INDUSTRY INSIGHT

buildingSMART International

What do Facility Managers need from BIM?

Case 4: Asset Management for Hospitals

A perspective from the Building Room

CONTENTS

1. Introduction

Building Information Modelling (BIM) has been integrated within digital design, construction projects and delivery processes for many years; however, it is still a relatively new concept in facility management with owners and operators' not fully aware of the potential benefits of using structured BIM data and processes in an asset's operational phase.

BIM within design and construction stages might be focused on technical, co-ordination and constructability aspects, whereas BIM when used within the operational stage may focus on space utilisation, asset management, maintenance planning, scheduling, and record purposes.

It is well understood that a significant part of the building information created in early phases of a project is relevant for the entire lifecycle of the building asset. Therefore, the use of building information models in facility management is generating discussion internationally, and existing BIM practices and terminology are evolving to create a long-term roadmap for BIM centric workflows and BIM based applications for the whole asset lifecycle.

One area that is spearheading this is the Healthcare sector, with clients and health trusts responsible for the operations of some of the most complex and critical assets in the built environment. BIM is traditionally used for creating the physical hospital buildings, but there is a lot of potential to continue updating the models with the latest & greatest FM attribute data for proactive maintenance purposes

Simultaneously, openBIM standards such as Industry Foundation Classes (IFC) and Model View Definitions (MVD), are firmly established as global standards for open building information transfer in digital construction projects and are increasingly used in the handover process to the operational phase. Enhancing openBIM standards based on FM-relevant use cases can help accelerate the merging of BIM into facility management processes and bring clarity to the information needs of the operational phase.

That being the case, "What do FMs need from BIM?" introduces new opportunities for the healthcare sector, including the existing hospital real estate and future health care facilities.

The goal of this whitepaper is to provide an insight and examples into the reasons why healthcare sector owners and operators should adopt openBIM standards and processes for the lifecycle management of their estate portfolios, facilities, and assets.

2. What do the healthcare sector clients need?

Hospital buildings are very people centric and introduce a unique set of facility management challenges and use cases. They have a function of curing and comforting those in society who are unwell, hence why the technical performance of a hospital building is more important and complicated than an average office building.

Special attention must be given to the building's size and usability, their unique needs for the patients and staff's health and safety, and the chaotic nature of emergency processes. Existing healthcare estates and new building assets need to be 100% reliable and operationally dependant 24/7, requiring a continuous balance of CAPEX and OPEX planning and management.

As hospital environments become ever more complicated with stricter physical, digital, and social environment requirements, the integration of BIM data and processes with simulation and analysis tools can enable better decision-making and support improved predictive asset planning and delivery. With clients and FM operators struggling to find enough time and resources to maintain statutory compliance and manage technical data checking, it is something that should be automated and managed digitally.

Delivering better outcomes for asset management in hospitals requires a clear understanding and definition of what do the digitally transformed end-user experiences look like when traditionally manual processes are digitalized, and the outputs of digitalized processes are digitized. This requires deep discovery of how people are currently managing their business and where are the gaps in data and information delivery within current processes. Through an understanding of the expected outcomes, it is easier to backtrack into what information clusters are needed for confident decision-making, and what data is required to process reliable information. The origin sources of the required data might be with other people or within disparate organisational and external systems. Regardless of the origins, unnecessary gatekeepers and siloes need to be removed while maintaining high data security and privacy standards.

Using OpenBIM as the foundation for collaboration and interoperable data exchange is an opportunity for better quality data flow, automated mapping, and information management across healthcare financial planning, building and asset management systems. To enable the change management related to organizations, openBIM needs to be addressed as a strategic tool for supporting digitally transformed processes and the redefined outcomes. People need ready-processed information based on reliable and conditioned data which is a necessity and an opportunity for developing tools that consume openBIM and output results and options to choose from.

3. What are the current issues and failure costs for FM healthcare?

In the context of this paper, the review of current issues and associated failure costs within healthcare FM are related to project information management and delivery.

Traditionally, at the handover stage of new projects, multiple paper operations & maintenance (O&M) manuals are delivered to the client by the contractor, along with a digital backup. Individual paper manuals are typically stored on and off site in different locations, thus making it an almost impossible task to keep all copies concurrently aligned and up to date.

Generally, the O&M handover manual contains design and construction record information e.g., drawings, schedules, reports, certificates, approvals etc., an asset register, maintenance instructions, product supplier and manufacturer information.

All this is valuable information for healthcare facility owners and managers, however following project handover is it often discovered that O&M manuals are missing information, are inaccurate, or difficult to navigate and reference due to the ad-hoc compilation structure and paper-based format.

Delivered asset register lists are also often inaccurate, missing spatial location data, and decoupled from relevant manufacturer information, warranties, and maintenance instructions. Such anomalies can heavily impact an owners or operators' ability to plan and deliver the necessary FM services from the outset, and can often require the commissioning of independent surveys of brand-new facilities, to obtain accurate records of the installed assets and spaces.

Reasons for the above issues can vary across projects, however poor requirements briefing, inadequate information planning, delivery and inconsistent site data capture are typical, fundamental problems. These issues can be addressed through the specified adoption and use of digitised O&M information, globally unique, interoperable and persistent identification standards (e.g. GS1), industry recognised classification systems, (e.g. Uniclass, Omiclass) the application of a standardized information management (e.g. ISO 19650) and OpenBIM delivery process (e.g. ISO 16739).

Adoption of the above will help healthcare owners to better understand and specfiy the 'what' and 'why' asset information is required, and also the 'how' , 'when' and by 'whom' it needs to be delivered at the project handover and duirng the operational stages.

4. Potential benefits and opportunities for the healthcare sector

4.1 Client & FM providers

Healthcare sector owners, operators, and users can acquire new operational and performance related benefits when asset information requirements are aligned to core organisational and business strategy objectives and delivered through a standardised information management and openBIM process.

The Institute of Workplace and Facilities Management notes 'to optimise built assets in operation or replace assets over their life, FMs need easy access to data and information about the assets and to be able to measure how the assets are performing. This requires good quality and well-structured information about the assets in the portfolio and the ability to produce reports on their condition and performance'. (1)

A group of FM information system (FMIS) suppliers indicates in a Facilities Management Netherlands (FMN) white paper that 'integrating BIM with our (FMIS) solutions has much to offer. In a nutshell, it improves information management processes for facilities, making information more reliable and more strategically useful.' (2)

The potential benefits within the healthcare sector are numerous and varied across estates, buildings, capital projects and operational expenditure scenarios. A range of example contexts, benefits and associated information requirements are considered in more detail in the following sub-sections.

4.2 Capital expenditure (CAPEX)

Captial expenditure is a one-off expenditure scenario 'that results in the acquisition, construction or enhancement of significant fixed assets including land, buildings and equipment that will be of use or benefit for more than one financial year'. (3)

In the healthcare sector this would include the construction and delivery of new hospitals, extensions, spatial reconfigurations or refurbishments, and the upgrade or replacement of core asset systems e.g. HVAC, alarm or fire-suppression.

4.3 Establishing the information requirements

Owner / organisations should establish their project and asset information requirements at the project outset in accordance with ISO 19650-2 and contracturalise the relevant design and construction team parties to deliver these requirements at relevant project stages. The project and asset information requirements should be established with key input from existing FM, user and operational stakeholders. (4)

Early engagement and input from these stakeholders is critcal, as typically it is these groups or individuals who will require access to, or need to update asset system information and data records in the operational phase. Their valuable experience and knowledge on existing FMIS or CAFM's needs to be captured and used to inform the project information handover requirements, especially where new FM software(s), technology platforms or sensor devices are being delivered and require integration with existing systems and networks. A further, crucial part of the information requirement is to establish an open, interoperable identification system so that locations, assets and building materials can be tagged and tracked from the design stage.

4.4 Potential benefits

The adoption of an OpenBIM process and common data governance standards will enable the delivery of asset data and information which can be used to improve the management and performance of the new healthcare building asset.

The as-constructed (as-built, final) BIM (Building information model) can provide an accurate digital, representation of the physical building asset which can continue to be updated by the FM team to maintain an as-is condition and live record of the building, and its inherent systems and assets.

Owners and FM operators can access the digital BIM/ AIM (Asset information model) to search and retrive technical, manufacturer and spatial location information on assets within a facility, or across an estate portfolio. This function can be performed either physically on, or remotely off-site by different stakeholders, and used for strategic planning and decison making.

Quality, accurate BIM records of the existing buildings and facilities can be used by design and contractor teams who may be appointed for future refurbishment, extension, decommissioning or demolition works across the healthcare estate.

Inherient data within a project BIM can be used to perform comparative analysis checks on design vs actual performamce and used to virtually simulate and test the design performance of any proposed building changes or extenstions during the operational phase.

4.5 Operational expenditure (OPEX)

Operational expenditure is an expenditure 'incurred as a result of the day-to-day operations of a business (or estate). Operational expenditure might include wages, utilities costs, maintenance and repairs, rent, sales, general and administrative expenses' (5)

In the healthcare FM sector this would include the costs associated with providing services to the faciliy owner to maintain and operate the estate, buildings and assets.

4.6 Establishing the information requirements

To deliver the technical and operational performance requirements of new and existing healthcare facilities, accurate, up-to-date asset data and record information is required. This includes the need to assign and register all maintainable, installed assets and their locations within the facility, so required maintenance works can be planned, or in the event of an operational failure, and the need for a reactive response, the faulty system or assets can be easily located.

ISO 55002:2018 states organisations should determine their information requirements and establish the necessary systems and processes to collect, collate, store, maintain and transfer asset information in order to achieve their asset management objectives. (6) Correspondingly, ISO 19650-3 sets out a standard information management process for asset owners and operators to adopt, plan and procure their asset information requirements across different and varing portfolios, assets, and associated trigger events in the operational phase. (7)

As discussed, physical asset systems and components that require periodic maintenance and control checks should be digitally registered and easily located within healthcare facilities. All associated digital operational and maintenance (O&M) information should be hosted within a common data environment (CDE) solution, and easily accessible by different stakeholder groups.

Within the CDE all records, BIM models, and documentation is centrally stored and exchanged in a structured and secure manner, in accordance with recognized international standards.

To achieve this level of functionality and accessibility, spaces, systems, and components need to be uniquely identified (name/ code) and classified so the associated O&M information and data can be linked.

4.7 Classification assignment

On new projects the assignment of classification values to BIM spaces and 3D geometry occurs during the design stage. The classification values are then checked, retained, or updated during the construction stage, to reflect the as-built or as-installed status. For the operational stage the classification values and unique asset identifiers (name/code) can be used to link the BIM spaces and objects to O&M documentation from both engineering, construction as well as the manufacturer's product documentation.

The type of classification schema adopted on new healthcare facilities is usually defined by the geographically location of the project. Globally there are four main construction industry classification systems, these being Omni class (North America), Uniclass (UK, also used in Europe, Australia), MasterFormat (North America) and UniFormat (North America). (8)

In addition to classification, healthcare clients often mandate the requirement to embed other industry standard references and codes within project building information models (BIM), for compliance and operational purposes. An overview of three primary examples is reviewed in the following subsections.

4.8 HTM/ HBN

In the UK, NHS England have developed HTM's (Health Technical Memorandums – e.g., HTM 03-01 specialist ventilation for healthcare buildings) to provide comprehensive advice and guidance on the design, installation and operation of specialized building and engineering technology used in the delivery of healthcare. They are applicable to new and existing sites (projects) and are for use at various stages during the building lifecycle. (9)

HBN's (Health building notes – e.g., HBN 00-08 the efficient management of healthcare estates and facilities) provide practice guidance on the design and planning of new healthcare buildings and on the adaptation or extension of existing facilities. (10)

The NHS framework delivery partners have worked together to develop a suite of 24 repeatable and configurable room arrangements using a standard components library which are compliant to the HTM/ NBN requirements. The layouts and components have been modelled using BIM, embedded with the relevant codes and product information and freely available to project stakeholders within the framework.

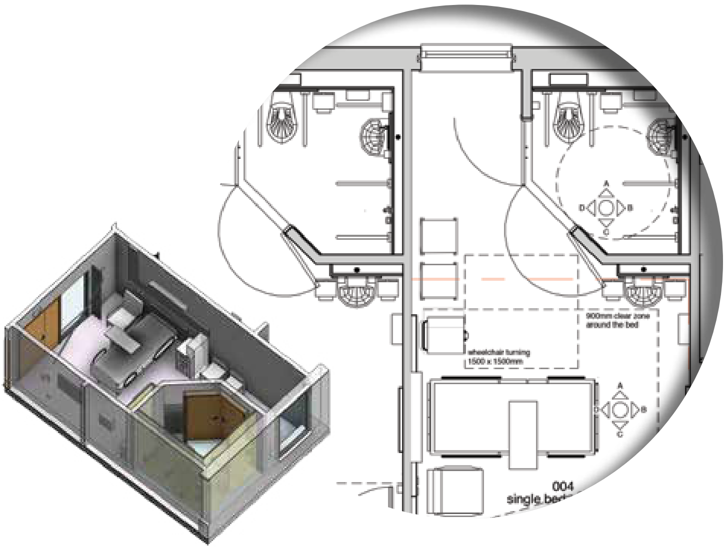

Figure 1: NHS, Repeatable Rooms in BIM

This work has seen significant cost reductions and time-savings for all parties involved in the consultation, design development, construction, and supply chain delivery processes.

Figure 2: NHS, Room arrangements in BIM, emergency dept

Figure 3: NHS, Room arrangements 360, multi-bed bay

There are exponential benefits to be gained through the extended utilization of the BIM healthcare room layouts, product data and the interactive virtual 360 environments in the operational phase, which is further explored in this paper.

4.9 GS1

GS1 open standards are based on ISO standards and used globally across 25 sectors, including Consumer packaged goods, transport and logistics, healthcare, and construction/ DIY. Currently, GS1 identification standards are the most widely used standards in the clinical and medical functions of healthcare including locations, assets, medical devices, implants, medication, food and beverages and hospital consumables.

The standards create a common foundation for businesses to uniquely identify, accurately capture and automatically share vital information about products, locations, assets and more. (11)

The identification standards establish unique identification codes (e.g., GTIN, the Global Trade Item Number, GIAI, the Global Individual Asset Identifier and GLN, the Global Location Number) which may be used by an information system to identify and refer to real-world entities (e.g., products, assets, and locations). The capture standards define barcodes (e.g., QR or Data Matrix) and radio frequency (RFID) data carriers to enable identification keys to be affixed to the physical locations and assets (fixed or movable). These are readable using hand-held scanners, smartphones, and the like. The share standards include data standards for securely sharing relevant data between applications and across a supply-chain network. (11)

Figure 4: GS1 system of standards

BuildingSMART International (bSI) and GS1 are currently collaborating to help digitalize the construction industry to find integrated workflows across the whole lifecycle of the build asset. Their aim is to provide a digital supply chain through the combination of openBIM® processes with the identification of products and assets, parties, logistics units, and more.

Alignment of their existing open standards has the potential to enable the interoperability and assessment of building asset and product data (e.g., identification, traceability, live operational performance) across all lifecycle stages, stakeholders, and supply chains, thereby overcoming the limitations of 'walled-garden' proprietary identifiers.

For example, when applied to Industry Foundation Classes (IFC), Global Trade Item Numbers (GTIN) would provide real opportunities to better understand information and products inside a building or facility. (12) The BSI and GS1 collaboration work is starting to deliver real benefits on real healthcare projects around the world. Two excellent examples of this are presented in the case studies section of this paper.

4.10 SFG20

SFG20 was launched in the UK by the Building Engineering Services Association (BESA) and recognized as the industry standard for building maintenance specifications. It is a web-based service, with a growing library of over 1200 maintenance schedules, covering more than 70 equipment types. The digital library is kept up to date with the latest legislation and can be choreographed to develop specific sets of maintenance schedules and task priorities for clients to mandate or adopt on their estate, buildings, systems, and assets. Within healthcare FM, HTM/ HBN guidance can be linked to SFG20 tasks and assigned to in-house or out-sourced operators to periodically check and maintain the installed assets in accordance with statutory compliance or product manufacturers requirements.

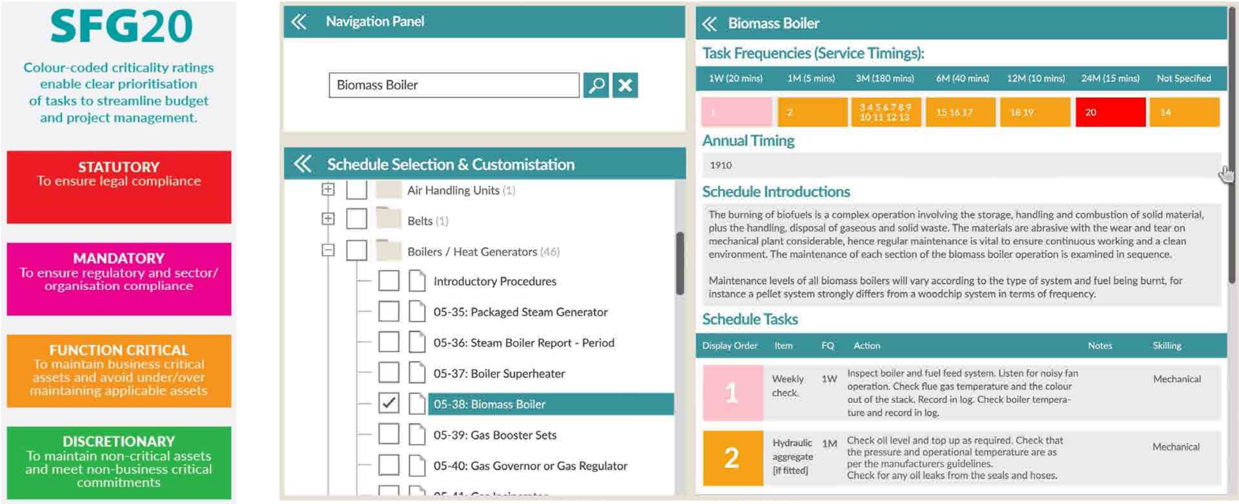

Figure 5: SFG20 criticality scale and schedule selection

Schedule tasks can be mapped to classification (e.g., Uniclass) and GS1 codes enabling the operators to review corresponding BIM spaces, 3D asset geometry and associated O&M documentation, on portal or handheld devices. Specific examples and benefits of this are discussed in the following section.

Section 8.0 of this paper outlines three healthcare project case studies which are currently or have adopted the standards and processes discussed in this section.

4.11 Potential benefits

Asset condition capture, monitoring and reporting.

An as-constructed BIM or asset information model (AIM) can be used to generate accurate inventory lists of all installed assets and linked spaces within a healthcare facility, particularly those requiring periodical condition survey, statutory compliance, and maintenance checks during the operational phase.

Mapping 3D model objects and associated O&M information to captured survey data can enable comparative reviews of the designed vs physical condition and performance of installed asset(s). Over a period, this database and analysis can provide insights into what assets are not performing as expected, prone to faults and likely to defect or fail. Further temporal and financial data associated with recorded incidents can improve future planning and budgeting and help assess whether certain assets can be replaced with more durable solutions. This can help prevent situations where the accumulative time and cost to repair problematic assets eventually outweigh the cost savings and benefits of installing a replacement earlier.

Eventually, this can be supplemented with data from sensors that continuously record both real usage, wear and condition and provide even better data for condition-based and predictive maintenance before an incident occurs. This valuable insight can help reduce risk and resultant costs arising from reactive works and operational down-time.

When unique identifier and classification codes (e.g., GS1 GTIN, Uniclass 2015) are linked to physical assets, captured performance data can be disseminated back across supply chain networks e.g., operators, clients, manufacturers, and designers, to improve the specification and selection of future systems and products.

4.12 BIM and dynamic system data integration for better FM operations.

Healthcare facilities and the services they deliver are complex and demanding, consisting of many systems and dynamic processes which need constant monitoring, orchestration and maintaining. Within the facilities there are many critical areas such as operating theatres, intensive care units, and laboratories. It is essential that systems in these areas are working 24/7 to help save lives and guarantee a high patient care throughout.

For that reason, installing equipment and system sensors in hospital buildings to track and react to arising issues have been in place for many years.

Nevertheless, often enough, the dynamic data that building systems deliver is hard to obtain, (e.g., within a proprietary BMS-building management system) and when obtained, it is not referenced with the correct source location in the building, making it hard to interpret and analyse.

Academic research in this area has highlighted BIM integrated with building system controls for monitoring building performance in real time, can enable facility managers to fine-tune building equipment for optimal performance. (13) In its smart hospital paper, Siemens notes 'one of the fundamental concepts of smart hospitals is not just to solve individual problems by implementing technology-led solutions, but to drive large additional benefits by integrating these new digital investments and the disparate legacy systems and devices within an open ecosystem. Only by integrating these different systems and ensuring the data is available hospitals can create large-scale benefits from digitalization rather than a collection of tactical initiatives. (14)

Therefore, the linking of asset identification, BIM information and dynamic system data, can provide new opportunities for owners and FM operators to perform analysis and evaluate how their buildings are behaving or deteriorating over time. In return this can help support better decisions on how to plan preventative maintenance work and to complete repairs.

4.13 Tracking and detecting asset and equipment failures

BIM models and associated asset (O&M) information can be linked to building management system and alarm systems to help facilities managers detect and react to asset/ equipment failures faster. Helping get the right maintenance task team or support specialist to the problem quickly, reduces the risk of patients and medical staff being affected by the unplanned incident.

Often, installed BMS or other systems with alarm functions will only provide a technical overview of the issue, and no indication of asset or alarm location. This is problematic for assigned specialist or in-house FM personnel who will need to know the location, what system or inter-connected systems are affected, and what departments or zones of the facility are potentially impacted. It is common for maintenance personnel to wander around in a building until the problem asset is located, and only when it is found, are the necessary access and repair requirements able to be determined. This added delay creates unnecessary downtime and potentially increase the risk of medical staff and patients' health and safety.

Having linked BIM spatial and asset data to the BMS alarm system, allows the response management team to quickly ascertain:

- the fault or failure location,
- what systems, inter-connected systems or asset(s) are affected,

- what personnel, safety / access equipment, temporary signage, spares, or specialist tools are required, and
- what medical staff or other building users need to be informed
- what precautions or actions need to be undertaken, and what alternative spaces, wards etc. are available if patients or staff need to be urgently or temporarily relocated.

4.14 Energy efficiency and optimization of system performance

Hospital estates and their facilities require significant amounts of power to sustain the non-stop demands of operational services and systems (e.g., heating, lighting, ventilation, refrigeration, communication, IT, security etc.), as well as the electrical medical and cleaning equipment.

Managing and controlling energy consumption within healthcare facilities is a constant challenge, particularly in the current age of rising energy costs and global climate change. Healthcare owners and trusts are recognising the vital role of interoperable technology and digital processes to help them capture the right data to gain control and management of their energy use, within the constraints of reduced financial budgets and demanding environmental targets, such as net-zero carbon.

To successfully use technology and data to help achieve their target outcomes, healthcare owner-operators firstly need to establish what type of data they require, where it is located and sourced from, and who or what are the data producers or providers. In addition, necessary protocols, processes, and procedures need to be established and implemented for the capture, exchange, storage and analyse of the data.

Using BIM -based BMS helps drive a better analysis of energy efficiency and system performance in the building, making the energy expenses more transparent. This can be done by tracking near real-time data of energy generation and by monitoring self-consumption and respective storage. Together with the system's location, an early corrective action to prevent budget overrun and inefficiencies are enabled. Additionally, associated CO_2 emissions and cost on global level can be tracked.

4.15 Tracking space utilization

With the help of BIM-based room comfort systems and dynamic data, a precise analysis of space utilization in the facility can be supplied. Space utilization analysis helps FM understand the spatial limitations and advantages of their managed assets. It can show areas of high utilization, which might create a bottleneck for day-to-day operations and emergency cases. It can also display areas with low utilization that should be redesigned for more critical processes. Spatial analysis and the combination of BIM-based comfort systems and dynamic data can help FM establish complex emergency operations like re-assigning building parts to the care of pandemic patients.

4.16 Better booking systems and better equipment utilization

Booking systems are used today to manage significant parts of the built assets of hospitals, such as operation and consultation rooms. Nevertheless, most booking systems used today cannot capture real-time data. As a result, the staff members cannot know if a room is utilized longer or shorter than expected. Combining BIM-based room comfort data and dynamic data from the building sensors allows a clear association of a room with its occupancy data. The booking system can then retrieve this data to enable a better and more precise understanding of the schedule. Improving the booking system with real-time data will help hospital staff achieve higher utilization of operating rooms and special equipment. It can help the cleaning team become more agile and efficient based upon the level of occupied use each the correct locations on time and reduce the manual effort of managing an unclear schedule.

Many more beneficial use cases can be enabled by simply linking BIM data with dynamic data from automation systems. For example, understanding equipment utilization can help achieve easier and quicker maintenance of hospitals equipment. Additionally, basing the cleaning services on real-time data and booking systems and analysing the air quality data of frequently utilized rooms can help create a more sterile work environment. In addition, advanced simulations of people-flow and airflow based on BIM and dynamic data can deliver insights about the possible spread of contagious diseases and the influence of emergency scenarios on operational activities in the facility.

Figure 6: Space booking system example

4.17 Clinical staff and hospital patients

The clinical staff are the largest user group in healthcare facilities. Before the BIM models are made available to the internal healthcare environment, the target user outcomes, benefits, and training needs should be established. The ability for users to easily feedback any technology-related issues or future development ideas are important. The day-to-day use of BIM geometry data through apps or handheld devices may require some users to adopt a different mindset to help realize the benefits and efficiencies.

One obvious benefit is the ability of clinical staff and patients to access the BIM 2D layouts and 3D spaces to help them navigate around or occupy parts of the hospital facility more efficiently. This is especially beneficial for new staff, patients, and visitors, for example:

- Out-patients or visitors arriving at the hospital for an appointment can virtually check-in and check-out via an app and receive a 2D location map and wayfinding instructions on where they need to go.
- Patients staying in the hospital can virtually control their local environment via a fixed touchscreen or smart phone app linked to services and sensor devices. The patients can adjust the local temperature, lighting and blinds around their bed or private room. Virtual 3D spaces developed during the design phase can be repurposed so patients can have a more interactive and immersive experience.

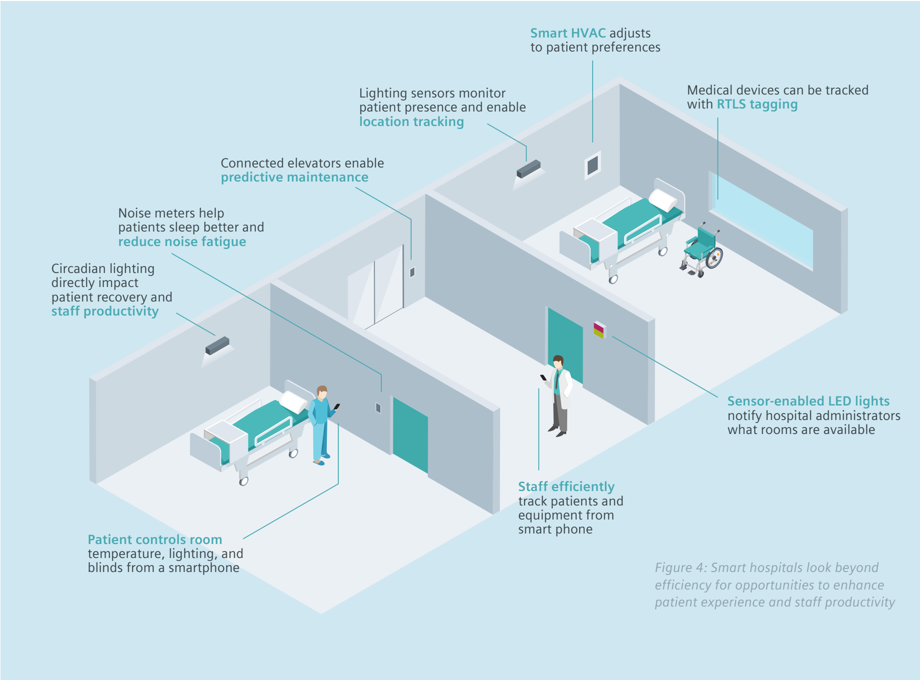

Figure 7: Smart hospital functionality, Siemens

- Staff can virtually search for available consultation or treatment rooms, via an app, book one and automatically receive a 2D map and wayfinding instructions from their current location. They can then release the space when finished, which will auto-alert the cleaning staff to come and sanitize before the next booking.
- Clinical staff can easily report building or equipment faults via a phone app and steps: initially scan a fixed identifier tag or barcode (e.g., GS1: GTIN + GLN) on the faulty asset, complete a short questionnaire on the problem form and send it along with a photograph to the FM team. Because the asset identifier code is linked to the BIM spatial and product data the FM team can automatically see where the fault location is, what the installed asset or product is, who the manufacture, installer was, what valid warranties, service support or spares are available etc.

Figure 8: GS1 identification for FM

- Moveable medical and patient equipment (e.g., already using GS1 identifiers) can be individually tracked within the healthcare facility using a combination of 2D plan layouts and real-time location sensors. This allows clinical and service support staff to easily locate patients and check availability of beds etc.

If the healthcare facility BIM and asset information is centrally located within an owners or FM operators' common data environment (CDE), any changes or updates within this environment can automatically update the same copied or referenced information within 3rd party software platforms or apps. This mitigates the potential risk of users receiving or making decisions from misinformation and allows the building information to be managed in a quality manner for the whole asset lifecycle, whilst other functionalities and 3rd party applications can be replaced.

The below table outlines a range of captured benefits, following the integration and use of open BIM within a Norwegian health-authority. All employees also had the opportunity to register building-related requests and issues in the same system that the operating personnel use. The table below highlights a range of different benefits and improved quality outcomes:

Stakeholder	Requirement	Benefit	Transformation
Clinical Management and healthcare personnel, clinics, and other units.	Sensor data at room level	High	Data driven planning and execution of patient pathways, as well as novel use of simulation and visualisations.
Clinical Management and healthcare personnel, clinics, and other units.	Properties from different phases, "as built" and "intended use/can be used as"	High	Better overview of capacity and possibilities within the existing building (exemplified by Covid-19)
ICT-personnel	Equipment in room	Median	Authoritative and continuously updated information about equipment localization.
Top management	Volume-models for area planning, capacity overview, scenario-simulations	High	Strategic management based on a virtual environment.
Society	Virtual buildings and infrastructure sharing data.	High	Autonomous systems across sectors. Interaction between healthcare enterprise, management, and users (smart hospital, smart city)

5. Navigating the standards (ISO 41000, 55000, 19650)

So far, this paper has highlighted the current issues causing the failure costs in Healthcare FM and reviewed a range of potential benefits (for owners, operators, staff, and patients), when static BIM information and live operational data is connected and utilised. Keeping the BIM record information centralised, live and up to date is critical, especially when it is being reliably used for analytics and daily operational management purposes.

The need for owners and operators to adopt current and relevant industry standards is essential, as this will allow the correct processes and procedures to be established and support open-data exchange and technology interoperability through the building asset lifecycle. Since 2018, the ISO 19650 parts 1-3 series have been released to provide a standard approach for information management using BIM in the project and asset delivery phases.

Understanding what these standards mean in practice and how they can be knitted into FM standards and processes already established within healthcare organisations can be challenging.

The below sections summarise key aspects of the international standards for facility, asset, and information management using BIM, which healthcare owners and operators need to be aware of and should consider adopting, if not already in place.

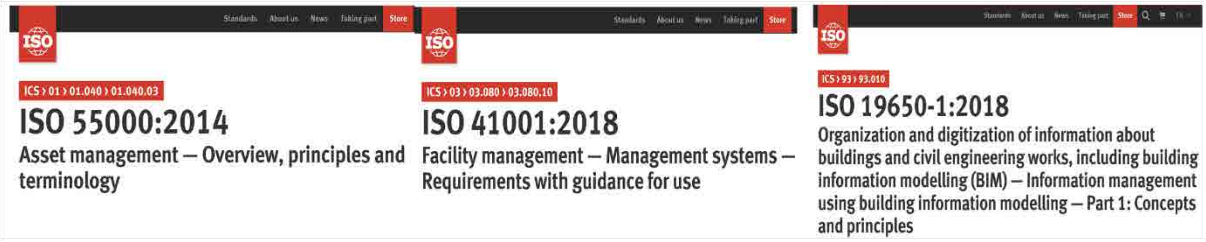

Figure 9: ISO standards for FM, AM & IM

ISO 41001:2018 Facility management – Management systems – Requirements with guidance for use.

The primary driver for ISO 41001 is to provide a common basis upon which FM can be assessed and measured, to raise the standard of care and increase levels of quality, thereby stimulating organizational maturity and competition for the delivery of FM. (15)

This standard outlines a 'process approach' and a Plan-Do-Check-Act (PCDA) methodology to develop, implement and manage the delivery of a FM system. At the outset, the FM organisation (operator) and the demand organisation (client/owner) need to work together to clearly define the core business strategy and outcomes, and then develop FM policies, aligned FM objectives and any necessary processes to enable the delivery of the business activities and organizational outcomes.

One of the key pillars of 'supporting the FM system' is the availability and provision of FM information and data to the owner and operators. The standard notes the importance of owner organisations determining what their information requirements are, and the need to establish appropriate governance and management procedures, to store, exchange, update and maintain the FM information and data over the facility lifecycle. Their information requirements should include monitoring and measurement data which enables the periodical review of the FM activities and performance. This will require the establishment of 'data collection processes', and the support of stakeholders to capture the data at known 'trigger' stages and events. Within the ISO 41000 series, ISO 41014:2020, further set outs a process for developing the FM requirements for different types of facilities and target outcomes. (16)

ISO 55000:2018 Facility management – Management systems – Requirements with guidance for use.

The objective of ISO 55000 and the companion ISO 55001 and 55002 standards is to enable organizations to achieve their business objectives through the effective and efficient management of its assets. The establishment of an asset management system forms part of the solution and provides assurance that the objectives are being achieved consistently and sustainably over time. (17)

Like ISO 41000, this standard discusses the need for organisations (owners) to develop an asset management system (17) including an asset management policy, objectives, and the necessary processes to help deliver key objectives, in areas such as risk reduction, asset performance, energy management, environmental management.

ISO 55001 sets out detail of the asset management system and includes the need for owner organisations to establish their information requirements to support the management of their assets, and the delivery of asset management objectives.

When determining their information requirements, the organisation should consider aspects such as roles and responsibilities, the asset management processes, required procedures and activities to capture the information, how the information will be stored, exchanged, and checked for accuracy and quality.

Lastly, the standard outlines the importance of performance evaluation, and the need to establish the right governance and processes for monitoring, measuring, analysis and evaluation of captured asset data. This will help ensure the facility is meeting any energy or sustainability targets aligned with the organisational asset management objectives.

ISO 19650: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling.

The ISO 19650 3-part series supports the management and production of information using building information modelling (BIM) during the life cycle of assets. When adopted, the standardised processes can deliver beneficial business outcomes to asset owners, operators, and the wider supply chain, and help reduce risk and cost through the production and use of the asset and project information models. The standard is applicable to build assets and construction projects of all sizes and levels of complexity and focuses of the pivotal need for all projects stakeholder to work in collaborative environments to communicate, re-use, and share the information efficiently and reduce risks associated with the use of poor quality or inaccurate information. (18)

The Part 1 (2018) standard establishes the concepts and principles for developing the asset information models (AIM) and project information models (PIM), using both structured (models, schedules, databases) and unstructured information (documents, videos), which require the clients, asset owners to understand and establish what their information requirements are, to support their strategic business operations, asset management, regulatory duties etc. The below figure illustrates the different types of information requirements and information models.

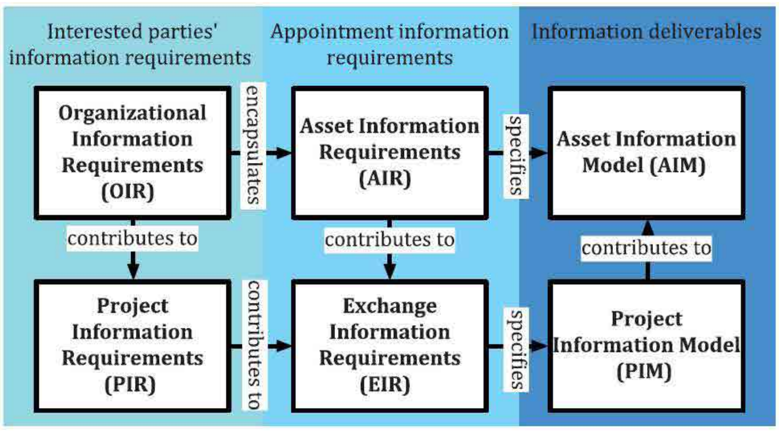

Figure 10: Hierarchy of information requirements, ISO 19650-1

Part 1 (2018) also sets out the requirements for the planning and delivery of the information models, including the appointments of the parties who will produce/ provide the information, the information breakdown, delivery verification and validation process, and the establishment of the common data environment (CDE) to host and manage the digital information during the project delivery and asset management phases.

Part 2 (2020) establishes the information management process during the delivery phase of assets, which includes agreeing the information to be delivered, milestones, standards, protocol, production methods and procedures, CDE setup and the tender process to appointment the project delivery team. In the UK a national annex for part 2 is available which sets specific classification (Uniclass 2015), naming conventions and information model exchange requirements. The adoption of IFC (Industry foundation class) as an open data format for file sharing and information exchange is recommended.

Part 3 (2020) establishes the information management process during the operational phase of assets. The information management process is aligned with the requirements outlined in part 2, allowing for continuity of information flow, delivery, and management between the different asset lifecycle stages. Determination of the asset information requirements in Part 3 is different and is based upon the scale and complexity of: the asset, the required response to foreseeable and unforeseeable trigger events (when information is needed), and the delivery team appointed. Within the annex, practical examples of typical activities, triggers events and information requirements are provided offering a real-life context and supporting adoption of the requirements.

6. The golden thread of information requirements

In the previous review of current international standards for facilities (ISO 41000) and asset management (ISO 55000), a repeated core need for asset owners and operators to establish their information and data requirements was identified. This was noted as essential for them to successful deliver their organisational objectives or business strategies and operate their assets effectively and efficiently across the full lifecycle.

There are many important aspects and reasons for requiring quality record information (static) and live operational data (active) for new and existing healthcare facilities e.g., legal, statutory, and legislative, health, and safety, environmental, sustainability, and in this current technological and digital information age, having an adaptable standard (ISO 19650) which enables digital information requirements to be collaboratively produced, exchanged and managed within an open, structured process is imperative.

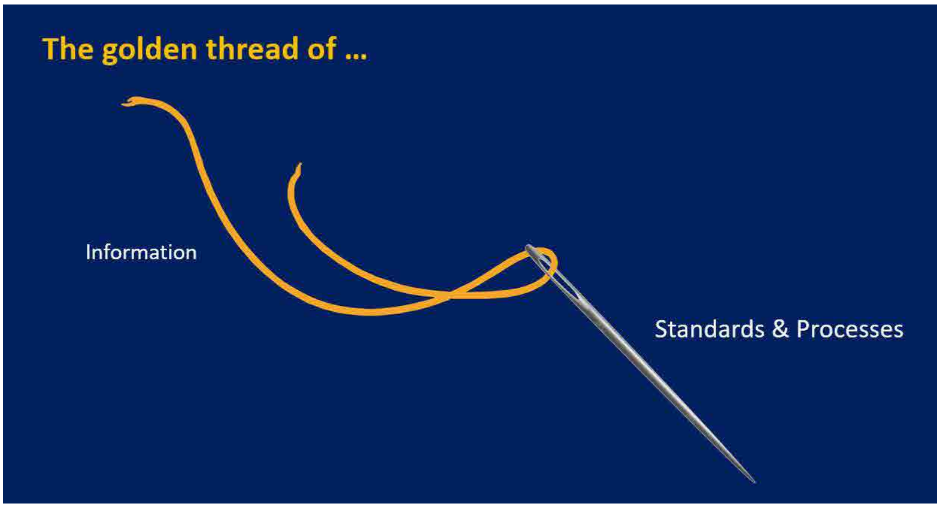

Figure 11: Standards & processes guides the golden thread of information

The term 'golden thread' has been used in different industries for some time and can relate to different contexts or scenarios depending on what industry you are involved in. With the UK the Building safety Bill refers to the golden thread as both:

- the information about a building that allows someone to understand a building and keep it safe, and
- the information management to ensure the information is accurate, easily understandable, can be accessed by those who need it and is up to date.

This legislation ensures it is the duty of the people responsible for a building (facility) to put in place and maintain a golden thread of information. Having a golden thread will mean that those people responsible will have easily accessible, reliable, up to date and accurate information. Without this information, it is very difficult to manage buildings safely. (19)

Implementation of the golden thread of information will require individuals and organisations responsible for healthcare facilities to have appropriate information management systems, standards and processes in place and a clear understanding of how information management supports building safety. What has been outlined in this paper thus far will help support this, in any geographical region.

7. The business case for openBIM for FM

As the construction and FM industries become fully digitalized, there will naturally be a need for better digital technologies, connectivity and interoperability across sectors, organizations and different technology levels. Currently, there is a growing demand to connect the virtual world to the physical world, to unlock new ecosystems and ways of working, to better manage our physical assets in more efficient and sustainable ways. Digital replicas, or digital twin technology can analyze data captured from live sensors within physical building spaces and system assets and calibrate the way they are utilized or perform, to meet operational, sustainable, reduced carbon or energy targets.

The rapid development of information technology within the construction sector and globalization of construction material and products, will also require international coordination of standards and classification systems. It was suggested in a 2016 research paper that there needs to be further study and clarification on 'how the classification structure of IFC (Industry Foundation Classes) as a neutral international open standard can be coordinated with established industry standards and classification systems.' (8)

7.1 What are the pains/gains in using BIM for this specific FM service?

There are so many benefits on leveraging BIM for digital asset management in hospitals. Some of the most important benefits are:

- Cost savings through facilities' lifecycle
- Improvement in information quality and accuracy
- Improved asset integrity
- Automatic and transparent audit trail
- Ability to adopt interoperable identification standards covering the FM, Building Operations and Clinical/Medical functions

Although there are numerous benefits in using BIM for digital asset management in hospitals, there are several challenges that can get in the way of implementing BIM for this use case. Addressing these challenges can help organizations with getting the most out of implementing BIM. These challenges include:

- Demanding industry skills and training: the rapid enhancements in digital technology are not always accepted by workforce. In addition, they need proper training to gain the required skills to be able to adopt the BIM technology. Therefore, educating people in organizations on the benefits of using BIM and having a solid training program is critical for organizations.
- Lack of comprehensive BIM standards: BIM requirements for asset data management are so fragmented in many countries. Different organizations adopt different requirements and that makes it difficult for design and construction firms to comprehend the standards.
- Data interoperability: lack of comprehensive BIM standards means data requirements are not well defined, which leads to data interoperability issues. Data interoperability is key for collaboration between different project stakeholders.

- Intellectual Property (IP) rights: when it comes to sharing asset data, intellectual property rights might become an issue between different project stakeholders. Some organizations are resistant to share the IP rights and are against sharing the organization's operational data and products.

7.2 Recommendations

To support this future use of BIM, clients and industry needs to agree on standardized digital building lifecycle process definitions, optimized open data & information exchanges, and to standardize critical information content with clear identification, classification, naming conventions, and consistent levels of granularity.

Within healthcare there is a need for greater interoperability and open-information exchange between the virtual BIM, facility management, organisational enterprise and building management systems. The enhancement of existing openBIM standards and IFC terminology to deliver these requirements is an obvious consideration. Known and well-proven openBIM benefits design and construction stages are also extendable to the handover and operational stages.

An open BIM for FM approach would ensure:

- Interoperability is centre and key to the digital transformation
- Open and neutral standards are used and developed to facilitate interoperability
- Reliable data exchanges would depend on independent quality benchmarks
- Collaboration workflows are enhanced by open and agile data formats
- Flexibility of choice of technology creates more value to all stakeholders
- Sustainability is safeguarded by long-term interoperable data standards (20)

The development of a FM information requirements protocol would help define how interoperability can be consistently achieved between the BIM/ asset information model, facility management (and the wider healthcare enterprise) in accordance with traditional layers of interoperability. Appendix A of this whitepaper outlines three specific layers of interoperability (semantical, technical, and organizational) in more detail.

8. Case Study examples

a. Vestfold Hospital, Norway

Background

The Norwegian Vestfold Hospital's "Tønsberg Project" is an ambitious multi-award-winning hospital construction project determined to utilize existing and new digital tools and methodologies to achieve measurable results in design, construction, and operation.

The regional health authority owning the Vestfold Hospital, the South-Eastern Norway Regional Health Authority, is responsible for over half of the population in Norway. In the health authority's regional development plan going forward to 2035, 'better use of technology and new ways of working' is emphasized as important for coping with the challenges facing modern healthcare.

In the "Tønsberg Project" IFC has been mandatory for all BIM exchange, and the project has aimed for a complete handover to a standards compliant OpenBIM FM documentation system. The project has achieved BREEAM Very Good certification, won the category for Design using OpenBIM in the 2017 BSI Award, and won the category for Handover using OpenBIM in the 2020 BSI Award.

Figure 12: Vesfold Hospital, Norway

Approach and benefits

The Vestfold Hospital has challenged the industry by implementing GS1 data standards extensively to facilitate unique identification and data capture, localization and tracking of products, assets, and locations, thereby making the building information model (BIM) into a digital twin that solves interoperability gaps between the project phase and the operational phase, as well as between the operators of buildings and the users of buildings. For example, a requirement that all suppliers identify and mark their products with serialized GTINs was difficult to achieve 100%, however, by doing that the project has exemplified an approach for other hospital construction projects within the region to adopt, and now there is no turning back.

A digital twin based on standardized identifiers for products, assets and locations enable interoperability and integration with other technologies employed in the wider context of the hospital, for example dynamic case management systems, clinical logistics systems, ERP and supply chain systems, medical equipment management systems, wireless network infrastructure and track and trace systems. Utilizing the GS1 Digital Link standard for tagging physical assets with GS1 GIAI, and physical locations (spaces) with GS1 GLN provides direct access to the digital representation of those assets and locations, not only for FM operating personnel, but also for patients, visitors, and external service providers. The supplier tag products with GS1 GTINs enabling complete traceability for the lifecycle of products constituting the building.

Importantly, the real benefit for the hospital is not how it can make the handover process more efficient, but how the hospital can utilize technology to support more efficient ways of working in their daily work and operation of the hospital.

An example of an immediate quantitative benefit the hospital has experienced is reduced time spent for the FM operating technicians in finding and accessing relevant information. With the traditional method time spent to find relevant information in a maintenance situation (both planned maintenance and acute maintenance) could range from 0,5 to 3 hours, but with a new method using an OpenBIM FM information tool on a mobile device, the time to find relevant information in a maintenance situation is reduced to 5 to 15 minutes – depending on the complexity.

In 2021 the hospital pioneered a proof of concept, on behalf of the South-Eastern Norway Regional Health Authority, by installing technology in the new built hospital for tracking of physical objects such as goods and shipments, and mobile equipment, e.g., trolleys, beds, medical devices etc. By utilizing the same GS1 standards as mentioned above, the proof of concept successfully demonstrated how, by using GS1 standards and openBIM approach, it is possible to fuse the built environment and fixed assets with dynamic movement and logistics. Now that is Facility Management 2.0

Figure 13: Proof of concept using automatic data capture technology to track movements and logistics

b. National Children's Hospital, Dublin, Ireland - Fexillon & GS1

Background

Figure 14: National Childrens Hospital, Dublin

Introduction

Patients, their guardians, visitors, and staff members are invited to download a Children's Health Ireland (CHI) App which provides them with access to several functions such as appointments diary, hospital contacts list, wayfinding, and menus for ordering meals. Included in this list will be an option to report any issues that they find with services, equipment, furniture, etc. CHI Facility Management helpdesk agents, or chatbots, can engage with the reporter to accurately determine the location and the assets involved and to get a more exact description of the observed issue.

The App will allow the user to scan the appropriate GS1 identification tags – the Global Location Number (GLN) of the location, the Global Individual Asset Identifiers (GIAI) or the Global Trade Item Numbers (GTIN) associated with the asset or part, and the Global Service Relationship Numbers (GSRNs) of the operator or reporter. This provides access to a rich set of data which can guide the agent into narrowing down the exact location and item involved, and to assess the probable root cause of the issue. An appropriate set of responses can be developed using data retrieved from multiple possible sources using the GS1 Digital Link standard. The sources may include some, or all, of the computer-aided Facilities Management (CAFM) system, the Building Information Model (BIM), the "Verified by GS1" service, the manufacturer, or suppliers Product Information System (PIM), electronic documents provided as part of the handover, SFG20 tables, sensors on equipment, CCTV, etc.

A decision tree can generate a set of dynamically sequenced questions to help the CHI FM team establish what the issue is and its likely source. Being able to locate the asset in the BIM model using the GS1 identifiers can provide additional information. For example, is it part of a system and if so, what is upstream or downstream of it? The reporter can be asked to check other parts of the system. The FM team can use the Building Management System (BMS), Industrial Internet of Things (IIoT) sensors and the Environmental Management System (EMS) to double-check the validity of the reporter's observation and ask further questions if required.

Given the size of the hospital and the time it takes for technicians to get around it, leveraging the cooperation of other users can lead to efficiencies. It also good for users of the facility to know that they can report issues and that their report is valued and will be acted on. The individual is recognised and thanked for their efforts to resolve the issue.

The appropriate operative or external service provider with the correct skillset is allocated to the task only when the MRO stores confirms that they can deliver the replacement parts and materials per the Bill of Materials to the work location on a Just-in-time basis. Thereafter, the visiting vendor specialist is aided by filtered knowledge streams that are specific to it needs to schedule their visit and enable them to perform all allocated tasks as efficiently as possible.

Once a response is determined, Maintenance, Repair and Operations (MRO) stores' inventory can be checked for replacement parts, consumables, tools, temporary hoarding, and signage. Where necessary, inventory can be ordered, and responders can be alerted to the earliest available start date based on availability of all required resources. The timing of the arrival of spares, tools and equipment, and technicians at the location of the issue can be synchronised using the power of the CAFM platform supported by a rich source of additional information. The person who reported the issue can be updated with information on the intended response and the estimated time for the issue to be resolved.

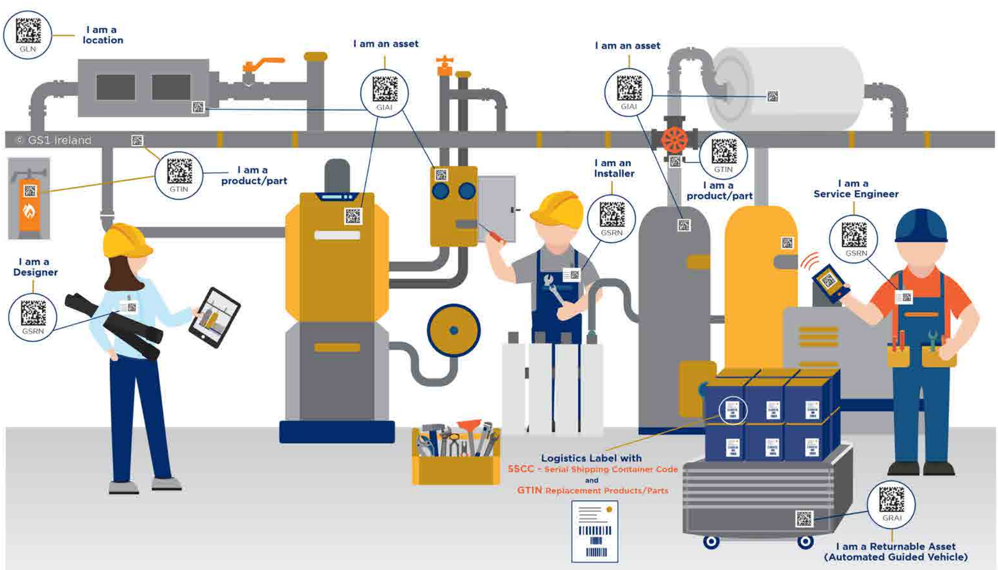

Figure 15: GS1 Identifiers in use in a Plant Room

Spares and equipment are despatched as shipments from MRO stores, Suppliers or Manufacturers stores or other external sources. The operative can scan the GLN and GTIN/GIAI to confirm they are in the right place.

Streamlined and Frictionless Record Keeping.

The technician scans the GS1 Serial Shipping Container Codes (SSCCs) of the consignment from the MRO stores. An Advanced Shipping Notice (ASN), in the form of an XML file, provides details of the content of each package so that the receipt of all necessary parts and equipment can be confirmed. If further information is required on any of the part (e.g., previous history), a lookup using GS1 Digital Link can interrogate the CAFM or manufacturers PIM or other appropriate source.

On validation that they have what they need, the technician can then proceed to complete a series of dynamic Health and Safety related questions on the App or Kiosk to confirm that they comply compliance with CHI policies.

In some situations, the operative could be directed to perform other tasks, such as preventative maintenance, while on site - leading to further efficiencies. Knowledge about the location and the exact assets or parts in it can be used to guide this activity.

When each task is completed, the field service technician is invited (via the App) to provide detailed feedback on the root cause and how the issue was resolved. This feedback can be provided to manufacturers or other interested parties (specifiers, installers, for example) to improve the quality of future products.

On completion, the operator marks the issue resolved. Other responders can then be alerted to complete any follow-up tasks (such as testing, janitorial/cleaning, removing signage, etc.) When all tasks are completed, other stakeholders (including the person who originally reported the issue) can be notified.

Because the Technician, location, asset, and parts are uniquely identified, together with all the timings of the activities, it is possible to accurately review the process to see what needs to be changed to improve future similar tasks.

All parts used are recorded against the asset. The CAFM system is updated. It should also be possible to update other repositories such as the BIM model and the stores Kanban modelling. The parts removed are also recorded and can be sent back to MRO stores. These parts and tools are put into the tote boxes and locked. The scan out on the GLN or GIAI automatically prompts the stores personnel to arrange retrieval of the tote boxes and removal of temporary signage and barriers etc.

Preventative maintenance dates and the predictive maintenance log are updated for all the assets worked-on. During the visit, the technician can make recommendations for future PM activities based on this experience. For example, consumables may need to be replaced more or less frequently, the reactive tasks could dictate changes in installation methods or materials for future visits. This information should be used to update the CAFM system and any other appropriate systems (e.g., Procurement, Inventory, Product Information Management)

A condition survey of the part or asset can be performed for future Predictive Maintenance Data Capture purposes. It can then be put back in stock or sent for refurbishment, repurposing or disposal. These activities are recorded for traceability purposes so that they are visible to future users of the products. Warranties on the returned parts are checked and any premature replacements are noted and, where appropriate, compensation can be sought from the supplier for parts that did not meet the expected performance criteria.

Conclusion

Being able to accurately measure all aspects of the FM function leads to better processes and a much better understanding of where improvements can be made. To achieve this, all locations and maintainable assets need to be uniquely identified using open, globally unique, interoperable, and persistent identifiers. Only the GS1 system provides this. Many stakeholders can become involved in the FM process leading to better outcomes for all. The safety and comfort of patients, and those who care for them, is enhanced.

c. Leeds Teaching Hospital – NHS Trust / SRO Solutions

Background

Leeds Teaching Hospital NHS Trust (LTHT) is one of Europe's largest teaching hospital trusts covering 500,000m² of floor space over 45 hectares of land and across 5 main sites ranging from Victorian listed buildings to new build developments.

To improve the experience and quality of care for the thousands of patients, staff and visitors that use the LTHT physical environment every day, the Estates & Facilities team have created a vision to build an outstanding healthcare environment for patients and staff, underpinned by six strategic goals to support and enable LTHT's objectives in maintenance (Ops & FM) productivity, sustainability (including Net zero carbon), estate rationalization & space optimization, supporting patient-centric and corporate requirements, and advancing digital maturity.

The Hospitals of the Future (HotF) programme, consisting of multiple new build projects as part of the UK Government's Health Infrastructure Plan (HIP), will provide LTHT long-term investment to ensure a world-class healthcare system and facilities, and the opportunity to review current ways of working and existing technology.

The HotF programme focuses on capital expenditure to undertake works such as a new Pathology Laboratory, Children's hospital, and adult hospital (the latter two aka HotF), however the overall estate is much larger than these specific projects, so consideration also given to estates legacy systems, tools, processes, and delivery capabilities to maintain step with the modern capabilities introduced through the new build activities.

SRO Solutions have been working alongside the PCSP (primary supply chain partners) and LTHT EFM (Estates and FM team) on the Pathology Laboratory, HotF and the wider legacy estate project in the capacity of independent digital advisors with a special focus on ensuring the design activity will dovetail into a best-in-class operational environment that will enable the Trust to deliver on their stated desired objectives and lay a foundation for innovation exploitation into the future. Our approach is designed to allow the Trust to keep the legacy in step with the new build programmes and deliver a truly digital hospital of the future across the Trusts whole estate.

Approach and benefits

For the LTHT new build projects, a key objective for SRO and LTHT is to ensure necessary active (e.g., real-time data from sensors) & static data (e.g., asset and location data) to achieve desired business outcomes is created, structured & shared between systems from early Design phase through to beyond In-Use phase thereby ensuring a 'golden thread of information' across whole asset lifecycle.

To achieve this, we are applying principles agreed with the Trust of using open, interoperable standards and protocols underpinning our integrated systems approach to facilitate creation, extraction, and manipulation of data. This approach will ensure 'future-proof' integration of best-in-breed solutions (assuming they are also using open and interoperable standards), therefore mitigating risk of vendor lock-in using closed, proprietary protocols and 'in-house' OEM standards.

Working as an ecosystem of the partners and software vendors (Fig. 16) with a whole asset lifecycle and data flow mindset helps overcome traditional AEC market flaws by:

- Design to Operate / End-of-Life rather than Design to Handover
- Providing integrated technology and removing data silos and instead driving reusable, sharable data for insights, trend analysis, alerts management, evidence-based decision making, etc.
- Creating an inclusive and sustainable way of working for all vendors and suppliers adhering to same 'open / interoperable' principles.

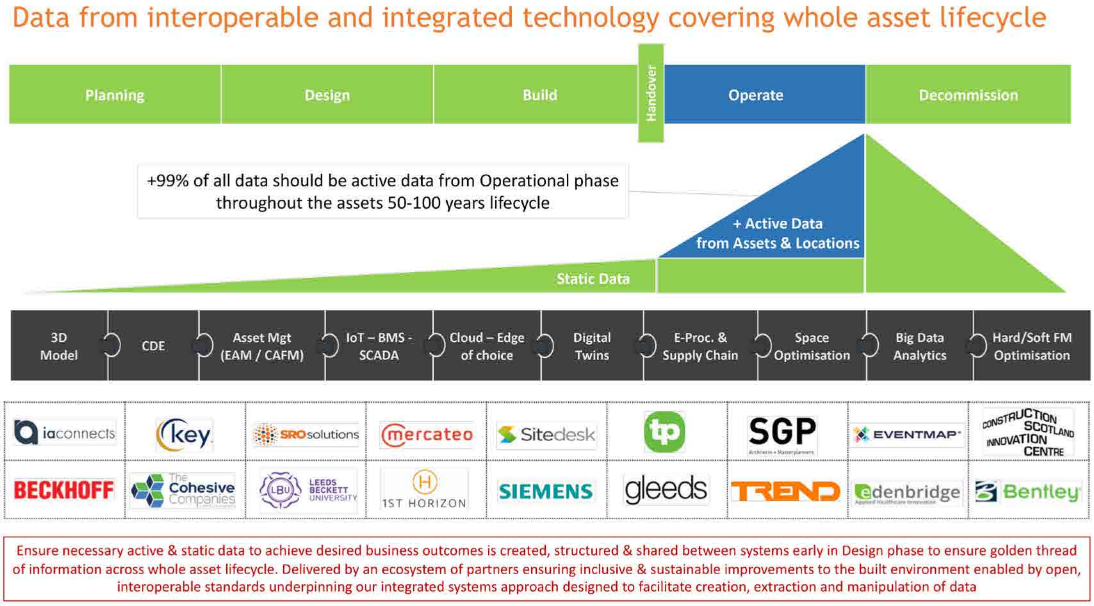

Figure 16: Ecosystem Partner offering

As impartial digital advisors & integrators covering whole asset lifecycle solutions for smart buildings, FM & Ops, SRO Solutions provide the Trust's EFM and PSCP's with education in 'art of the possible' and 'with-end-in-mind' business outcomes thinking. This is a key step in overall approach due to the current lack of knowledge and understanding of what technology – underpinned by BIM processes – can enable for the BE and the benefits that rich, structured, and accessible data can provide.

Data flow supporting 'BIM-to-FM' and driving business outcomes

Starting 'with end in mind' and focus on Operational phase of building where typically 80% of TCO (total cost of ownership) and CO² footprint found (Fig. 17), SRO work backwards from desired business outcome and identify necessary data needed to achieve. For example, if desired outcome is NZC, then ensure static and active data aligned early in D&B phase, e.g., capture energy consumption from assets and locations and compare with presence detection.

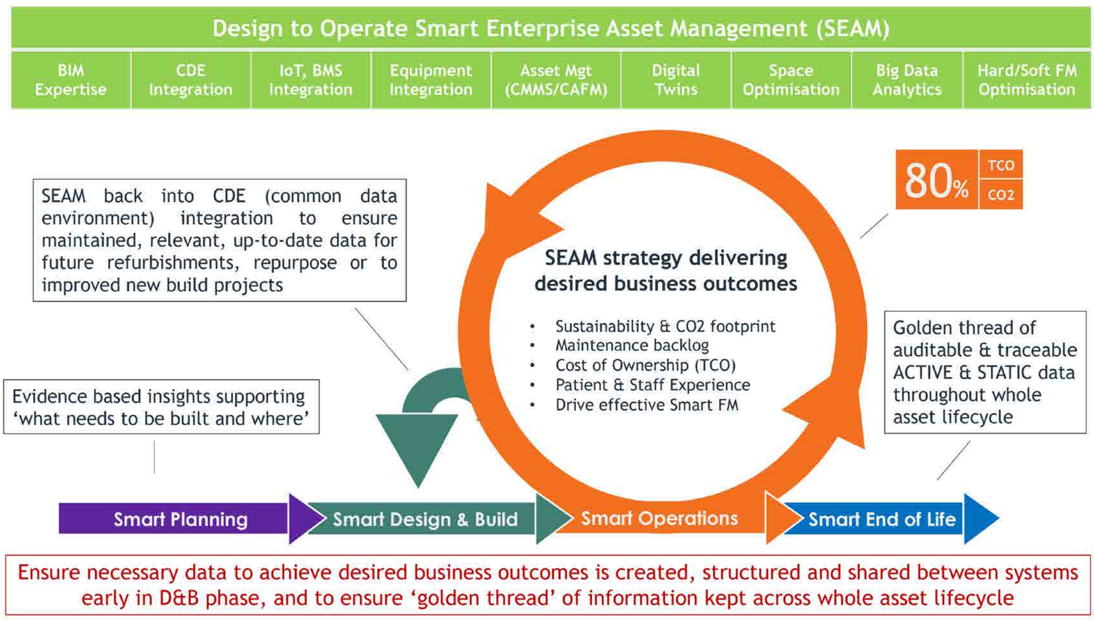

Figure 17: Design to operate SEAM

As these types of scenarios are multiplied for different desired outcomes, more active and static data identified. Ensuring this data is re-usable and accessible data allows different teams (FM, Operations, Energy Management, Clinicians…) to extract and manipulate for additional insights and outcomes. Capturing this data once from interoperable and integrated systems also reduces silos: data, solutions, and cultural / teams (Fig. 18).

The data flow to expose this static data across solutions includes BIM (Revit) model to CDE, CDE to SEAM (smart enterprise asset management: CMMS/CAFM), SEAM to Analytics and SEAM to procurement / supply chain for spares and consumables for job plans (some imported from SFG20) & work-orders – of which can be imported by SFG20 or defined in HTMs. Integration between solutions is done via open-exchange IFC, COBie, APIs, or simple iFrame, punch-out.

Data flow integration for active data includes ability to extract data from OEM assets (e.g., a Siemens BMS) and exposing it via an open & interoperable JSON and MQTT standard.

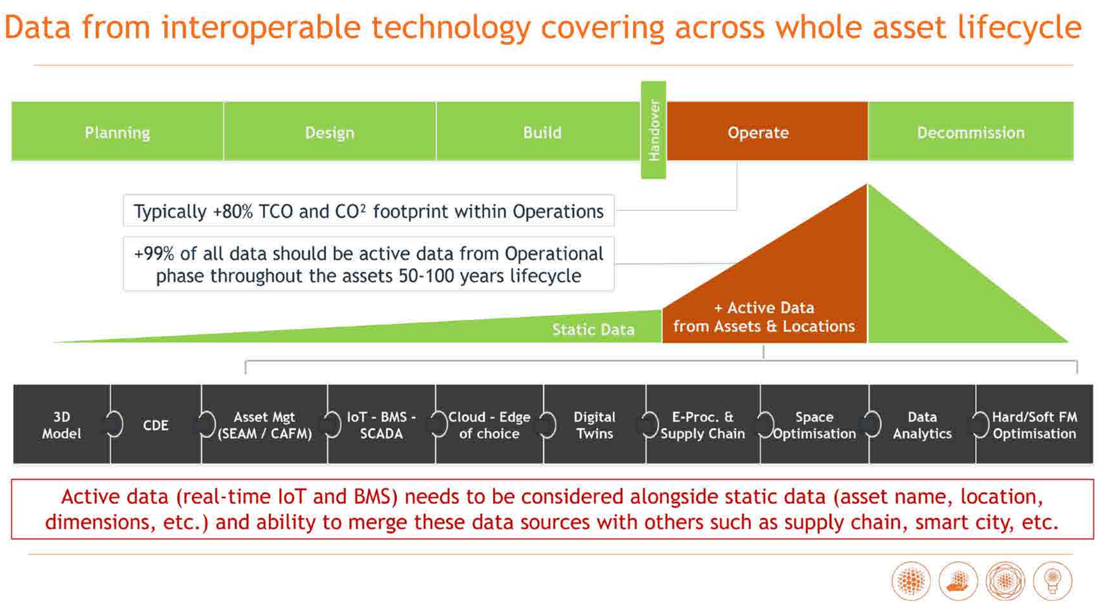

Figure 18: Whole asset lifecycle interoperability

Having a robust metering and monitoring strategy mixed with an integrated solutions approach will enable Scope 1, 2, and 3 benefits (Fig. 19). Although the biggest carbon saving found in Scope 3, benefits are typically overlooked as more difficult to measure and achieve. Examples of how LTHT are looking to reduce Scope 3 via use of SEAM includes:

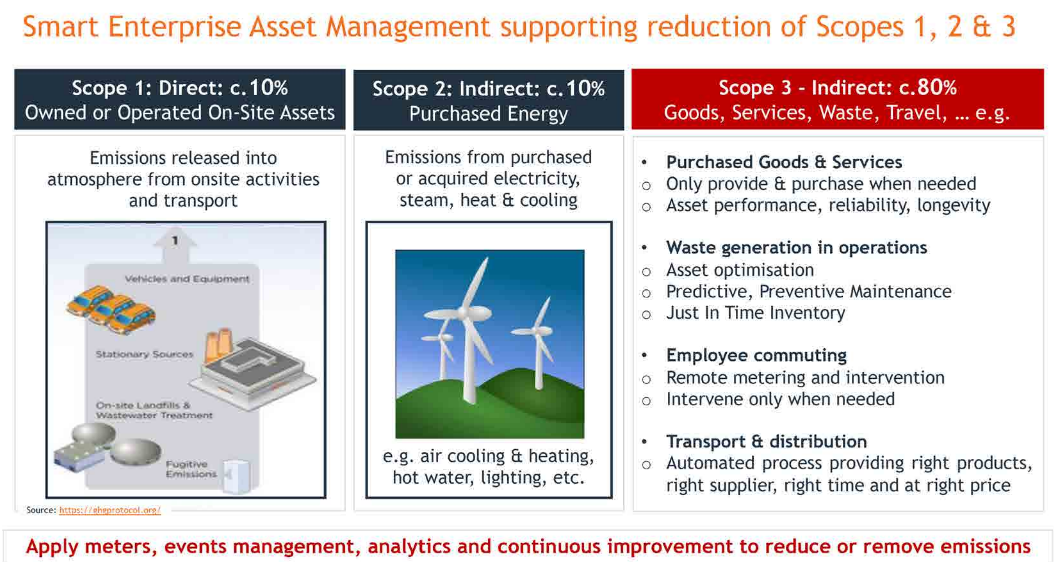

Figure 19: SEAM supporting scopes 1,2 and 3

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10. Figures

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12. Appendix A

12.1 Semantically

Semantical interoperability ensures that the precise format and meaning of shared and exchanged data and information is preserved and understood throughout exchanges between parties, in other words 'what is sent is what is understood'.

- Semantical interoperability perceives data and information as an asset that should be appropriately generated, collected, managed, shared, protected, and preserved.
- Semantical interoperability put in place an information management strategy at the highest possible level to avoid fragmentation and duplication. Management of metadata, master data and reference data should be prioritised.
- Semantical interoperability encourages the establishment of sector-specific and cross-sectoral communities that aim to create open information specifications and encourage relevant communities to share their results on national and international platforms.

IFC and BCF constitute the semantic model for building information modelling, however, the subset of information required for the various facility management services has not been defined, and it is likely that individual information elements have different meaning depending on the context available to the consumer of the information. In addition, there is a need for data standards for unambiguous identification of various objects both in their physical and digital representations. The use of GS1 standards to identify products (GTIN), assets (GIAI and GRAI) and locations (GLN) is important.

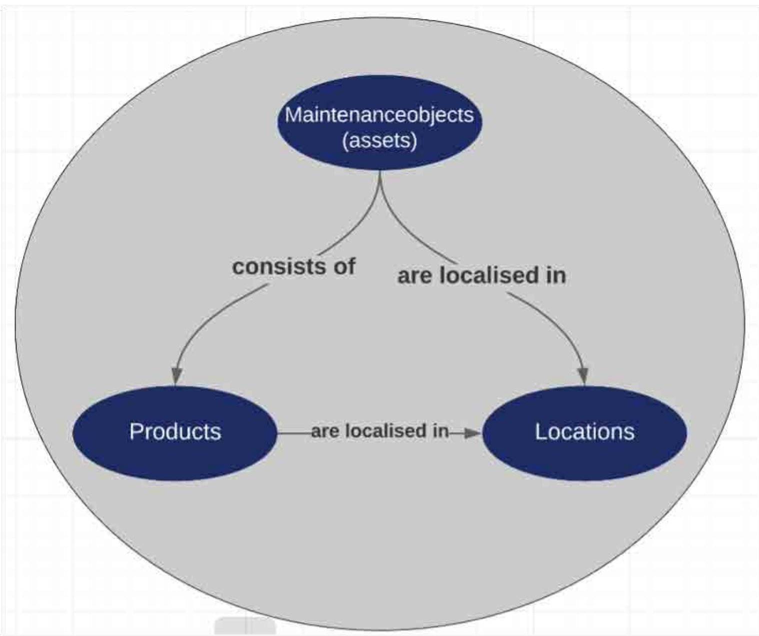

Figure X - Key concepts for data standards to achieve semantic interoperability

12.2 Technically

Technical interoperability covers the applications and infrastructures linking systems and services technically. Aspects of technical interoperability include interface specifications, interconnection services, data integration services, data presentation and exchange, and secure communication protocols.

- Technical interoperability encourages the use of open specifications, where available, to ensure technical interoperability when establishing interoperability between BIM and facility management technology.

BuildingSmart does not provide modern technical standards for how to achieve interoperability between various applications and technologies used in the operation of buildings. The building smart technical roadmap partly address the work that will be required in this area, where important keywords are REST and JSON.

However, attempts should be made to position the digital twin in a suitable IT reference architecture that describe the technical capabilities that is required. The reference architectures developed by the Industrial Internet Consortium can serve as example of IT architecture necessary to realise a digital twin.

It is necessary to conceptualise the internet of things, and the fact that in a hospital context there is concurrently a "medical internet of things", an "industrial internet of things", as well as "consumer-oriented internet of things". Sophisticated patterns for providing and consuming events, and streams of data, in ways that are secure and scalable is crucial to utilise the opportunities created by for example applying machine learning.

12.3 Organisational

Organisational interoperability refers to the way organisations align their business processes, responsibilities, and expectations to achieve commonly agreed and mutually beneficial goals. In practice, organisational interoperability means documenting and integrating or aligning business processes and relevant information exchanged. Organisational interoperability also aims to meet the requirements of the user community by making services available, easily identifiable, accessible and user focused.

- Document the business processes using commonly accepted modelling techniques and agree on how these processes should be aligned to deliver BIM and facility management.
- Clarify and formalise your organisational relationships for establishing and operating European public services.

It is likely that professionals and practitioners of BIM, Facility Management, and the healthcare enterprise, need to develop mutually agreed interoperability profiles for core use cases that define actors, transactions between the actors, and the technical and semantical design of the interaction. This will create opportunities for validating how various applications and technology conform to solve use cases. Such interoperability profiles would constitute the protocols that enable true interoperability.