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Revolutionizing the AEC Industry Through the Use of BIM and KM

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Abstract
Building Information Modelling (BIM) is deemed to be one of the prominent tools of the 21st century in the Architecture, Engineering and Construction (AEC) Industry, helping construction stakeholders, and clients to gain value from their projects. Moreover, information and lessons learned during a construction project, i.e. what can be called "project knowledge", face some kind of leakage during the design and construction phases. In other words, knowledge provided by some stakeholders, such as Tier 2 sub-contractors, is unexploited; hence the value of the project diminishes. For this reason, BIM is integrated within the project to be able to exploit that knowledge before its loss, and retain its value within the project. This paper will discuss the design and information tools before the advent of BIM followed by the multiple definitions and concepts of knowledge management (KM) in construction projects. Then it will present an overview of the possibilities for the use of BIM in managing knowledge in construction projects.

Keywords
Building information modelling (BIM), Knowledge management (KM), Technology.

1. Introduction

The Architecture, Engineering, and Construction (AEC) industry faces challenges of cost, quality, and project delivery time. However, as identified by many proponents in the area of construction, BIM has the potential to solve these problems (Azhar et al.2008; Azhar, 2011). The approach is to create a virtual version of the project, referred to as a Building Information model. This model contains data about the project that can be used in supporting the design of the project, as well as its procurement, fabrication, and construction phases (Eastman et al.2008; Azhar, 2011). BIM's advantages and benefits outweigh its challenges and disadvantages, and consequently it brings great efficiency and harmony among construction stakeholders. Furthermore, BIM has been recognised for its role of improving

communication of the project design between project players (Deshpande et al., 2014). On the other hand, construction project knowledge is considered as one of the most important organisational and project resources, which leads the organisation to innovation and success (Egbu, 1999a, 2000; Nonaka and Takeuchi, 1995; Egbu, 2004). Knowledge can also increase the competitiveness of organisations, and reduce project time and cost as well as improving the quality of the project (Kivrak et al., 2008). For these reasons, and reflecting the vital role that knowledge plays within construction organisations, it is of interest to explore whether knowledge can be captured and stored through BIM technology and processes. For example, Deshpande *et al.* (2014) have argued that lost knowledge, dispersed information and knowledge that is fragmented can be captured or retrieved after the event using BIM platforms in order to increase the value of the project for the client. In this paper, an overview of the information and design tools that have been used before the advent of BIM will be presented followed by definitions of BIM, its benefits and challenges in the industry. The next section will discuss definitions and concepts of knowledge management (KM) cited by different sources, which will lead to another section that will discuss the use of BIM to manage construction knowledge in a project. Finally, the paper will conclude with AEC perceptions and the positive outcomes of using BIM in the future.

2. Design process and information tools

The construction industry has used many tools to support the architectural design process transitioning from hand-produced documents to 2D computer-aided design (CAD) software to 3D CAD (Clayton et al., 2010). However, these traditional approaches did not readily allow information-sharing and collaborative working; something that BIM has the potential to promote. The British Standards Institute (2010) has argued that BIM reduces delivery costs and risks of delay in projects delivery within the construction industry. Furthermore, it can assist in the uptake of an environmentally friendly approach to construction, leading to a sustainable environment. BIM has brought more maturity to the architectural documentation process, which has evolved throughout time (Kumar and Mukherjee, 2009). In order to retrieve and capture project information, tools such as documents, manuals, and standards have been used in the past. However, these tools were not efficient, because of their diverse procedures and the ability to lose that information afterwards: this is why BIM has been acknowledged for its important role of capturing that information, storing it and retrieving it, even after several years.

3. The advent of BIM, its benefits, and challenges

In the past, the Architecture, Engineering, and Construction (AEC) industry has exchanged documents and drawings in 2D format. The collaborations between all stakeholders were more or less 2D-based until the advent of object-orientated Computer-Aided Design (CAD) (Singh *et al.*, 2011). However, the increased use of CAD and automation in the construction process encouraged the exchange of 3D data in the collaboration between the stakeholders (Singh *et al.*, 2011). According to Singh *et al.* (2011), BIM is a higher level of CAD, which expands its use through the application of relationships between elements in the building model. Both geometric and non-geometric data such as object attributes and specifications are included in the BIM model, which allows the extraction of 2D drawings, documentation concerning the building and other useful information. The AEC industry has witnessed big changes since the uptake in the use of BIM. In addition to a better design, a good quality of production, and automated assembly, the advantages include; the accurate representation of the building in an integrated data environment, faster and efficient processes, an accurate visualisation of the project (Azhar *et al*., 2008). According to Azhar *et al*. (2008) BIM helps in controlling the whole lifecycle of the construction project and its phases, besides of easily convincing the client (Azhar *et al*., 2008). Furthermore, BIM improves the safety on construction sites by detecting hazards and other issues related to the construction sites in advance (Zhang et al., 2013). Most importantly, as Hardin and McCool (2015) have observed the value of BIM that resides mainly in information because of the accurate results needed in the construction process, and better guidance in using this information.

Despite the perceived benefits of BIM, it still faces challenges represented by issues of learning technological challenges in implementing BIM, and organisational problems such as cultural issues in adopting new technology (Yan and Damian, 2008). Moreover, there are other issues such as the lack of

investment in training, adoption of new software tools and infrastructure, undefined fee structures for additional scope, insufficient framework for involving owners' views in design and construction, and shortage of evidence in terms of positive return on investment (Becerik-Gerber *et al.*, 2011).

4. Definitions and concepts of Knowledge management in construction projects (KM)

Construction projects are characterized by their originality, creativity, complexity and dynamism. They are realized based on the knowledge and information acquired from the stakeholders (Rezgui *et al.*, 2011). However, Tupenaite *et al.* (2008) have emphasised that in the past, there has been no way to acquire learning from construction projects after their completion. It is well established that the construction industry is an economically 'fragmented' one, and this has traditionally been seen as an impediment to knowledge sharing (e.g. Alashwal, et al., 2011). However, this very fragmentation makes information exchange and communication between the parties involved in any project, if it were to be successfully captured, an ideal engine for promoting innovation (Rezgui *et al.*, 2011). Several researchers have defined knowledge management (KM), some of the definitions will be presented in the table below.

Table1: Summarised definitions of KM in construction industry

Sources	Definitions of Knowledge Management (KM)
Quintas et al. (1997)	KM is the process of continuously managing all kinds of knowledge in order to achieve new opportunities.
Davenport and Prusak (1998)	KM is a process through which value is created from organisation assets.
Coleman (1999)	KM refers to a wide variety of functions related to knowledge activities; such as creation, storage, and sharing of knowledge.
Alavi & Leidner (2001)	KM is related to different processes that are interdependent; such as knowledge creation and maintenance, storage and retrieval, distribution and application.
Darroch (2005)	KM helps in converting the available resources (financial resources and people) within the company into real capabilities.
Kivrak et al. (2008)	KM plays a significant role within organisations by improving the ability of employees to learn, thus improving the business performance of the construction industry.
Zheng et al. (2010)	KM improves organisational effectiveness by focusing on three important factors, namely: strategy, culture and structure.
Forcada et al. (2013)	KM is the activity of identifying and managing

	the intellectual assets of an organisation in order to increase its profitability and value.
Grover & Froese (2016)	KM is the effective use, capture, development and share of knowledge within organisations.

The list of research works in the table above demonstrates the interest of researchers in implementing KM in organisations in order to achieve better results and value. Most of the definitions above refer to KM as a process that is concerned with knowledge activities such as sharing, storage, and capture in order to increase value and competition for organisations.

5. Integration of BIM use in managing construction projects knowledge

The opportunities offered by Building Information Modelling (BIM) have been discussed by various authors (Meadati, 2009; BSA, 2012; Treasury, H. M., 2012; Liu *et al*., 2013; Charlesraj, 2014). Most of these authors have defined BIM as a technological tool that represents a building in a three dimensional digital model and a platform where all stakeholders can access and exchange information and data concerning the project. However, BIM is not only about technology, it encompasses other aspects such as the relationships between the stakeholders and the process of delivering a construction project. According to the report by UK Treasury (2012), BIM is a collaborative way of working between the stakeholders using the contemporary technologies that facilitate the design and construction processes. Despite the different definitions of BIM, there are several on-going research projects investigating aspects of managing knowledge in construction projects delivery using BIM processes. The most recent of these studies include those shown in Table 2:

Table 2: current practices of BIM and KM in the construction industry (Bouazza et al., 2015)

Author	Framework	Contribution
Hadikusumo, & Rowlinson, (2004)	Capturing safety knowledge using DFSP Tool	DFSP (Design for safety and process) is a tool designed to capture safety knowledge using real case studies. The tool is based on three elements, namely: DFX (Design for X capability), VR (Virtual Design), and construction site safety, and identifies safety hazards in a virtual version of a real project.
Oxman (2009)	The shift from BIM to BKM	As well as facilitating the collaboration among team members in digital design BKM can assist BIM in enhancing design creativity.
Konukcu & Koseoglu (2012)	Building Knowledge Model (BKM)	BKM integrates BIM into the construction supply chain to improve information flow and knowledge management between stakeholders throughout the project lifecycle.
Liu *et al.* (2013)	Development of a Building Knowledge Model (BKM) approach	Integrating BIM and KM to capture and reuse knowledge in BIM processes though the use of 'knowledge+' that helps connect BIM to a Knowledge Management System (KMS).
Jan *et al.* (2013)	BIM-based Knowledge Sharing Management	BIMKSM enhances construction project knowledge sharing with a BIM approach and web technologies.

	(BIMKSM) System	
Deshpande *et al*. (2014)	Framework to capture knowledge though using parametric models of BIM	The work illustrates the capture of knowledge and innovative ideas learned through the design and construction process by using parametric BIM models through Industry Foundation Classes (IFC).
Charlesraj (2014)	K-BIM framework	The framework improves the process of facility management through the use of BIM and KM by using three components: a Knowledge base, a K-BIM layer and stakeholder interfaces.

The research works in the table above is by no means exhaustive, but demonstrates the increasing interest of researchers in integrating BIM and KM for improving the effectiveness of construction organisations in delivering construction projects. However, construction organisations and the industry still have a significant gap to bridge to reach best practice in their use of BIM systems in managing knowledge in project delivery. It is clear that some developments are still needed to exploit the full potential of BIM in this respect.

6. Conclusion

Architectural, Engineering, and Construction (AEC) organisations are using Building Information Modelling (BIM) progressively in order to improve projects realisation. The subject of BIM adoption is a huge and expansive one, as well as being very topical and the subject of considerable debate within the industry as well as academia. BIM is still under experiment in countries such as the US, the UK, and some European countries like France, Sweden, and Germany. Others, even in the developing world are applying BIM and making its use mandatory in public-funded projects. In this review, it has been argued that BIM involves an innovative way of thinking for stakeholders, not only in its technology, but additionally in the associated opportunities for collaboration and process improvement. With the advent of BIM, the industry has already started to witness changes in terms of relationships between people working on the same project. There is the potential for the improvement of trust, collaboration and communication between each other and process of designing a project from the inception to the demolition including the whole lifecycle. Interestingly, it is quite possible that the fragmentation of the project delivery side of the industry, long criticised as a barrier to efficiency and effectiveness, might actually, through the intelligent integration of BIM with KM, contribute to more extensive and effective communication and information exchange between project participants, and ultimately result in a more innovative industry.

7. References

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