What is the Internet of Facility Management things?

White Paper

IoFMT



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Executive Summary

What does Facility Management look like for 2023 and beyond? How are global events and socioeconomic pressures driving a change in what we demand from building services and services delivered as we journey into what could be considered a new industrial revolution?

Worldwide Investment behaviours have been changing. There is a call to action on governments and organisations to consider Environmental, Social and Corporate Governance (ESG) factors, 'in every deal' - paving the way for Real Estate and Facility Management to become more considerate towards its contribution to 40% of global greenhouse gases.

Reducing or off setting use of these gases by 2050 from building services and services delivered to support a global goal of 'Net Zero' has meant a change for both the Hard and Soft Services within Facility Management (FM). FM has experienced a transformation in recent years with Covid-19 and remote working making occupancy levels unpredictable and creating a more digital environment which, fuelled by energy prices surging has produced a cooking pot of necessity for change which is propelling innovation and creating a shaken snow globe of solutions.

The Internet of Things (IoT) and its subcategory the Industrial Internet of Things (IIoT) have integrated their way into FM. These Interoperable internet accessible technologies and sensors are generating Big Data and providing insights like never before. This is changing the way FM – Hard Services, Soft Services and their Management can be delivered by transitioning into an interoperable, data driven landscape that is providing clear and hidden benefits for organisations that can adapt to the change. IoT, IIoT and FM bring about IoFMT, the Internet of Facility Management Things.

IoFMT is a hybrid of IoT and IIoT (similar to the Internet of Medical Things IoMT) which sits across both Hard and Soft Services and can support Facility Managers with access to Big Data Analytics, Building Controls and Automation, Machine Learning, Virtual and Augmented Reality, Digital Twins and the Metaverse. Shifting a change in industry that will revolutionise the way we use our indoor spaces and the management of them.

Professional institutions such as the Royal Institute of Chartered Surveyors (RICS) and the Institute of Workplace and Facility Management (IWFM) recognise that there are gaps in our understanding of how to integrate these technologies into our building services and to what extent do we need to digitally upskill the workforce to prepare for the IoFMT integration into 'the way we do things'

The UK Government is mandating change by introducing new legislation, regulations and guidance relating to Energy and Facility Management that can offer incentivisation (and penalisation) and provide a strategic roadmap for Facility Management for those who don't want to be behind the curve

FM organisations that wish to retain a competitive advantage and follow the principle of 'knowing what they have will always turn a profit' will need to acknowledge the importance of the quality, quantity and range of their data. IoFMT is the digital response of the FM sector to support drivers for change in Real Estate. These changes include Occupancy and Wellbeing and Global and Government mandates to achieve Net Zero by 2050 and more recently, a surge in energy prices. ESG is providing a set of reporting factors and, whilst ESG reporting requires standardisation from the United Nations it will be data driven and for FM, powered by IoFMT.

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Introduction

This white paper has been produced to collate the findings of research so the drivers for change in Facility Management (and Real Estate) can be understood, along with the response of the FM sector by introducing IoT (and IIoT) which is changing the way in which Hard and Soft services (and the management of) can be delivered. IoT sits within the Fourth Industrial Revolution, but competency and the range of building accreditations also need to be considered along with the assets – it all starts with the assets.

1 What is Facility Management?

What are hard services, soft services, what is Facility Management and how is the sector growing?

2 Who Cares Wins

What is driving change in Facility Management? ESG, Net Zero and Carbon Neutral, Scope 1,2 the organisational boundary, Scope 3, and the Circular Economy

3 The Fourth Industrial Revolution

IoT and IIoT, Cyber Security, Wireless Technologies for IoT, Statutory Compliance and IoT, Maintenance Methods and IoT, RoI and IoT, Big Data Analytics, Augmented Reality, Digital Twins, The Metaverse, 'AI' and Machine Learning, User Experience, Gamification

- 4 Competency
- 5 Government Support and Penalties
- 6 Building Accreditations
- 7 Asset Collection and Verification

The below flowchart shows the layout and flow of this paper



1 What is Facility Management?

The Institute of Workplace and Facilities Management has adopted the ISO Standard, to which, ISO 41011: 2017 defines Facilities Management as:

"An Organisational function which integrates people, places and processes within the built environment with the purpose of improving the quality of life of people and the productivity of the core business" [90]

In contrast and without undertaking an in-depth literature review of defining facilities management, Geoff Gidley summed Facilities Management up in three words:

'Multi-skilled jiggling' [120].

In recent years, the Facility Management sector has seen progressive change within the built environment. [9] In 2018, the ISO Standard 41001: Facility Management – Management Systems was published and around 2018 the Institute of Workplace and Facility Management (IWFM) produced structured qualifications that are recognised as part of the UK National Qualifications Framework. [129]

The development of underpinning qualifications and international recognition now put Facility Management on par with their sector colleagues: Asset Management and Property or Real Estate Management.

Facility Management comprises of Hard Services, Soft Services encompassed in the underpinning management of the Facility or Facilities.

What are Hard and Soft Services?

Facilities Management services can be generally categorised as Hard and/or Soft Services, and management

Hard Services	Soft Services					
 Physical Assets that are attached to the building Cannot easily be removed Mechanical, Electrical, Plumbing, Building Fabric 	 Tasks performed by people to carry out particular services These services relate to the building environment and user experience 					
 Includes: Statutory compliance Mechanical and Electrical Maintenance Fabric Maintenance Portable Appliance Testing Forward Maintenance Register (FMR) Furniture, Fixtures and Equipment 	Includes: - Cleaning - Window Cleaning - Pest Control - Landscaping/Horticultural - Gritting/Snow Clearance - Waste Management - Mail Room - Internal Planting - Catering & Vending - Security - Reception - Audio Visual Services / Equipment					
Management						
Responsible for, but not limited to, the delivery of services and resources for the safe and continued running of the facility						
need of the organisation, service users and service providers						

[144]

Growth and Investment in Facility Management

Digital technology continues to transform Facility Management. It has been and continues creating oppurtunities for new and emerging technologies to be deployed as larger scale, cost effective solutions.

"Facilities management is poised for growth over the next 24 months and beyond. As technological transformation spreads to every corner of the industry, the proliferation of devices and platforms threatens to turn the built world into digital spaghetti" [107].

Growth is linked to the global economy and workforce to which organisations and investors are becoming more interested in Environment, Social and Corporate Governence (ESG) to determine investment strategies. The understanding of ESG for clients, occupiers and and individual and organisations are intrexicably linked to this growth.

Limitations of growth have been projected over the next 5 years by the Building Cost Information Service (BCIS) in their June 2022 report:

- 1. Maintenance costs rising by 14.5%
- 2. Cleaning costs rising by 28.8%
- 3. Energy costs rising by 4.2%



Areas of FM expected to see the strongest growth over the next 12 months

FM projections for growth are aligning with ESG factors driven by the UN and local governments such as the UK [102]

Areas of sustainability that have seen the strongest growth in investment over the past 12 months

The focus of investment has been energy management, with the prices increasing demand for reducing energy is paving the way for change in Facilities Management [102]

[14]

50

40

30

20

10

0

Health and safety

Waste management

and recycling

Energy

management

Water management

Health and well-

being

2 Drivers for Change: Who Cares Wins

It is widely accepted that corporations have a responsibility towards society, this is not a new concept, and it is one that can be traced back for centuries. The transition to more recent ways of decisions for investing has been evident since the 1960s when investors began to utilise more ethical strategies to support the basis of their investment. Tobacco products, Climate 'Change' and/or involvement in political regimes began to creep into decision making for investors and their portfolios. [17], [64].

The United Nations Global Compact (2000)

The United Nations Global Compact launched (2000) was initiated to 'bring business and the United Nations together to give a human face to the global market'. One of their first publications brought forward a set of recommendations for the financial industry to better integrate environmental, social and governance issues in analysis, asset management and securities brokerage.

Entitled 'Who Cares Wins', the report involving 18 financial institutions from 9 countries with leveraged managed assets of over 6 trillion USD (2004) who brought forward ESG as a way of remaining competitive in a more globalised, interconnected world through the quality management of analysis, asset management and securities brokerage, concluding that by adopting the recommendations set out in the report, financial institutions could increase their shareholder value whilst meeting the intentions and principles of the Global Compact. [148]

The United Nations Global Compact, Principles for Responsible Investment, PRI (2006)

Soon after the publishing of the report, the United Nations launched the PRI, or Principles for Responsible Investment (2006) which acts in the long-term interests of the signatories, the financial markets and economies in which they operate and ultimately, of the environment and society as a whole. Since its launch the number of signatories has increased from 63 (2006) to 3826 (2021) and the assets under management have soared from 6.5 to 121.3 trillion USD. [149]

The significant increase in signatories to the Principles for Responsible Investment (PRI) since 2006 shows that ESG concerns are not negatively impacting returns, but rather the opposite. A systematic study of over 2,000 separate studies on the impact of ESG propositions on equity returns shows 63% positive findings compared to 8% negative [54] and further to this, real estate displays (71.4%) a noticeably higher share of those positive findings over equities (52.2%) and even bonds (63.9%) [38]. 'Who Cares Wins' is therefore a suitably coined term which has delivered positive results for investors, with the real estate sector reaping the most positive outcomes.

International Financial and Reporting Standards (2021)

Following 26th UN Climate Change Conference of the Parties (COP26) in 2021 the International Financial Reporting Standards (IFRS) further cemented ESG in organisations with the creation of the International Sustainability Standards Board (ISSB) which has the intention of delivering a global baseline of sustainability-related disclosure standards for investors [58], supported by 73% of companies who want to use a recognised framework when preparing their ESG reporting [27]

Environmental, Social, (Corporate) Governance (ESG)

Whilst the framework is in development, the core principles of the United Nations Global Compact, Principles for Responsible Investment (PRI) can be explored. The PRI considers these factors as those that 'need to be considered for every deal' [146] and should therefore be understood, interpreted, and integrated into a plan, do, check, act cycle which can provide continuously improved information for investment.

Environmental	Social	Governance		
Biodiversity and Habitat	Community Development	Anti-bribery and money laundering		
Climate Change	Controversial tenants	Cybersecurity		
Land Contamination	Health and well-being of occupants, contractors and the local community	Board diversity		
Energy Consumption	Human rights	Independence of board members		
Greenhouse Gas Emissions	Accessibility	Remuneration policy (including ESG-linked incentives)		
Indoor Environmental Quality	Inclusion and diversity	Data protection and privacy		
Location and Associated Infrastructure	Labour standards and working conditions	Legal and regulatory fines		
Materials	Social enterprise and partnering	ESG clauses in contracts		
Pollution Prevention	Stakeholder relations	Asset data collection framework an /or management systems		
Resilience to Catastrophe/Disaster	Occupier amenities – showers, changing rooms	Procurement standards and requirements		
Renewable Energy		Tenant engagement frameworks		
Sustainable				
Procurement				
Waste Management				
Water Consumption				
		[146]		

Information for Investment

The PRI further suggests that the information required to assess each issue and ultimately determine the level of investment and associated risk can originate from Raw data utility bills, building management systems, building logbooks, existing environmental management systems, engagement with tenants, Third Party Reports energy audit reports, certification reports, surveyors' reports, reports from other specialists and technical consultants; Independent databases and vendors geospatial databases, scenario analysis, flood records, green rating schemes. [146].

Some of the more specific factors within real estate that can lead to discounted valuations and should be considered not just when making a decision, but throughout the entire investment process, some of these factors include:

- 1. Additional Capital Expenditure Equipment upgrades to improve energy performance
- 2. Increased Costs Higher insurance premiums due to physical risk factors
- 3. Future income Uncertainty Tenant and leasing disruption due to extreme weather events
- 4. **Obsolescence Risk** Buildings that do not meet minimum energy performance standards set by legislation

Scope 1,2 and 3 Emissions

In the late 1990s the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) recognised that an international standard was required for Greenhouse Gas accounting reporting and created the Greenhouse Gas (GHG) Protocol in 1998. [41]. They formed a coalition of collaboration with 170 international companies and non-governmental organisations to develop a method of quantifying GHG emissions.

The "GHG Protocol Corporate Accounting and Reporting Standard" categorised the emissions as direct and indirect activities undertaken by organisations and classified them into three categories – Scope 1, Scope 2, and Scope 3. [43] Together the three scopes provide a comprehensive accounting framework for managing and reducing both the direct and indirect Greenhouse Gas Emissions a company creates in its own operations and the wider value chain [32], both upstream and downstream. [42].

Scope 1

Direct emissions that occur from sources that are owned or controlled by an organisation. There are some notable exclusions, such as the direct CO2 emissions from the combustion of biomass and GHG emissions which are not covered by the Kyoto Protocol, this includes emissions such as CFCs and NOx. [43]. Scope 1 covers emissions such as the burning of fuel like gas or the fuel from vehicles.

Scope 2

Indirect emissions that occur from sources which are purchased by the organisation. Electricity consumed by an organisation which is generated outside the organisational boundary is the most prominent example [43], this could also extend to electric vehicles which would be considered under scope 2 if they are charged outside the organisational boundary. [33]

The Organisational Boundary

An organisations GHG report must be relevant, it must contain the information that internal and external users to the company need for their decision making. This means that the legal boundary of an organisation (such as the organisations structure), may not be the only consideration for GHG reporting.

The choice of this inventory boundary of reporting could therefore be influenced by the characteristics of the company, the intended purpose of information, and the needs of the users.

There are therefore several factors to consider when choosing the inventory boundary for reporting including Organisational Structures (operational and financial control), ownership, legal agreements, joint ventures), Operational Boundaries (on-site and off-site activities and processes, services and impacts) and Business Context (nature of activities, geographic locations, industry sector(s), purposes of information and users of information. [43].

A range of these organisational structure may also be used by businesses, government agencies and non-profit organisations to define the degree of ownership of control they have over different activities. The GHG emission inventories can be constructed to reflect three different views of an organisational boundary:

Operational Control – The operational authority and extent of the control of the organisation to carry out Health, Safety and Environmental policies. The extend of this may be limited by the organisations structure, a joint venture for example would require joint approval from the partner

Financial Control – The financial authority to direct the financial policies of an activity and gain an economic reward, the organisation has the financial control to make financial decisions

Equity Share - Within the Equity Share, the organisation would account for GHG emissions according to the share of equity in each activity

[42]

Scope 3

Scope 3 emissions are indirect emissions which are not covered by Scope 1 and 2. [43]. They are emissions which occur as a consequence of the activities of the organisation which are not controlled by the organisation [80] and originate from up and down the value chain [81]

The GHG Protocol produced a Scope 3 Accounting and Reporting Standard for the Corporate Value Chain [42] and quantitatively, the significant of measuring what is said to be more than 70 percent of an organisations carbon footprint [34] can produce data to inform decisions that:

- Assess where the emission hotspots are in their supply chain
- Identify resource and energy risks in their supply chain
- Identify which suppliers are leaders and which are laggards in terms of their sustainability performance
- Identify energy efficiency and cost reduction opportunities in their supply chain
- Engage suppliers and assist them to implement sustainability initiatives
- Improve the energy efficiency of their products
- Positively engage with employees to reduce emissions from business travel and employee commuting.



[124]

Scope 1, Scope 2, Scope 3 [42]

Scope 3 in Real Estate

In Real Estate the lessee and lessor's perspective, the type of leasing arrangement and the organisational boundary approached can determine who is responsible for the Scope 1, Scope 2 and Scope 3 emissions. The tables below provide an example from the GHG Protocol of a lessee and lessor arrangement with different organisational boundaries based on operational, financial and equity control, these should be defined to determine the type and content of the data management plan(s).

A-1 Type of leasing arrangement						
	Financial/capital lease	Operating lease				
Equity share(s) or financial control approach used	Lessee has ownership and financial control, therefore emissions associate	Lessee does not have ownership or financial control, therefore emissions associated with fuel combustion and use of purchased electricity are scope 3 (Upstream leased assets)				
Operational control approach used	Lessee has operational control, therefore emissions associated with fuel combustion are scope 1 and use of the purchased electricity are scope 2	Lessee does have operational control, therefore emissions associated with fuel combustion at sources in the leased space are scope 1 and use of purchased electricity are scope 2				
		[42]				

A-2	Type of leasing arrangement	
	Financial/capital lease	Operating lease
Equity share or financial control approach used	Lessor does not have ownership or financial control, therefore emissions associated with fuel combustion and use of purchased electricity are scope 3 (downstream leased assets)	Lessor has ownership and financial control, therefore emissions associated with fuel combustion are scope 1 and use of purchased electricity are scope 2
Operational control approach used	Lessor does not have operational control, therefore emissions associated with fuel combustion and use of purchased electricity are scope (Downstream leased assets)	Lessor does not have operational control, therefore emissions associated with fuel combustion and use of purchased electricity are scope 3 (Downstream leased assets)
		[42]

GHG Emissions - Data and Quality Assurance and Control Management Plans

GHG accounting and reporting of a Scope 3 inventory should be based on a set of principles to include: Relevance, Completeness, Consistency, Transparency and Accuracy. This can be combined into a data and quality assurance checklist:

- 1. Responsibilities
- 2. Boundary and Inventory Description
- 3. Data Summary
- 4. Emissions Calculations
- 5. Data Storage Procedures
- 6. Data Collection, Input and Handling Activities
- 7. Uncertainty Estimates
- 8. Data Documentation
- 9. Calculating Emissions
- 10. Checking Calculations

[42]

Reporting Boundaries

Reporting boundaries can be defined to include GHG sources which are relevant to an organisations operational and sustainability goals, but these must be in accordance with the principles of GHG accounting. The reporting boundary may match the organisational boundary, or it may be a subset of the organisational boundary.

Reporting boundaries must be publicly defined, and the relevant inventories defined using parameters such as:

- Geography which includes the reporting of reasonably locations such as countries, counties or regions, business units and/or facilities. Any facilities that are excluded should be recorded as exclusions in the reporting boundary.
- The reporting period which is annually
- GHGs including CO2, Methane, Nitrous Oxide, Hydrofluorocarbons (HFCs),
 Perfluorocarbons (PFCs) Sulphur Hexafluoride (SF6) and Nitrogen Trifluoride (NF3). Any gases excluded should be recorded within the self-defined boundary form.
- GHG Sources include Scope 1,2 and 3 emissions and additional GHGs (such as Biogenic emissions and non-Kyoto GHG emissions) are reported separately or out of scope.
 Reporting Period and Geography/Business Units

[125]

Carbon Neutral, Net Zero and the Circular Economy

Carbon Neutral

If a person or organisation can absorb of the same amount of carbon that they emit, then this is considered Carbon Neutral. Carbon Dioxide emissions account for 76% [82] to 82% of global warming [145].

This is supported by guidance from within the industry such as the Carbon Neutral Protocol who offer certification through a 'rigorous and transparent' framework for businesses to deliver carbon neutrality programmes for their business, products and/or activities. [16]

The five steps which the Carbon Neutral Protocol outlines are:

这 这 次 次	Define	Understand exactly what should be covered in your footprint
+ - × ÷	Measure	Calculate it accurately and conservatively
Ċ	Target	Set goals to reduce the footprint you defined and offset all remaining emissions
\searrow	Reduce	Deliver internal reductions and offset all remaining emissions through financing verified emissions reductions and removals
	Communicate	Demonstrate your climate action and engage your teams, customers, and stakeholders
		[15]

Net Zero

"Cutting out Greenhouse Gas Emissions as close to Net Zero as possible, without any remaining emissions reabsorbed from the atmosphere, by oceans and forests for instance" [150]. The Paris Agreement (2015) puts a commitment on all member countries of the United Nations to reduce emissions by 45% by 2030 on a path to Net Zero in 2050. [151].

In simple terms, Net Zero means that we are not adding new emissions into the atmosphere. Industries will produce Carbon and other Greenhouse Gases, but this will be balanced or offset by other activities (such as planting trees), therefore creating a balance where the emissions caused by human civilisation are equal to or less than the emissions produced, they are 'Net Zero' [147]

Within Facilities Management, UK Government guidance requires each organisation to have a net zero strategy and action plan in place for their Facilities Management activities, with a requirement for regular management information that feeds into the wider organisational net zero reporting. [139]

Net Zero was first considered in 2009 when a paper was published highlighting that Carbon Dioxide is the main driving factor of the rise in global temperatures, by 2012 an alternative framework was suggested for representing cumulative carbon emissions. This was enshrined by the International Panel on Climate Change in 2012 with the fifth assessment report which highlighted that limiting global temperatures change meant limiting the amount of CO2 emissions in the atmosphere. In 2014 the first use of the term 'Net Zero' was used to refer to the requirement of a global climate agreement that should provide a clear pathway to net zero emissions before the year 2100. In 2015 the Paris Agreement was signed in which countries of the United Nations formally committed to reducing their contribution of greenhouse gases to the planet. [63]

Carbon Neutral

An organisation that can absorb the same amount of Carbon Dioxide that they emit

- Carbon Dioxide emissions account for 76%-82% of global warming
- Some organisations cannot be Carbon Neutral to function
- They will produce more Carbon Dioxide than they can absorb





Net Zero

An organisation that does not add new emissions into the atmosphere

- The organisation balances or offsets their emissions with other activities, such as planting trees
- This means that the total emissions the organisation produces Nets Zero new emissions into the atmosphere

The Circular Economy

The idea behind the circular economy is not producing waste in the first place. It is based on three principles and supported by the British Standards Institute [11], these principles include:

- Eliminate Waste and Pollution
- Circulate Products and Materials (at their highest value)
- Regenerate Nature

[37]

The circular economies importance in Facilities Management is centred around designing out waste and pollution, keeping resources in use for as long as possible and regenerating our natural systems. This means use less, share more and source what we do use, sustainably. [59]

The industry is changing, ESG provides a set of reporting factors and the idea of a more sustainable, circular economy is growing in popularity as the global drive for Net Zero continues. This transition is being supported by a new Industrial Revolution.



**							
	First	Se	cond		Third		Fourth
	1784	1	870		1969		2022+
	Steam Water Mechanical production equipment	 Division Electricit Mass pro 	of labour ty oduction	-	Electronics IT Automated Production	- - - -	The Internet The Internet of Things Augmented Reality Virtual Reality The Metaverse Artificial Intelligence
		•					[28]

3 The Fourth Industrial Revolution

The Fourth Industrial Revolution

Innovative technologies are developing fast and moving quickly into most sectors, including the built environment. [152]

These technologies can be described as 'Disruptive Innovations' by taking root in simple applications at the bottom of the market at a low cost with high accessibility, they can filter their way upmarket and eventually displace established competitors who failed to realise their potential [18].

In 2016 we were 'on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another'. This transformation has been argued to have the scale, scope and complexity of unlike anything humankind has experienced before. [152]. The World Economic Forum was referring to Industry 4.0, or the fourth industrial revolution, which is now upon us.

The above statement was 6 years ago, since then we can see disruptive developments unfolding in our own daily activities, industries, and careers. The fourth industrial revolution involves the amalgamation of physical assets with new and emerging digital technologies [31]. Some of the categories and considerations under The Fourth Industrial Revolution include:

- The Change in Return on Investment
- The Internet of Things
- The Industrial Internet of Things
- Big Data Analytics

- Cyber Security
- Augmented Reality
- Digital Twins
- The Metaverse
- Artificial Intelligence

The Internet of Things

Embedded systems, wireless sensor networks, controls systems, home and building automation have enabled the Internet of Things (IoT). Interconnected computing devices and sensors embedded in everyday objects which enable them to send and receive data using the internet. [85]

There are numerous practical applications of these technologies in buildings which cover energy management, environmental monitoring, and asset optimisation, plus many more. The idea of interconnected devices linking digital and mechanical machines to combine and automate everyday tasks is nothing new...

- 1989 The World Wide Web was invented in 1989 by Tim Berners-Lee.
- John Romkey created the world's first IoT device a toaster that could be turned on and off over the internet.
- The University of Cambridge installed the Trojan Room Coffee Pot, which monitored the amount of coffee in the brewing machine
- Mark Weiser created a water fountain to which the flow and height mimicked the price trends and volume of the stock market in real-time
- The Internet of Thing is first coined; Kevin Ashton titled a presentation he made to Proctor and Gamble "The Internet of Things"
- The Navbaztag, an earlier version of Alexa and Google Home was shaped like a rabbit and could speak to its owner about the weather, stock market and news feeds of interest
- IoT is born, according to Cisco, IoT was conceived between 2008 and 2009 when the number of connected machines surpassed the number of humans on the planet. In 2021 there were about 21.5 billion connected devices around the world
- IoT devices begin using sensors thermostats and home lighting started using sensors so people could control home lighting, garage doors and thermostats from their phones
- The first "Smart City" is created, dubbed a testbed Smart docklands in Dublin provided a platform for innovators to test cutting-edge technology solutions to local challenges, such as smart bins and sensors monitoring flood levels
- 2018 IoT enters the healthcare and insurance industries Healthcare devices represent one of the fastest growing sectors of the IoT market. Sometimes called the Internet of Medical things (IoMT), it is predicted to reach a value of \$176 billion by 2026. Medical solutions include blood glucose, heart rate monitoring, pacemakers, fall detection and location monitoring
- 2020 IoT steps up in response to COVID-19 Thermal cameras and proximity sensors directly supported organisations abilities to manage the spread of COVID-19. The drive for innovating new ways of working has opened up a new chapter in the Internet of Things as its exposure to the built environment through necessity in combination with reduction in energy and operating costs have support a reduction in the cost of manufacturing and supplying IoT solutions. The demand is high [126]
- IoFMT is introduced as IoT becomes more commonly adopted across the FM sector responding to drivers for change for real estate

IoT Solution Providers

Identifying business objectives and the up-front costs can be a starting point to narrow a search down to a specific solution provider which can support the delivery of the organisation's goals. Strategic questions should be considered continuously to ensure the IoT provider is suitable and sufficient. Choosing the right IoT team is a vital part of the process.

Some of the topics for consideration when selecting an IoT Solution Provider may include:

Expertise and Competency

- Do they have a history of offering connected solutions?
- Do they offer multiple capabilities essential to an IoT solution such as device connectivity, services platform, and analytics?
- Is the IoT Solution Provider competent to understand the industry with its legal requirements and guidance of best practice

Integration

- Do they work within your existing infrastructure?
- Do you have to replace all your devices?
- Can they adapt to a changing market different wireless technologies and obsolescence

Scale

- Can you start small and grow as needed?
- Do they require a long-term commitment up front?
- Does their platform enable you to incorporate new capabilities as your business needs change?

[75]

IoT Platforms

Companies are realising that building end-to-end IoT systems from scratch is a tedious task and a big risk with many businesses case still shaky and not clearly validated.

The market has responded to this demand by producing lots and lots of companies that over out of the box IoT systems that can be adapted to different verticals in the market.

These solutions are known as IoT Platforms. [57]. In 2016, The Gartner-Hype Cycle was produced which is one way of showing IoT Platforms place and journey to adoption within the Fourth Industrial Revolution.

IoT Platforms facilitate communication, data flow, data management and the functionality of applications. By creating a framework, the platform can allow multiple applications to connect to machines, devices, applications, and people to data and control centres. The diagram below shows how IoT Platforms can cover the data value chain. An IoT Platform can be developed into an IoT Platform Strategy, providing the underpinning framework to allow for an organisation to adopt IoFMT technologies in a strategic way that allows them to continuously review the benefits from the original business case(s)



Wireless Technologies for IoT

"There is not one single wireless technology that meets the needs of each and every IoT application"

[153]

The Radio Frequency Spectrum

The radio frequency spectrum refers to the electromagnetic spectrum which is usable for radio wave transmissions. It is made up of radio frequencies, from extremely low (3 Hz) to extremely high (300 GHz). All our wireless devices – Television, Radio, Mobile Phones need to be able to use sections or channels of this spectrum to function. Not all countries use the same channels, they are not internationally harmonised. [122] For the UK, the full frequency allocation table is available from Ofcom [84]



[122]

The IoT Radio Frequency Spectrum

The Internet of Things starts with the availability of connectivity to the internet. There is no one size fits all solution as the building fabric, limitations of access and principles on which the technology works can yield different results. Each solution has its own benefits and disbenefits - exploration of these technologies should be considered as part of a comprehensive IoT Platform Strategy.

Developments in smartphones, mobile applications and cloud or web-based systems has provided a new way of introducing IoT and/or Machine-to-Machine (M2M) technology at a lower cost to the consumer and regulatory bodies acknowledging a need to increase the availability of wireless frequencies for IoT development. [71]

Licenced and Unlicensed Radio Frequencies

Sub 1GHz frequencies have been made available for licence free operation in the industrial, scientific, and medical (ISM) bands of 433MHz and 868 MHz (Europe) and 915 MHz (US), they offer a better range than Wi-Fi but one of the consequences is the same frequency cannot be used around the world. However, they are much less susceptible to interference and can transition from a 'sleep' mode to 'wake' and communicate their data in milliseconds.

In 2015, the UK Office for Communications (Ofcom) understood the appearance of the demand for Machine-to-Machine (M2M) applications, especially in rural and hard to reach locations, so they produced a document to encourage investment and innovation in the Internet of Things (IoT) using 10.1 MHz of radio spectrum within the 55-68 MHz, 70.5-71.5 MHz and 80.0-81.5 MHz bands.

This means there is now a licensed (in the UK through Ofcom) and an unlicensed radio spectrum that can be used for IoT technologies. [85]

The IoT Radio Frequency Spectrum

Frequency Spectrum	Wireless	Description	Some Example
	Name		Dallus
General local area	Bluetooth	Connection of computers within a	2.4 GHz
network	Wi-Fi	limited geographical area, (one	5 GHz
(LAN)		building or one estate/campus)	
Dedicated local area	Wi-Fi	A LAN but dedicated for the data and	870 – 876 MHz
IoT network	Zigbee	use of IoT devices	915 – 921 MHz
Dedicated Low Power,	SigFox	A Wireless Area Network Connection	400 MHz
Wide Area Network	Weightless	of computers within an unlimited	870 – 876 MHz
(LPWAN)	LoRA	geographical area (buildings across	915 – 921 MHz
		countries)	
Mobile network	3G / 4G / 5G	A WAN that uses a base station which	800 MHz
		covers a delimited area (cell) to	900 MHz
		connect users to the base station	1800 MHz
		from one base station to another	2.1 GHz
Fixed/Mobile Remote	Bespoke/Custom	A Wireless Sensor Network can be	55-58 MHz
sensors networks		created by a licenced or unlicenced	70.5 – 71.5 MHz
(WSN)		user (depending on the frequencies	80.0 – 81.5 MHz
		required) to create specific solutions	
		using IoT sensors and devices (single	
		use case rather than a network and	
		infrastructure)	
			[85]

Ofcom present 5 categories of spectrum available for use with Internet of Things technologies:

IoT Wireless Technologies

A timeline of wireless technologies can be seen below, their development is continuous as enhancements and developments in technology allow us to utilise the electromagnetic spectrum more efficiently, we can see this with the cellular network of 1G in 1979 being launched in Tokyo, Japan compared with the 4G and 5G we see today (2022).

1979	Mobile Cellular Network (1G)
1997	WiFi
1999	Bluetooth
2003	Zigbee
2009	LoRA
2010	Sigfox
2012	Weightless
2016	NB-IoT & LTE-M/Cat.M

Modern Cellular Network (3G/4G/5G)

Cellular networks are very common and widespread, they odder reliable broadband communication but require high operational costs and power requirements. They are not usually viable for many of the IoT applications which require battery powered sensors however, they can be useful in connected vehicles and transportation where consistent power is readily available and the operating costs are justifiable. [39]

Bluetooth and BLE

Bluetooth and Bluetooth Low-Energy are categorised as Wireless Personal Area Networks (WPAN). Nokia developed a low energy version of Bluetooth in 2006 (called Wibree), this was then integrated into Bluetooth 4.0 in 2009 providing the market an LPWAN Bluetooth equivalent using Bluetooth Low Energy– WPAN BLE. A Bluetooth Mesh specification was released in 2017 which has supported the scalability of BLE devices. [5]

WiFi

Wi-Fi or Wireless Fidelity is globally common, but for IoT it is usually one of the least feasible solutions for the application of sensors in large spaces such as industrial and buildings, this is due to the power requirements and signal limitations that can occur in the different fabrics and characteristics of the environments they are to be installed. [96]

Zigbee

Whilst Zigbee has been standardised since 2003, it is designed for personal networks, such as domestic markets and whilst it is able to cater for data collection from offices and medical environments its inability to upscale and traverse longer distances (due to the wavelength used) means that LPWANs have become more favourable. [113]

Low Power Wide Area Networks (LPWANs)

The response of industry to support the development of IoT technologies over a wide area using a low amount of power by transmitting on low frequencies (when compared to WiFi),

LoRaWAN

'The LoRaWAN specification is a Low Power, Wide Area Networking open-protocol designed to wirelessly connect battery operated 'things' to the internet in regional, national or global networks to meet requirements such as bi-directional communication, end-to-end security, mobility and localization services' [67].

LoRa Alliance

The LoRa Alliance started in 2015. It was set up by a number of companies including Cisco and IBM with the aim of promoting global adoption of the LoRaWAN standard. Its members closely collaborate to share experiences and promote and drive opportunities for wide scale adoption of LoRaWAN technologies supported by consistency, quality, collaboration for improvement and underpinned by certification. [66]

Sigfox

The Sigfox systems requires the installation of antennas on towers which receive data transmissions. [109] The protocol focuses on autonomy, simplicity, cost efficiency and small messages. Licences are available and subscriptions for users and developers. As of 2022, Sigfox has 10.1 million activated devices. [110]

Weightless

Originally set up of LPWAN open wireless technology standard – Weightless-N (LPWAN), Weightless-W (TV Whitespace) and Weightless-P (Bi-directional narrowband technology). The hardware was originally released by UBiik Inc. in 2017 and has grown to 100 companies in over 40 countries. [153]

Narrowband Internet of Things (NB-IoT) and LTE-M/Cat.M

The 4G Mobile Network is also known as the Long-Term Evolution Network which offers higher bandwidth, speed and reliability than its predecessors. However, IoT devices do not require all the bandwidth and speed of something like a smartphone and the industry has been adopting Low Power Wide Area Networks to meet the demand of the industry. NB-IoT and LTE-M/Cat.M are different wireless technologies that utilise the existing Global System for Mobile Communication (GSM), making use of bandwidth and frequencies which are not used by smartphones.

LTE-M provides lower latency, higher bandwidth and throughput with the added benefit of including voice for simple use cases, a comparison between these two, relatively new technologies is shown below. [53]

	LTE Cat.M1 (LTE Cat.M)		LTE Cat. NB (NB-IoT)		
		1,4MHz CAT M1 5Mhz CAT M2		180/200KHz	
DATA RATE (peak) (UL/DL)	(t+	1Mbps/1Mbps CAT M1 7Mbps/4Mbps CAT M2	(+)	63kbps / 27kbps CAT NB1 158kbps/124kbps CAT NB2	
COVERAGE / PENETRATION	Ĭ.u	20/23dBm	1.1	20/23dBm +14dBm CAT NB2	
LATENCY	Ö	10ms to 4s	Ö	1.4s to 10s	
MOBILITY	P P	Connected mobility with some limitations (inter freq. handover)		limited, changing cells without handover	
VOICE	5	restricted voice for simple use case	1100 1010 0101	no voice, data only	
BATTERY LIFE		extended with PSM or eDRX		extended with PSM or eDRX	
ANTENNA	Ţ	single Antenna	Ť	single Antenna	
		FOTA capable	<1 kB	Incr. FOTA only	

[123]

IoT BMS Integrations

If a building(s) or estate has a Building Management System (BMS) then this should be considered first and foremost, especially if a refurbishment i.e. being undertaken when cables and wired connections can be significantly cheaper to install.

IoT Technologies have the ability to connect to the Building Management System through the following ways:

API Application Programming Interface, an interface that can be used to help a programme interact with software components or external resources i.e. other programmes
 BACNet Building Automation Controls Network. The industry standard communications protocol for building automation and control networks. Specifically used for multiple devices to communicate across building automation systems. Used by users and manufacturers alike
 Modbus A network protocol that is best used for industrial automation systems such as electronic equipment. Its simplicity allows it to be a useful tool for building automation as well

[91]

BMS Integration for an IoT application such as Indoor Air Quality, then the changes required will require human intervention. This would also extend to CAFM integration. Automating the workflow using a Building Management Integration that has been considered as part of a strategy provides the opportunity to transition to a smarter building.

IoT BMS Integration – API



IoT BMS Integration – BACNet or MODBus



The Industrial Internet of Things (IIoT)

By connecting sensors to equipment and obtaining big data for analytics feedback can be provided to organisations so they can make identify efficiency gains, accelerated productivity which can result in unplanned downtime and optimise utilisation and efficiency. [45] It is a subcategory of the Internet of Things which focuses on manufacturing process and output, the table below shows a comparison of the differences between IoT and IIoT

Differences between Ilot and IoT

Industrial-IoT	ΙοΤ
The Internet of Things in Industrial	The 'umbrella' category of the Internet of
Applications and Sectors	Things
 Large Scale Networks 	 Small Scale Networks
 Thousands of Sensors 	 Small Numbers of Sensors
 Long Life Cycles 	 Shorter Life Cycles
 High Reliability 	 Less Reliability
 Oil, Gas, Power Plants 	 Homes and Offices
	[26] [95]

IoT Sensor Measurement

There are many measurements which sensors can take, some of the most common, in principle (as the application may differ) can be seen below, this list is non-exhaustive



Ĵ

Air Quality





Occupancy



Pressure





Water

Sound

Temperature

Vibration



]:

Cyber Security

In 2016 malicious hackers hacked into 300,00 products such as routers and smart cameras, known as the 'Mirai' attach it used the collective computing power to attack major internet platforms and services which left much of the East Coast of the United States without internet.

By 2025, it is expected that there will be more than 30 billion IoT connections, almost 4 IoT devices per person on average. Approximately 127 new devices are connected to the internet every second. [10]

One of the biggest questions over adopting IoT technology is that of data and security.

The UK-GDPR

When the UK left the EU the General Data Protection Act (2018) was replaced by the UK GDPR (2021). It sets out seven key principles:

- 1. Lawfulness, fairness and transparency
- 2. Purpose limitation
- 3. Data minimisation
- 4. Accuracy
- 5. Storage Limitation
- 6. Integrity and Confidentiality (security)
- 7. Accountability

[56]

The Product Security and Telecommunication Infrastructure Bill (2021+)

The UK Government has realised that the UK GDPR is not suitable and sufficient when covering the new and emerging technologies and as a result have produced the Product Security and Telecommunications Infrastructure Bill (2021), which whilst it has not reached Royal Assent to be enshrined into law it underpins the importance of security when considering the Internet of Things. As the adoption of connected devices increases the disruption that can be caused by digital attacks such as a Distributed Denial of Service Attack (DDoS) can be detrimental on a large scale. [104] For this reason, the penalties are likely to result in heavy financial losses – up to £10m or 4% of global turnover as well as up to £20k per day [20]

Cyber Threat Landscape

The image below is an effective way of representing the security threat(s) of IoT deployment across a number of verticals. [101]



[101]

IoT Accreditations

There are several different accreditations for the Internet of Things, from systems, to components, to the wireless frequencies they operate. Some of them are listed below and any procurement strategy or IoT Platform Strategy should consider the accreditations for the IoT deployment and the organisation. The list is non-exhaustive

British Standard Institute (BSI)

- Work collaboratively with manufacturers, network providers and government agencies to develop assurance services
- State-of-the-art IoT laboratory where experts work with clients to address the risks posed by digital and connected devices.
- Offer assurance with a number of services to mitigate risk, support local regulations and build trust

IoT Security Trust Mark

- This IoT Security Certification sets out the principles and basis for third party conformity assessment
- The vendor's cybersecurity claims will be independently evaluated and confirmed they conform with internationally established baseline security requirements
- Enables confidence that the baseline requirements and security features claimed by a vendor in an IoT product have been evaluated

[102]

[14]

Statutory Building Compliance (and IoT)

The General Principles on Reliability for Structures, ISO 2394: 2015 sets out the criteria to be fulfilled to determine compliance. With the focus on delivering a compliant service being one that should ensure the safety and security of all personnel [128], this includes compliance with current legislation to ensure legally compliant operations to avoid costly remedial actions for non-compliance [140]

The highest risk compliance areas are:

- 1. Asbestos
- 2. Electrical
- 3. Fire
- 4. Gas
- 5. Water

[140]

Also known as 'The Big Five', continuous monitoring through audits should be undertaken by duty holders and those responsible for the facilities. Compliance can include:

- The Law
- Policies
- Requirements
- Rules
- Standards
- Governance
- Regulations
- Transparency

[128]

Statutory Building Compliance and IoT

An analysis of statutory building compliance and its application in IoT would be welcomed as it is not without risk - this is supported by the Institute of Fire Engineers:

"Shifting to IoT isn't without its risk, especially from a cyber security perspective. Inevitably, as twoway communication between fire safety devices and maintenance organisations increases, so does the potential risk of an attack from hackers. Furthermore, there are always going to be concerns about what happens, if for whatever reason, the technology fails and is unable to provide data." [94]
Maintenance and IoT

There are the four types of maintenance recognised in the UK Government Facilities Management Standard: Planned, Condition Based, Breakdown or Risk Based and Corrective [144, pg.22]

This should be underpinned by a reliability centred focus to all assets. Reliability Centred Maintenance outlines an approach of structure and defence against downtime to increase uptime of assets, but it must be based on cost and risk in line with the overall maintenance policy and strategy.

"Reliability Centred Maintenance has been slow to emerge in Facility Management"

[9]

Reliability-Centred Maintenance (RCM)

- Uses condition monitoring in association with the asset register
- Records of breakdowns
- Records of failures
- Records of repairs
- Forward maintenance requirements
- Age
- Condition

Preventative Maintenance

- This method of maintenance follows a structured time-based approach to the maintenance tasks associated with the assets
- The intention is a plan of actions which are aimed at avoiding breakdowns and failures
- The method aims to avoid or mitigate the consequences of failure and to minimise maintenance-induced failures and their consequential costs and is based on the criticality of failure
- This can include shutdowns of operational assets and systems, sometimes requiring planning in advance for if it is not tested, do not expect it to work
- In the UK and other countries, the Building Services Engineering Association (BESA) has produced and renewed SFG20 which is a standard for maintenance
- But it should always be noted that manufacturer's instructions and datasheets of the assets requiring maintenance are identified first

Condition-Based Maintenance

- Condition Based Monitoring provides information to determine adjustments to maintenance frequencies based on the results, this can be manual or automatic
- Performance indicators will need to be determined from the conditions monitored so that a maintenance event can be created
- Any maintenance strategy should consider the risks before transitioning from industry standards such as SFG20, this can be achieved with controlled trials and case studies
- The industry would benefit from a more collaborative approach to the case studies of new and emerging technologies such as IoT

Example of a Condition Based Maintenance Strategy

- Identification of critical assets and risk profiling proposed products
- Determine thresholds and performance indicators
- System integration and format of data analytics
- Change control and updated programme of works
- Transition into condition-based maintenance with a frequency of review

Risk Based and Breakdown Maintenance

- The restoration of assets after a breakdown
- It can result in the entire replacement of an asset as the repair costs can exceed the replacement
- This method does provide a low initial maintenance resource and hence, reduced cost
- Usually reserved for facilities where there are few users and no critical environments to support
- Run-to-Fail and Risk Based Maintenance Strategies fall under Breakdown Maintenance, when maintenance strategies fail, assets breakdown unexpectedly.
- Can disrupt large parts of the facility, including emergency situations for persons and property
- Immediate action can be required, priorities are used to distinguish different types of corrective maintenance
- This is also known as 1st fix or make safe

Corrective Maintenance

- Unplanned Maintenance
- A trigger is identified that causes a maintenance event it is not scheduled
- It is used to resolve a problem and ensure a return for the correct or satisfactory performance of the asset from its previous condition
- If an asset requires remedial work after a planned maintenance or condition-based maintenance event it would be corrective work
- The work required to put an asset that had broken down from breakdown maintenance would be corrective maintenance
- This is also known as the second fix or repair

Integrating IoT with Maintenance

Both Hard and Soft Services Maintenance conditions can be monitored but consideration should be taken to having an IoT Platform Strategy, experienced IoT Solutions Providers and satisfactory Cyber Security. In the table below we can see some of the many applications of IoT and IIoT across Facility Management, some are notably the same triggering the introduction of IoFMT as a way of navigating the integration of IoT into FM

Hard Services	Soft Services	Management
Mechanical and Electrical Assets	People Services	Metrics for:
 Door Sensors 	 Door Sensors 	 Performance,
 Pumps and Motors 	– Visitor	– User
 Lighting and Power 	Management	– Experience
 Occupancy 	 Security Systems 	 Statutory responsibilities
 Indoor Air Quality 	 Occupancy 	 Operational
	 Indoor Air Quality 	– Financial

When transitioning away from planned maintenance strategies, any performance Indicators should be carefully considered suitable and sufficient riskbased approach. Deviating from Legislation, Regulations and Guidance (Approved Codes of Practice i.e. British Standards) (statutory compliance) should be considered extremely cautiously

Return on Investment and Rol with IoT

Return on Investment is complex when considering the tangible and intangible, foreseeable and unforeseeable benefits, IoT is explained in the next section, 'The Fourth Industrial Revolution' but the research suggests that there should be a structured approach to determining return on investment for new technologies, especially IoT as there can be hidden benefits by doing so.

Calculating Return on Investment

Return on Investment is a financial ratio used to calculate the benefit an investor will receive in relation to their investment cost.

Two of the most common methods of calculating return on investment are:

$$RoI = \frac{Net \, Income}{Cost \, of \, Investment}$$

$$RoI = \frac{Investment \ Gain}{Investment \ Base}$$

Limitations of the ROI Formula

- It does not include the factor of time
- Investments can produce a different yield over time.
- In 1 year to 5 years one investment could be better in the short-term but fail in the long term and vice versa
- The ROI Formula is susceptible to manipulation
- ROI formulas can be subjectively used to show more desirable results for those seeking investment
- Any investor should look at the true ROI
- The true ROI accounts for all possible costs incurred when each investment increases in value
- When an ROI is portrayed as good or bad it is important to ask them to clarify exactly how they measure it

[21]

Return on Investment with the Internet of Things

"No one knows what they don't know, and they certainly don't know the cost of what they don't know". IoT sheds light on the dark corners of a business and there are several obstacles' companies face both in calculating and realising ROI from IoT. [69]

Further to this, a lack of available data and the savings only coming to fruition over longer time periods can inhibit a persuasive ROI calculation from the offset [50]

Calculating the ROI from IoT need not be complicated, however, it can involve a process of continuous review and analysis to quantify the tangible benefits.

Stage 1	Stage 2	Stage 3
Basic Calculations	More Complex, Less Obvious Calculations	Non-Financial
IoT Equipment and Set Up Costs	Implementation downtime costs	What can be qualititatively quantified
Installation Costs	Retrofitting costs	Building on the existing
What can be quantified?	Consulting costs	Revenue-Generating Capabilities
	Platform costs	
	Ongoing operational costs	
	Security costs	
	Lock-in costs	

Start with the basic calculations

IoT Equipment and Set Up Costs

The cost of the IoT solution and the business mode, increasingly IoT service providers are offering Software as a Service (SaaS) whereby hardware and software (access to the cloud) services are amalgamated into subscriptions

Installation Costs

Depending on the solution and location there could be inhibitors for the technologies, if it is a wired solution is their sufficient power available i.e. plug sockets, is access available throughout a building (landlord/tenant demarcations) that could inhibit wired or wireless technologies from reaching their potential against the cost

What can be quantified?

Time, labour frequency of visits, travel distances, equipment and travel costs are some of the simpler tangible benefits that can be quantified when building a business case for return on investment

Then Factor in the more complex, less obvious calculations

Implementation downtime costs

How will the equipment be installed? If IoT solutions are being installed on utility metering supplies or mechanical and electrical assets is there an operational impact and financial losses to consider, will it increase the installation costs through out of hours installation and commissioning?

Retrofitting costs

Does the asset require any retrofitting for the solution to work, older assets may not have the connectivity to be suitable for IoT, also when considering wireless technologies, is there a suitable connection to the internet?

Consulting costs

How can the data obtained transform into savings – big data analytics require analysis and continuous monitoring to ensure the IoT solution is continuing to operate and yield results as planned. Without sufficient competencies to undertake this, consultancy costs for external third parties may need to be factored in. Especially after any 'quick wins' have been identified

Platform costs

Whilst SaaS is becoming more popular, what happens after the initial subscription period, could the costs increase? If the savings have been identified, then will the return on investment be continuous?

Ongoing operational costs

Wireless technologies, routers, power supplies all require operating costs, if using GSM Sim Cards then these require subscriptions in addition to the IoT solution, the cost of batteries and replacement sensors? – what is not included in the IoT solution to ensure it can continue to operate?

Security Costs

Cyber Security and Physical Security, to what extent is compliance with organisational policies and the UK-GDPR (2021) and Data Protection Act (1998) suitable and sufficient? Physical security, what happens if a plug switch is turned off? Are additional controls required to prevent unauthorised access to the IoT equipment and data contained within the cloud from being used maliciously

Lock-in Costs

The adaptability of the IoT equipment and service provider. As organisational needs change to what extend is the solution continuously suitable to meet any new or amended requirements for the organisation. Is it scalable? Is it available in other countries?

Continuously Consider the Non-Financial

What can be qualitatively quantified?

Employees, customers – stakeholders. With suitably structured questionnaires the responder's information can be quantified to produce metrics that can feed into a return on investment

Building on the existing

Expansion and futureproofing – Are the solutions fit for purpose when considering the future? Once an IoT solution is installed it can be lower cost to increase its capability to other use cases. To cater for this is it more appropriate to invest in a more expensive system that can adapt with the organisational needs even though the ROI could be over a longer period?

Revenue-Generating Capabilities

Whilst operating costs is a major focus of IoT solutions, other benefits may become apparent as the data available is analysed. New trends could reveal new revenue and new opportunities for growth.

Data as a Commodity

Big Data has a financial benefit to other companies, there is the potential for large datasets to have a monetary value to customers and third parties



[74]

Big Data Analytics (BDA)

In 2018, the Royal Institute of Chartered Surveyors, RICS produced a report entitled "Big Data: A new revolution in the UK facilities management sector", the report states that 'many within the FM sector have yet to fully recognise this value'. [101]

Big data is data that contains a great variety, which arrives in increasing volumes and at more velocity. More complex datasets from multiple sources allow for analysis which has not been previously possible. [76]

Collecting the Data

Volume	the volume or amount of data
Velocity	the frequency, speed or rate at which the data is generated and delivered
Variety	the large number of different sources to which the data is generated
Veracity	the integrity, validity and reliability of the data

Value the worth of the data. There are costs to be justified when collecting analysing and using the data that should be considered and justifiable when calculating returns for a business

[87]

Analysing the Data

Analytics is the science of analysis, within the context of a business, analytics can be used interchangeably with business intelligence and business analytics. [86]

There are four main categories of data analysis, it is important to note that more than one of these categories maybe required to provide suitable information for a decision to be made, there is not necessarily a one size fits all approach

Descriptive Analysis

- Least complex and basic type of analysis
- Describes what happened

Diagnostic Analysis

- Root cause analysis why did something happen?
- Focuses on the cause of the result and not the actual result itself
- Failure mode analysis, why did an asset fail, what is the cost both financially and nonfinancially

Predictive Analysis

- Reviews and interprets current data and trends over time
- The intention is to predict future events based
- Predictive analysis is often used by businesses to optimise their growth
- Provides the opportunity to become proactive and reduce the likelihood of asset failure

Prescriptive Analysis

- Offers outcomes and courses of action based on either descriptive or predictive analysis
- The intention is to provide an answer to What should we do?

[35]

Sources of Big Data in Facilities Management

Information Management Systems Categories	
Interoperability	IFC, COBie, Protocols, Exchange Methods
Sensor Mobile and Real-time Location Systems	GPS, Mobile Data, NFC, Wi-Fi, LAN, WSN,
	Optical Fibre, Teblets, RFID Bar Codes, SMS,
	CCTV, PIR
Work-Flow Systems	ERP, CMMS, CAFM, IWMS
Field Data Capture System	Remote Sensing, Photo-grammetry, Drones,
	Laser Scan
Facilities Intelligence Systems	BAS, BMS, BEMS
Communication Systems	Website, Intranet, Applications, Social Media,
	Services
Data Repositories	DataBase, Digital Archives, Spreadsheets, BIM
	Models, VR/VE, CAD, GIS
	[101]

Augmented Reality

Augmented Reality or AR, continues the transition of the computer user to move away from the desktop into the mobile connected world that we live in. It is a large enabler of the transition in the fourth industrial revolution by providing the unique quality or providing a direct link between the physical and digital world. [105]

AR has been suggested as the next game-changing innovation for building managers. The results of a survey conducted in 2021 showed that the adoption of AR technologies was being adopted by:

- 30% Hospital and Medical Facilities
- 26% Manufacturing Facilities
- 25% Educational Facilities
- 23% Corporate Offices
- 22% Shopping Centres

[121]

This is expected to increase to over 70% in the next two years as Facilities Management is expected to see explosive growth. The use of Augmented Reality enables facilities managers to complete their responsibilities as they can streamline operations for example by introducing remote diagnostics upon assets. It also unlocks new opportunities to deepen visitor experiences and expand the ways in which big data analytics can be used [106]

Digital Twins

A digital twin is a virtual representation of real-world assets and their living spaces, such as the mechanical and electrical assets in buildings. They are virtual models that are designed to reflect real-world objects. [55]. They can support design processes, construction operations, handover and proactive and predictive maintenance [108]

Digital Twins can make these processes more efficient by considering what-of scenarios without financial or operational impacts to the assets in the real-world.

They are only as good and reliable as the data connected to them, without the real-life data having appropriate volume, velocity, variety, and velocity it will be difficult to justify the value of the digital twin. [108]

Digital twins in some forms can be seen together in streets, this digital universe, or metaverse is snowballing in investment. Meta has spent \$36 USD on developing its version the Metaverse since 2019 [29]



The Metaverse

The dramatic response to the Metaverse reflects the growing belief that it is the next great computing and networking platform, similar in scope to the transition from the personal computer and fixed line internet of the 1990s to the mobile era and cloud computing we live in today [3]

In fact, 3D virtual environments have been used in commercial applications such as aviation, engineering, real estate, education, medicine, virtual conferencing, tourism, space exploration and more. Microsoft is one of the first movers in commercial metaverse. It will launch Mesh for its video conferencing platform Teams in the first half of 2022, where its customers can interact as well as collaborate using 3D digital avatars in offices, or on shop floors (Business Today in 2021) [61]

"We need to have a clear vision of what we want our real world to look like to make the most of the opportunities offered by the virtual one." [36]

- The Metaverse is the internet
- It can be a force for good
- It has a place in the future of our work
- We should start with societal impact and work back
- Think big, start small, test often [36]

How will employers manage the risk of the metaverse?

Duty to provide a safe working environment

Employers have a legal obligation to provide employees with a safe working environment and to protect them from harassment. To what extent will employers be able to control access to their office in the metaverse?

One suspects that employers will adopt virtual workspaces which only their employees can access – much like in a Teams call. But the likelihood is that will evolve, to the point where social interactions take place much like they do in the real world. Employers should start thinking about the controls they'll need to maintain a safe working environment.

Protection from third party threats

In a world of virtual work, could employees 'subcontract' their work to someone else without their employer's knowledge or consent, thereby exposing the employer to breaches of their confidentiality and data privacy obligations to third parties?

An understanding of what constitutes 'harassment' will need to evolve

Social media has unfortunately brought with it a wave of trolling, bullying and harassment. A virtual world is likely to bring with it similar behaviours, exposing employers to increased risks of bullying and harassment in the workplace.

Employers will need to adapt existing policies and update their training to demonstrate that they have taken reasonable steps to prevent it.

Dress codes and appearance

Employers will need to revisit the rules around dress codes and appearance in the metaverse. For example, participants in Teams calls can easily change their backgrounds to suit their mood or preferred location.

We can assume it won't be hard for them to alter their appearance in the metaverse at the touch of a button. Employers will want to ensure existing rules on dress codes are adapted to accommodate the virtual world too.

Age discrimination

Employers need to account for intergenerational attitudes towards a virtual working world. Younger members of the workforce, perhaps brought up in a world of virtual reality gaming, will more than likely be capable of working in a virtual world – even enthusiastic about it.

On the other hand, older members of the working population may find it harder to adapt, as it requires learning a new skill and accommodating a new way of interacting at work. So that worker populations do not feel ostracised or left behind, training will need to be considered, as will ensuring the real and virtual work environment can co-exist.

Digital immigration

The metaverse opens the possibility of employees outside the UK working in a virtual office that's also occupied by UK-based colleagues. It raises an interesting question: If the workers based abroad are not physically stepping foot in the UK, but entering via the virtual world, do they still need the legal right to work in the UK?

Currently, those working remotely for a UK entity but in another jurisdiction do not. But if the virtual working world becomes so closely associated with the real one, this may need to be revisited by legislators.

Ultimately, it will be up to employers to manage the risk

The metaverse poses significant opportunities, both for the economy and society. Yet it poses some interesting challenges that may force legislators to revisit the rule book. In the meantime, though, it is employers who will need to grapple with the risks they may be exposed to and take steps to mitigate them. [3]

Artificial Intelligence and Machine Learning

Artificial Intelligence

The term Artificial Intelligence was coined in 1956 by John McCarthy, Marvin Minsky and other scientist at Dartford College [114]. Since then, Artificial Intelligence has become a topic of increasingly continuous debate with both positive and negative viewpoints into its integration into society and, the built environment. [56] It can be defined as the capability of a computer system to mimic human cognitive functions such as learning and problem-solving by using maths and logic to simulate the reasoning of a human, the way we learn and absorb information to make decision. [72]. It is already in our lives and can be broken down into different categories:

Artificial Narrow Intelligence (ANI) or Domain Specific (Weak AI)

Covering most of the AI systems in use, it represents specific domains to which a model can be built based on rules which govern the domain. Like a computer 'learning' how to play a chess game, it's ability to learn is restricted to the domain to which it was programmed, and it is nowhere near on par with human level intelligence. The Weak or Narrow AI is only better at humans in a limited capacity. [115]

Artificial General Intelligence (AGI) or Human Level (Strong AI)

All AI is aiming to reach this pinnacle, the intelligence learned in a single domain can be generalised and applied to different domains which can be related or unrelated. This is a limiting factor in the technologies of artificial intelligence and whilst AI can traverse across domains it is still not considered that of the level of a human. [116]

Artificial Super Intelligence (ASI) or Better than Human

This is where machines are more intelligent than humans in every aspect. The computer has the ability to reprogram itself, no need to rest and continue cycling through continuous improvement until it surpassed the intelligence of humanity. For this reason, Artificial General Intelligence and Super Intelligence sit much closer on the paradigm than the Narrow Intelligence we see today. [117]

Machine Learning

Artificial Intelligence is based on the use of algorithms which is a clear logical and mathematical set of instructions from a computer. Algorithms can be supervised (the algorithm can only operate with input) or unsupervised (the algorithm can find patterns in input without linear input) [119]

Machine learning is an application of unsupervised Artificial Intelligence, the computer understands the process of using mathematical models of data and can learn without direct instruction. This allows a computer to begin learning and improving on its own.

Machine learning is considered a subset of AI, with AI being the actual 'intelligent' computer which thinks like a human (but not at huma level intellect) and can perform tasks on in its own but Machine Learning is the process and journey of how the computer system developed its 'intelligence' [118]

Machine Learning is becoming more widespread through the new and emerging technologies such as IoT and its ability to provide billions or trillions of datapoints. The more data the better, plan before doing and think end to end are some of the mindsets which are suggested to understand, adapt to and adopt prior to embarking on a journey of machine learning. [88]

The Process and Relationship of Machine Learning and Artificial Intelligence		
Step 1	An AI system is built using machine learning and other techniques	
Step 2	Machine learning models are created by studying patterns in the data	
Step 3	Data scientists optimise the machine learning models based on patterns in the data	
Step 4	The process repeats and s refined until the models' accuracy is high enough for the tasks that need to be done	
	[73]	

Capabilities and Benefits of Machine Learning and Artificial Intelligence in the Built Environment

Organisations in every industry are discovering new opportunities through the connection between AI and Machine Learning. Some of these relating to the built environment include predictive analytics, recommendation engines and image and video processing. This can create powerful benefits which include more insights into data, increasing operational efficiency and better, fast decision making. [73]

Artificial Intelligence ins better described as Machine Learning and supporting the quality of the data into the systems that provide algorithms to undertake in depth analysis will provide organisations with significant insights. The way in which we interface with computers and begin to use automation and business intelligence software it is likely that a demand for a workforce that can support quality data input will be sought after, this means the user experience and how the interoperability of the systems we work with becomes another characteristic of managing a facility now and in the future.

Service Area	AI-Enabled Solution and Roles
Catering	Robotic chefs prepare food in the kitchens and autonomous guided
	vehicles (AGVs) and actroids service it; later, they clear utensils and
	waste
Cleaning	AGV's are used for internal and some external cleaning of surfaces.
	Actroids supercede them for certain tasks. aerial vehicles (drones) are used for cleaning building facades
Security/Inspection	AGVs and drones with UHD and thermal-imaging cameras increase the
	efficiency of security services and inspection regimes, whilst reducing
	risks to personnel
Maintenance	Mechanical and electrical services maintenance is planned and organised
	by smart apps and carried out by drones, AGV's and robots. Parts are 3D
	printed in situ.
	Fabric maintenance is planned and organised by smart apps and
	executed by drones, robots and later, actroids
Reception/Helpdesk	Actroids perform reception and helpdesk duties supported by smart
	apps and data analytics.
	Remove monitoring and feedback are assisted by smart apps
Logistics – Deliveries	Actroids oversee deliveries by driverless vehicles and coordinate
and Waste Disposal	porterage duties using AGV's. Smart collection points improve removal
	ad recycling of waste
	[100]

Typical Service Areas in Facilities Management and their AI Solutions

User Experience

What is the User Experience in Facility Management?

The experience of the user which encompasses all aspects of their interaction with the facility and its services. [83], including third party contractors.

Measuring User Experience

Measuring User Experience and determining the metrics can be supported using a journey measurement system, which when used in decision making about software, systems and interoperability, this holistic approach to an integrated management system can begin to provide clear linkages between metrics at every level [92]. IoFMT can provide the data for these metrics, allowing for more quantifiable user data from a wider range of sources

The three steps below show a way in which a process for determining metrics can be applied when considering user experience

- 1. Define journey measurement model
 - i. Define top-line metric linked to desired outcome
 - ii. Prioritise customer journeys that drive satisfaction
 - iii. Identify key operational metrics by customer journey
- 2. Design journey measurement system
 - i. Design executive-level and journey-owner dashboards
 - ii. Define survey structure, triggers, and audiences
 - iii. Identify alert triggers and escalation processes
- 3. Select journey measurement system
 - i. Design platform-selection criteria and scorecard
 - ii. Select technology partner
 - iii. Define and implement incentives and practices to optimise system [6].

Types of Data – Wellbeing and Air Quality

In the IWFM Sustainability Survey the following were identified as important factors to measure when determining wellbeing and air quality

- 1. Workplace
 - a. Air and Water Quality Management etc.
- 2. Working Practices
 - a. Flexible Working, Training and Development, Charity, Community etc.
- 3. Mental Health and Stress
 - a. Support, First Aiders, Employee Assistance Schemes, Counselling etc.
- 4. Physical Health and Exercise
 - a. Cycling initiatives, gym, health checks etc.

[60]

Wellbeing – CIPD

- The CIPD has identified seven inter-related 'domains' of employee wellbeing
- Similar to IoT, there is no 'one-size-fits-all' approach to designing a health and wellbeing strategy
- There is guidance available and IoT data can support an effective strategy
- The seven domains are listed below [19]

1. Health

Physical health - Health promotion, good rehabilitation practices, health checks, wellbeing benefits, health insurance protection, managing disability, occupational health support, employee assistance programme.

Physical safety - Safe working practices, safe equipment, personal safety training.

Mental health - Stress management, risk assessments, conflict resolution training, training line managers to have difficult conversations, managing mental ill health, occupational health support, employee assistance programme.

2. Good work

Working environment - Ergonomically designed working areas, open and inclusive culture.

Good line management - Effective people management policies, training for line managers, sickness absence management.

Work demands - Job design, job roles, job quality, workload, working hours, job satisfaction, worklife balance.

Autonomy - Control, innovation, whistleblowing.

Change management - Communication, involvement, leadership.

Pay and reward - Fair and transparent remuneration practices, non-financial recognition.

3. Values/Principles

Leadership - Values-based leadership, clear mission and objectives, health and wellbeing strategy, corporate governance, building trust.

Ethical standards - Dignity at work, corporate social responsibility, community investment, volunteering.

Inclusion and diversity - Valuing difference, cultural engagement, training for employees and managers.

4. Collective/Social

Employee voice - Communication, consultation, genuine dialogue, involvement in decision making.

Positive relationships - Management style, teamworking, healthy relationships with peers and managers, dignity and respect.

5. Personal growth

Career development - Mentoring, coaching, performance management, performance development plans, skills utilisation, succession planning.

Emotional - Positive relationships, personal resilience training, financial wellbeing.

Lifelong learning - Performance development plans, access to training, mid-career review, technical and vocational learning, challenging work.

Creativity - Open and collaborative culture, innovation workshops.

6. Good lifestyle choices

Physical activity - Walking clubs, lunchtime yoga, charity walks.

Healthy eating - Recipe clubs, healthy menu choices in the canteen

7. Financial wellbeing

Fair pay and benefit policies - Pay rates above the statutory National Minimum/Living Wage, flexible benefits scheme.

Retirement planning - Phased retirement such as a three- or four-day week, pre-retirement courses for people approaching retirement.

Employee financial support- Employee assistance programme offering debt counselling, signposting to external sources of free advice (for example, Citizens Advice), access to independent financial advisers. [X20]

Gamification

What is Gamification?

Gamification consists of using game-based techniques and mechanisms in a non-game context for the purpose of engaging people, motivating action, promoting learning and problem solving. [51]

It is not a new concept; it has been used in other industries such as the restaurant and tourism

The restaurant industry – McDonalds Monopoly Game, a promotion running since 1987 and resulting in \$40 million worth of prizes being given away [130]

Tourism – Pokémon Go has promoted individuals to travel to places they may not have done to try and 'catch them all'

Gamification in Facilities Management

'The 'WorkAI' Trial, 2020

Perhaps one of the most prominent studies in gamification in facilities management has been undertaken in Finland in 2020. The results of the study which used an interface called 'WorkAI' similar to What's app asks users 15 different questions with 9 themes.

- The results were positive and the gamified features were favourably perceived
- Half of the respondents found the experience motivating collecting trophies and a progress map were found to be the strongest examples in the study
- Most importantly highlighted is that the application did not interfere with the respondents work routines

The key takeaways from the WorkAI trial on gamification in the facilities management industry included:

- 1. The solution needs to be easy to adapt
- 2. It should not disturb work routines
- 3. It should operate on relevant issues and offer new insights such as on wellbeing at the workplace
- 4. Gamified elements play an important role when motivating respondent to use the solution on a daily basis
- 5. Know your target group and keep it simple

[130]

4 Competency

The Health and Safety Executive defines competency as "Someone who has the sufficient training and experience or knowledge and other qualities" [52]. This is expanded on in PAS 8673: 2022, Definitions: "skill, knowledge, experience and behaviours required at task level to achieve a defined outcome" [12]

Skill	Experience
Knowledge	Behaviours

[12]

Training improves the effectiveness of people in their occupation [156], a methodology for this is through vocational training which is defined by the CEDEFOP, as (An) 'Activity or programme of activities designed to teach the skills and knowledge required for particular kinds of work. Training...usually takes place at working places, whereas education...takes place at educational establishments' [68].

"If you think safety is expensive, try the cost of an accident" [23] whilst this quote was generated from the chemical processing industry regarding safety and accident causation it is increasingly apparent in a world that is introducing new technologies, systems and processes. If we modify the quote – if you think training is expensive, try the cost of operational failure. We can see they are similar in nature. Without investing in training and maintaining competency through change, failures will occur.

Accident causation can be represented by the sharp and blunt end, the sharp is the 'boots on the ground' the engineers, technicians and operative undertaking planned and reactive maintenance whilst the blunt end is the management driving the individuals forward to meet contractual requirements. If we take this analogy as a pen or pencil, then too much pressure and it can snap.

The balance of management and leadership against the day-to-day for employees is something that should be carefully considered, especially with 'top-down' strategies and the introduction of new and emerging technologies into the workplace.

As we introduce more digital technologies into the workplace, competency should be rigorously and continuously reviewed to ensure that individuals are able to adapt and adopt these new technologies, with success criteria being measured on quantitative indicators based on feedback loops from the individuals expected to use and maintain the IoT, or IoFMT systems

Government Support and Penalties

Energy Efficient Plant and Machinery

The UK Government provides the Energy Technology List, a government list of energy efficient plan and machinery, available online [133]. It provides an independently verified list of energy efficient equipment including:

Automatic Monitoring and Targeting (aM&T)	Lighting
equipment	Motors and drives
Boiler equipment	Pipework insulation
Boiler retrofit equipment	Radiant and warm air heaters
Combined heat and power (CHP)	Refrigeration equinment
Compressed air equipment	
Heat pumps	Solar thermal collectors
	Uninterruptible power supply (UPS)
Heat recovery ventilation units	Waste heat to electricity conversion
Heating, ventilation and air-conditioning	equipment
(HVAC) equipment	Wastewater heat recovery systems
High speed hand air dryers	

[138]

Potential Government Funding

Further to this, the UK Government department for Business, Energy and Industrial Strategy has (as of 2022) £5 billion in funding to help UK businesses to support the government's commitment to reach net zero emissions by 2050. [141] These are considered under a staged and phased competition methodology in which funding is provided based on a review of the submissions received. Some of the programme's funding include:

- Heat Pump Ready Programme
- Low Carbon Hydrogen Supply 2
- Heat Network Investment Project (HNIP) Funding
- Direct Air Capture and other Greenhouse Gas Removal technologies competition

Penalties

Whilst positively reinforcing compliance for promoting innovations to support the journey to net zero there are also negative reinforcements in the form of financial and reputational penalties. Within the 2020-2021 financial year there were more than £27 Million of fines issued to 33 companies for breaches of the European Union Emissions Trading System. The largest single fine issued in the UK was £344,000 [2].

The Carbon Penalties and Incentives Report identified a number of recommendations, one of which specifically relates to real estate professionals who should develop a better understanding of environmental matters, and their implications, to integrate them alongside standard legal and valuation concerns. Essentially, every investment, action and activity should consider the environment akin to health and safety law. The study found evidence that by adopting greener buildings owners and occupiers could benefit from lower operating costs, lower risk exposure and increased marketability [30]

5 Building Accreditations and Certifications

A certification is confirmed by a third-party through an audit of an organisations systems or products, whilst an accreditation is an independent third-party recognition that an organisation has the competence and impartiality to perform specific technical activities. [131].

Both are used interchangeably but there are subtle differences especially when referring to buildings. Some of the most prominent building certifications and accreditations available are covered in this section. The focus is on operational facilities which are in use rather than new buildings which are in the construction phase.

When considering an IoFMT strategy, building accreditations and certifications can influence the type of system and the data expected.

BREEAM

The Building Research Establishment Environmental Assessment Method (BREEAM) is one of the most prominent and well-known environmental assessments of buildings that is well established, appearing in 1990. It started as a 19-page BRE report and has now expanded to a 350-page technical guidance. [13]

Certification involves trained assessors who assess evidence against the criteria and report it to BRE. BRE then validate the assessment and issue the certificate.

There are different schemes available for certification that include Offices, Retail, Industrial, Education, Eco-Homes/Code for Sustainable Homes, Healthcare, Multi-Residential, International, Courts, Prisons and Bespoke under a number of different categories which include Management, Health and Well-being, Energy, Transport, Water, Materials, Waste, Land Use and Ecology and Pollution.

BREEAM certification will provide a rating of Pass, Good, Very Good, Excellent and Outstanding.

They have very precise requirements which has a complex weighting system with a market profile and a cost of compliance, but it does allow comparison and benchmarking of different buildings, is independently audited and is adjusted to UK legislation with the added benefit of adaptability to any building if the bespoke version is used.

BREEAM In-use standards provide a framework which enables property investors, owners, managers and occupiers to determine and drive sustainable improvements in the operational performance of their assets, this supports benchmarking which is beneficial for large diverse portfolios whilst also providing assurance and validation of operational asset data. [7]

LEED

The Leadership in Energy and Environmental Design (LEED) originated from the United States Green Building Council (USGBC), devised in 1994 to encourage sustainable practices from design to development through the use of tools and criteria for performance measurement.

Certification does not specifically require the use of trained assessors however, there is an additional credit available if an "Accredited Person" (AP) is used. The AP has the role of gathering evidence and advising the client. The evidence is then submitted to the USGBC who will undertake the assessment and issue the certificate

LEED certification is growing, the number of assessors on the LEED USGBC website totals 66 LEED Accredited Professionals in the UK which is the fifth highest behind the US, Canada, UAE and China.

There are different schemes available which include New construction, Existing building (operation and maintenance), Commercial, Interiors, Shell and core, Schools, Retail, Healthcare, Homes and Neighbourhood Development. These are enveloped under a number of different categories which include Sustainable sites, Water efficiency, Energy and atmosphere, Materials and resources, Indoor environmental quality and Innovation in Design.

LEED certification will provide ratings of Certified, Silver, Gold and Platinum [13]

Through the scale of LEED they have been able to provide strong marketing and lots of information available to drive their message of "the most widely used green building rating system in the world" [65] with the added benefit of no requirement for assessors and training prior to enrolling on the process of certification, however they are based on US systems with intense documentation required and no independent audits of assessment. [13]

WELL

The United States Green Business Certification Incorporation (GBCI) was founded in 2008. [40], they launched The WELL Building Standard, Version 1 (v1), in 2014 following the newly created International WELL Building Institute (IWBI) in 2003. [62]. The WELL Building Standard claims to be the first building standards to focus on enhancing people's health and wellbeing through the built environment. The WELL Building Standard, Version 2 (v2) was launched in 2018.

WELL Standard Certification involves monitoring and measuring features of the built environment that impact human health. Training is provided for individuals who wish to become WELL Accredited Professionals (WELL AP's). [127]

The standard measures attributes of a building and its impact on occupant health by looking at seven factors, these include Air, Water, Nourishment, Light, Fitness, Comfort and Mind which reach across a number of categories including Real Estate, Finance, Hospitality, Entertainment and Education. [155]. These are all founded on 6 principles to include Equitable, Global, Evidence-based, Technically robust, Customer-focused and resilient.

The WELL Building Standard is a points-based scorecard which offers Bronze, Silver, Gold and Platinum. [154]

The WELL Building Standard has demonstrated huge benefits and returns to developers, owners, and the companies that work in these spaces. Businesses found, overall that employees were more enthusiastic, passionate, happier, less stressed and more productive

GRESB

The Global Real Estate Sustainability Benchmark (GRESB) was launched in 2009 with a focus providing ESG data on the real estate sector. It was established by a group of large pension funds who wanted to have access to comparable and reliable data on the ESG performance of their investments. The United States Green Business Certification Incorporation (GBCI) acquired GRESB in 2014 and in 2020 it was acquired by Summit Partners who were founded in 1984 as a global alternative investment firm. [46]

GRESB provides a consistent framework to measure the ESG performance of individual assets and portfolios based on self-reported data. Performance assessments are then guided by what investors and the wider industry consider to be material issues, which are then aligned with the United Nations Sustainability Goals, The Paris Climate Agreement and major international reporting frameworks [48]. In 2021, GRESB covered over \$5.7 Trillion real estate assets under management with the assessment covering nearly 117,000 assets across 66 countries [47] it is used by more than 100 institutional and financial investors to make decision that are leading to a more sustainable real asset industry. [48].

The GRESB framework for Real Estate Assessments has two benchmarks. The first is the GRESB Real Estate Benchmark which considers management and performance factors, and the other is the GRESB Development Benchmark, which considers management and development factors. These carry their own score which is then factored into the entity or organisations GRESB Score and GRESB Rating.

The components of the benchmark have subsidiaries which make up the score, these are determined through an assessment process which involves validation, objective scoring and peer benchmarking and are compiled from a number of different categories.

The Management component measures the entities strategy and leadership management, policies and processes, risk management, and stakeholder engagement approach, composing of information collected at the entity/organisational level. The categories included in the benchmarking are Leadership, Policies, Reporting, Risk Management and Stakeholder Engagement whilst the

The Performance component measures the entity/organisations asset portfolio performance, composing of information collected at the asset portfolio level. It is suitable for any real estate company or fund with operational assets. The categories included in the benchmarking are Reporting Characteristic, Risk Assessments, Targets, Tenants & Community, Energy, Greenhouse Gases, Water, Waste, Data Monitoring and Review and Building Certifications.

The Development component measures the entity/organisations efforts to address ESG-issues during the design, construction, and renovation of buildings. This component is suitable for new construction and/or major renovation projects. The categories included in the benchmarking are Reporting Characteristics, ESG Requirements, Materials, Building Certifications, Energy, Water, Waste and Stakeholder Engagement.

The assessment process involves validation, objective scoring and peer benchmarking which are compiled from the individual categories. The Assessment Portal for 2022 opened on April 1st, 2022, with a submission deadline of the 1st July 2022, this provides a 3-month deadline for organisations to prepare their submissions. The final results are then published on October 1st following a preliminary publishing of the results. [49]

RESET

GIGA was founded in 2008 and in 2013 they started the Regenerative, Ecological, Social and Economic Targets, RESET Accreditation focusing on air quality monitoring and continuous data to drive investment decisions for the promotion of wellbeing and health.

Ecological is in reference to the global environment, including flora and fauna being sustainable. Social is the reference to people, the community and society in general. Economic is in reference to the economy, their undertaking is that the only way to successfully make an ecological and social impact is to simultaneously make an economic impact, otherwise there will be no investment.

The RESET Standard provides a set of standards and assessment tools and service which are focused on the data quality and data transparency with the purpose of helping built environments become healthier and more sustainable. [44] It is founded on the principle that you cannot effectively solve what you cannot measure, and the focus is on asking the question: "How does the built environment become more sustainable with the lowest cost and effort?" [97]

RESET professionals, known as Accredited Professionals (AP's) are required for every project to guide it through the process. It is known as a perfect fit for designers, engineers, and consultants who work or offer services related to smart buildings, operational efficiency, or achieving health and sustainability targets. [99]

Through continuous monitoring, data transparency, analytics and benchmarking the RESET Standard has the vision of affecting policy with its leverage of the data, analytics ad benchmarking. The RESET Standard provides a structure and strategy for policy makers to make the best decisions [98]

UKGBC

The United Kingdom Green Building Council, established in February 2007, they are a charity with over 600 member organisations which reach across multiple sectors and represent the voice of the industry's current and future leaders who are striving for transformational change.

The UKGBC mission is to "radically improve the sustainability of the built environment, by transforming the way it is planned, designed, constructed, maintained and operated" [132]

The issues they work on are derived from their vision which encompass the global problems of climate change, resource use, nature and biodiversity, health and wellbeing and socio-economic impacts and whilst not a certification or accreditation as such, membership with the UKGBC provides the opportunity for member organisations to collaborate, enable, advocate and inspire through the development of guidance, showcasing solutions and sharing knowledge and best practice. [132]

NABERS (and NABERS-UK)

The National Australian Built Environment Rating System (NABERS) Launched in Australia in 1998, provides simple, reliable, and comparable sustainability measurement across sectors such as hotels, shopping centres, apartments, offices and data centres.

They are founded on proving that "What gets measured gets managed" [79], with 7 key principles that include the measurement of actual impact and not intent, remaining relevant to building operations, meaningful ratings, simple and easy to perform ratings, reliable, trustworthy and collaborative.

NABERS ratings are valid for 12 months, they have a rating of one to six stars which measure building efficiency across Energy, Waste, Water and Indoor Environment.

Some of the benefits include fair benchmarking for a buildings energy and water efficiency which enables comparisons across portfolios, validation and communications with independent validation of sustainability data, the option to track and improve with annual ratings, performance improvements and reduced energy and emissions that all provides a competitive edge as the building transitions into that which has a lower environmental impact and lower running costs [79]

In the UK, the scheme administrator for NABERS is the Building Research Establishment (BRE) and currently only rates the energy performance of offices only. In Australia this includes more sectors and is planned for future development with more members utilising the NABERS ratings system since its launch in late 2020 [77]

They have two schemes, NABERS UK Energy for Offices and NABERS Design for Performance, a NABERS Energy rating can be achieved without a NABERS Design for Performance. Assessors are professional sustainability consultants who are trained and licences to perform NABERS ratings.

The assessors carry out physical assessments of buildings to collect and verify the data required, the data is then reviewed, and the rating is calculated. The assessor then submits the rating to the NABERS technical team who undertake an audit before issuing the final rating. [78]

The UK Government National Performance-Based Policy Framework

The UK government has set out plans to introduce a national performance-based policy framework for assessing energy use and carbon emissions in commercial and industrial buildings above 1,000m2. This will likely require annual ratings and mandatory disclosures which will be publicly available online, the initial consultation which rain in 2021 is currently being reviewed by the UK government however, it is likely to include a similar system to that of NABERS. [134] Adopting NABERS can provide benefits for those organisations that would like to stay ahead of the curve

EPC – Energy Performance Certificates

EPC's are a requirement of the Energy Performance of Buildings Directive (EPBD) which is a European Union measure designed to tackle climate change by reducing the amount of carbon produced in buildings. The principle of the directive is to make the energy efficiency of buildings transparent by requiring an energy performance certification showing the energy rating of buildings, accompanied by recommendations in energy efficiency improvements [136]

In 2020, the UK government produced an EPC action plan to determine the effectiveness of the Energy Performance Certificates with actions designed to deliver, firstly, an EPC system that produces accurate, reliable and trusted EPCs, secondly, an EPC that engages consumers and supports policies to drive action and finally, a data infrastructure fir for the future of EPCs. In total there are 35 actions, of which 11 of these will require changes to the Energy Performance of Buildings Regulations 2012. [142]

MEES

Under the Energy Efficiency (Private Rented Property) (England and Wales) Regulations 2015, the UK Government introduced the Minimum Energy Efficiency Standard (MEES). The MEES guidance means that in respect of a non-domestic private property, it must not be rented out unless the minimum standard in the energy performance certificate of 'E' or above is attained for the building. [143] This was in 2015, by 2030 this is increasing to an EPC level of 'B' or above and is expected to impact 85% of non-domestic rented stock, by 2027, an EPC level of 'C' or above is to be required by 2027 under the 2015 regulations which are expected to reach a revision in 2025. [89]

IBOS

The International Building Operation Standard launched by the Royal Institute of Chartered Surveyors is a new approach put forward to measure and manage how buildings perform for people through data.

It aims to deliver an international standard for the operation of buildings to meet the needs of occupiers, investors, advisors, and end users by providing a global benchmark for delivering better buildings for people, society and the planet

This is combined with its intention to achieve a consistent benchmark for cost measurement and delivery of value for all real estate assets

IBOS equips professional with a range of data to inform decisions around ES and sustainability, building optimisation and user-experience. It has been developed alongside the market and endorsed by a range of organisations. [103]

ESOS

The Energy Savings Opportunity Scheme was established by the UK Government under the ESOS Regulations 2014. They are a mandatory energy assessment scheme for organisations in the UK that meet the qualification criteria with the Environment Agency being the UK scheme administrator.

ESOS assessments must be caried out every 4 years, these consist of an audit of the energy used in the organisations buildings, industrial processes and transport so that cost-effective energy saving measures can be identified. [135]

There are currently 4 compliance periods, with the first two ending in December 2019. Compliance period 3 runs from December 2019 – December 2023 and the last compliance period runs from December 2023 – December 2027 [137]

To determine if the regulations apply, there are a number of factors which when considered and quantified may require an organisation to comply with the ESOS Regulations. These include total number of employees and turnover and balance sheet totals. [137]

New Performance-Based Policy Framework

The limitation of EPCs is that they do not measure actual metered energy consumption and carbon emissions. Therefore, a high EPC score does not guarantee that a building will use less energy and consume less carbon. [89]

The Smart Industry Readiness Index

To support the manufacturers, the Smart Industry Readiness Index was created by the Singapore Economic Development Board in partnership with leading technology companies, consultancy firms, and industry academic experts. Abbreviated to SIRI,

it comprises of a set of frameworks and tools that cover three core elements of Industry 4.0: Process, Technology and Organisation to help manufacturers sustain their transformation journey in Industry 4.0 utilising the Industrial Internet of Things, IIoT. In 2020, the first inaugural batch of Certified SIRI Assessors graduated to begin supporting the industry with the adoption of the framework [112]

The World Economic Forum is accelerating the adoption of SIRI as the international standard for Industry 4.0 benchmarking and transformation. In 2022, the International Centre for Industrial Transformation (INCIT) was also established. This is a new non-governmental, not-for-profit organisation that will underpin the delivery of SIRI across the globe. [4]

CRREM

The Carbon Risk Real Estate Monitor Project (CRREM) has the overall goal to increase the energy efficiency investment in the real estate sector by addressing the need to understand the downsiderisk of climate change. The focus of CRREM is the decarbonisation of assets under management rather than focusing on the progress of the overall industry sector.

They have three objectives:

- **Objective 1** Downscaling & transparency: Breaking down INDCs by sector, company and property level for more transparency and capacity building
- **Objective 2** Strategic implication of "Stranded assets": Defining areas for improvement and strategic options
- **Objective 3** Framework, Toolkits & Methods: Making decarbonisation in the commercial real estate sector measurable

[22]

6 Asset Collection and Verification

If you can count all your assets, you always show a profit. [111]. It all starts with the assets, as we move through the fourth industrial revolution the quantity, quality, and range of the data available is one of the most important success criterions of any facilities management strategy.

ISO 55001 defines an asset as a "thing, object, item or entity'. [9].

The following information relating to the facilities assets should be held in the asset register and processes that are continuously improved deployed and fully understood so that the content and data within the asset register is kept up to date. This extends to spare parts and warranties. The understanding and comprehensiveness of this data should minimise disruption and/or loss of business continuity in the event of breakdown or failure of the asset.

There are many iterations of the content required to be in an Asset Register for a building, the UK Government has released a standardised non-exhaustive list, that provides a harmonised approach to the content of asset registers.

A list of the contents of the UK Governments guidance for an Asset Register can be seen on the next page.

Asset Register (Non-Exhaustive List)

- 1 Asset Classification Code
- 2 Asset Classification Description
- 3 Asset Criticality
- 4 Asset
- 5 Maintainer
- 6 Parent Organisation (InSite Reference)
- 7 Organisation (InSite Reference)
- 8 Site/ Establishment Name (InSite Reference)
- 9 Building/Block Name (InSite Reference)
- 10 Building/Block (UPRN Insite Reference)
- 11 Building/ Space (InSite Reference)
- 12 Floor
- 13 Space/Room/Zone
- 14 Asset Condition
- 15 Asset Beyond Economic Repair
- 16 Asset Operational Status
- 17 Date of last condition survey
- 18 Remaining Life Expectancy (Years)
- 19 Last Activity Date
- 20 Next Activity Date
- 21 Inspection Report ID
- 22 Quantity
- 23 Unit of Measure
- 24 Location Ontology (Country/Region/Site/Building/Space/Function)
- 25 Asset Classification
- 26 Condition and Asset Remaining Life
- 27 Maintenance Activity
- 28 Serial No.
- 29 Warranty Details
- 30 Policy Number
- 31 Asset Barcode and Technical Documents
- 32 Surveyor/Engineer Maintenance requirement(s)
- 33 Inspection frequency (months) No. of issues till date Inspection type
- 34 Inspection sub-type Health & Safety issues Inspection notes
- 35 Health & Safety compliance
- 36 Purchase price (GBP) Operational cost (GBP/month) Replacement cost (GBP)
- 37 Power source/Fuel type Duty/Rating/Capacity (kWh)
- 38 Refrigerant type Heating/Cooling provision Battery type
- 39 Emission
- 40 Energy efficiency ratings

[140]

The Importance of Asset Data

The understanding and comprehensiveness of asset data should minimise disruption and/or loss or business continuity in the event of breakdown or failure of the asset

The UK Government Facility Management Standard for Property 002 – Asset Data sets out a number of objectives for the public sector, the importance of these objectives should be transitioned into the private sector.

Objective	Description
Consistent reporting across	Improving aggregation and collation of asset data across
government	organisations to facilitate cross-government comparison and
	evidence- based decision-making.
Improving reporting within	Suppliers applying consistent asset data standards to facilitate an
organisations	improvement in FM reporting within organisations.
Improving data to support	Increasing transparency and accuracy of asset data to support
nrocurement	contract pricing discussions with FM suppliers increasing
procurement	interoperability and transferability of data between EM suppliers
	when changing service providers.
Compliance and safety	Enhancing transparency around mandatory and statutory
	maintenance to support safety and compliance monitoring.
Sustainability	Supporting the government's sustainability agenda through
	having more readily available asset data to support sustainability
	programmes.
Evidence-based investment decision-	Increased data availability and quality to inform and support
making	evidence-based decision-making for asset maintenance
	investment, backlog maintenance and replacement costs
	optimisation.
Collaboration and knowledge sharing	A common standard and language across asset data will facilitate
	collaboration and knowledge sharing between organisations.
Les and the statistic state of the state of	
Improved visibility and confidence in	Increased data transparency between organisations and suppliers
suppliers	to reinforce confidence in the services being provided.
Improved user experience	Better asset data to contribute positively to FM delivery across
	the government estate, benefitting the service user and
	enhancing employee experience.
	[140, Page 7]

Asset standardisation provides us with significant benefits in the quantity, quality and range of data analysis available, reducing errors and time/cost. The UK Governments guidance sets out a standardisation for asset data that if, all were to follow the benefits for all would be truly monumental.

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