whether by investing in a new product or technique, the early adopters mitigate their risks via detailed research, empirical trials and comparative tests, from which results are collated and reports produced. Stakeholders and executives then make informed decisions.

How such risks are managed reflects the appetite, confidence and courage of these individuals and associated teams. Analysis in business schools of early adopter case studies identifies common character traits of logic, intuition, rational thought, blended with focused, agile developments, through a matrix of milestone assessments and progress reviews.

6.7.3 Progress pace and judgement errors

Limited by restrictive criteria such as time, resources and budget, projects that gather the data and information needed and complete the discovery phase quicker, tend to do so with planned, progressive steps. There is no tolerance for unjustified assumptions or guesswork: the focus is in "scrum" techniques, on achieving bursts of progress via collaborative, dynamic work groups.

Parallel assessments can develop different results which will then challenge the organization's decision-making process. Depending on the profile of the product and the need to upgrade versions and models, some software and hardware technology-based companies will even risk their brand reputation to either speed up or slow down a rollout or upgrade; this is recorded as being driven by the psychological profiles of their early adopters, whose product and process selections are expressions of their individual personality.

Businesses dependent on effective FM that are early adopters of FMTech can be considered to be within that same risk-defined scope: confident sufficiently to experiment with new technology and rollout new software. By these steps, they are the ones that grow and develop faster than others, often migrating into new market sectors as they go.

6.7.4 Risk mitigation

The risks of early adoption of specific technology are sometimes mitigated by a different, coincidental campaign or transition, driven by other sectors with differing levels of momentum. Examples of this are the telecoms industry and the development of the smartphone, and the DEC industry and BIM. For the latter, the ISO 19650 series manages information over the whole life cycle of a built asset using BIM. The ISO 19650 series contains all the same principles and high-level requirements as UK BIM framework and is closely aligned with the UK's 1192 standards. Yet, for companies, the stakes for adopting new technology early are higher financially speaking, as they tend to lose more and the rewards are sometimes not as high as one would expect.

Early adopter companies are also the first that have to frequently deal with programming bugs and systems glitches that will be fixed in later editions, address compatibility issues and defective units, as well as rise up to the ultimate marketing challenge of guiding their clients via new activities. In summary, the early adoption of technology carries with it a higher modicum of risk, yet the potential rewards and benefits are proportionately greater.

6.8 FM technology maturity

6.8.1 Gap analysis

Understanding capabilities, opportunities and challenges based on the FM technology maturity of the demand organization is crucial. [Figure 4](#) is a matrix that demonstrates five different levels of technical maturity, measured against an FM team's ability to extract value from FMTech. An alternative measurement is done via a digital maturity model (DMM) – using pre-determined organizational ratings, applied by objective analysis, with status ratings of reactive, organized, digitized, connected or intelligent.

Hence, alongside the implementation of FM technology, the actual FM operational team and all associated support service functions will also each have to go through their own digitalization induction and maturity development process. To integrate with new technology, team members will need tool kits for the transformation journey to implement fully cognitive functions for services, buildings, assets, and the expected, achievable results. The progressive dynamic nature of technology means all such FM technology strategy plans need to adapt and mature alongside the FM operation, unifying and integrating across other functional aspects of the organization. Examples of the FM strategy plan components are:

- leadership,
- operation,
- improvement,
- warranty and DLP information,
- planning,
- performance,
- governance,
- space planning,
- support,
- evaluation,
- budget,
- occupancy use data and analysis.

6.8.2 Assessment of business needs

For developing a successful business case, the technology operating platform satisfies both the end user and service provider requirements. This often includes an extensive list of criteria to meet delivery requirements. The facets of an operating platform necessary to deliver outcomes to the end user are broadly outlined below:

- access to a portal with live data,
- asset sizing information (number, type, users),
- asset register details,
- budget management status,
- common data environment,
- continuity of systems to minimize manual intervention points, e.g. field mobility and functionality,
- customer satisfaction, plus complaint rates,

- defect liability periods, asset warranty TS and CS,
- document management solutions,
- environmental works, carbon neutralization, adaptation to green deal,
- flexible workflow management,
- HR management,
- innovations register,
- life cycle forecasting and scenario modelling,
- meeting room booking system
- occupancy rates,
- reactive, planned and capex management,
- safety recording and reporting,
- service history,
- specialist contractor information,
- training register of employees (including induction and onboarding compliance),
- asset condition data,
- asset shutdown, outage and disposal,
- backlog maintenance (PPM tasks not done),
- call waiting time reported,
- consumables, stock and itinerary management,
- CRM system and operations,
- cyber security for FM-related data and systems,
- defects reporting,
- energy management,
- fleet management,
- FM training,
- HSEQ and customer incident reporting rates,
- internal functionality or interface with business intelligence reporting solutions,
- meeting and work order scheduling,
- number of customer calls per priority,
- procurement and contract management,
- risk and compliance register,
- service levels and key performance indicators (KPIs),
- space planning and utilization,

- sustainability reporting,
- quality management.

6.8.3 Demand functionality

The demand organization aims includes a combination of multiple activities, vertical topics and business organization functionality.

6.8.4 Maturity levels

Assessments determine the latent technology maturity status, to provide a baseline for planning and progress purposes. The key categories are level 0 through level 4, as shown in [Figure 4](#).

Technology Maturity in FM

	Level 0 Acknowledged	Level 1 Ad Hoc	Level 2 Initial Integration	Level 3 Optimized Integration	Level 4 Transformational
Maturity					
Description	Technology is known within the industry, but not yet used in any operational setting.	The technology is being tested in small applications or trials. Benefits are being explored but not yet realized on a operational level.	Technology is being applied in operational setting, benefits are passed on in a limited fashion while benefits vs cost of implementation reach an equilibrium.	Technology is now fully operational. Benefits and usage are well known to both the FM and the Facility Users. At this stage it might be difficult to operate without this technology.	The technology goes above and beyond initial expectations. It has revolutionised workflows, interfaces, data and procedures for all building stakeholders. Truly revolutionary.
Strategic	Strategic R&D initiatives of industry leaders and early adopters might explore opportunities. Strategic leaders will theorize about potential benefits to their organization.	Strategic leaders will start to trial solutions within the organization to see what the benefits and impact could be.	Strategic initiatives are now pulled through to tactical management and implementation. Initiatives will start to see returns and start to transform business flows.	Strategic leaders are dependent on the technology for fluent operation. Moving away from the technology is no longer feasible and leaders might even hesitate to further innovate.	The technology has advanced to the extent where it transforms ways of working and industries. Strategic leaders must embrace the technology in order not to fall behind.
Tactical		Some tactical leaders might get involved with trial initiatives - testing the benefits of the technology.	Tactical leaders will report back to senior management on operational benefits achieved. After initial investment, financial benefits become substantial and sustainable.	Tactical leaders will become responsible for using the technology in their day-to-day operations. It can be difficult to imagine their workflows without these technologies at this point of maturity.	The technology impacts and benefits the business workflows significantly such that roles of tactical management could be significantly altered by it
	-	Ability of FM team to extract value from Tech			+

Figure 4 — Matrix of FM technical maturity versus facility management team abilities

Note the need to consider developing a per-facility input for practical (i.e. below tactical) issues likely to be experienced at level 0 or level 1 in [Figure 4](#). This is where most industry stakeholders limit the design and development teams to sufficiently validate and develop successful proposals using their experience to provide feedback.

Every demand organization is different and can choose to adapt and expand this matrix, to reflect their specific, respective project criteria, asset age and condition, budget available, and of course the critical human interaction factors of participants in terms of technology capability, organizational leadership and workflow KPIs. The organization and operation will also mature in different ways at different times so the maturity rating can and will change as well as be different in the way it aligns to the different parts of the operating model to monitor each respective area as well as the connections and exchanges between these areas to bring a holistic understanding and support a value-based roadmap in line with the operational need.

A series of short, regular, FMTech workshops can provide insight, education and awareness for an organization's key project members, which in turn will allow for better-informed executive decisions and a more productive transformation project.

The FM organization perspective includes specialist functionality as outlined below:

- single point of entry to input and access data, via secure app portal with biometric-reader and blockchain data storage,
- local and team KPI measurement and reporting,
- dynamic labour scheduling,
- inventory management,
- ability to input work data on job activity that meets all of customer requirements,
- customer feedback,
- labour productivity and utilization data,
- financial management.

6.8.5 Additional considerations

Technology solutions generally comprise of an app at the front end with supporting functionality to meet business needs. Integration with an ERP system supports:

- the management of invoicing;
- tracking of purchase orders, procurement and supply chain issues;
- entries for time and attendance, time on task; consumables and expenses; and
- other finance-related details and other financial details.

The business needs analysis considers how both the demand and FM organizations leverage benefits that are mutually exclusive and integrate, where feasible, in a seamless way.

6.9 Harnessing of opportunities available through technology

6.9.1 Point of intersection with facility management practice

[Figure 5](#) outlines the flow from a customer-buying process, through the FM interface requirement, through to supplier delivery. Sample role titles shown are addressed in more detail in ISO 41001.

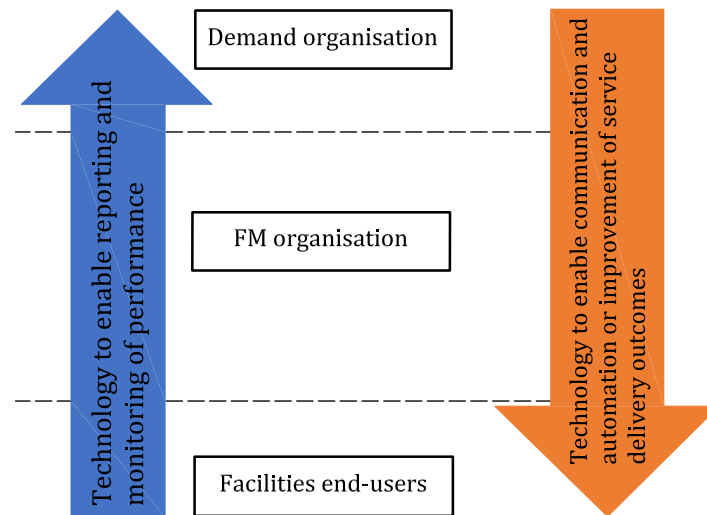


Figure 5 — Technology purpose in organization information flow

6.9.2 Intersection by stakeholders — Supporting change

[Figure 6](#) illustrates the connection between “demand organization” and “FM organization”.

The demand organization is driven by upper management, often via procurement professionals. They will also typically engage a facilities client / supplier interface. This person's responsibility is to align the demand organization's goals with the FM organization's key performance metrics.

Each of the key roles relating to the respective FM organization is identified, through a summary of activities, initiatives and responsibilities, considered via a technology-based solution, as shown in [Figure 6](#) and [Table 10](#).