July 2018

Building Information Modelling to support healthcare built asset management
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Special acknowledgements:
Authors wish to thank estate and facilities division of Princess Alexandra Hospital for their collaboration as a case study organisation.

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Published by the Royal Institution of Chartered Surveyors (RICS)
RICS, Parliament Square, London SW1P 3AD
www.rics.org

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Executive summary

Purpose and scope of document

Each year, England’s NHS spends a significant amount of money to maintain its estates. In 2015/16, maintenance costs were £8.3 billion, with £2 billion specifically spent on hard facilities management. In addition, the English NHS has a continuing burden of backlog maintenance (circa £5 billion as of 2015/16). Due to financial pressure and this large level of backlog maintenance, most NHS hospitals are less capable to run a planned maintenance strategy for their estates. Furthermore, there is a lack of quantifiable evidence to demonstrate the relationship between asset management investment and overall organisational performance improvements. Therefore, many organisations consider asset management as a cost burden.

This research investigated how Building Information Modelling (BIM) can benefit the NHS by demonstrating the links between built asset maintenance spend and added value to the organisational performance, which can then help NHS estates make better-informed investment decisions on their built assets.

Research methods

The research used a comprehensive literature review and a case study of an NHS hospital to achieve the research aim. The case study provided data at multiple points in the research and allowed access for action research. A conceptual framework for BIM enabled healthcare Built Asset Management (BAM) was developed and informed by:

- a literature review
- initial data from the case study organisation relating to:
  - asset management
  - asset related data collection practices of NHS hospitals
- the capabilities of BIM.

This framework demonstrates how a wide range of interdepartmental data can be digitally integrated to link maintenance strategies and organisational performance. The concept proposed in the framework was validated by developing a cloud-based BIM model for a carefully selected space in the case study organisation. The model was then validated through two focus groups to investigate viability and validity of the concept and evaluate the conceptual framework for its implementation. The illustrational BIM model was further improved through the findings from the focus groups.
Results

BIM is an advancement to ICT use

• NHS estates use Computer Aided Facility Management (CAFM) Systems, Computerised Maintenance and Management Systems (CMMS), and Building Management Systems (BMS) for the management of their facilities. These primarily serve as monitoring and administration tools and are not used for advanced information modelling.

• The BAM BIM model proposed in this research facilitates a platform for asset managers to communicate with building users and consider their concerns within the maintenance strategy/programme. The model is able to cope with dynamic organisational (technological and functional) demands highlighted through user requirements.

• The digital capabilities of BIM can advance current levels of data processing within NHS asset management by modelling and analysing a wide range of information. These BIM models can provide evidence and decision support tools to establish sound asset management strategies that are linked to organisational performance.

BIM can integrate a wide range of asset related interdepartmental data

• To demonstrate the added value of maintenance expenditure to the organisational performance, BAM BIM needs to be integrated with a wide range of interdepartmental data related to asset management and health service performance (see the framework below).

Figure 1 Conceptual framework for BIM enabled healthcare built asset management
Built environments can have a significant impact on the performance of the care provided within buildings. This is particularly poignant for the healthcare sector. BIM models can be integrated with information relating to the impact of asset management activities on care provision. NHS hospitals collect some qualitative data relating to the quality and safety of the built environment and its impact on staff and patient satisfaction. This information can be filtered from secondary data sources such as patient and staff surveys, health and incident reports, and other quality of care audits. Currently however, the existing data is qualitative – this evidence does not flow efficiently into the BAM decision-making process and is therefore not used to justify asset management investment decisions. Feeding these qualitative data into BAM BIM models can be resource consuming. This research finds that a higher level of automation is required to enable the inclusions of a more diverse set of information into the BIM model.

**Functionality of the developed BAM BIM model**

- The prototype BIM application developed in this research can support asset management decision-making by modelling and analysing outstanding asset maintenance work. In particular, a BIM model can prioritise outstanding maintenance activities based on rectification costs and risks. This benefits NHS estates in two ways:
  - Firstly, this analysis can inform strategic decisions such as allocation of budget, or the choice to refurbish or build new.
  - Secondly, at operational level, this analysis could be used to prioritise maintenance activities to suit the asset maintenance budget.
- The BAM BIM model can establish fault and spending patterns by analysing completed maintenance work over a certain time period. In particular, these patterns can identify cost and resource intensive elements/components within the organisational estates by analysing costs, frequency and duration of maintenance activities. This pattern analysis can in turn inform further appraisals and strategic maintenance decisions such as whether or when to replace or refurbish individual elements/components.
- The BAM BIM model can locate individual elements/components within backlog maintenance and retrieve their as-built information and repair and maintenance history. This data can be used to analyse the effectiveness of individual elements/components as well as to supplement the new job tasks for individual elements/components.

**BAM BIM models are significantly advanced compared to design and construction phase BIM models**

- The development and updating of BAM BIM models is heavily resource consuming. New buildings may have BIM models handed over at the end of the construction phase. Existing technological advances are capable of producing semi-informed building models for existing buildings, with limited level of asset maintenance related information.
- Implementation of comprehensive BIM models capable of integrating a wide range of interdepartmental data for existing healthcare buildings is highly resource consuming and requires significant effort for manual data feeding.
- The burden of manual data feeding and information entry is currently a significant barrier preventing the use of information and communications technology (ICT) based BAM systems to their full potential.

**Conclusions and recommendations**

The digital capabilities of BIM can provide an advancement to current levels of ICT use for asset management within NHS estates. BIM can facilitate advance modelling and analysis of a wide range of interdepartmental data to provide evidence of how asset management strategies and activities impact organisational performance. These will prevent organisations seeing asset maintenance as a cost burden and will help organisations to develop asset management strategies that are linked to organisational strategies.

The additional benefits of implementing BIM that integrate a wide range of interdepartmental data may include streamlining existing healthcare (building and health) auditing systems through data sharing and advanced modelling. BIM can enable an electronically stored and centrally managed dataset which will minimise data duplication and facilitate up-to-date data sharing between various decision-makers. Such systems can support decision-making at the organisational and national level. These may include both internal and external auditing systems.

Many BIM applications in the design and construction phase of buildings are designed taking a technology-driven approach with little or no consideration given to individual project requirements. The results of this research indicate that BAM BIM models need to be developed
taking a demand-pull approach (developed based on individual organisational circumstances and the practices of individual NHS estates). In particular, the models should support the functionalities required by the organisation-specific BAM procurement arrangements and resources.

- For organisations whose maintenance activities are managed with in-house staff and operatives, BAM BIM models could model and analyse work-hour demands and allocation strategies based on organisational performance requirements.

- For organisations whose maintenance activities are procured through external trade contractors with agreed schedules of rates, BAM BIM models could model and prioritise outstanding maintenance tasks to suit a fixed budget by analysing risks and resulting performance improvements.

- For totally outsourced maintenance contracts on a fixed lump sum per year, BAM BIM models could be used to monitor and evaluate maintenance costs over a period of a year and use such data during the negotiation of the annual lump sum price with the maintenance contractor.

Based on the findings of this extensive research, the following key recommendations are made:

1. Demand-pull approach to BAM BIM models: as NHS estates have distinct estate portfolios and BAM procurement arrangements, BAM BIM models need to be developed, taking a demand-pull approach to respond to individual estate requirements.

2. Top down organisational level approach: implementing BIM linked with organisational performance requires integrating interdepartmental data and changes to data collection practices within other departments. Therefore, a top down organisational approach is required to facilitate a wide range of electronic data storing and sharing between different departments and stakeholders within the NHS hospitals.

3. BAM BIM models for existing buildings: comprehensive BAM BIM models capable of advanced functionalities and linked with organisational performance modelling require a significant investment of resources. Based on the circumstance of the estate portfolio (such as building age, demand for services), individual NHS estates should make strategic decisions regarding the extent to which BAM BIM should be implemented within their estate. Therefore, national level targets are not suitable for implementing BIM for existing healthcare estates.

4. Automated data feeding: implementation of technology for automation of data entry and data feeding will increase the acceptance and efficiency of comprehensive BAM BIM models by reducing the burden associated with manual data feeding. Therefore, more research and investment is required on automated data collection and sharing techniques for healthcare BAM BIM.

5. Linking semi-informed building models to an asset management database: comprehensive BAM BIM models are more than 3D building models and should be capable of integrating an enormous amount of data and information handled during the building operational phase. Creating a dialog on BAM BIM among property related professionals and building owners will encourage the development of a comprehensive BAM BIM model capable of linking asset management activities and organisational performance. However, resultant BAM BIM models could be significantly large to store and use. Alternatively, a semi-informed building model and a separate asset management database can be linked together with advanced functionalities associated with BIM to allow for communication and use of data between the model and database.

6. Published cost and man-hour data on asset maintenance: resource data for asset management activities (time and cost) is crucial in asset management procurement decision-making and asset maintenance investment decisions. There is a lack of externally published detailed maintenance resource data. In particular, organisations in which asset maintenance is procured with in-house operatives will benefit from published data on the man-hours needed for building maintenance activities. RICS can improve Building Cost Information Service maintenance and repair rates databases to provide man-hour requirements and improve the usability and popularity of the BCIS maintenance dataset amongst asset management professionals.
1.0 Introduction

1.1 Overview

Many organisations plan and conduct their asset management activities based on asset physical condition surveys, cyclical asset maintenance plans or statutory requirements. This approach to maintenance management is primarily concerned with the physical conditions of assets and fails to assess how maintenance investment contributes to organisational performance (Jones and Sharp, 2007). Many organisations therefore see the maintenance of assets as a cost burden and do not see value added to the organisation by investing in assets. Subsequently, asset investment drops in priority within the organisational budget, causing a backlog of maintenance.

Public sector asset management should ensure best value for money from property assets in serving the strategic needs of public sector organisations (RICS, 2008). It should entail strategies to align business and property asset strategies, ensuring the optimisation of an organisation’s property assets in a way which best supports its key business goals and objectives (RICS, 2012). This should be achieved by systematic planning and acquisition (business case), operation and maintenance, and disposal or replacement of assets. Once the strategy is in place, the majority of the asset management activities should then be associated with operation and maintenance of assets on a regular basis. This involves work necessary to keep, restore or improve the performance of buildings, fabric and equipment to acceptable standards and sustain the utility and value of assets.

The National Health Service (NHS) in the UK is one of the largest public sector organisations, operating over 1,200 hospitals and nearly 3,000 other treatment facilities. The occupied floor area of the NHS is 24.3 million m²; the equivalent of nearly 3,500 football pitches (DH, 2016). The total cost of running the complete NHS estate is around £8.3 billion (ibid.). This includes estates and facilities finance costs (such as cost of leases), hard facilities management costs and soft facilities management costs. It is essential that any public (or private) sector estates and facilities are managed keeping their contribution to the organisation’s strategic goals in mind. In the case of the NHS, the priorities are to provide effective, safe, responsive, caring and well-led care (NHS, 2014).

Due to the financial pressure and level of backlog maintenance, most NHS trusts are unable to run a planned maintenance strategy. Maintenance needs are frequently prioritised in reaction to failures in the physical condition of buildings (for example, blocked toilets or light fittings that are not working) and maintenance strategies are rarely linked to the organisation’s strategic goals. As such, it is difficult to demonstrate the link between the cost of maintenance and the value added to the organisation, for example, in improved service quality and patient care.

The in-use phase of building management comprises a vast amount of sector-specific data that could be used to improve the management of buildings. In particular, NHS estates and facilities could be better managed by integrating a range of information relating to a built-asset’s impact on care provision, in addition to data and information concerning just the physical condition of an asset. This research investigates how the digital capabilities associated with BIM could support a multi-faceted approach to the maintenance of healthcare buildings and assets.
1.2 Aim and objectives

The aim of the research is to develop a performance-based approach to healthcare Built Asset Management (BAM) that is supported by the capabilities of BIM.

The research objectives are to:

1) Review literature related constituents of asset management BIM models.
2) Investigate the existing information channels in NHS hospitals that could be used to link asset management and the strategic goals of the NHS.
3) Develop a framework to illustrate BIM enabled multi-faceted decision making for healthcare built asset management.
4) Develop a prototype cloud-based BIM application to demonstrate and evaluate the capabilities of BAM BIM.

1.3 Research methods

1.3.1 Literature review

Existing literature sources were reviewed to clarify the scope and direction of the research and verify the link between asset management and organisational performance. The literature review establishes the state of the art in BIM, the potential for utilising this BIM during the in-use phase of building management and the constituent sources of information required for asset management BIM models. In addition, the Department of Health UK and related publications are reviewed to investigate the asset management practices of the NHS and to review asset related data/information collection and analysis practices within different departments of the NHS.

1.3.2 The case study

The research uses a single case study design in order to facilitate an in-depth investigation and to develop a BIM model based on reflections from the case study organisation. This methodology allows for data collection at multiple points of the study, in the following phases:

- **Phase 1** – development of the conceptual framework of BIM supported healthcare built asset management (focus group).
- **Phase 2** – development of a prototype BIM application to demonstrate the concept proposed in phase 1 (interviews and document review).
- **Phase 3** – validation of the prototype BIM model developed in phase 2 (focus group).

A regional hospital with a varied building portfolio was selected as the case study for this research because it provides easy access to a rich set of data. Researchers at Anglia Ruskin University were also engaged as an additional case study organisation to validate the BIM model in phase 3.

**Phase 1 – development of conceptual framework of BIM supported healthcare built asset management**

Contemporary BAM practices within NHS estates were reviewed to identify how BAM strategies are formed and how BAM performance is measured. This review was supported by the literature, as well as data gathered from a focus group discussion organised with staff members (four BAM professionals) from the case study organisation. The focus group data and findings were then used to establish typical/potential user requirements of a BAM BIM model; a model that could link BAM strategies and NHS organisational performance.
The data and information collection practices and the analytical practices within NHS hospitals were also reviewed. As a result, the research identified the data requirements for BIM models that could link BAM strategies with overall organisational performance. These data requirements were incorporated into the conceptual framework proposed for BIM enabled healthcare built asset management.

Phase 2 – development of a prototype BIM application to prove the concept proposed in phase 1 (focus group, interviews and document review)

During the second phase, the conceptual framework was developed into a fully operational BIM model for a shower room in the case study organisation. A shower room in the maternity ward was selected because it provided a rich set of data that could be used to develop a BIM model:

1. The case study organisation had a partially completed 3D (revit) model for their maternity ward.
2. As verified through the maintenance activity records of the maternity ward, shower rooms require frequent maintenance compared to other spaces within the hospital.
3. Shower rooms involve maintenance activities representing a variety of trades such as plumbing, electrical systems, alarm and warning systems.

Five subsequent face-to-face interviews with BAM professionals in the estates department of the case study organisation were used to gather additional data on BAM procedures and maintenance records to develop the BIM model.

Phase 3 – validate the BIM application developed in phase 2 (focus group)

As part of the final phase of the research, the BAM BIM model that had been developed was discussed with a focus group comprising five asset and facilities management (FM) researchers at Anglia Ruskin University. A second focus group discussion was held with facilities management professionals at Anglia Ruskin University and asset management professionals at the case study organisation. These discussions helped to assess:

- how useful the model is
- the user-friendliness of the model
- future development requirements
- additional functionalities expected by users and their view on the effectiveness of the BAM model compared to the current level of information and communications technology (ICT) use for BAM.

The comments from these discussions were used to further adjust and refine the BAM BIM model. Some of the key changes include incorporating operative-hour resource data into the maintenance database and improving the visualisation of analyses produced by the model.
2.0 Background

2.1 Asset management

2.1.1 Asset management – overview, definitions

Public sector asset management is ‘a structured process that seeks to ensure [the] best value for money from property assets in serving the strategic needs of public sector organisations’ (RICS, 2008). Asset management consists of two key components: strategic and operational asset management. In its broadest sense, strategic property asset management is the process that develops asset management strategies that best support the organisation’s key business goals and objectives (RICS, 2012). More specifically, BAM should follow a well-established strategy during the planning and acquisition (through the business case), operation and maintenance, disposal or replacement of assets. Strategic BAM also seeks to ensure that the service life of an asset (and its parts) will equal or exceed its design life and optimise the maintenance and running costs (adopted from Rich-Mahadkar, 2015). A good asset management strategy should be informed by organisational resource management and ICT strategies (Howarth, 2006).

This research is primarily concerned with the operation and maintenance of assets during the in-use phase of the building life cycle. The value addition by investment in these asset maintenance activities should be explicitly linked to the ability of built assets to support organisational performance (Jones and Sharp, 2007). This research explores how the capabilities of BIM could be used to create evidence demonstrating the contribution that investment in operation and maintenance makes to organisational goals and objectives.

Operation and maintenance activities typically include:

1) Planned and preventive maintenance: Maintenance activities identified, organised and carried out to a predetermined plan at predetermined intervals of time. These activities are primarily identified through stock condition surveys or cyclical maintenance demands for certain assets.

2) Reactive maintenance: Maintenance activities carried out to no predetermined plan; in response to failures as they occur, or in emergency situations to avoid serious consequences.

Despite understanding the importance of linking investment in assets and asset maintenance to organisational performance, most organisations see the maintenance of assets as a cost burden (Sherwin, 2000; Tsang, 2002). This is because the maintenance and performance of any physical asset are evaluated via surveys of the asset’s condition (physical condition based maintenance; PCBM) (Jones and Sharp, 2007). There are a lack of business tools to support FM managers in aligning BAM activities with organisational performance when compared with the number of tools used for major BAM decisions related to acquisition and disposal or replacement of built assets. For example, capital investments within NHS organisations in England are supported by guidance in the form of the NHS England business case approvals process (DH, 2013) and the Capital Investment Manual (DH, 1994), which facilitate strategic considerations such as the business case development and wider stakeholder consultations. Conversely, there is very little national level guidance to support strategies for day-to-day maintenance activities within estates and facilities divisions and they are primarily developed based on past experience.

Major criticisms (Sherwin, 2000; Tsang, 2002; Jones and Sharp, 2007; Chapman, 1999) of contemporary approaches to maintenance management argue that:

- PCBM allows buildings to perform to their originally designed capacity with only incremental improvements at best; PCBM does not consider the dynamics of organisational (technological and functional) demands.
- PCBM costs exceed the funds available for maintenance, and PCBM fails to demonstrate the link between asset maintenance investment and organisational performance. Organisations therefore struggle to justify spend on non-vital maintenance. This causes further increases in the backlog of maintenance as assets fail to operate at maximum capacity, potentially leading to a spiral of decline.
- PCBM does not encourage building managers to communicate with building users or consider their concerns within the maintenance strategy/programme.
- The results of the PCBM are subjective and depend on the variations in levels of experience of those conducting surveys.
- PCBM does not provide the ability to predict long-term cost requirements, does not inform long-term maintenance planning and provides unusable or inappropriate data.
- Traditional approaches to maintenance management lack a feedback loop allowing for lessons learnt to feedback into improved asset maintenance and operation.
In order to demonstrate the contribution that maintenance activity can make to organisational goals and objectives, a good maintenance management approach should comprise a maintenance policy, a maintenance framework and maintenance data. In particular, maintenance data enables effective decision-making at the strategic asset management level.

BAM data management has substantially developed over the last decade. With the aid of ICT, the use of Computerised Maintenance Management Systems (CMMS) and Computer Aided Facilities Management Systems (CAFM) in facilities management are now common (see Section 2.2.2 for more details). Despite the popularity of CMMS and CAFM, these systems are usually used to handle only a limited amount of asset related data. BIM can integrate, model and analyse a wide range of data. This includes data from the asset management department and data on the impact of assets on care provision and data gathered from staff, patients and visitors of other departments. Accordingly, BIM capabilities could improve current asset management practices and provide evidence to highlight the value of investment in asset maintenance. Utilisation of the capabilities associated with BIM allows for more efficient performance management and the closer monitoring of operation and maintenance activities. The utilisation of BIM can also aid decision-making on planning and acquisition (the business case) and decision-making on the disposal or replacement of assets.

2.1.2 Healthcare built asset management

The NHS estate

The NHS estate is spread over 66 million m² of land area, which is managed by 238 NHS trusts providing secondary care and ambulance services (Estates and Facilities, 2016). Of this, the 24.8 million m² gross internal floor area within these premises is used as clinical spaces (63%), non-clinical spaces (37%) and about 2 million m² internal floor area is reported as not occupied (EC Harris, 2013). It is also reported that about 15% of occupied floor area is functionally unsuitable (12.9%) or under used (2.5%). Furthermore, the Lord Carter Review (2016) highlighted that the use of floor space varies significantly between individual trusts; where one trust uses 12% for non-clinical purposes, another uses as much as 69% for non-clinical purposes. The review recommends that individual trusts’ unused floor space should not exceed 2.5%, and floor space used for non-clinical purposes should not exceed 35% (Carter, 2016).

Figure 2 demonstrates the age profile of the buildings within the NHS estates as of 2016. According to this data, NHS estates in England have a considerable proportion (circa 40%) of older buildings (buildings built before 1985) and 16.5% of the NHS estates were built before 1948.

![Figure 2: Building age profile of NHS estates](source: Estates and Facilities, 2016)
FM costs and capital expenditure

According to the Estates and Facilities (2016), the total cost of running the NHS estates was £8.3 billion in 2015/16. This includes:

- Estates and Facilities Finance costs (such as the costs of leases relating to estates and facilities, depreciation and amortisation, cost of finance)
- hard FM costs (estate services)
- soft FM (hotel services) costs.

Estates and Facilities (2016) further identified that the hard FM cost alone amounts to approximately £2 billion, and capital invested (for new build, improvement of existing buildings and for equipment) on the NHS estates for the year 2015/16 amounted to £2.14 billion.

Backlog maintenance and quality of buildings

The report (ibid) also identified the level of backlog of maintenance for their buildings and equipment for the NHS estates in England. At current levels, the backlog of maintenance on high and significant risk assets alone amounts to £2.3 billion within a total of a circa £5 billion backlog.

Figure 3 shows the level of the backlog in maintenance as of year 2016. During the last reporting year, the backlog of maintenance cost for high and significant risk assets has risen significantly (69.3% and 47.6% respectively). This backlog could be associated with the continuing financial pressure on NHS trusts and on the prioritisation in trust budgets for direct expenditure on medical care.
2.2 Built asset management and BIM

ICT has been in use in the construction sector since the 1980s, when construction documents were passed among stakeholders in electronic versions through CAD (Computer Aided Design) systems (Day, 2002). Since the early 1990s, object oriented CAD was used to simplify building section drawings by linking building graphics with non-graphical data on common building elements. With the digital revolution, the philosophy of BIM experienced rising popularity within the construction sector. ICT tools have been developed to incorporate BIM philosophy into different aspects of construction projects and throughout a building’s life cycle. BIM is most often used in the early stages of the building life cycle, with progressively less use in the latter stages (Eadie, et al., 2013). The following sections provide an outlook on BIM capabilities and explore the application of BIM during the in-use phase of the building life cycle.

2.2.1 Building information modelling – definitions

BIM can describe a way of working. The BIM Task Group (2017) defines BIM as:

‘essentially value-creating collaboration through the entire life cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them’.

A BIM model is a shared digitally represented product realised with object-oriented software that consists of parametric objects (representing the building components) that can be used to form a reliable basis for decisions (adapted from ISO, 2016, Volk et al., 2014). In their comprehensive literature review, Volk et al. (2014) found that these parametric objects may have:

- **geometric (3D) attributes**
- **non-geometric attributes**, consisting of information that can be categorised as:
  - functional e.g. installation durations or installation costs
  - semantic e.g. connectivity, aggregation, containment or intersection information
  - topologic e.g. related to information about an objects’ location or adjacency.

**Figure 4**

UK BIM maturity levels

<table>
<thead>
<tr>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawings, line arcs text etc.</td>
<td>Models, objects, collaboration</td>
<td>Integrated, interoperable data</td>
<td>A fully integrated and interoperable BIM(M) has the potential to mitigate risk throughout the process and to increase profit by +2% through a collaborative process.</td>
</tr>
</tbody>
</table>

95% produce 2D drawings lacking coordination increasing costs by 25% through waste and rework.

2D 3D spatial coordination based on BS 1192:2007 has the potential to remove error and reduce waste by 50%.

Source: Model developed by Mark Bew and Mervyn Richards. Figure adapted from GCCG (2011).
The maturity of a BIM model is determined based on the level and type of data attached to the BIM model (see Figure 4 on page 16). More details of these levels can be found in the BIM report for the Government Construction Client Group (BIWG, 2011).

### 2.2.2 Use of ICT for the in-use phase of building life cycle

FM during the in-use phase of a building uses substantially more ICT than that used during the design and construction phases. In particular, organisations tend to use the following:

- **Computer Aided Facility Management (CAFM) Systems**: often referred to as Workplace Management Systems, CAFM software provides the facilities manager with the administrative tools to manage a wide range of FM administration functions.

- **Computerised Maintenance and Management Systems (CMMS)**: specifically designed to manage a sub-set of FM (maintenance), CMMSs are used to schedule and record operation and preventive/planned maintenance activities. These systems store useful information associated with each maintenance activity in a database, allowing for the tracking of past maintenance activities. In addition, these systems can also store information such as asset records, stock records, conditions of assets, etc. However, the analysis of historic data and information modelling is limited within these systems.

- **Building Management System (BMS)**: BMS is a computer-based system that controls and monitors the building’s mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems and security systems. One of the key purposes of BMS is energy management within buildings.

BIM models present an advancement to ICT use within FM. At present, FM or asset management systems are not fully benefiting from the advanced capabilities of BIM. For example, BIM models allow for the retrieval of information necessary for analyses of the relationship between breakdowns and repairs, providing insight (for example, into the root causes or possible impacts) that might not have been gained from traditional databases or CMMS systems (Akcamete et al., 2010).

The existing use of ICT in FM provides a strong basis to facilitate the adoption of BIM. BIM could be developed as an advanced version of CMMSs or CAFMs, with digitally represented building/asset and information modelling software attached to the usual maintenance management system in order to produce more intelligent analysis to support asset management provision. Currently, some of the commercially available BIM tools support the importation of digital facility data to a CMMS. For example, FM Desktop by Autodesk facilitates data (.dwf file format) exporting from BIM tools to CMMS systems. However, this transfer of data is at present limited to certain types of information. For example, asset information about the spaces and elements can be transferred from 3D models to CMMS systems, but spatial and topological relationships that could be included within BIM models cannot be retrieved by CMMS systems.

Previous research has explored the potential for integrating some BIM capabilities into CMMS systems or for exporting CMMS data into BIM models. Lavy and Jawadekar (2014) have investigated how Construction Operations Building Information Exchange (COBie) data received at the end of the construction phase could be integrated into a CMMS system, while Akcamete et al. (2010) explored how work orders generated through CMMSs could be integrated into the BIM model.

### National initiatives to promote BIM for the in-use phase of buildings

Key national level initiatives to promote BIM for the in-use phase of the building life cycle are the BIM4FM task group, the COBie standards and the Digital Built Britain initiative.

BIM task groups were established in the UK as a government initiative to support BIM implementation within the construction sector. Under this initiative, the BIM4FM Group was established to support BIM and GSL (Government Soft Landings; adopting a mind-set and a process to align design and construction with operational asset management and purpose) implementation within the in-use phase of the buildings. Leading institutes, trade associations and professional bodies representing the built environment have joined together to form the BIM4FM group, supported by the Cabinet Office Government Property Unit. Initial tasks of this group include:

- defining what BIM means to FM
- identifying the benefits of BIM and GSL to FM and for owners and occupiers
- raising awareness of BIM and GSL
- producing guidance/communication and documentation for facilities managers.

COBie standards and its accompanying spreadsheet help construction stakeholders organise information about new and existing built facilities. This can also be used as a means of transferring information from the design and construction phase to the in-use phase. However, although COBie includes information on material and sustainability, it does not contain information on the design aspects, such as frame structures, walls, or roofs, which are essential for refurbishment or deconstruction planning.

Early UK government BIM targets mandated the use of Level 2 BIM on all public-sector projects. The Digital Built Britain initiative intends to promote the implementation of BIM at Level 3 (see Figure 4) by defining advanced standards, creating new commercial models and identifying technologies to transform contemporary approaches to social infrastructure development and construction.
2.3 Constituents of BIM for the in-use phase of buildings

If the generic definition of a BIM model is adopted for the in-use phase of a building, a BAM BIM model can be defined as a shared digitally represented product with intelligence and information attached to it. This product and the associated intelligence or information provides a reliable basis for decision-making about the functionalities associated with the in-use phase of buildings. This could be a 3D model of a building viewed by people working at estates and facilities such as senior managers of the organisations and external traders on site carrying out maintenance activities. In simplest form, the users of a BAM BIM model should be able to identify information such as size, layout or material properties of building components. More intelligent BIM models should be able to provide users with further analyses such as rate of deterioration or patterns of repair and maintenance costs for buildings and their components. Volk et al. (2014) found that many existing BIM models cope with (semi-) automated modelling of building surfaces or components, but only with respect to their geometrical representations. These models often do not attach component properties or semantic information (such as containment or intersection information), or any other intelligence. As the type of information handled during the in-use phase of a building is often complex, the systems that utilise BIM with ICT software integrate three key components:

1. Digitally represented built assets
2. BIM data input applications: these are technological applications providing monitoring, data capture, data import, data processing or the transformation of captured data into BIM (e.g. through laser scanning/scan to BIM or through applications to input maintenance pricing schedules)3.
3. BIM data outputs applications (BIM functionalities): these facilitate various analyses and related reports to support decision-making (e.g. structural and energy analyses or clash detections).

A. Digitally represented built assets

New construction projects could develop a BIM model as they progress through the design process. However, if BIM is to be implemented for managing the existing building stock, these buildings need to be modelled in a digital space. Manually developing a BIM model for existing buildings is time consuming. However, recent advancements in data capturing technology allows for the automatic capture of data from existing buildings and the subsequent development of BIM models (through points-to-BIM or ‘scan to BIM’). These technologies can capture a reasonable level of data (using techniques such as laser scanning, photogrammetry, Radio-Frequency Identification (RFID) or barcode tagging) and incorporate them into a digital building model. Volks et al. (2014) claim there is also a prospect for more comprehensive auditing of the material and structures of existing buildings, if these existing data capture techniques are combined with other non-destructive methods (such as material or texture-based recognition, ground penetrating radars, radiography, magnetic particle inspection, sonars or electro-magnetic waves testing).

Volk et al. (2014) provide an overview of different data capture techniques. Some of these could be used to develop BIM models for the existing building stock, while others could be installed during a retrofit as a means to feed real-time data into BIM models. This captured data can then be integrated into BIM models using data processing software (to recognise functionality-relevant BIM objects) and object recognition techniques. While data capture techniques can allow for the capture and modelling of a significant level of information, the inclusion of functional attributes (such as installation date and duration) may still require intense user input and interaction.

B. Data input applications during the in-use phase

BIM models calibrated to operate throughout the in-use phase of the building require a continuous feed of data. These may include real-time data feeds such as rate of deterioration, temperature, fault identifications and cost data as contracts are updated. Technologies and techniques for data input during the in-use phase are associated with either synchronous or asynchronous technologies. Synchronous technologies are those that can respond in real time and asynchronous refer to technologies that do not respond in real time. In addition to this, other data input techniques include:

- speaking: continuous speech recognition
- typing on a keyboard, handwriting
- drawing
- pointing, clicking, dragging
- various three-dimensional manipulations (stretching, rotating, etc.)
- manipulations within a virtual reality environment: same range of speech, gesture, point, click, drag, etc., as above, but with three dimensions and broader field of view
- manipulation unique to virtual reality environment
- using more hardware technologies
- microphones
- light pen/drawing pads, touch-sensitive screens, whiteboards
- video display screen and mouse and keypad
- touch-sensitive screen (pen or finger)
- virtual reality input gear (glove, helmet, suit, etc.; also body position detectors).

3 There has been a considerable effort into developing this software (Volks et al., 2014). However, most of the research in this area focuses either on capturing construction data, or on geometries of existing buildings for processing into digital building models.
C. Data output applications – BIM functionalities

The current use of BIM during the FM phase primarily concerns transferring information from the design and construction phase into the operational phase and maintaining an up-to-date model of buildings. Specific functionalities for BIM models used in the in-use phase of the buildings are:

- Functionalities associated with repair and maintenance: by recording the changes made to the building during repair and maintenance activities, BIM models can eliminate the time and cost associated with re-surveying elements for repair and maintenance activities. BIM can also eliminate the time and costs associated with re-drawing (shop drawing) for repair and maintenance activities, and enable the rapid creation of drawings, clash detection, quantity take off, cost calculation or cash flow modelling, scheduling, sub-contractor and supplier integration and creating and updating assets digitally (Becerik-Gerber, et al., 2011; Lavy and Saxena, 2015).

- Documentation and data management: storing non-geometric information – functional, semantic or topologic; and other related information such as maintenance warranty and service information (Volk et al., 2014).

- Visualisation (virtual reality, Volks et al., 2014) and locating building components which requires repair or maintenance (Becerik-Gerber, et al., 2011).

Depending on the stakeholders’ needs and the project requirements, a BIM model may also facilitate limited but advanced functionalities associated with performance monitoring and simulation. This can include:

- Operational performance monitoring: energy/thermal analysis and control, carbon foot printing, performance measurement and monitoring through sensors, structural analysis, environmental analyses (Volks et al., 2014; Carrbonari and Jones, 2014).

- Simulation (day light simulation).

- Data mining and establishing performance patterns across temporal and spatial domains, for example, identifying recurrent faults in physical systems or underperformance across building attributes (Carrbonari and Jones, 2014).

- Evaluating alternative space management strategies in combination with user behaviour modelling based on end-user feedback (Carbonari and Jones, 2014).

- Real time data access, for example, real-time monitoring of stresses on structural elements of buildings (Kenny, 2016; Lavy and Saxena, 2015).

- Emergency management: simulating human behaviours within buildings in emergency situations such as fire (Wong and Fan, 2013; Becerik-Gerber et al. 2011).
2.4 Healthcare asset management and BIM

2.4.1 BIM4Health

BIM4Health is a sub group of the BIM task group (see Section 2.2.2) established to support BIM implementation within the healthcare sector in the UK. This group is currently led by the Institute of Healthcare Engineering and Estate Management (IHEEM) in affiliation with other representatives from organisations within the healthcare sector who are engaged in the design, construction and maintenance of assets. The key goals of the group are to:

- raise awareness and understanding of Health BIM within the healthcare marketplace
- articulate business benefits of BIM for health sector
- produce metrics to benchmark Health BIM performance
- assist and provide guidance towards implementing BIM within healthcare sector
- coordinate with the other BIM4 task groups and the Construction Industry Council (CIC) to provide a voice for the healthcare sector in reflecting their concerns and interests back to the BIM task group (BIM4Health, 2016).

The group set three key milestones to achieve its goals. In the short term (until 2016) to provide a platform to promote the use of BIM to the healthcare sector. In the medium term (up until 2018) to provide technical focussed assistance and knowledge to the healthcare sector clients and consultants to achieve BIM level 2. In the long term, (up until 2020) the group intends to further develop the technical knowledge to provide a range of sub groups to assist in achieving BIM level 3 and beyond. During a review of the progress of BIM4health goals, Shuckford (2016) stated that many NHS trusts have not considered BIM and its requirements, articulated a plan/strategy or made a start.

2.4.2 BIM and healthcare asset procurement

Integrating BIM during the design and construction phases of the building life cycle is mandatory for public-sector projects and it is becoming increasingly popular in private-sector projects as well. BIM is frequently used in the design and construction of healthcare assets nationally and internationally. Some leading UK examples include Doncaster & Bassetlaw Hospitals and Barts and the Royal London Hospital. The multi-box fan (MUB) Project at Doncaster & Bassetlaw Hospitals NHS Foundation Trust has achieved Level 2 BIM during the design stage of their project (Shuckford et al., 2016). They have utilised visual models of the design to aid space allocation and management, patient pathway modelling, mechanical and electrical design information and co-ordination, building service systems and components identification. Barts and the Royal London Hospital have used BIM for construction and facilities management. Through improved planning and coordination facilitated through BIM, the project has achieved significant savings and reductions in waste during the design and construction phases. In particular, clash prevention has benefited the project in a number of instances and has avoided unnecessary demolition and reworks. CAD objects has helped cost savings by accurately extracting a bill of quantities and material lists and the building services model has been a key driver in the decision to use linked services in the corridors resulting in significant programme savings (Hartyl et al. 2014).

2.4.3 BIM and healthcare asset maintenance

Researchers claim that healthcare FM is to some extent different from any other sector. Hospital buildings are built to provide care (compared to adoptable office spaces) (Lavy and Fernades-Solis, 2010) and consist of complex mechanical, electrical and plumbing (MEP) systems needed for patient care (Lavy and Saxena, 2015). Furthermore, buildings and assets impact on the health of patients (Codinhoto et al., 2009; Ulrich et al., 2008); the key business of healthcare organisations. Due to this, much of the maintenance in healthcare needs to be well planned, however, changing care needs and statutory requirements mean that a mix of planned and reactive maintenance is more feasible for maintenance management (Chanter and Swallow, 2007).

A relatively small body of literature has explored how BIM is used in the practice of healthcare asset maintenance. A significant analysis and discussion on the subject is presented by Shohet and Lavy and his team (Lavy and Shohet, 2007; Lavy and Jawadekar, 2014). Lavy and Jawadekar (2014) investigated how 3D models for existing assets could support maintenance and refurbishment decision-making and the benefits of keeping records of as-built data in a comprehensive 3D model. Keeping the as-built data in a digital form could avoid re-creating them for subsequent repair and maintenance work (ibid). Lavy and Shohet (2007) developed a computer aided facility management model integrating key performance indicators. However, this early model did not use any features of BIM.

Ensuring the compatibility of construction data with BAM BIM models is another concern among those wishing to use BIM to support asset maintenance. Lavy and Jawadekar (2014) investigated how COBie data received at the end of the construction phase could be integrated into a CMMS system. The research found that the data submitted by the contractor was not in an interoperable format and hence needed to be re-formatted by a consultant before exporting into the CMMS system. Under the proposed new arrangements for the UK healthcare sector, Principle Supply Chain Partners (PSCPs) will have to handover all required documentation, data under GSL requirements, BIM data and CDM documentation, before certification of the scheme completion (Redmond, 2016). The Department of Health also encourages the creation of long-term joint ventures and strategic estates partnerships between NHS clients, PSCPs and their supply chains to better manage healthcare estates to support the NHS vision (Building Better Healthcare, 2015).
Lavy and Saxena (2015) investigated the potential to integrate existing maintenance systems and their data with BIM features. Their research used work order data exported from a case study organisation’s CMMS as a means to investigate how BIM could impact work order processing time. Comparing the number of hours taken to process maintenance work orders for two campuses, the research found that work order processing time was not reduced by using BIM for FM. To explain this unexpected result, Lavy and Saxena state that the results may not convey an accurate scenario as there were no standard policies for recording work order data across all campuses.

Some NHS estates have developed or considered developing BIM models for existing buildings, for example, the case study organisation used in this research: Princess Alexandra Hospital in Harlow has developed a basic 3D model of their buildings. Some NHS estates have used BAM BIM models to manage asset related information. For example, Procure21+ (Procure21+, 2013) identified that BIM is being applied to the redevelopment of Wrightington Hospital in the UK in order to enable the launch of estate and asset management systems capable of handling the complexity of the hospital’s operational requirements. Wrightington Hospital intends to use electronic project and asset information, documentation and data to assist asset operational activities. Another example (Harty et al., 2014) is the Barts and the Royal London Hospital BIM interactive model, which can be used to:

- check for safe access for operation and maintenance
- confirm major plant and medical equipment installation/removal strategies
- link to construction programmes and monitor progress.

Although these examples indicate positive movement towards BAM BIM integration, there are few examples of the comprehensive use of BIM models integrated with a wide range of asset maintenance data.
3.0 Conceptual framework – BIM assisted BAM information integration

This chapter presents a conceptual framework of how BIM can integrate a wide range of interdepartmental data relating to asset management and health service performance. The framework was developed based upon data gathered from existing literature and data from the case study organisation. Published literature from the Department of Health UK and related publications were used to investigate healthcare asset management practices and asset related data collection and analysis systems within NHS hospitals. In addition, the data collected through the case study organisation was used to fill the gaps of knowledge on contemporary practices related to healthcare asset management.

The initial version of the framework (see Figure 5) was conceptualised taking a deductive approach based on the research view discussed in the previous chapter of this report.

3.1 Review of information channels to support healthcare BAM decision-making

3.1.1 Built asset information, registers and related information

Facilities managers use a vast array of building information related to an enormous number of elements and small components (e.g. joinery, thermostats) contained in buildings. Some of this information evolves from design drawings and other documentation handed over at the end of construction projects, which are largely text-based. These documents also include:

- health and safety (H&S) files
- warranties and guarantees
- operation and maintenance (O&M) files
- records of any changes made to the building during later repair and maintenance.

Figure 5

Proposed approach to use digital capabilities to integrate a wide array of information for asset management decisions

- **Step 1**: Identify asset data informed data collections by all the stakeholders of the NHS organisation
- **Step 2**: Asset related information filtered
- **Step 3**: Asset related information linked to a digitally represented building model
- **Step 4**: Improve the BIM model (improvements to existing data collections and new data requirements)
This data, if incorporated into a digital 3D model of the building, can provide a starting point for the BAM BIM model. However, advances in ICT technologies can also facilitate BIM models that integrate a wide range of information that supports asset management decision-making. This supplementary information could be categorised into three key themes concerning BAM BIM for the NHS estates:

1. built asset performance related data
2. organisational resource arrangements to manage built assets
3. built assets’ impact on quality of care, available within the systems/records of different stakeholders of the healthcare organisation.

The next section discusses the potential of integrating a wide range of existing data and information from the all three of these sources to create the proposed BAM BIM model.

3.2 Built asset performance related data

a) Premises Assurance Model (PAM)

The NHS PAM evaluates the performance of NHS premises over five domains (Department of Health, 2016):

- **Safety (hard and soft):** How the organisation provides assurance for estates, facilities and its support services; ensuring that the design, layout, build, engineering, operation and maintenance of the estate meet appropriate levels of safety to provide premises that supports the delivery of improved clinical and social outcomes.
- **Patient experience:** How the organisation ensures that patient experience is an integral part of service provision and is reflected in the way in which services are delivered. The organisation will involve patients and members of the public in the development of services and the monitoring of performance.
- **Efficiency:** How the organisation provides assurance that space, activity, income and operational costs of the estates and facilities provide value for money, are economically sustainable and meet clinical and organisational requirements.
- **Effectiveness:** How the organisation provides assurance that its premises and facilities are functionally suitable, sustainable and effective in supporting the delivery of improved health outcomes.
- **Organisational governance:** How the organisation’s board of directors deliver strategic leadership and effective scrutiny of the organisation’s estates and facilities operations. How the other four domains are managed as part of the internal governance of the NHS organisation. Its objective is to ensure that the outcomes of the domains are reported to the NHS boards and embedded in internal governance and assurance processes to ensure actions are taken where required.

The performance of these domains is evaluated based on qualitative data gathered via a series of self-assessment questions on an electronic template provided by the Department of Health. NHS hospitals first gather evidence of organisational performance for each domain via feedback from patients and staff. A numeric value (1-5) is then assigned for performance against each self-assessment question. Numbers 1 to 5 are assigned respectively for ‘outstanding’, ‘good’, ‘requires minimum improvement’, ‘requires moderate improvement’, and ‘inadequate performance’. The PAM template is formulated to calculate overall results for each domain based on organisational answers to the self-assessment questions.

b) Building condition survey

NHS estates conduct a non-mandatory detailed survey (often every five years) to assess the physical condition of the estate assets and their compliance with mandatory fire safety requirements and statutory safety legislation. This comprehensive survey enables the allocation of condition rankings to approximately 223 components within each building. The data from this survey is primarily used to plan maintenance strategies and ensure all built assets are kept in an appropriate condition. The data from the survey is also used to produce risk rankings for assets and to calculate risk adjusted backlog (building) maintenance cost for the healthcare organisation.

3.3 Built asset financing data

Built asset management requires finance to facilitate planned and reactive maintenance as well as capital investments.

a) ERIC data (Estates Return Information Collection)

Each NHS trust (an organisation within the English NHS generally serving either a geographical area or a specialised function) must submit an annual estates return, which is made available to the public via the ERIC database. ERIC collects information relating to the costs of providing, maintaining and servicing the NHS estates that are used in the delivery of secondary care and ambulance services. Each trust must compile data relating to the portfolio of buildings (age, building area), details of capital investment, cost of providing soft and hard facilities management, quality of buildings (backlog maintenance levels), energy costs and non-renewable energy consumption.
b) Maintenance cost data

Building maintenance cost is a combination of in-house maintenance staff costs and related overhead costs, material and equipment purchase costs and costs paid to external contractors for outsourced maintenance activities. The extent to which building maintenance services are contracted out varies among different NHS estates. In some cases, only the management functions are provided by in-house staff and in some instances in-house design professionals may be available (such as architects or building services engineers). In many cases cyclical maintenance activities (e.g. annual service of lifts and other plants such as boilers, generators) are frequently contracted out. Outsourced maintenance activities are procured through term partnering contracts. This is a contract between the NHS estate and a maintenance contractor to provide specified maintenance activities at pre-agreed rates (cost per activity) over a specified period of time. Term contracts often extend for longer periods based on the contractor’s performance. Records of these agreed rates are normally scattered among various contracts for services that have been procured by the organisation. Some NHS trusts prefer to contract out all of the services (maintenance activities and administration) to an external FM organisation. In these cases, the NHS estates pay a fixed annual fee to the FM organisation.

c) Backlog maintenance data

Each NHS estate calculates the accumulated maintenance cost associated with assets that fall below an acceptable minimum physical condition defined in the NHS guidance. This is according to the risk-based methodology for establishing and managing backlog and statutory minimum standards as specified in fire safety and health and safety legislation. Based on this NHS guidance, each NHS trust then prioritises the portion of the maintenance backlog that presents a high and significant risk if it fails.

d) Hospital revenue data

NHS trusts in England are funded through ‘Payment by Results’. This mechanism calculates costs for a series of defined clinical activities at the individual NHS organisational level. The calculation considers the direct costs associated with each clinical activity/procedure while the cost of maintaining buildings is apportioned between the clinical activities performed within the premises. These costs are then averaged at the national level in order to determine the tariff that is payable for each clinical activity. Hospitals are then paid a sum of money (revenue) calculated by multiplying the number of clinical activities they performed by relevant tariff. Further guidance on how ‘Payment by Results’ works can be found in the Department of Health guidance: ‘A simple guide to Payment by Results’ (DH, 2012). This mechanism fails to consider or account for variations between different trusts’ estates’ circumstances such as age of the buildings, occupancy details, and actual configuration portfolio of the building. Therefore, in financially difficult times, NHS trusts tend to spend the majority of the revenue on clinical services and defer the costs associated with building operation and maintenance.

3.4 Built assets’ impact on quality of care

In current practice, the performance of built assets are measured for few key criterion relating to physical condition and functionality. However, as stated in the literature review, there is a growing body of evidence claiming that built infrastructure can have an impact on the provision and quality of patient care. PLACE (Patient-Led Assessment of the Care Environment) evaluates the quality of care-providing premises to some extent. Generic patient and staff experience surveys and health and safety incident records can also contain useful information related to how built environment can support quality of care.

a) PLACE (Patient-Led Assessment of the Care Environment)

The PLACE assessment is based on patient and staff feedback. PLACE assesses the performance of premises in relation to:

- cleanliness
- food and hydration
- privacy
- dignity and well-being
- condition
- appearance and maintenance of healthcare premises
- dementia and disability support services.

The category ‘appearance and maintenance of healthcare premises’ directly assesses the maintenance of the estates over six type of categorised spaces (ward, toilet, bathroom, treatment area, social and communal areas, other) within both acute and community hospitals. Within each category the patient assesses whether they ‘Pass’, ‘Qualified Pass’ or ‘Fail’ each of the above spaces for the quality of internal decoration, internal fixtures and fittings, floors, seating, lighting, natural light, linen quality, linen storage, general storage, general tidiness, and waste management.

b) Patient experience surveys

NHS hospitals gather qualitative data on the quality of care received by patients. This includes local level patient experience surveys as well as data collected for more formal assessments, for example, for Care Quality Commission (CQC) audits. Local surveys are not necessarily oriented on the performance of a built asset. However, if relevant data is filtered and extracted (e.g. the ratings/comments on the cleanliness and other open-ended comments on substandard facilities such as old
beds), this could provide valuable information on how users rate the performance of built environments and other assets. The CQC audit has direct questions related to the safety and suitability of premises (under CQC outcome 10). According to the Health and Social Care Act (2008) UK, inspectors measure the compliance of assets to ensure the ‘safety and suitability of premises’, by means of ‘suitable design and layout’, ‘appropriate measures in relation to the security of the premises’, ‘adequate maintenance’ and ‘proper operations [of] … premises… and grounds’. This data could be extracted and provide useful insights for management of built assets.

c) Health and safety incidents records
All NHS trusts must record all health and safety incidents. In addition, the National Reporting and Learning System (NRLS), collects confidential reports of patient safety incidents from healthcare staff across England and Wales. Clinicians and safety experts analyse these reports to identify common risks and opportunities to improve patient safety and provide feedback on how to improve patient safety. According to Monitor (2016), around 6.6% of total incidents have been directly attributable to physical and organisational structures and facilities such as, staffing, facilities and built environments. The data does not distinguish the proportion of built environments related incidents, which would be the responsibility of estates maintenance management. Furthermore, it is well established that poorly designed and maintained buildings can indirectly cause safety incidents, for example, poor lighting levels in hospitals can contribute to medical and documentation errors or poor floor/wall finishes can contribute to slips and falls. However, the current incident reporting and analysis system is not capable of attributing these indirect incidents to the maintenance and operation of built environments. If incidents such as these were identified, they could provide insight and assist in the prioritisation of asset management activities.

d) A Staff and Patient Environment Calibration Tool (ASPECT)
ASPECT is a design evaluation toolkit supported by over 600 pieces of research providing evidence as to how buildings and their design can impact health outcomes. ASPECT toolkit could be used to evaluate hospital spaces for eight key aspects:
- privacy, company and dignity
- views
- nature and outdoors
- comfort and control
- legibility of place
- interior appearance
- facilities
- staff.

The toolkit was introduced as a voluntary design evaluation tool; however, there is the potential to use the tool as a means to evaluate the quality of existing healthcare environments.

3.5 Information integration through the capabilities of BIM
A thorough investigation into the above explained performance evaluation mechanisms, revealed the following weaknesses and opportunities for improvement:

- Except for the building condition survey, all other existing performance evaluation mechanisms are general and do not assess the performance of individual spaces or building elements. Evaluations at building, space or element level may be used to allocate maintenance and other FM expenditure more appropriately.
- Except for ERIC data, all other mechanisms are mostly supported by sentiment surveys that are highly subjective; data is gathered through forms that staff and patients can fill in themselves. In some cases (PAM, ASPECT) this qualitative data is then converted into numerical values to gain better outlooks on performance. The use of these numerical ratings both loses the richness of the qualitative data (that could support decision-making by the asset management team and any other user) and carries the risk that the data is misinterpreted as being more objective than it is.
- Particularly for the healthcare sector, the way the buildings are designed and maintained can have a significant impact on the performance of the care provided within those buildings (see for example, Codinhoto et al. 2009, Ulrich et al. 2010). None of the key nationwide performance evaluation mechanisms attempt to evaluate how the NHS environments impact the quality of care provision. ASPECT was primarily designed for this purpose; however, this is not a mandatory tool.
- It is clear that some of the data collection procedures above have the potential to share the data gathered (see Table 1, page 27). For example, data from the ‘condition survey’ could be used to calculate backlog maintenance costs; however, backlog maintenance costs need to be calculated more frequently (at least annually) than the condition survey. Outstanding backlog maintenance costs should be submitted to ERIC data collection annually.
- The use of qualitative data relating to the performance (quality and safety) of facilities during asset management is limited. At the very least, this data, gathered from patient experience surveys and health and safety incidents records, could be shared with asset management teams. At best, patient experience surveys and health and safety incident recording systems could be improved to gather more specific and meaningful data relating to the performance of healthcare estates.
• Digitally available data can facilitate more comprehensive analyses, which can support decision-making at the organisational and national level. For example, the exact cost of maintaining buildings and assets could be easily integrated into the calculation of the payment by results tariff. This tariff could also be adjusted to reflect variations in the building portfolios of individual trusts.

• Finally, some of the data relating to estates and facilities are provided and/or accessed by internal decision-makers (such as facilities managers or directors) and external organisations (such as CQC, other external auditors). An electronically stored and centrally managed dataset would minimise data duplication and facilitate up-to-date data sharing between various decision-makers.

In order to mitigate the weaknesses of current healthcare asset management practices discussed above, this research proposes a conceptual framework on how to improve healthcare asset management utilising advanced ICT capabilities associated with BIM (see Figure 6). In particular, the framework integrates a wide range of interdepartmental data to support asset management decision-making within the estate and facilities division. Table 1 on page 27 further explains the types of data that could be integrated via BIM and identifies potential BIM inputs and outputs.
## Table 1
Integrating healthcare information and assets management decision-making

<table>
<thead>
<tr>
<th>Spaces</th>
<th>Elements/aspects of building elements</th>
<th>Potential BIM input</th>
<th>Potential BIM output</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PAM</strong></td>
<td>Rating related to design, layout and use of premises, asbestos, medical gas systems, natural gas and</td>
<td>Conduct PAM for each space [or integrate with condition survey] and attach results to</td>
<td>Supplement reports on quality of selected individual building elements/spaces.</td>
</tr>
<tr>
<td></td>
<td>specialist piped systems, water safety systems, electrical systems, mechanical systems and equipment</td>
<td>digital model.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ventilation, air conditioning and refrigeration systems, lifts, hoists and conveyance systems,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pressure systems, fire safety, medical devices and equipment and management approaches to estates.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Building condition survey</strong></td>
<td>Over 9 key building elements [structures, external fabric, roof, internal fabric and fixtures, external building works drainage systems, energy centre systems, heating systems, hot &amp; cold water system, ventilation and air-conditioning, medical gas pipeline services, lifts &amp; hoists, fixed plant/equipment, electrical systems, alarm and detection systems, communication systems, miscellaneous].</td>
<td>Conduct condition survey for each space and attach results to digital model.</td>
<td>Reports on quality of selected individual building elements/spaces.</td>
</tr>
<tr>
<td><strong>ERIC data</strong></td>
<td>Cost spent towards, hard FM, soft FM, energy, transportation, waste management, finance costs and</td>
<td>Analyse cost spent towards each space and attach to digital model.</td>
<td>Supplementary cost data for reports on quality of selected individual building elements/spaces.</td>
</tr>
<tr>
<td></td>
<td>existing backlog maintenance cost levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance cost data or/and in-house resource levels</strong></td>
<td>Mostly based on a schedule of rates for all the works associated with different elements of</td>
<td>Develop a registry of maintenance activities associated with each element [schedule of</td>
<td>BIM should be able to model backlog maintenance cost for individual spaces and elements based on maintenance cost data and condition survey results.</td>
</tr>
<tr>
<td></td>
<td>buildings.</td>
<td>works] and update with term contract rates for each activity.</td>
<td></td>
</tr>
<tr>
<td><strong>Backlog maintenance data</strong></td>
<td>May be available for different elements of buildings [e.g. within costed action plans].</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hospital revenue data</strong></td>
<td>Not related to building elements.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PLACE</strong></td>
<td>Internal decoration, internal fixtures and fittings, floors, seating, lighting, natural light,</td>
<td>Attach patient led assessment results into relevant elements of BIM model.</td>
<td>Supplement reports on quality of selected individual building elements/spaces.</td>
</tr>
<tr>
<td></td>
<td>linen quality, linen storage, general storage, general tidiness, waste management.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Patient experience surveys &amp; health and safety records</strong></td>
<td>Protocol generic to the premises, (however, description may contain information on relevant space)</td>
<td>Filter data relevant to spaces and elements and attach to BIM model.</td>
<td>Supplement reports on quality of selected individual building elements/spaces.</td>
</tr>
</tbody>
</table>
4.0 Illustration of the BIM model – modelling a shower room in the hospital

4.1 Overall approach of the BIM model

One of the key limitations associated with technologies used to develop 3D building models (Autodesk Revit in this case) is the (large) size of the file. This can be problematic when trying to upload and download files from a cloud-based system. Due to this issue of the size, many BIM models are developed as semi-automated modelling of building surfaces or components with respect to their geometrical representations and they are not integrated with component properties or semantic information which increase the size of files (Volk, et al., 2014). There is the potential for large amounts of data to be gathered during the in-use phase of a building’s life cycle, in particular, relating to the non-geometric attributes (such as functional, relational, economic or semantic information). This information would, however, be too large to store and use in a Revit (or similar) BIM model. The FM BIM model proposed in this research takes an alternative approach, producing:

1. a semi-informed building model
2. a separate asset information database
3. an expert functionalities database that uses information from the asset information database and the 3D building model (see Figure 7, and see Figure 8 on page 29 for the details of the system architecture).

The asset management information database proposed in Figure 6 (see page 26) could be understood as an improved version (or a version of its full potential use) of the CAFM systems used by facilities managers. Individual organisations can create BAM BIM models by developing 3D building models and a user interface to link the building model to the asset database or the improved CAFM systems. The BIM model proposed in this research could be adopted by asset managers as an improved approach to their current practice.
This research developed a web-enabled BIM model to illustrate the concept proposed in this project. Figure 8 presents the system architecture of this model.

4.2 3D building model

The case study organisation had a partially completed Autodesk Revit based 3D building model. This research improved the model’s record of the selected shower room space by detailing the building elements and components.

4.3 The asset maintenance information databases

An asset maintenance database was developed to model the selected shower room of the case study organisation. The decisions in the following sections were made during the organisation of data.

4.3.1 Structure of the elements

An appropriate structure of building elements, sub-elements and components was crucial in organising asset information. Three potential element structures were compared:

1. a structure based on the maintenance pricing schedule
2. the structure used for the healthcare building condition survey
3. a structure based on the 3D building model and Revit.

Adoption of a building element structure based on (1) (maintenance pricing schedule) would be ideal for this model because it primarily concerns maintenance cost management. However, building maintenance activities at present are primarily based on the condition of buildings and their components, suggesting that (2) may be easier to adopt. Furthermore, integrating existing condition survey data into a different building element structure (3) would be highly problematic. This model therefore adapted the building element structure used in the building condition survey by all NHS estates.

4.3.2 Categorisation of spaces

The healthcare organisation currently has a registry of assets and asset codes to record maintenance activities. The existing coding system contains information about the building in which the asset is located, but not necessarily about the individual space within the buildings. For example, the maintenance work history records for the maternity ward of the case study organisation between 01/09/2015 and 30/09/2016 show 59 records on blocked toilets and 48 records on doors requiring repairs, but the exact location of these repairs is not recorded. A more meaningful analysis on the condition and functionality of individual WCs or doors could be conducted if these maintenance activities were assigned to individual spaces. A new spaces code registry was therefore developed to label individual spaces within the healthcare premises.
This new code would also allow maintenance data to be stored in a more meaningful way and linked with individual spaces of the 3D building model. For example, the shower room modelled is labelled as ‘SamsWC1’ using the name of the ward and the type of space.

4.3.3 Condition survey data
As stated in Section 4.3.1, the building element/component structure is identical to the structure of the condition survey. Data concerning the physical condition of each sub-element/component for each space within the estate and the level of compliance with mandatory fire safety requirements and statutory safety legislation could easily be recorded. In addition, records on the age of the element/component and the remaining useful life years were added to supplement condition survey data.

4.3.4 Planned Preventive Maintenance (PPM) data
The organisation currently has task codes for some maintenance activities (e.g. A001 refers to ‘lamp switch does not work’ or code ‘B’ refers to ‘blocked toilet’ jobs), however, not all maintenance activities have been assigned a task code. Even though the CAFM system could attribute codes for maintenance activities using the facility of cost centre codes and cost code, this facility was not used by the case study organisation. The model developed in this research uses a task coding system that links tasks and maintenance costs. Two generic and broad task registers were developed for PPM tasks and resource management (RM) tasks, based on the maintenance activities listed in the ‘BCIS schedule of rates for repair and maintenance’. PPM1 and RM8 below are examples of two task codes used in the model:

- **PPM 1 (relevant BCIS cost code, 4.356.0):** Underpinning & strengthening, In-situ concrete in underpinning, 100–150 mm thick foundation, with plain concrete (1:3:6–20mm aggregate) filled into formwork in foundation trenches
- **RM 8 (relevant BCIS cost code, 6.130.0):** Ease door without removal

As a result of the difficulties associated with accessing details of the contracts with sub-contractors (their terms and rates), this research used the BCIS pricing structure and a dummy set of data for the repair and maintenance concerns for the selected WC space.

In addition to the description of the task and its cost, the tasks in the PPM and RM task registers were further supplemented with details of the sub-contractor carrying out maintenance works, generic task duration and any other relevant details. When a new maintenance job is entered into the system, the system can retrieve some common supplementary data (based on the task code) related to maintenance task.

4.3.5 Any other asset related information
Any other asset related information such as warranties and guarantees and health and safety related files can be electronically stored and retrieved within the system alongside the individual building elements or components. This feature could be used to attach and store changes to the building model until the 3D building model is repopulated, as it is laborious/time consuming to regularly repopulate the 3D building model. As there was no such specific information to attach to the model for the selected WC shower room, the model developed in this case study does not include this feature.

4.4 Functionalities of the BIM model

4.4.1 Performance monitoring – analysis of outstanding maintenance work

The model can produce the following outputs relating to outstanding maintenance work for the selected space(s). The space(s) can be selected on the 3D model or on the 2D plan.

1. Cost of outstanding PPM and RM tasks: the model allows asset managers to filter outstanding PPM and RM tasks and their associated costs. The records also show any qualitative comments/complaints made by users regarding individual elements or components (see Figure 9 on page 31).

2. Resource requirements for outstanding PPM and RM tasks: the model incorporates the human resources (skilled and non-skilled operative hours) required for each of the maintenance activities. The model is therefore able to analyse whether skilled or non-skilled operative hours are required to perform outstanding maintenance activities. This data could also be used to make decisions on adequacy of existing in-house operatives.

3. Priorities of outstanding PPM and RM tasks: the model allows asset managers to further filter outstanding maintenance work based on their priority (High; Moderate; Low). This is useful if the organisation has a restricted budget or for managing PPM and RM tasks to suit available resource levels. The asset manager can prioritise the expenditure on the high and moderate priority jobs. Further qualitative information taken from user sentiment surveys can also be accessed to inform decision-making. For example, relaying floor finishes may be ranked as a low priority task, but if there are recent complaints regarding the floor finishes, BAM can reset the priority to high or moderate and allocate maintenance expenditure accordingly (see Figure 10 on page 31).
Analysis of outstanding maintenance activities

Figure 9

Prioritising outstanding maintenance activities

Figure 10
4.4.2 Establishing patterns – analysis of completed maintenance work

Analysis of historic data on maintenance activities can inform future maintenance strategies in many ways. The model developed in this research allows two types of analysis:

1. Value/resource consumption of repair and maintenance for a given period (PPM and RM): this feature of the model helps decision-makers to identify building elements and components within their estates that are consuming a lot of energy or producing high levels of cost. They can then gather further evidence on such building elements and components and make decisions on replacing or refurbishing individual elements/components (see Figure 11).

2. Frequency of repair and maintenance (PPM and RM): frequent repair and maintenance activities could disrupt the efficient use of estates or even functionality of estates or its parts (e.g. constant faults in door locks may shutdown the functionality of shower rooms). This model allows estates managers to identify elements/components with frequent maintenance requirements. This data can also help to make decisions on replacing or refurbishing individual elements/components in order to avoid disruptions.

![Figure 11](image)

Example analysis of completed maintenance activities for a financial year

**Value of repair and maintenance (£m)**

- **Electrical systems**: £14m
- **Internal fabric and fixtures**: £25m
- **External Fabric**: £105m
- **Roof**: £64m
- **Hot and cold water systems**: £96m
- **Structures**: £143m

![Figure 12](image)

Locate items requiring maintenance and maintenance history

<table>
<thead>
<tr>
<th>Element</th>
<th>Sub-element</th>
<th>Sub-sub-element</th>
<th>Repair work</th>
<th>Repair work required</th>
<th>Subsequent repair work</th>
<th>Maintenance history</th>
</tr>
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<tbody>
<tr>
<td>INTERNAL • Fabric</td>
<td>Internal doors</td>
<td>Internal doors</td>
<td>RM 15</td>
<td>Jan 08</td>
<td>10 m</td>
<td>Door locks too tight</td>
</tr>
<tr>
<td>INTERNAL • Fabric</td>
<td>Internal doors</td>
<td>Internal doors</td>
<td>RM 14</td>
<td>Aug 09</td>
<td>10 m</td>
<td>Door locks too tight</td>
</tr>
<tr>
<td>INTERNAL • Fabric</td>
<td>Internal doors</td>
<td>Internal doors</td>
<td>RM 14</td>
<td>Sep 10</td>
<td>10 m</td>
<td>Door locks too tight</td>
</tr>
<tr>
<td>INTERNAL • Fabric</td>
<td>Internal doors</td>
<td>Internal doors</td>
<td>RM 14</td>
<td>Sep 10</td>
<td>10 m</td>
<td>Door locks too tight</td>
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<td>RM 14</td>
<td>Sep 10</td>
<td>10 m</td>
<td>Door locks too tight</td>
</tr>
</tbody>
</table>

4.4.3 Locate items and history of repair and maintenance (for individual elements/components)

The model allows NHS estates to view the repair and maintenance history for selected individual elements/components (see Figure 12). This data can be used to analyse the effectiveness of individual elements/components as well as to supplement the new job tasks for individual elements/components.

4.4.4 Better updated condition survey and supplement other auditing reports

NHS estates conduct a detailed physical condition survey every five years. For the purposes of interim monitoring and decision-making the proposed model enables a desk-based update of this condition survey based on the records of repair and maintenance activities and other qualitative data stored against each space in the buildings. Furthermore, as the BIM model stores data related to individual spaces, it also facilitates the production of condition survey reports for both individual and multiple spaces.
5.0 Discussions, conclusions and recommendations

5.1 Discussions

The potential of BIM informed BAM: providing multi-faceted information for more strategic maintenance management

BAM BIM models can facilitate more strategic building maintenance management by integrating a wide range of data relating to the physical condition of the building and its assets, the performance of the building and assets as perceived by building users, and the level of resource available. The BIM supported asset management approach presented in this research eliminates issues associated with maintenance approaches that only consider, or respond to, the physical condition of an asset (as identified in Jones and Sharp, 2007; Sherwin, 2000; Tsang, 2002). The BAM BIM model proposed in this research facilitates a platform for asset managers to communicate with building users and consider their concerns within the maintenance strategy/programme. The model is able to cope with dynamic organisational (technological and functional) demands highlighted through user requirements. Investment decisions based on organisational (top management and end-user) demands in turn provides evidence of how investment into asset maintenance impacts organisational performance. By demonstrating this link between asset maintenance activities and organisational performance, decision-makers should be able to justify investments in maintenance activities.

The asset management BIM models contain a history of maintenance activities for individual spaces or components within the estates. These details could be used to produce updated reports on the physical conditions of estates. This may eliminate some of the weaknesses associated with the physical condition surveys for buildings identified in the literature review. Integrating interdepartmental data into BIM models will require significant changes to current data collection, data storing and data sharing practices in NHS hospitals. Support for the operational changes and investment required to implement a BAM BIM model therefore needs a top down approach incorporated with the lead and support from senior managers in organisations.

Design requirements for BIM models depend on procurement routes

Many BIM applications in the design and construction phases of buildings are designed taking a technology-driven approach with little or no consideration given to individual project requirements. The results of this research indicate that the BAM BIM model instead requires a demand-driven approach; one that considers individual organisational requirements. These could be primarily associated with the functionalities required by different types of asset management procurement options.

The BAM BIM model developed in this research can be used to store and manage the agreed contractual rates
Building Information Modelling to support healthcare built asset management

included in maintenance trade contracts. The model used two registers of RM and PPM activities. These were integrated with the costs of each maintenance activity. The model therefore supports the following cost management related functionalities:

- establishing the cost of outstanding PPM and RM tasks
- prioritising outstanding PPM and RM tasks to suit a fixed budget (risk based, space based and staff and user comments based).

The next generation of BAM BIM models for this type of maintenance contract should facilitate e-tendering. The development of such a model could be inhibited by the lack of a standard schedule of rates to support maintenance contracts for complicated buildings such as those in the healthcare sector.

For NHS estates whose maintenance activities are managed with in-house staff and operatives, a slightly varied version of the original model was developed to support time management related functions. The registers of RM and PPM activities were integrated with man-hours and material costs for each maintenance activity. Approximate skilled operative hours and non-skilled operative hours for different types of operatives (e.g. carpenters, plumbers, electricians) were entered against each activity to support the following time management functionalities:

- establishing the work hours required for outstanding PPM and RM tasks
- prioritising outstanding PPM and RM tasks to suit a fixed staffing resource level (risk based, space based and staff and user comments based).

Externally published data on the supervisory, skilled operative and non-skilled operative resources required for maintenance activities is very limited. Organisations therefore have to rely on their in-house data to estimate operative demands for their maintenance activities. For totally outsourced maintenance contracts on a fixed lump sum per year, the BAM BIM model could provide useful evidence on annual maintenance costs that could inform contract value negotiations with the maintenance contractor. NHS estates could also use the data from the model to compare the competitiveness of the lump sum contract with that of other contractors when tendering.

Benefits of BAM BIM models during the operational phase of buildings

The advantages of BIM for the asset management phase are slightly different for those in the design and construction phase. Key advantages of BIM during the design and construction phases are associated with effective information management, visualisation of the design and collaboration among members of the project team. BAM BIM models facilitate benefits associated with these aspects in varying levels as explained below.

- Visualisation is not seen as a significant benefit of BAM BIM modelling, since buildings and assets are physically observable during the in-use phase. However, visualisation serves as a benefit during the maintenance activities associated with refurbishment or repairs in concealed spaces. Visualisation of spaces and elements has some benefits during entering and filtering maintenance or building data of a given space or an element.

- BAM BIM models also facilitate collaboration. Existing CMMSs facilitate a reasonable level of collaboration between the asset management team and external organisations providing asset management services, particularly for sharing work orders. BAM BIM models can improve this collaboration by providing more detailed, qualitative and up-to-date information for use in contract negotiations and work scheduling. Advanced BAM BIM models could also encourage more collaborative working relationships between the various departments in NHS hospitals thus facilitate multifaceted performance monitoring of built assets through sharing a wide range of interdepartmental information (for example, sharing comments and complaints by clinical staff and patients related to the performance of built environment). The model can also facilitate better collaboration between estates and facilities divisions and senior managers of the organisation. Senior managers of the organisation can access more efficient and accurate models of costs and cost analyses for their estates, different spaces and for elements in real time. This can be used to inform maintenance investment decisions and especially investments in backlog maintenance.

- Integrating a wide range of interdepartmental data is another unique benefit of BAM BIM modelling. The BAM BIM model needs to integrate and manage a wide range of information related to the asset management resources, the performance of the physical assets of the estates and its contribution to the quality of healthcare. These can therefore support a more effective multi-faceted decision-making approach to maintenance management. However, the process of manually inputting information into existing CMMSs is a significant burden to NHS estates. This research finds that a higher level of automation is required to enable the inclusion of a more diverse set of information into the BIM model.

- BAM BIM models could be used as a reporting tool for asset management. Effective and fully functional BAM BIM models integrating a wide range of data are able to produce various reports to support decision-making at departmental (FM) level as well as organisational level. As explained above, at the departmental level, the model can produce various reports on outstanding maintenance work and their costs. The model can support budget allocation decision-making at organisational level through the reports on time series analysis for resource invested for maintenance management of given space(s). These reports could also be used to establish benchmarks and KPIs (Key Performance Indicators) for individual campuses within the same organisation, or even compare performance of buildings maintenance nationally.
BIM for existing buildings

Implementing BAM BIM for use in existing buildings needs significant resource investments. The literature revealed a series of techniques that could be used to develop “scan to BIM” models for existing buildings. However, in order for the BAM BIM model to perform the advanced functionalities proposed in this research, a significant level of manual data entry and data feeding is required to capture other information (such as maintenance contract data and maintenance history data and data gathered from clinical departments within the hospital). This burden may prevent the development of comprehensive BIM models for existing buildings, particularly those that are becoming obsolete. NHS estates in England have a considerable proportion (circa 40%) of older buildings built before 1985. It is likely that NHS estates will need guidance and support to implement BIM for the in-use phase of existing buildings.

Properly implemented BAM BIM can go beyond the capabilities of CMMSs and can support maintenance decision-making through the analysis of a wide range of data. Many organisations use CMMS systems to manage the maintenance of their existing built assets. The burden of data entry has prevented organisations from utilising the full capabilities of CMMSs. NHS estates will still face the burden of feeding information into the BIM model in order to utilise all the functionalities and intelligence associated with BAM BIM models. BAM BIM models should be integrated with the automated data feeding techniques discussed in Section 2.3 (such as sensors to feed room temperatures, patient and staff feedback recorded via speech recognition techniques) to reduce the burden associated with manual data entry.

BIM models could be developed and deployed to facilitate management of statutory requirements that need to be performed by organisations on a frequent basis, for example, the testing associated with Legionella or the testing associated with fire regulations.

5.2 Conclusions

This study has shown that by utilising the capabilities of ICT technologies to integrate a wide range of data and advanced functionalities, BAM BIM models can:

- facilitate more strategic and multifaceted decision-making in the maintenance management of buildings
- eliminate the deficiencies associated with traditional physical condition based approaches to maintenance management.

The advantages of BAM BIM are greater than those advantages of using BIM during the design and construction phases of the building life cycle. A key benefit of the BAM BIM model is its capability as a powerful reporting tool. The reports that a BAM BIM model can produce could support in-house organisation-level decision-making and could be used for external auditing purposes. Digitally integrating a wide range of interdepartmental data will enhance more up-to-date data sharing and reduce data duplication. Therefore, BAM BIM modelling can help to streamline existing healthcare (building and health) auditing systems.

Integrating interdepartmental data into BIM models will require significant changes in the current practices of data collection, data storing and data sharing within the non-estate departments (such as medical wards) of the NHS. Therefore, support for the financing and development of BAM BIM should be initiated from the top level senior managers of NHS hospitals taking a top down implementation approach. BAM BIM models need to be developed taking a demand-orientated approach, so that they are tailored to the specific circumstances and practices of individual NHS estates. These circumstances include the age and organisation of the building, the organisation’s use of in-house and out-sourced sub-contractor teams in asset maintenance, the capabilities of staff, the organisation’s facilities management budget and the current levels of ICT use for maintenance management.

BAM BIM model capabilities can exceed those of CMMSs. However, it is worth noting that the burden of manual data entry has prevented asset managers using existing CMMSs at their full potential. BAM BIM models should be integrated with automated data capturing and feeding techniques so that BIM models can be used to their full potential. The implementation of BAM BIM in existing buildings (where there has been no use of BIM in the design and construction phase) requires significant resource investments. This burden may prevent comprehensive BIM model development for existing healthcare buildings. Imposing national level targets (time targets and level of adoption) for adoption of BIM for existing buildings may therefore not be suitable since the resource requirements and amount of work associated with BIM adoption for existing buildings is dependent upon the building portfolio of individual NHS estates.

The findings of this report provide insight into the challenges and opportunities associated with the implementation of BAM BIM in NHS estates. However, further research is needed to establish the strategies and the resources required to implement BIM for existing healthcare buildings.
5.3 Recommendations

More standards and guidance are required on procurement of asset management for the in-use phase of buildings

Procurement of construction work is supported by a significant level of guidance and externally published resources. This includes guidance on procurement route selection, contract formation and cost and time resources required for new construction work. However, there is a relative lack of guidance for procurement of asset management.

- Asset management professionals will benefit from tools and guidance to help them choose between various asset management procurement options based on their individual circumstances. These can also include detail guidance on implementing and managing each procurement route. This guidance will help NHS trusts to identify the most efficient ways to manage their estates and negotiate competitive prices for the maintenance activities they contract out.
- Professional bodies, such as RICS, representing asset management professionals could provide specific knowledge portals and competencies frameworks to asset management activities.

Published cost and man-hour data on asset maintenance

Data concerning asset management activities (the time taken and the cost) is crucial to both asset management procurement and asset maintenance investment decision-making. However, this data is not publicly available.

Organisations that organise asset maintenance in-house will benefit from published data on the working hours needed for the maintenance activities associated with buildings and their assets. The data contained in existing private sector price books on working hours needed for construction activities is unsuitable for use when managing assets with in-house staff. Data on the working hours required from skilled and non-skilled operatives in different trades (such as electricians, plumbers and carpenters) and for different types of maintenance activities will help organisations to:

- more effectively recruit skilled and non-skilled operatives based on anticipated maintenance work load
- more efficiently manage the maintenance budget.

Organisations that totally or partially outsource asset maintenance will benefit from asset maintenance cost models, functional unit rates, cost per m² rates or similar evidence-based norms to negotiate a competitive market price (a lump sum per year) and substantiate the outsourcing decision.

- BCIS data on maintenance and repair rates should be calibrated to support the above listed needs.

More research and investment on automated data collection techniques

BAM BIM models require a significant level of manual data entry. This burden of data entry has prevented the optimum use of existing computer aided asset maintenance systems, such as CAFM and CMMS. The use of intelligent buildings data capture technologies supports the development of an integrated, user friendly and efficient BAM BIM system to perform more intelligent analysis.

- In order to perform the advanced functionalities proposed in this research, the BAM BIM model requires data from other departments within the organisation. Realisation of the full benefits of BIM for asset management and FM is therefore dependent on automation and information sharing across the organisation.

Creating a dialog on BAM BIM among property related professionals and owners

Due to the current popularity of BIM, organisations may rush to implement BIM to support asset management and FM functions. However, creating a building model (Revit model) without any of the other systems will not provide the advanced functionalities to support asset management described in this research. Any investment in creating a building model (Revit or similar) without a strategy to link maintenance investments and healthcare organisational performance would be less profitable.

- More dialogue on BAM BIM among property-related professionals and owners would provide the support needed by FM professionals and building owners who wish to implement BIM during the in-use phase.
6.0 References


Building Information Modelling (BIM) Task Group, 2017. What is Building Information Modelling (BIM)? Available online: http://www.bmtaskgroup.org/bim-tasq/


Confidence through professional standards

RICS promotes and enforces the highest professional qualifications and standards in the valuation, development and management of land, real estate, construction and infrastructure. Our name promises the consistent delivery of standards – bringing confidence to markets and effecting positive change in the built and natural environments.

Americas

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