BIM AS AN EFFECTIVE INFORMATION MANAGEMENT TOOL FOR ACHIEVING KEY PERFORMANCE INDICATORS IN CONSTRUCTION PROJECTS

K.A.D.N.C. Wijekoon*, Anupa Manewa, Andrew Ross and Dianne Marsh
School of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

The UK Government mandates the implementation of Building Information Modelling (BIM) for all centrally procured Government contracts from 2016. This of course challenged the industry to shift away from the traditional 'silo' practices to 'collaborative' working environments. BIM provides a collaborative platform to share information between project stakeholders and also guides to deliver products/processes effectively and efficiently. However, what strikes for the practitioners to move for a BIM platform is how it will support the achievement of project specific Key Performance Indicators (KPI). There are massive information generation and heterogeneous flows can be identified throughout a project lifecycle and the value of that information is enormous. From the definition itself, BIM has the capability of absorbing every benefit which can be obtained through information management.

This paper explains the use of BIM as an effective information management tool for achieving the KPIs in construction projects. Initially, an extensive literature review was conducted to identify the application of BIM in construction project lifecycle and its role as an effective information management tool. In addition to six (6) numbers of interviews were conducted among the construction industry professionals to identify the practical use of BIM in construction projects and its effectiveness in achieving project KPIs. The findings of the study illustrate the BIM driven construction project KPIs and their importance in achieving project goals.

Keywords: *Building Information Modelling (BIM); Construction Projects; Information Management; Key Performance Indicators (KPI).*

1. INTRODUCTION

Building Information Modelling (BIM) is a fascinating concept that has been defined in wide range of aspects by different people as it has mean to them (Demian and Walters, 2014). BIM was initially for the design and construction stages of construction projects (British Institute of Facilities Management, 2012) yet, the impact of implementation can be achieved throughout the building life cycle (Eadie *et al.*, 2013). BIM is continuously expanding its potentials with information processing by moving from 3D modelling to facilities management (FM) (Royal Institute of British Architects, 2012). Capturing and storing information related to the building is the initial success factor for a well-planned facility management (Akcamete *et al.*, 2011) and data stored in BIM are beneficial for most of the FM tasks (Becerik-Gerber *et al.*, 2012). Despite, most of the construction projects do not handover the 3D model and CoBie (Construction Operations Building Information Exchange) dataset at the commissioning which prevents the grasping of BIM advantages in FM (Eadie *et al.*, 2013).

The application of BIM in construction industry has expanded significantly while BIM has translated into a support tool for various tasks in construction phase (Ding *et al.*, 2014). In UK, construction industry has a higher potential growth and the Government is in interest to support its growth (HM Government, 2013). In fact, BIM has become a good technique to speed up this growth. Government has set its vision to reach efficiency and technically advanced construction sector by 2025 by promoting "smart

* Corresponding Author: E-mail - K.A.Wijekoon@2015.ljmu.ac.uk

construction" and "digital design" (HM Government, 2013). Smith (2014) emphasises that the success factor to BIM implementation is the government initiation or leadership. As a result, Government has mandated that all centrally procured government contracts should adopt BIM by 2016 (HM Government, 2013; Eadie *et al.*, 2015).

In a typical construction project, time and cost overruns are frequent issues, which bring negative outcomes for the construction industry (Olawale and Sun, 2015). When a multi-disciplinary team is working together complexity, conflicts and uncertainties are experienced more often (Khosrowshahi and Arayici, 2012). Lack of information management techniques used in the construction industry has led to a complex data flow through the project life cycle and consequently has resulted most of these common issues (Masood *et al.*, 2014). BIM is identified as an effective tool to overcome most of the problems in construction industry. The findings of many researchers reveal that BIM positively support the project KPIs and also enhance the collaboration (Bryde *et al.*, 2013; Masood *et al.*, 2014).

2. BUILDING INFORMATION MODELLING

BIM has given a plethora of definitions by different researchers (Ding *et al.*, 2014). Masood *et al.* (2014) explain BIM as a process of creating and implementing a digital model to integrate the phases of building life cycle. Barlish and Sullivan (2012) emphasise that BIM is a platform which carries complete building life cycle information without being bias to a group of stakeholders. In construction aspect, BIM is the process of creating and making use of created information through building life cycle (McGraw-Hill, 2009). In facilities management perspective, BIM is a holistic approach to be applied throughout building life cycle (British Institute of Facilities Management, 2012). Having considered many of those definitions, National Building Specifications (2013) explain BIM as "an efficient process for effective management of building information, which are created during the pre and post-construction stages of particular asset" (Construction Products Association and NBS, 2013).

BIM is developed with many features and it keeps expanding its potential. Three Dimensional (3D) modelling is the well-known feature of BIM (Construction Products Association and NBS, 2013). It is an important basic achievement for BIM to deliver high project performance (Eadie *et al.*, 2013). Structured data is the strongest feature in BIM which attracts popularity (Construction Products Association and NBS, 2013). Although there are many other solutions available in the practice, information richness with smart objects is the key difference of BIM compared to other 3D modelling (Ding *et al.*, 2014; Demian and Walters, 2014; Howard and Björk, 2008). Moreover, BIM simplifies many tasks occurring throughout building life cycle (Czmoch and Pękala, 2014). BIM cannot be considered as an isolated tool since its implementation may have influence on all the processes within the project lifecycle (Eadie *et al.*, 2013). BIM maturity model explains how BIM was conceived from CAD and then developed into a rich information model (Royal Institute of British Architects, 2012). It keeps expanding its dimensions and Figure 1 illustrates development of these dimensions under different BIM maturity levels.

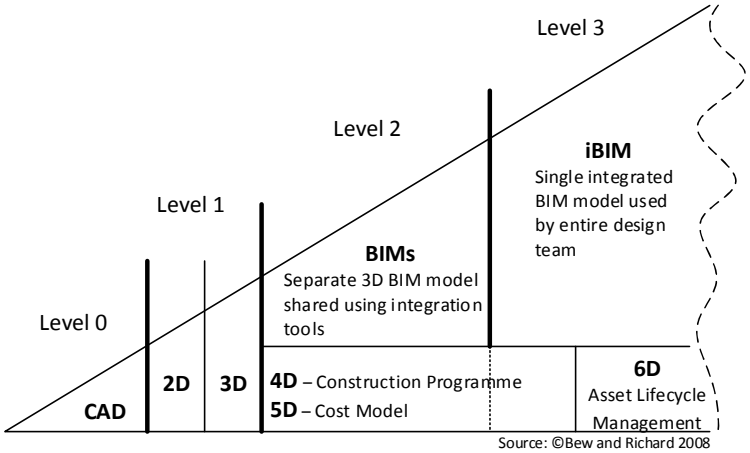

Figure 1: BIM Maturity Model
Source: Monaghans (2013)

Starting from 3D modelling, it has extended to project scheduling (4D), cost estimation (5D) (Bryde *et al.,* 2013), sustainability (6D) and currently most updated feature of Facilities Management (7D) (Construction Products Association and NBS, 2013). However, the outcome of each of the extension is based on the accuracy and the availability of robust information.

3. INFORMATION MANAGEMENT IN CONSTRUCTION INDUSTRY

The BIM Task Group together with Royal Institute of British Architects (RIBA) developed the stages of assets in the built environment from its creation to operation and end of life (Manning, 2014). Manning, (2014) explains that RIBA Plan of Work 2013 is a rout through the development of asset information through the built asset life cycle. Accordingly, information is being created throughout these stages in different quantities. These information is managed through PAS 1192-2 (Manning, 2014).

From the earliest stages in building construction the need for communication within the project team can be identified as a primary requirement (Construction Products Association and NBS, 2013). For many centuries they used 2D paper based drawings (Czmoch and Pękala, 2014) and there are many conflicts with the traditional practice (Khosrowshahi and Arayici, 2012). Initially CAD (Computer Aided Design) change this process (Czmoch and Pękala, 2014) yet, technology by itself could not make a complete difference (Khosrowshahi and Arayici, 2012). Therefore, industry is keep moving fast from CAD to information rich Building Information Modelling (BIM) (Malsane *et al.,* 2015).

With regard to information exchange Demian and Walters (2014) pointed out that electronic mails (E-mails) remain to hold the popularity among the construction industry for information and document exchange regardless of the new technology. Although, to manage project information, that is to create, store and use; BIM has been captured as the best and fastest growing solution. Ma and Liu (2014) explain how BIM can be used to move into automated cost estimation and accruing accurate construction information. BIM has become a solution for the adhering to the compliance making it much easy by promoting automated compliance checking (Malsane *et al.,* 2015). BIM promotes early creation of critical information related to design, coordination and logistics which brings a significant progress on later phases of project life cycle (Demian and Walters, 2014). This feature is much beneficial at the construction stage. Further, even the asset information management standards are extending its areas to be align with BIM (Hayes *et al.,* 2014). Construction industry is heading towards sustainable practices and BIM is a powerful tool which assist sustainability in construction projects (Antón and Díaz, 2014).

According to NBS (2014) BIM awareness level is increasing and organisations are getting involved in BIM more frequently. Demian and Walters (2014) noted that necessary precautions should be taken when generalizing the benefits of BIM as an information management tool. Time, cost, quality are the most important KPIs of a construction project (Toor and Ogunlana, 2010). The success of the project is benchmarked with the KPIs (Ali *et al.,* 2013). Therefore, to have reflect on the project benefits made through BIM adoption, they should reach the project KPIs. The overall benefit of BIM is not yet completely identified and construction project stakeholders are still struggling to make the decision on BIM (Barlish and Sullivan, 2012). Looking deep into the situation, there are many research highlighting the benefits of BIM but they are in much broader and technical view. The large number of Small and Medium Enterprises (SMEs) are still reluctant to adopt BIM in their agenda.

4. ADOPTED RESEARCH METHODS

This preliminary paper is highly based on a literature review on construction project KPIs and BIM contribution towards improving project KPIs. Firstly, the project based KPIs and application of BIM in construction projects were identified through an extensive literature review. In addition,6 interviews were conducted among construction professionals (3 Quantity Surveyors, 2 Project Managers and an Engineer) to identify how BIM could be utilised as an effective tool to achieve project KPIs. Also same set of interviews were used to identify the challenges and future potentials for BIM in construction projects. The interviews were analysed through content analysis using NVivo10 software. Content analysis was used to determine the most significant negative and positive factors.

5. DATA COLLECTION AND ANALYSIS

Data collection was undertaken in two phases. Initially the data was gathered through existing literature and they were presented to the industry practitioners for validation and trace their impact on project KPIs. Interview questionnaires were developed and piloted among few academics who have industry exposure to identify clarity and readability of questions before circulation. Seven participants were invited for interviews however, six of them did so. All of the interviewees have a perceived understanding of BIM in industry and each has extensive experience in their profession. The respondents' experience varied from 5 – 20 years by giving a good spread.

The pool of interviewees consisted with 3 quantity surveyors, 2 project managers and an engineer. As the respondents are from a variety of locations and professional backgrounds, working on different projects, a wide range of views and perceptions were expressed, also leading to some conflicting opinions. Through these interviews, the main areas of concern have been recognised and analysed in particular groups in order to accurately compare and highlight the opinions conveyed, giving the researcher a wider overview in which to derive an overall conclusion.

The interview guideline was used to structure the interviews, which mainly consisted two sections. The first section of the interview guideline was structured with few introductory questions to make the interviewee more comfortable with the interview. The second sections of the interview consisted with three main questions to gather the participants' view on project KPIs and BIM contribution and also to identify challenges and benefits of implementing BIM in construction projects.

All six interviewees' responses highlighted that collaboration feature of BIM is the most useful in a construction project as it involves multi-disciplinary team members, who are working on a single project model. It is the key factor which stimulates the consequent benefits of BIM. Quality improvements of the end product is the final outcome of the BIM adoption. Quality is improved through information availability, automated corrections made through the BIM process and creating a good platform for decision makers by allowing knowledge sharing. The fact to admire in BIM adoption is, unlike other quality improvement techniques, BIM reduce the project cost while enhancing the quality. The improved decision making platform reduce the excess labour cost and rework. As it brings instant cost reductions in construction; the quality built facility will reduce the operation and maintenance cost in long term. There were both positive and negative reactions towards the time factor. The negative reactions on time was especially related to the initial few projects or time requirement for BIM adoption. For instance, the time target should be achieved as in theory things should be built quicker. Since, fewer resources will be needed to do what 2 or 3 other people were doing 10 years ago. By contrary, achieving the time target could be problematic as it is difficult to get sign-off on the model. BIM modelling phase of the project will probably extend and it will potentially delay getting projects on the ground. However, time was influenced mostly by all considered BIM features. Likewise, it's clear from different viewpoints; by improving in timely delivery cost of construction and quality of the end product can be improved from the first project itself with BIM.

6. FINDINGS AND DISCUSSION

In the initial stages of implementing BIM into a construction project requires a BIM Execution Plan and it is essential for the success and smooth running of the project. It is seen to be advantageous as the main personnel involved in the project at the early stages to discuss and define what is wanted from the model. If this is done correctly, then, most of the benefits are beyond deliver.

Another benefit was the ability to perform clash detection tests in order to identify any practical issue that may occur during construction. A clash detection test is commonly performed when integrating models to make one collaborative model using a software package such as Navisworks. In theory through the use of this concept, it should eradicate any issues on site, as they are dealt with at the design stage through the model. This method checks buildability prior to committing resources and materials to site, saving time and money.

Decision-making is a key benefit that is currently experiencing by BIM users. The final advantage that was agreed among the respondents was the 'visualisation' that BIM offers. This provides the answer to

the problem with people taking 2D drawing and trying to represent that in 3D in their mind. This allows the navigation within the model and trace the things which cannot be traced in a drawing. The benefit of visualization makes the process easy when dealing with clients who have difficulty interpreting the construction processes off a 2D drawing, and acknowledges that BIM completes this process for them.

BIM should be something that everyone can use in terms of logistics, sequencing and quantities; all the way through to the end user, and facilitating through the lifecycle of the project. In essence BIM brings a value for money for every stakeholder, who has different level of interest and influence towards the project goal.

BIM entails openness and transparency if utilised correctly. This is the desired result if it is ensured that everyone is working on the same model, using a BIM execution plan and collaborating at the early stages. It is important that there is an effective change management system, so that if a design is changed on the BIM model, it automatically updates and this will further improve decision making and release professionals to perform other tasks. Ultimately this allows the project to always have readily available information. In a nutshell BIM enables to be more proactive than reactive.

6.1. PROJECT KPIS AND BIM CONTRIBUTION

If the BIM model is set up properly at the early stages of a project and if efficient information management processes is in balance, effective decisions can be made and KPIs should be achieved; they should only be capable of being improved. Literature reveals the key benefits that can be gained through BIM. Yet, it is rare to find research on how to gain these advantages or how BIM becomes negative to certain organisations. Rather than just understanding the advantages of BIM, this paper illustrates how different features of BIM brings positive impacts on project KPIs. However, few significant KPIs (time, cost and quality) were selected to analyse on how BIM implementation would help to achieve those KPIs effectively. According to the research findings, it was evident construction project time being the most influential consideration on BIM implementation compared to other project KPIs. Time has been emphasise since it has instant progress with BIM implementation and every improvement is visible and quantifiable. Consequently, quality seems to be untouched not because BIM has less or no impact on quality but because the quality improvements are not instant and cannot identify as a direct improvement made by a single fact. However, it carriers both negative and positive impacts. The findings of the interviews used to identify/confirm BIM positive and negative factors towards project KPIs (see Table 1). However those factors were not in a priority order as 6 numbers of interviews were not sufficient to rank them in a priority list.

Table 1: Impact on BIM in Project KPIs

KPI	BIM Positive										BIM Negative						
Time	Collaboration & Communication	Visualization	Details on building performance	BIM execution plan	Automated information	Design error identification(Clash Detection)	Information for future projects	Improved documentation	Simultaneous access	Complying to Government rules	Additional Effort	BIM execution plan	Design liability	Not completely developed	Business process changes	Risk of quality of information	Process / Technology implementation & training
Cost																	
Quality																	
Ref. No.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N1	N2	N3	N4	N5	N6	N7

As noted in Table 1, multiple BIM based factors influence positively and negatively on time, cost and quality of a construction project. Referring to the BIM positive, the most common and basic features which will bring a positive impact has been lined up by analysing the interviewees' opinions. Similar to the previous findings in literature, collaboration and communication (P1) is a key feature in BIM. BIM

reduces the time spent on collaborating the ideas and work of different parties involved in the construction process by making information available to all the parties in construction process and bringing them onto a single platform. This will also reduce the construction cost because every party in the team understand each other and avoid contributions which can be costly from another angle. As a result, it improves the quality of final product since BIM creates space to interact and correct each parties' work before it goes on the ground. Similarly, P2 - visualization and details on building performance have a positive impact on the all three KPIs directly through supporting the decision making process and reducing rework. As a result, 3D visualization and detailed information on building performance make positive impact on time, cost and quality.

BIM execution plan (P4), automated information generation (P5), design error identification (P6) and providing information for future projects (P7) do make a positive difference to the project time and cost. Specifically, BIM execution plan (P4) helps the smooth flow of the construction work once started since the planning is done for the time ahead. It makes the team to think about the time ahead and will generate a clear picture on how the project will flow. Being aware about the upcoming tasks is directly helpful for supplier handling and cost planning which brings cost reduction and timely completion of the project. Yet, referring to the N2: BIM execution plan as a negative factor, it delays the start date of a project. Although it is theoretically advantageous, in practice contractors look forward to take over a project and finish it within least time in order to move out to the next project. A delay in the project start date is a consideration. Even this time gap can be catch up from the total project duration, in practice it is preferred to look for time savings in the moment they are working on. Next, improved documentation (P8), simultaneous access (P9) to the drawings and project details primarily make an impact over the project completion time. Finally, P10 brings the advantage of government support. Since the Government has mandated to comply with BIM by 2016, getting involved with BIM will save time at the project handing over stage converting the project details into BIM platform.

Almost every feature carries it positive and negative impacts. Similar to the BIM positive, it explain how each of the feature negatively effect on time, cost and quality. To adopt into the BIM culture organisations need to invest money, time and human resource (N1). This additional efforts have been always holding back any organisational change. Also, with the simultaneous access there is a rising issue on liability for the final product or on a certain failure (N3). On the other hand, the features and capabilities of BIM is not yet fully developed (N4). This will limit the full experience of BIM advantages as mentioned in theory. Similarly, business process change (N5) and process implementation together with training (N7) consume time and incur a cost. Also, the benefits of BIM highly depend on the information fed into the process (N6). Therefore, there is a risk of the quality of information. BIM will deliver the output based on its input.

It is clear that, time is the KPI which is most impacted yet, quantitatively the time delay which occurs through negative impacts are far much less than the time saving made through positive impacts.

6.2. CHALLENGES FOR IMPLEMENTING BIM IN CONSTRUCTION INDUSTRY

The most conversed challenges of BIM are related to the cultural changes. Getting the industry to change or getting people to change is probably one of the most difficult things. These theories have further been backed up by the old-school supervisors and the old-old generation of managers and foremen who still rely upon hard-copy drawings etc. and are not computer literate.

Another challenge disclosed on the implementation of BIM is related to the start-up and finances needed to introduce BIM into a company, no matter how large or small. The initial costs of setting up these projects for the client has been more expensive. It will drive up supply chain costs as they try to get up to speed with the right people and the right training. The larger supply chain should be able to cope with the transition but the smaller contractors and perhaps even SMEs won't be able to afford it, ultimately limiting the supply chain.

Also, there is an issue with software that companies are holding back as they are unsure of the best software package to buy into. Further to this, everyone is using different operating systems and the government won't actually move forward and identify one type of software that will be compatible for all organisations. As a result of this issue, companies are not integrating BIM, therefore are not embracing

the full concept of BIM. Even with the BIM software installed, the computers have to be renewed in order to cater for a full integrated model and therefore are too very expensive to upgrade or renew.

Although the issue of adequate training can be overcome in due course as the colleges are offering courses in BIM, and consultancies are running BIM academies try to equip professionals with the adequate skills to deliver projects in BIM it was noted that there are more students attending these events than contractors any other profession, therefore this highlights to that the interest in adopting BIM into organisations still needs to be looked at and enforced.

Another issue comes up in practice is integrating separate models into one combined model. Again this leads to the issue of software. Currently Navisworks is being used as an integration tool, but for larger projects and more complex projects this software is not suffice for the intricacy of the projects. It is thought that in the BIM execution plan, a specific software should be determined for all the designers to use, therefore when it comes to integrating the models, it should be '*all singing, all dancing'*.

Now, in respect of the actual BIM models, there are models with too much information, sometimes needless, but on the other hand there are a lot of models that don't actually have enough data in them for the project team to work with. This issue is caused due to the clients and clerical teams for clients being all over the place, and they don't actually know what they want from the model, which leaves the model very vague. This leads to the model developed being of no use to the contractor or client as it is not built up properly and cannot be used. An exception to these is the large clients who generally know what they want from a model. Other organisations should take notes of their execution plans in order to achieve their desired project goals. However, it was clear that many firms are burying their head in the sand and are afraid of adopting BIM, therefore are in no urgency to buy into it. It is not the issues in BIM hold them back.

7. CONCLUSION

BIM has a value to every aspect of the construction industry and all professionals should embrace the modernity and innovative concept of BIM. The advantages that stem from effective information management through BIM are; speed, speed of decisions, therefore saving time and the accuracy of these decisions will then improve costs. It gives programme certainty as players can do simulations and do a two or four week look-ahead to forecast productivity and costs. In relation to quality, the model moves towards design for manufacturer and assembly, therefore resulting in better quality. Theory issues can be eradicated through the clash detection, leading to a better quality finish and fitting on-site. In further, quality is improved due to the seamless design where everything is fully integrated.

The findings of this study suggest that BIM has major influence in project KPIs. In fact project performance can be improved through a proper application of BIM and this will lead to improve the project profitability. As BIM provides a great platform by replacing silo concept through collaboration all the stakeholders may get good opportunity to involve in the project however their interests and influence may different. This will provide win-win solution to each project stakeholder.

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