Strategic Management of Assets and Compliance Through the Application of BIM and Digital Twins: A Platform for Innovation in Building Management

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Abstract

Building Information Modelling (BIM) is an intelligent 3D model-based process that gives asset managers the insight and tools to manage buildings and associated infrastructure more efficiently. BIM is the industry standard model to deliver insight on how a building will perform once built and to manage its performance and asset lifecycles. While BIM processes are established for new buildings, older buildings are not maintained, refurbished, or deconstructed using this method. BIM enables the benefits of efficiency, resource management and compliance. It can overcome uncertainties of building condition and deficient documentation that are prevalent in older buildings. It also acts as a centralised platform, accessible by all stakeholders to hold 'one version of the truth'. Due to complex built forms and increasing legislative pressure from the government for multiple occupancy buildings, a state-of-the-art overview with an easy to use visualisation of compliance and accountability is required for our existing building stock. From a review a step by step proof of Concept (PoC) digital twin model is proposed. The work will show accountable outcomes that can be validated at each stage, the time and cost saving, as well as Halton Housing's goals of creating places to be proud of, addressing customer safety, and asset strategy can be achieved. The aim is to assist in creating a healthy organisation by improving IT platforms, making it easier for colleagues to do their jobs and promote brand and reputation, cementing position and maintaining a strong voice in the sector. Furthermore, the review will demonstrate how an existing building can be modelled into a digital twin via a 3D BIM implementation. Starting small with clear phases and utilising data already available, the development proposed offers an exciting innovative cross platform implementation, that aims to explore the 'art of the possible' and opportunities to scale-up by adding important assets and integrating IOT sensors to gain further insights. Most importantly, the review highlights the advantages to the business at every stage and can adapt to business assets in an exciting and innovative way.

INTRODUCTION

BIM modelling was introduced in the early 2000s to support building design for architects and engineers (Sacks, et. al., 2018). They focused on the improvement of preplanning and design, clash detection, visualization, quantification, costing, and data management. In addition, recently there has been the appendage of basic functionalities, such as energy analysis,

structural analysis, scheduling, progress tracking and jobsite safety (Volk, Stengel, and Schultmann, 2014).

The current use of BIM focuses on life cycle stages for maintenance, refurbishment, deconstruction, and end-of-life considerations (Ilter and Ergen 2015). BIM is now an integral part of a business's building asset management strategy and BSI (2000) maintains that an integration of BIM into asset management will ascertain accurate as well as up-to-date asset information. A benchmark in best practice asset management using BIM processes (i.e. BIM Asset Management Kitemark) has been developed by BSI (Sacks, et. al., 2018).

When BIM is used for facilities management in new buildings, clear benefits are reported e.g. regarding improved information flows and project management, risk mitigation and positive return on investments (Ilter and Ergen 2015). In many existing buildings, incomplete, obsolete, or fragmented building information is predominating. Missing or obsolete building information might result in ineffective project management, uncertain process results and time loss or cost increases in maintenance, retrofit and remediation processes (Ashworth et al., 2019). Existing buildings often lack as-built documentation due to omitted updating. BIM implementation in existing buildings has benefits of improved documentation management, clearer information on maintenance of warranty and service information, assessment and monitoring, energy and space management, emergency management and retrofit planning.

Various digital tools for building capture and auditing are available, such as 2D/3D geometrical drawings, tachometry, laser scanning or automatic locating of images. If building documentation is inadequate for maintenance or deconstruction processes, capturing and surveying techniques with different qualities are applied to audit and gather the existing buildings' characteristics. The functionality-related level of detail and the corresponding data capturing technique influence all following steps of BIM creation and its associated effort.

Although on the one hand, implementation of BIM both in new and existing buildings induces profound changes of processes and information flows, on the other hand it accrues considerable advantages. It can enhance project management and risk mitigation or to limit costs and duration of facilities management. It might also affect sustainability ratings and certifications. It could be possible to monitor energy consumption, wastewater, and maintenance costs. It would be achievable to illustrate environmental effects of the building and to verify and monitor consumption and emission values. It would also validate data management, maintenance schedules and equipment warranties with respect to deterioration and cause-effect relationships. When a building reaches its end of life there is the ability to consider its recyclability on a component level. With the addition of the latest technologies including IOT, sensors, automated compliance and future trends of automated capture, onsite progress tracking, measurements and monitoring can be shown through cloud computing solutions depicting building information and live transformations.

This can make serious improvements to the way buildings are managed. We aim to show the business advantages and prove cost, time and efficiency savings whilst depicting the environmental factors and how we can improve them.

Notwithstanding, those benefits listed, it is essential that the business need and the stages for implementation are addressed and communicated to all parties, if BIM processes are to be effectively implemented (Wang et al., 2018). While BIM Level 2 is claimed to be

widespread, it is often poorly delivered (Attril, 2020). There is a need to clearly define the process and expectations, and also to identify the barriers to the execution of BIM (Siebelink et al. 2020; Attrill 2020).

DRIVERS FOR AN INTEGRATED BIM ASSET MANAGEMENT MODEL

Wang et al. (2015) have discussed how BIM could be exploited to support fire safety management. A key driver for such a change is the introduction of new fire safety legislation for properties with more than one dwelling which has resulted from the Hackitt Report (Hackitt, May 2018; Ministry of Housing, Communities and Local Government, 2020) into the Grenfell Tower fire. The proposed Bill (UK Government, 2020) is currently at the stage 3 Committee stage in the House of Commons and will likely result in the introduction of new regulations which will extend the Fire Safety (Regulatory Reform) Order 2005; this will be supported by new and comprehensive Buildings Safety legislation. A draft version of the Bill will likely appear this summer and the contents is expected to further clarify the responsibility of building owners. Extending fire risk assessments to include the whole of the building, and additional responsibilities for the design and construction of new build properties. Other elements of fire safety will likely include compartmentation and fire mitigation measures. The solution would demonstrate a fire safety model, including records of who fitted what where and when, the materials used, time/date for replacement and other auditing checks. The advantages would include insight into when maintenance, service and checks need performing. We would have easily accessible records of building fabric and internal wall structures etc. Integration of BIM within asset management would help appropriately address regulatory compliance (Sacks, et. al, 2018).

Studies are embracing BIM at the knowledge and decision making level, yet few capture practical and meaningful application. The potential application of a BIM knowledge management system during operation and maintenance has been recognised, however, with the exception of Wang, et al. (2015) few considered the importance of fire compliance. The following case study describes the method adopted to provide an integrated BIM Asset management model, with a clear need to ensure effective fire compliance.

CASE STUDY: PROCESS-INTERACTION FLOW: AN INTEGRATED BIM ASSET MANAGEMENT MODEL

The process-interaction flow for an integrated BIM asset management model is proposed and the schematic depicted in Figure 1. The process makes it easy to find the building, identify the part of the building or the asset to which the data is linked. The chronology of data linked to the asset can then be found.

The list of interactions is as follows:

- Centred around a web-based portal for the buildings, a 3D model is developed with the ability to focus in on areas of interest;
- Live information about each individual component is displayed on demand;
- Pop up of alerts for upcoming scheduling information;
- Click on relevant location/asset for compliance documentation and certification;

- Data is sourced from external datasets, and it feeds back to the dashboard creating a full live building model.

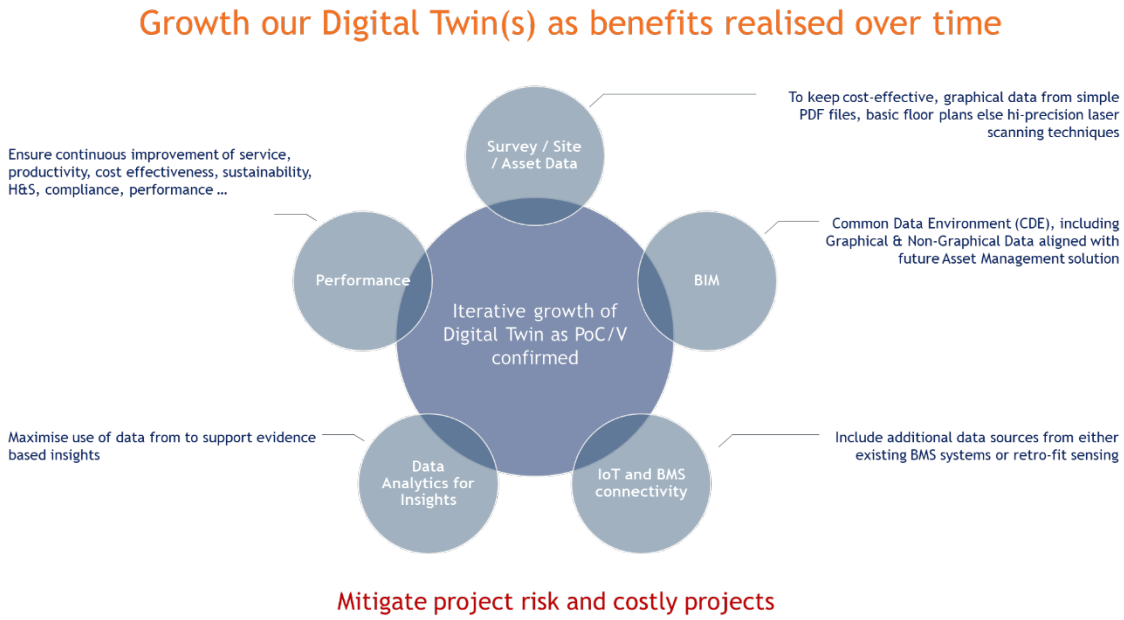
Figure 1. Schematic and flow process for asset data management.

DIGITAL TWIN AND BIM-ENABLED ASSET MANAGEMENT

Innovation is the successful exploitation of new ideas and by partnering with SiteDesk and ecosystem partners to introducing a small-scale model, we demonstrated the value of BIM to the business. Lu et al. (2019) proposed integrating the Digital Twin concept into Smart Asset Management. Thus, future aspirations include an integrated Digital Twin, for lifecycle BIM-enabled asset management for all multiple occupancy and single occupancy buildings (note: the number of buildings currently within the groups holdings exceeds 7000).

Illustrated below in Figure 2 are the key drivers following industry best practice and positive business outcomes when creating an integrated digital twin based on 4 sources of data within an asset management ecosystem. They are: asset (or survey) data; BIM-related data; IoT sensor data; performance-related data.

Figure 2: Digital Twin for BIM-enabled Asset Management



The integrated digital twin will undergo an iterative growth as proof of concepts are verified and validated. To reiterate, the aim of this integrated digital twin is to improve workflows and demonstrate an improved fire compliance and fire safety system. It evidences compliance requirements set out in current legislation with quick access to certification and direct links to our management information system. It will reduce management overhead costs and most importantly make customers safer in their homes. The prototype demonstrates the foundations of a BIM system that facilitates intelligent data lead decisions and focus resource into areas that need them the most.

Smart BIM-Enabled Asset Management Ecosystem

Figure 3 BIM Enabled Asset Management EcoSystem (Components required).

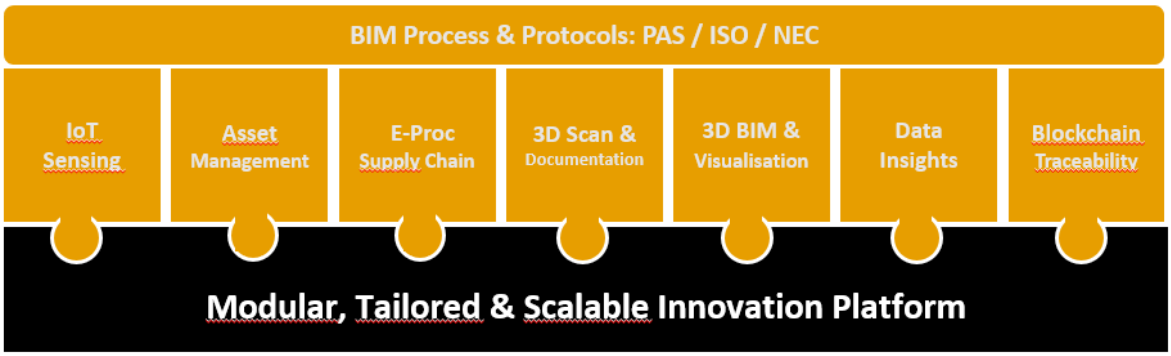
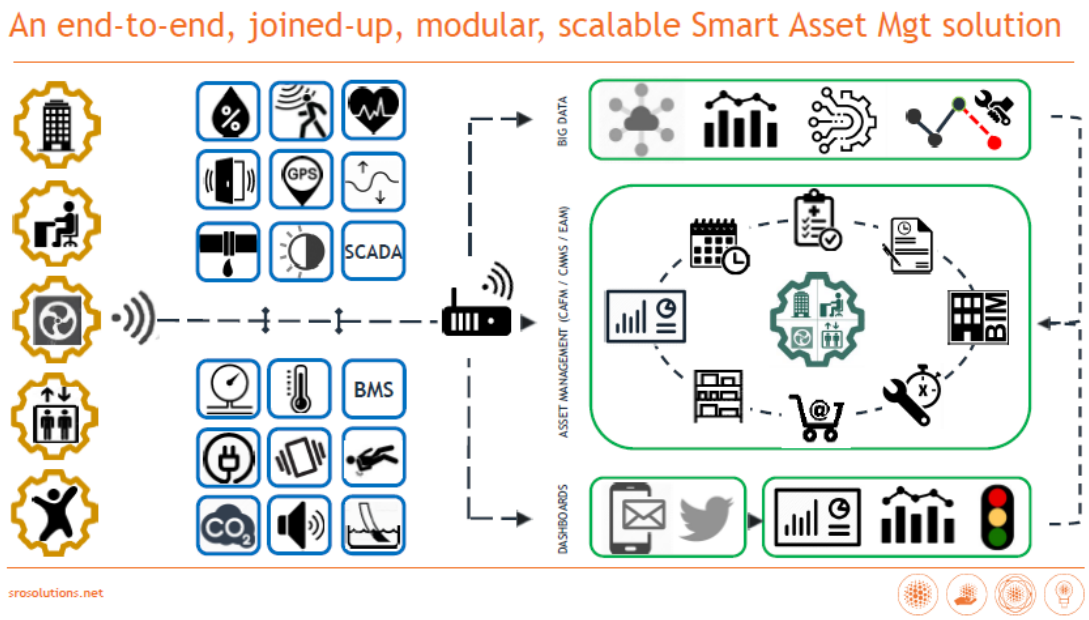


Figure 4 presents an integrated schematic of an end-to-end, joined up, modular, and scalable digital framework to provide room for future organic growth. Relevant components are: data GPS; data analysis (e.g. using big data analysis to provide insights); data for management and control (e.g. building management system for automation; SCADA; asset management); data visualization (through dashboards); data acquisition (through IoT sensors, SCADA)

Figure 4: Smart Asset Management Solution



A list of functionalities for our proposed Smart Asset Management Systems is as follows:

a. **User Interface:** A web-based solution that everyone in the business can have access to and provide them with the information from any platform;
b. **Control Centre:** Control for offline and online assets and related work-orders;
c. **Management:**
    - manage, measure, optimize work orders and staff;
    - manage compliance, Health and Safety ensuring right qualified resource to complete the job;
    - manage, measure, optimize 3rd party contracts and pull data from existing models and visualizations and interact from within an Asset Management window;
    - **Service Level Management:**
        i. Details of KPIs and Service Level Management for Ops teams, suppliers, and critical assets the system will directly link to E-procurement for spares and consumables;
        ii. Service Level Management for Operations, Suppliers & Assets: SLAs vs Costs of service;
    - **Inventory Management:** To ensure inventory and reduce procurement overheads;
d. **Procurement:** Procurement model would ensure right product, right price, right lead-time based on right criteria– to ensure uptime, compliance, H&S, SLAs, target KPIs;
e. **Data Analytics:** Directly linked into data analytics displaying energy consumption and carbon footprint with evidencing positive improvements;

f. **Predictive Maintenance:** Planned & IoT enabled Predictive maintenance to ensure parts delivered on-time, in stores and reserved for jobs;
g. **Performance Improvement:**
    - Improve uptime: and optimizing Procure-to-Pay for materials, spares and consumables;
    - Improve Supplier Performance, Management and Consolidation;
h. **Auditability, Traceability, and Transparency:**
    - Real-time auditable trail shared between customer and 3rd parties to ensure SLAs, Compliance, Pricing, Contractual Agreements respected and improved;
    - Smart Contracts - reduce procurement overheads and optimise P2P process via a traceable end-to-end process;
    - Compliance – auditable trace of genuine products & certified operators (insurance & auditors);
    - Transparency between customer & suppliers to increase loyalty – one version of truth.

METHODOLOGY

The pieces of the puzzle illustrated (in Figure 4) will create a smart asset management framework by bringing each piece of the puzzle systematically together. At each stage, the process can be assessed, determining if the benefits have been realised the business advantage remains. The road is mapped out creating a digital vision that is assured through performance. Our roadmap will have three-phased approach namely: ***Start Small***, with the ability to ***Scale Fast***, whilst ***Thinking Big*** (see Figure 5).

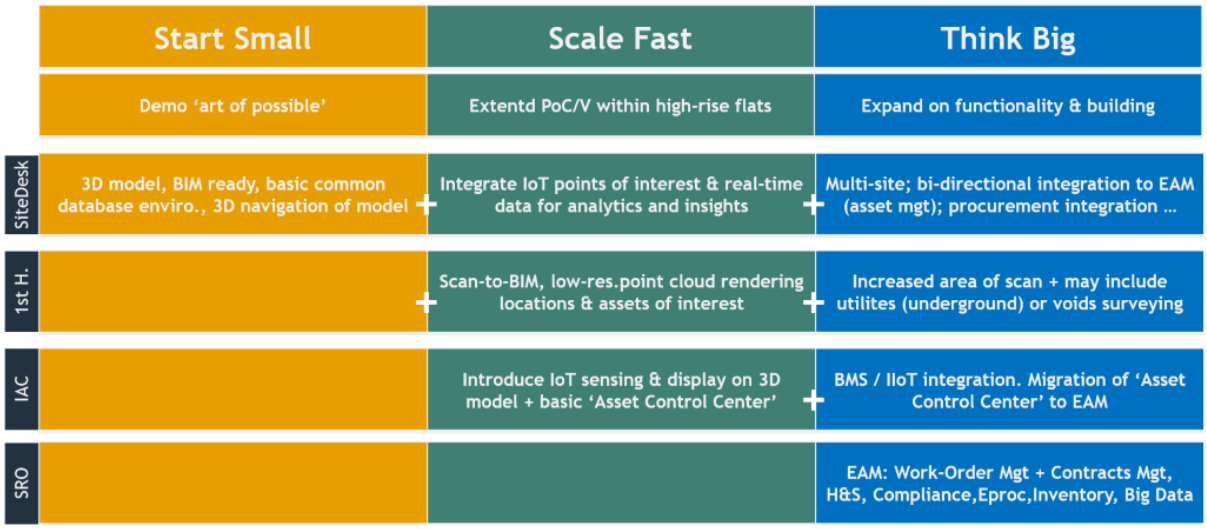


Figure 5: 3-Phased Approach for Smart Asset Management

To achieve the target of an Integrated Digital Twin for end-to-end whole lifecycle Asset Management, an agile methodology (Rigby, et. al., 2016) will be adopted. It will be underpinned by three principles: *Start Small*, *Scale Fast*, Think Big. Risk aversion will be demonstrated to evidence its benefits. This is supported by the 'Try then Buy' ethos (Coghland, 2017) and Minimal Viable Product (MVP) (see Technopedia 2020) concept. A key premise behind the idea of MVP is that you produce something of value of which to

demonstrate as a solution to the business problem. This may be no more than a landing page, or a service with an appearance of automation, but which is fully manual behind the scenes. Seeing what people do with respect to a product is much more reliable than asking people what they would do. The primary benefit of an MVP is we can gain understanding about the business' requirements for the product without fully developing the product.

Following the MVP approach by completing phase 1 then building from, whilst the whole time keeping the overall goal in mind. We have chosen a vehicle as an analogy (see Figure 6). We first begin to build a test scooter to prove we need wheels and demonstrate its benefits. However, our ultimate aim is to make a self-driving car.

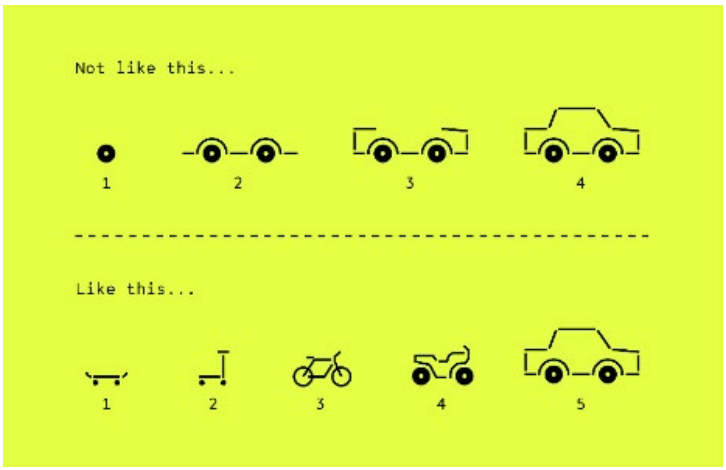


Figure 6: A Vehicle Analogy: From Building a Test Scooter to a Self Driving Car

USE CASE: CASE STUDY BUILDING 1A (CSB1A)

The process of moving to a digital twin solution started by incorporating available 2D and 3D data for CSB1A (See Figure 7) into BIM models which Sitedesk made available as a digital twin – Sitedesk is the BIM visualisation component of the Ecosystem offering and it provides a simple and easy to use environment through which users can interact with 2D and 3D digital twins and also access the underlying power within the various elements of the Ecosystem. Initially Sitedesk's own common data environment (CDE) was used to underpin the collaborative process.

Figure 7: CSB1A

The building has 11 floors with 44 apartments and the documentation for this building is limited. Using the plans shown below (Figure 8 (a)-(c); Figure 9), SiteDesk have created the building as a 3D model to use for the visualisation and contains the addition of the extra asset details not in the original drawings.

Phase 1– Start Small

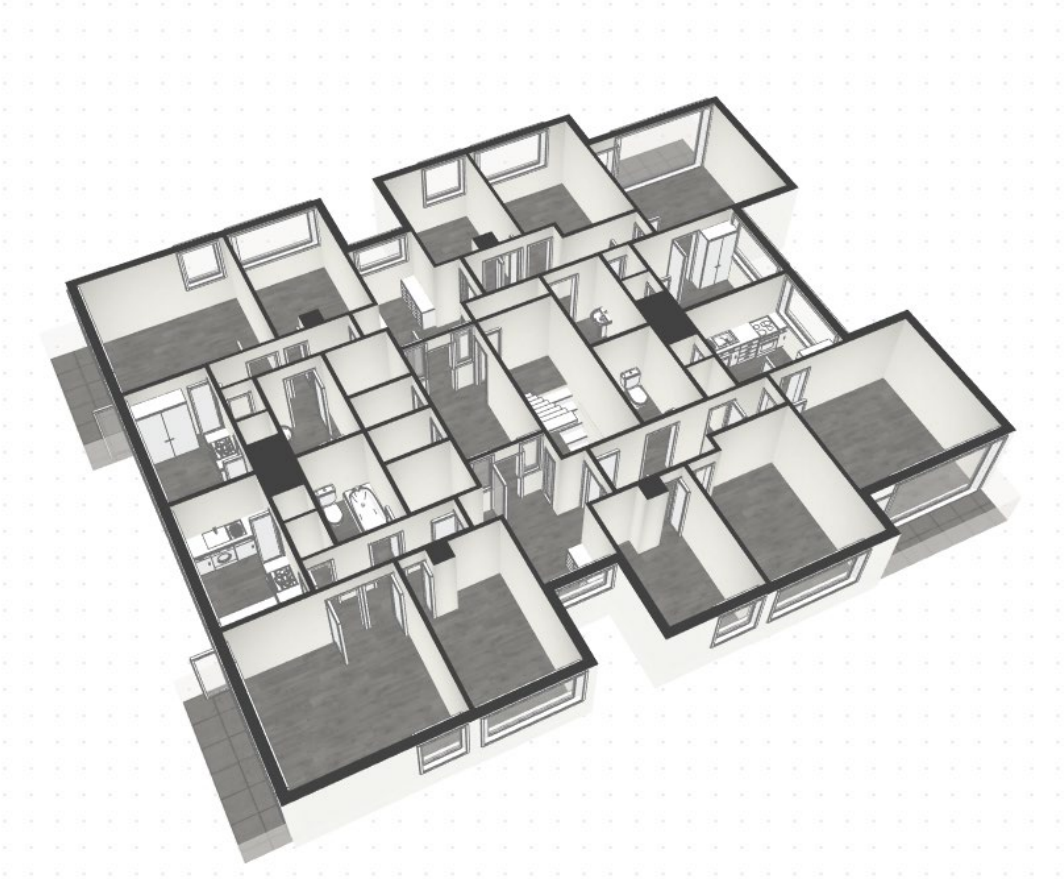
By interacting with the digital twin of CSB1A , Halton Housing were able to identify key components and areas which came under the umbrella of the revised regulatory requirements. Once identified SiteDesk enabled Halton Housing to monitor the workflow and store all associated documentation to provide a complete record of what had been undertaken to comply with the legislative requirements.

The benefits Halton Housing experienced as a result of using SiteDesk are:

- Higher quality data controlled within a central system rather than being kept in an unstructured way within multiple systems
- Improved productivity through simple, intuitive interaction with the digital twin to locate and report on assets/locations of interest
- Improved monitoring and adherence to Health and Safety and Compliance obligations by having centralized data with auditable operations and intervention tracing.
- Ability to access the digital twin and all its associated documentation using mobiles, tablets and laptops
- Being able to make the most of the variable quality of data available for sites being controlled – some sites have 2D documentation only for example

(a) Ground Floor – Access Level

(b) Example Floor Plan



(c) Basic 3D Floor Diagram

Figure 8: CSB1A Plans

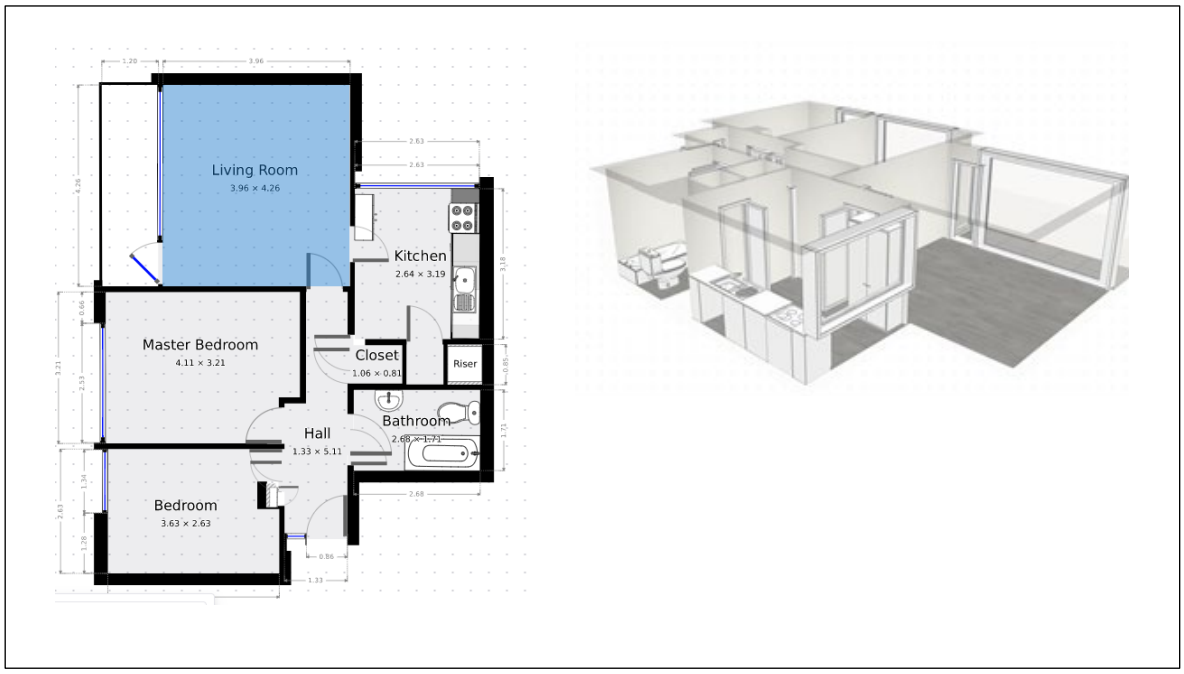


Figure 9: Example of a Single Apartment

In the future, as Halton Housing's requirements grow to necessitate deploying other sophisticated components within the Ecosystem, the data within SiteDesk can be used to seed these other components to provide a straight-forward migration path to the further advanced functionality that is available throughout.

Working with SiteDesk on Phase 1 demonstrated the art of what is possible by create the first piece of the puzzle (highlighted in Figure 10 below) now the prototype has been developed, it is in its testing phase, working on functionality with the business partners and stake holders.

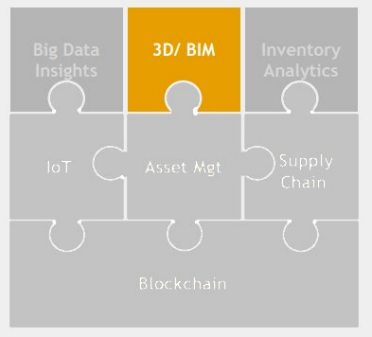


Figure 10: 3D/BIM Modelling

The goals (achieved) for Phase 1 are to:

- Demonstrate the art of possible
- Build the 3D model
- Create a basic database environment

- Construct a navigation system
- Record business critical assets
- Create framework for collaboration and management of risk
- Record Assurance and compliance
- Support cultural change through training and mentoring

Advantages found are:

- Ease of information access
- Auditing strategies
- Business acceptance
- Traceability
- Compliance

Phase 2 – Scale Fast

Phase 2 is the next step and the foundations have been put in place to start this expansion with the goals to improve collaboration and integration of known assets during the life cycle phase of the building. Using the 3D models previously created allowing interactions with assets and locations in an intuitive manner to be able to have quick and easy retrieval of asset condition, service records and location information automatically by connecting the model to data sources. As depicted in Figure 11 below, it adds more pieces to the puzzle expanding functionality, performance, and automation.

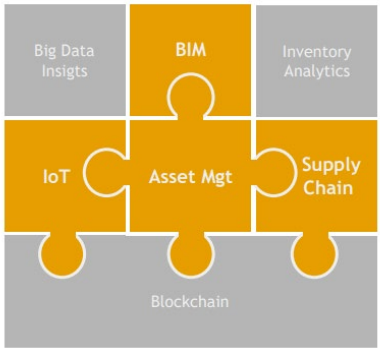


Figure 11: BIM, IoT, Supply Chain and Asset Management

Goals

- Extended PoC within the high-rise flats
- Integrate IoT points of interest
- Generate and demonstrate real time data
- Scan to create point cloud renderings of locations and assets of interest
- Introduce IoT sensing and display on 3D model
- Add a basic asset control Centre
- Record supply of recorder building materials and associated traceability

Advantages

- Ease of information access
- Auditing strategies

- Business acceptance
- Traceability
- Automated compliance
- Real-time data from overlaying IoT devices for increased productivity
- Automatic ordering of faulty parts
- Boiler house monitoring

With a constant stream of live data from people, sensors and devices the model can encompass all effecting factors. Looking at the final pieces of the puzzle and bringing them online will change the way the buildings are not only managed but lived in as well. Asset management can be challenging. With phase 3 it would be possible to offer comprehensive solutions for managing physical assets on a common enterprise platform for many built forms. Now we are talking about the building as single living asset (see Figure 12).

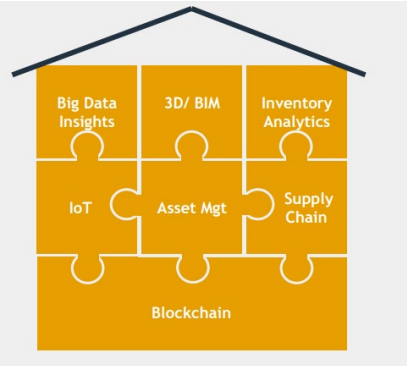


Figure 12: Building as a Single Living Asset

Advantages

- Operations Productivity and KPIs
- Improve Asset Uptime
- Optimise Asset Usage and Performance
- Improve Energy Sustainability
- Gain insights from connected assets
- Reduce P2P overheads and cost of spares
- Reduce inventory and consolidate suppliers
- Improve Service Level Management and introduce Smart Contracts
- Compliance and Health and Safety: apply, trace and report
- Improve employee working environment
- Procurement integration

CONCLUSION: FUTURE DEVELOPMENT

With phase one completed and the business desire to continue to the next phase the changes to building lifecycle management is profound. By expanding to a constant stream of live data from people, sensors and devices the model can offer comprehensive solutions for managing assets using Building Information Modelling to develop the digital twin of CSB1A and improve strategic management of assets and compliance. This is the start of a platform for future innovations in building management in the social housing sector.

- The power of MVP to instigate rapid change in business thinking.
- Demonstrated art of what is possible.
- The next stage has gained stakeholder acceptance within the business.

It is clear that many organisations face challenges when transforming to digitised practice. Prior research evidences the confusion that some organisations face, as they engage with the BIM framework (Winfield and Rock 2018). The initial steps taken in this case study arose out of a desire to bring about improved performance and capability to the business and also as a result of needing to adequately address the changes to building regulations and fire safety compliance. The phased adoption will allow the business and board to witness the changes, financial implications and benefits.

While the industry is aware of BIM and the potential benefits of digitisation, the transformation within the sector remains slow (Volk, Stengel, and Schultmann, 2014; Sacks, et. al. 2018). The initial steps taken, demonstrates that it is essential that the desire to disrupt and digitise the sector should be met with a clear business need. The regulatory changes, recent events such as the Covid-19 pandemic, are bringing about a need to rationalise and improve data collection, communication and rapid response processes. While previously acknowledged (Ashworth et al. 2019), the need for collaborative platforms, advancing the way information is delivered and managed is clearly evident. This project has documented the step change and phases adopted through a case study. The work and research is ongoing, with further reflections to be shared.

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