Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-28 (2016) 191–196

Building Information Modeling as Assest Management Tool

A.J. Guillen*, A. Crespo*, J. Gómez*, V. González-Prida*, K. Kobbacy, S. Shariff****

** School of Engineering, University of Seville, Seville, CP 41092*
Spain (e-mail: ajguillen@us.es, adolfo@esi.us.es, juanfrancisco.gomez@juntadeandalucia.es, vicente.gonzalezprida@gdels.com).
*** Chair for Operations & Maintenance. University of Taibah, Medina, KSA (e-mail: kobbacyk@gmail.com, samshariff@yahoo.com)*

Abstract: BIM models are transforming the way buildings or, in more general terms, facilities or infrastructures are conceived, designed, constructed and managed. But current use of BIM concentrates on preplanning, design, construction and project delivery rather than maintenance and operation management. This despite the fact that it is estimated that operation and maintenance phase constitutes approximately 60% of the total lifecycle cost of a facility or building. Asset Management, which is a broad discipline including Facilities Management (FM), provide an advance approach getting more efficiency and efficacy in the lifecycle management of building and facilities. This paper introduces how the development of AM in this particular field is going to be supported by the application of BIM models as key tool that will allow asset management information system effective implementation.

© 2016, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.

Keywords: Building Information Model, BIM, Facilities Management, FM, Computer Aids Facilities Management (CAFM), PAS 1192-2, PAS 1192-3.

1. INTRODUCTION

Are Asset Management (AM) and BIM (Building Information Modeling) a natural partnership? Both are powerful research and development lines in this moment. The integration of BIM tools within AM approach ensure that the organization obtains the results that expects (Love et al. 2014).

It is estimated that operation and maintenance phase constitutes approximately 60% of the total lifecycle cost of a facility or building. Within the components of this cost is interesting to highlight those related to inadequate interoperability between different roles and stakeholders involved in the building lifecycle. For example, a study by the US National Institute of Standards and Technology (NIST) showed that the annual costs associated to inadequate interoperability among software systems was $15.8 billion (Gallaher et al. 2004). Two thirds of this cost was incurred as a result of on going facility operation and maintenance activities (Shen et al. 2010). The sector has realized that information management is one of the main reasons of this over cost. BIM is a holistic approach to the design, construction and management of these facilities. The introduction of BIM can addressed this challenge, but not alone. Incorporating AM view and tools appropriate operational and lifecycle information can be incorporated into this model, and all the stakeholders will have all the information needed to take decisions.

BIM in the literature is more properly linked with facilities management (FM) than AM. But actually FM can be understood as a part or tool of AM (ISO:55000; PAS 1912-3:2014). So talking about BIM as a FM tool supposing, by extension, link BIM and AM.

AM approach allows connecting BIM technology application with a relevant fact: the necessity of managing the asset value. With this view, the implementation of BIM should not be considered an isolate IT effort for an organization but integrated within the asset information system in the asset management system. (PAS 1912-2:2013)

The literature shows that, despite many attempts to BIM-FM implementation exist and apparently provide good results, they are still piecemeal and FM cases showing extensive use of BIM are lack (Kassem et al., 2015; Volk et al., 2013). Moreover, case studies generally are focused on specifics FM area and still present many gaps, issues and challenges to be implemented correctly (Parsanezhad et al., 2014). Perception of BIM (lack of benefit evidence, lack of FM engagement), standards and policy (interoperability, tools integration), risk and uncertainty (potential lack of interest from investors, creation new market and new roles, validate BIM data), building physical aspect (create models of existing facilities, different management strategies), information management and technology (data repetition and loss, overload of data, use of different software, information update), education and skills, are few examples resumed by Ashworth (2015). However one of the most relevant changes appears in the attitude of the FM team that becomes more process oriented and seeks to identify process inefficiencies that could be mitigated by the adoption of BIM (Fukuda et al., 2014).

The growing rate of BIM users can pull the AM application development. Following similar approach standards as PAS

2405-8963 © 2016, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.
Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.11.033

1192-2 and 1192-3, they have been recently developed where the AM principles are connected and used together with BIM.

2. BACKGROUND

2.1 BIM background

In the past decades, there had been a growing interest in the use of Building Information Models (BIM) by the construction sector due to many benefits and resource savings during design, planning, and construction of new buildings (Eastman et al 2013). Despite the development of 3D modelling started in the 1970s, BIM modelling was not introduced in pilot projects until early 2000s to support building design of architects and engineers (Volk et al. 2014). Comparing BIM with 2D CAD, this uses views and representations that are difficult to check and update considering that, if one view is modified, the rest should be revised too. Traditional 2D CAD only includes graphical entities in contrast to the intelligent contextual semantic of BIM models that include geometric and non-geometric data, characterizing, among others: the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories, project schedule and operation and maintenance. BIM is an "object oriented" approach to CAD where designers and stakeholders work primarily with architectural elements instead of vector based graphics. Objects have "intelligence" that provide a certain degree of automation

Nowadays the term BIM (Building Information Modelling) can indicate a process, a discipline or a technology. This model is much more than a 3D representation of the building. Its real strength and power lies in the knowledge database, which can be used in conjunction with other software to deliver quick and reliable information in areas of sustainability, estimating, structural analysis, demolition and reconstruction (Zhang 2009).

In this sense, the given definition of BIM by the Building Smart Alliance introduces the following aspects that serve to understand the holistic view of BIM conception and its potential:

- A digital representation of physical and functional characteristics of a facility. Not only graphical information of the building elements but also the rest of information types that can be used to manage all the lifecycle phases: manufacture and vendor data, service and use requirements, operation and maintenance data, performance parameters, energy consumption, etc.
- A shared knowledge resource for information about a facility, forming a reliable base for decision during its lifecycle.
- A platform for collaboration by different stakeholders at different phases of the facility lifecycle in order to insert, extract, update or modify information in the BIM support reflecting different roles according to each stakeholder's interest.
- The BIM is shared digital representation founded on open standards for interoperability. In addition to the standardization needs, this point highlights the open character of BIM conception, in order to allow the combined use of different software an application (3D design, FM software and others) and to support the successive software updates.

In order to illustrate the progressive introduction of capability or functionalities within the models, the following terms have been employed:

- 2D models: classical 2D CAD model application.
- 3D models: 3D design and tools. Parametric and object oriented approach. 3D digitalization.
- 4D models: Scheduling and project sequencing. The capabilities of capture data and information representation is used for planning and control project and construction execution.
- 5D models: Cost estimating. Budget estimation and control of the construction phase.
- 6D models: Sustainability. Control of the impact of construction and operation.
- 7D models: Facilities Management. Including operation and maintenance planning and execution and the rest of life-cycle considerations.

In this "n-dimensional" treatment of the BIM applications it is clearly showed the tendency to BIM and AM integration. Despite this, the AM approach includes even more ambitious objetives than 7D models.

Governments around the world have recognized in general terms the inefficiencies affecting the construction industry. As a result, different regulatory initiatives have appear that either recommend or mandate the use of building information modelling as a strategy to address a declining productivity (Kassem et al. 2015). In this case, the most significant reference is probably UK. UK has mandated BIM level 2 on all centrally procured projects from 2016, including the handover of digital data required for the operational phase (PAS 1192-2:2012). Although this mandate prescribes an operational handover specification, there is still a limited amount of research on the FM industry with regards to BIM. Due this, new research projects focused on getting use cases for application of BIM in FM are being promoting.

2.1 AM and FM background

AM and FM are overlapped disciplines. The terms AM and FM are often used interchangeably, although there are differences in approach between the asset management and facilities management disciplines. FM is focused on the infrastructure and building sectors while AM has a broader application field. Especially in the building sector FM considered a consolidated profession (IFMA 2013). Both have generated their own standards or specifications and both have evolved their own language of preferred and defined terms. The ISO 55000 lists FM among the asset management activities. With this view FM can be considered as a part or tool of AM, since AM goes beyond FM providing a more comprehensive view and more potential benefits.

Fig. 1. Relation between AM, FM and O&M

FM is defined by EN 15221-1 as "the integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities.". The optimization of building operational phase is a complex issue. Together with its intrinsic complexity of such facilities, it has to be considered the legislation and sustainability demands, fitting with usage requirements. (Zhang et al., 2009). This complex scenario is completed with the trend to outsourcing services, and the introduction of procurement routes that include operation and maintenance in integrated supply contracts. FM as discipline provides a holistic view of the building operation and maintenance, an overall management of the resource available towards the strategic objectives of facilities' users and owners. Here is located the potential of FM rather than the accumulation of maintenance task or new software applications. FM is a broad concept, covering everything from real estate and financial management to maintenance and cleaning (Atkin and Brooks, 2009).

The benefits of AM are proven in many industries and business environments, improving the performance along the lifecycle and the contribution to safety, health and protection of the environment. Together with organizational commitment to quality, performance or safety, it helps to mitigate the legal, social and environmental risks associated to accidents in industrial facilities. Asset Management, as a discipline, allows organizations to optimize the whole life value of managing assets portfolios. For a single organization, the list of assets or portfolio may contain diverse assets in nature, distributed over extensive geographical areas, and may be subjected to differing demand/utilization requirements. In agreement to ISO 55000, AM can be applied to all kind of assets, including physical assets (elements, inventory and properties) and intangibles assets (leases, brands, digital assets, use rights, licenses, intellectual property, etc.)

The general principles of AM have been defined by the family of standards ISO 55000, ISO 55001, ISO 55002. Among the aspects contained in this approach, those who can be described as more innovative, and representing a significant advance in the optimization of asset management, they may include:

- Managing the value of the asset. AM supports the realization of value while balancing financial, environmental and social costs, risk, quality of service and performance related to assets.
- Risk based decision-making. Effective control and governance of assets by organizations is essential to realize value through managing risk and opportunity, in order to achieve the desired balance of cost, risk and performance.
- Integrating the longer term activity of asset management with the shorter term activity of asset
- Stakeholders' treatment. The stakeholders requirement but also the information exchange and the suitable access to the information (right information, to right person at the right moment)
- The information requirement and its treatment. AM is intensive in data/information management. Asset information system can be extremely large and complex and creating, controlling and documenting this information is a critical function of the asset management system.

This last point reinforces the importance of information management in AM. The Information System is one of the key elements in asset management systems (AMS) defined by ISO 55000-1 (Fig. 2). An asset management system is a set of interrelated and interacting elements of an organization, whose function is to establish the asset management policy and asset management objectives, as well as the processes needed to achieve those objectives. In this context, the elements of an asset management system should be viewed as a set of tools, including the information systems, which are integrated to give assurance that the asset management activities will be delivered. For building asset management this required information system could be implement from the implementation of the BIM model.

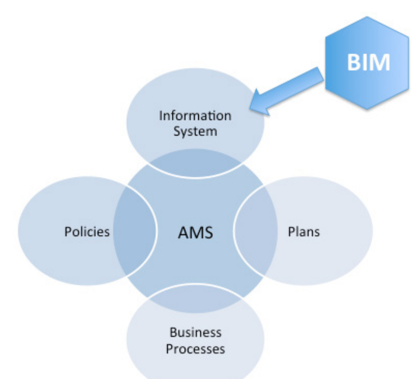

Fig. 2. AMS (Assets Management System) elements

3. INFORMATION AND DATA MANAGEMENT & TECHNOLOGIES INTEGRATION

One of the key points of BIM application is the information and data management. BIM development provides the opportunity to get and manage more information with more quality, incrementing its use and applicability. At the same time, it is a great challenge to obtain such a powerful information system, including the integration of other software and technologies that can be information sources.

3.1 Information requirements and/or needs

A first step in this process is the determination of information needs. Two views have to be managed at the same time: the election of the element breakdown structure for the organization (until the so called intervention level) and the level of development of elements (LOD). Both views are connected but express different aspect of the system and its elements. O&M task management is very sensible to final description of the system and, by extension, FM and AM. Jointly with this last consideration, there are two problems, totally opposite one to the other, that must be taken into account:

- Information filtering: Much of the information typically included in models is unnecessary for day-to-day operations
- New information needs: Relevant information for maintenance and reliability management is not present or is not reliable for advanced approaches. In some cases it is possible to find CMMS or CAFM, but this can result an additional complication.

Determining what Level of Development (LOD) is necessary to achieve the benefit for that specific model element. The Level of Development describes the level of completeness to which a Model Element is developed. There are several ways that Level of Development can be documented. The most widely accepted by the industry is LOD defined in the model progression specification and adopted in AIA E202

Table 1. Level of Development descriptions.

Level of development (LOD)	Description
LOD 100: Schematic Design Model	Overall building massing indicative of area, height, volume, location and orientation may be modelled in three dimensions or represented by other data
LOD 200: Design Development Model	Model Elements are modelled as generalized system or assemblies with approximate quantities, size, shape, location and orientation. Non-geometric information may also be attached to model elements.
LOD 300: Construction Documentation Model	Model Elements are modelled as specific assemblies accurate in terms of quantity, sixe, shape, location and orientation. Non-geometric information may also be attached to model elements
LOD 400: Construction Model	Model Elements are modelled as specific assemblies accurate in terms of quantity, sixe, shape, location and orientation with complete information assembly, and detailing information. Non-geometric information may also be attached to model elements
LOD 500: Record Model	Model Elements are modelled as constructed assemblies actual and accurate in terms of size, shape, location, quantity and orientation. Non-geometric information may also be attached to model elements

Regarding what information should include a specific BIM model; one important reference is about the BIM maturity levels. PAS 1192-2 and PAS 1192-3 are both known as BIM Level 2, in response to the UK Government's Construction Strategy published in 2011. Following this approach, four maturity levels are distinguished, from level 0 to level 3. This level 2 includes:

"Managed 3D environment held in separate discipline "BIM" tools with attached data. Commercial data managed by an enterprise resource platform. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary). The approach may utilize 4D programme data and 5D cost elements as well as operational systems." In addition to this, collaboration at BIM Level 2 is file-based in opposition to paper-based (BIM Level 0) or through integrated web services (envisaged as BIM Level 3 at the time of writing).

3.2 Interoperability and standardization.

Interoperability is one of the keystones of BIM models and its uses. Different organizations and roles take part along the building lifecycle. They may apply different software or may demand different types of data. The Industry Foundation Classes (IFC) is a standardized non-proprietary data format for sharing and accessing construction and facility management data, enabling interoperability between heterogeneous software applications. This format is described by the ISO 16739:2013 "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries". It is an open international standard for BIM data that is exchanged and shared among software applications used by the various participants in a building construction or facility management project.

The Construction Operations Building Information Exchange (COBie) is a data exchange model for the publication of building information subsets focused on delivering non-geometric information and asset data, rather that geometric information. It is a subset of the IFC, but may also be conveyed using spreadsheet. Initially COBie was developed by the US Army Corps of Engineers as a method of delivering O&Ms specific data in a standardized format, delivered in a spreadsheet format.

COBie helps capturing and using information essential to support operations, maintenance and asset management. The COBie file may contain data from consultants, the contractor, sub-contractors, suppliers, and even the client. Ultimately, the data will provide information for the efficient operation and management of the facility. COBie consists of multiple sheets documenting attributes of the facility, its systems and assets and details of their product types, warranties, maintenance requirements etc. While the project is developing, additional attributes, issues and documentation can be associated to specific items. UK government has introduce de COBie format as principal part of Level 2 BIM requirement that will be mandatory for all centrally procured Government contracts from 2016. Level 2 BIM includes 3D

BIM models and project and asset information available in COBie format (Carbonari et al 2015)

Particular technologies, such as the use of cloud computing, passive RFID tags and 3D scanning, have facilitated added value to BIM in a Facility Management/Operations context (McArthur et.al 2015). Vice versa, the BIM potential aids in the introduction and effective use of these technologies and others as condition monitoring and predictive maintenance, energy consumption control, etc. Actually, these technologies can be seen as information sources that are integrated and used in the building management through the BIM implementation and its interoperability with rest of software packages, which are linked to the operation and maintenance of the building (Figure 3)

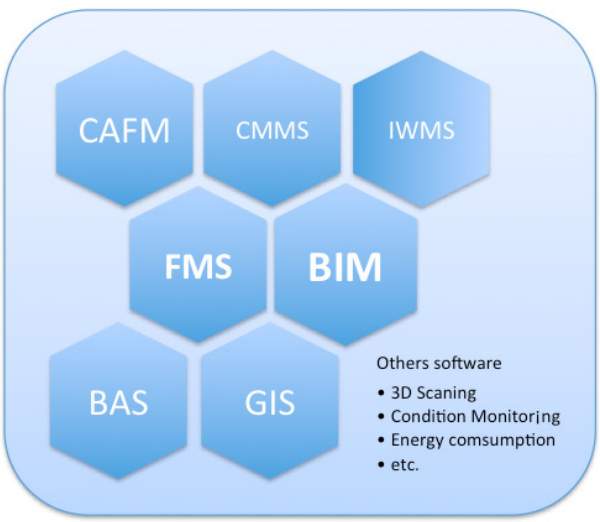

Fig. 3. Environment of software interoperability of AM

Facility Management Systems are software packages that support the maintenance and management of a facility. It helps to manage work orders, assets, inventory, and safety. Some names that can be classified under Facility Management Systems include Computerized Maintenance Management Systems (CMMS), Computer-Aided Facility Management (CAFM), and Computerized Maintenance Management Information System (CMMIS). If an organization has a FMS, it should be evaluated for its ability to support the BIM Data and Uses as defined in the previous steps. If an organization does not have a FMS, it is important that a proper one is selected. According to the interoperability requirements of the building asset management approach, the FMS should support the importing and/or exporting of data to other systems. It is especially important to consider the integration and acceptance of BIM Data, i.e. FMS should have the ability to import and/or export BIM data directly from the BIM Model. For this purpose, FMS have to support open standards for data transfer such as COBie. Finally FMS should be able to handle other graphical data such as photographs and plans and the interface with others technologies (BAS, Condition Monitoring, etc.). Comparing with the simple application of CAFM or CMMS software, the use of BIM models aids in two aspects:

- Allow introduce AM and FM from the very beginning of the building lifecycle (designing and constructions)
- BIM software as interface: intelligent and detailed representation of physical and functional characteristics

Building Automation Systems (BAS) have a main role in new intelligent buildings. They conform the control system of the building and include facilities control and the interaction with users. These systems are going to produce relevant information and will be one of the main sources for FM. Once again, the problem to use these data is the interoperability of BAS hardware/software with FMS and BIM.

This environment of software interoperability of AM, with BIM models as a central element, is totally aligned with the E-maintenance principles, term that serves as a conceptual support to general use and applications of ICTs in maintenance. This is related to the effective introduction of new capabilities at the service of maintenance and asset management among lifecycle product stages. This approach helps to understand the scope of maintenance evolution provided by these technologies. Muller et al. (2008), analyzing the potential improvements in the e-maintenance concept application context, introduce the following references to the maintenance tasks evolution:

- Cooperative/collaborative maintenance:
- Remote and on-line maintenance:
- Maintenance documentation/record and knowledge capitalization and management
- Fault/failure analysis and predictive maintenance

3.3 BIM and AMS. PAS 1192-2 and PAS 1192-3

PAS 1192-2:2013 "Specification for information management for the capital/delivery phase of construction projects using building information modeling" and PAS 1192-3:2014 "Specification for information management for the operational phase of assets using building information modeling", are complementary documents that specified an information management process to support building information modelling (BIM) Level 2, referred previously in this chapter in: (i) the capital/delivery phase of projects, PAS 1192-2, (PIM, project information model); (ii) the O&M phase PAS 1192-3. (AIM, Asset Information Model)

PAS 1192-2, PAS 1192-3 applies to both, building and infrastructure assets, and the intended audience for these documents includes organizations and individuals responsible for the procurement, design, construction, delivery, operation and maintenance of buildings and infrastructure assets. These standards cross-reference with other existing standards concerned with the management of assets. In particular, are closely related to the ISO 55000 series of standards that provide one overarching framework for the adoption and implementation of PAS 1192-2 and PAS 1192-3.

PAS 1192-2 focuses specifically on project delivery, where the majority of graphical data, non-graphicaldata and documents, known collectively as the project information model (PIM), are accumulated from design and construction activities. PAS 1192-3 focuses on the operational phase of assets. Progressively working through the various stages of the information delivery cycle (Fig 4), the requirements within this PAS culminate with the delivery of the as-constructed asset information model (AIM). AIM is handed over to the employer by the supplier once the PIM has been verified against what has been constructed and it is used to support the portfolio management activity for the life of the asset.

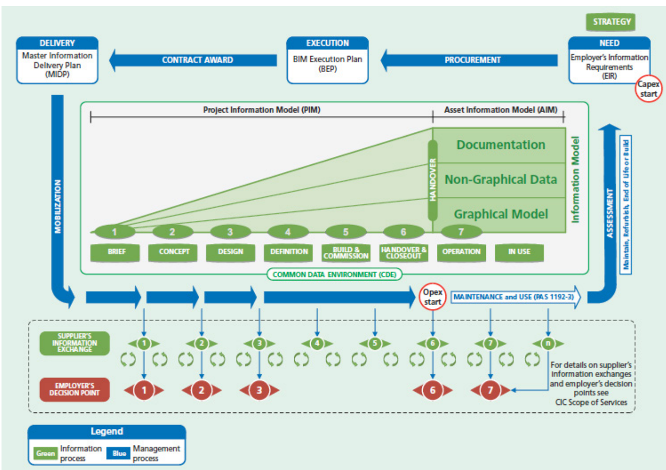

Figure 4.- AIM and PIM. The information delivery cycle (PAS 1192-2:2013)

6. CONCLUSIONS

The current evolution of the sector is promoting a great increment of BIM applications. But these applications are mainly focus on design and construction. The use of BIM models for operation and maintenance phase is not so extended. For this reason, although there are a lot of references about the potential benefits of BIM use, there are few references about the quantification and realization of these benefits in practical cases for operational phases. In conclusion, BIM benefits for AM are not well characterized. Methodologies and application frameworks have to be proposed and tested to develop reference use cases that will allow extending the knowledge about AM supported by BIM model as the base for an asset management information system. In this sense, the PAS 1192 standards series jointly with the most general ISO 55000, are the main references for this development process and for any particular implementation attempt.

REFERENCES

Azhar, S., (2011). Building Information Modelling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadership Manage. Eng., 11(3), 241–252.

EN 15221-1: 2006. European standard in facility management–Part 1: Terms and definitions.

Fukuda, S., (2014), BIM for FM: A Case Support for Business Life Cycle. PLM 2014, IFIP AICT 442, pp. 63-74, 2014.

Gallaher, M. P., O'Connor, A. C., Dettbarn, J. L., and Gilday, L.T. (2004). Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry. National Institute of Standards and Technology. http://fire.nist.gov/bfrlpubs/build04/PDF/b04022.pdf

ISO 55000:2013, Asset Management - Overview, principles and terminology

IFMA, International Facilities Management Association. What is FM?, Accessed 28th May 2013, available at: http://www.ifma.org/know-base/browse/what-is-fm 2013.

Kassem, M., Kelly G., Dawood, N., Serginson, M., Lockley, S., (2015). BIM in facilities management applications: a case study of a large university complex. Built Environment Project and Asset Management Vol. 5 No. 3, 261-277

Love, P.E.D., Matthews, J., Simpson, I., Hill, A., Olatunji, O.A., (2014). A benefits realization management building information modelling framework for asset owners. Automation in Construction 37, 1–10.

McArthur, J. J., (2015). A building information management (BIM) framework and supporting case study for existing building operations, maintenance and sustainability. International Conference on Sustainable Design, Engineering and Construction. Procedia Engineering 00

Muller, A., Marquez, A. C., & Iung, B. (2008). On the concept of e-maintenance: Review and current research. Reliability Engineering & System Safety, 93(8), 1165-1187.

PAS 1192-2:2013, Specification for information management for the capital/delivery phase of construction projects using building information modeling

PAS 1192-3:2014, Specification for information management for the operational phase of assets using building information modeling.

Parsanezhad, P., Tarandi, V., (2013). Is the age of facility manager's papers boxes over? CIB World Building Congress.

Shen, W., Hao, Q., Mak, H., Neelamkavil, J., Xie, H., Dickinson, J., Thomas, R., Pardasani, A., and Xue, H. (2010). Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review. Advanced Engineering Informatics, 24(2), 196-207.

Volk, R., Stengel, J., Schultmann, F., (2014). Building Information Models (BIM) for existing buildings – literature review and future needs. Automation in Construction 38, pp.109-127.

Zhang, X., Arayici, Y., Wu, S., Abbott, C., Aouad, G., (2009). Integrating BIM and GIS for large scale (building) asset management: a critical review. Twelfth International Conference on Civil, Structural and Environmental Engineering Computing.