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Review Article

Improving Cost and Time Control in Construction Using Building Information Model (BIM): A Review

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ABSTRACT

The control of cost and time in construction projects is one of the most important issues in construction since the emergence of the construction industry. A successful project should meet not only quality output standards, but also time and budget objectives. The management and control of cost and time in construction is fundamental in every project. An effective cost and time management and control technique for construction projects is important in managing risk of cost overrun and delay in completion of projects. Construction projects are becoming more complex as they now involve many stakeholders from different disciplines. The emergence of Building Information Model (BIM), an alternative technology is believed to solve issues related to project cost and time control as it efficiently increases collaboration between stakeholders. The aim of this paper is to review and summarise the causes of delay and cost overrun in construction industries, which are the main causes of disputes and abandonment of projects in the industry. It was found that delays and cost overrun eat deep into the industry and leave the construction industry with a bad image for decades even with rapid advancement in technology. The review of the applications of BIM showed that most of the applications are geared towards minimising construction cost and time spent on projects. This means that the use of BIM in the management of construction projects has great impact on project cost and time.

Keywords: BIM, cost control, delay and cost overrun, time control

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INTRODUCTION

Control of cost and time in a construction project is one of the most important issues in construction since the emergence of the industry (Minchin et al., 2013). In this light, a successful project should not only meet quality output standards, but also time and budget objectives. Time and cost performance is a fundamental criterion for the success of any project. However, delay of project completion is very common in the construction industry due to ineffective cost and time control (Forbes & Ahmed, 2010). The essence of cost and time control is to ensure that projects are finished on time, and this is attainable through constant measurement of progress, evaluation of plans and taking appropriate action on the project (Kerzner, 2013). Buttressing this also is the Project Management Body of Knowledge (PMBOK), which suggests that in order to achieve the baseline objectives of any project, there has to be effective monitoring of project cost and time control (PMI, 2013).

Inherently, cost and time are two major concerns in managing construction projects (Rasdorf & Abudayyeh, 1991). However, construction projects are becoming more complex as they now involve many stakeholders from different disciplines. Most of the features of projects that give rise to delay and cost overruns do vary alongside with the project type, location, size and scope. Most of the time, construction projects that are large in nature and scope are characterised by their complexity and capital demands (Torp et al., 2016).

In addition, the construction industry has many branches, and as such, it encompasses a lot of information about any one construction project. This is information that is very important to a project, and can be the basic foundation for decision-making, procurement and collaboration. The success of a project requires cost management among other factors to be considered before the commencement of the project (Masrom et al., 2015). Cost management starts with quantification, which takes a lot of time and is tedious in nature. Traditionally, the process is manually completed most of the time with high likelihood of human error, which tends to be higher when preparing estimates for complex projects. The use of computer-related applications allow for the making of more reliable decisions (Martínez-Rojas et al., 2016).

Globally, the construction industry is replete with high-profile projects that are faced with significant delays and cost overrun (Smith, 2014). For example, in Saudi Arabia, it was found out that only 30% of construction projects were completed within the scheduled completion dates and that the average time overrun was between 10% and 30% (Assaf & Al-Hejji, 2006). Malaysia, a fast-developing country in Southeast Asia, is no exception from this global phenomenon. In 2005, about 17.3% of government contract projects in Malaysia were considered sick due to three months of delay and therefore, abandoned.

However, the construction industry in Malaysia plays a vital role in the nation's economic growth. It brings job opportunity and increment to the people's quality of life by providing essential socioeconomic infrastructure, such as offices, roads, houses and schools. Additionally, Malaysia is progressively marching towards industrialisation and the role of the construction industry is to enhance and at the same time, realise the needs and aspiration of its population (Alaghbari et al., 2007). Unfortunately, construction project delays and cost overrun are the norm in the Malaysian construction industry, leading to additional project costs (Enshassi et al., 2009).

The Malaysian construction industry is regarded as an industry facing poor performance leading to failure in achieving effective and efficient cost and time management (Ismail et al., 2013). In addition, the Chartered Institute of Building (CIOB) stated that in 2008 the quality of time management of construction projects was generally poor (Purnus & Bodea, 2013). Research conducted by CIOB in 2008 indicated that growth in training, education and skill levels within the construction industry in the use of time management techniques has not kept pace with the technology available (Zhang & Gao, 2013). As such, the emergence of alternative techniques is believed to minimise the issues relating to project cost and time control. Furthermore, it is also believed that the emergence of the Building Information Model (BIM) can lead to greater efficiency by means of increased collaboration (Zhang & Gao, 2013).

The National BIM Standard (NBIMS) Project Committee of the Building SMART alliance (2010) referred to BIM as

> A digital representation of physical and functional characteristics of a facility, as such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life-cycle from inception onward. The BIM is a shared digital representation founded on open standards for interoperability. (Succar, 2009)

This suggests the Building Information Model (BIM) as an alternative approach to construction design; it does not only make digital representation of designs easier, it also provides all the necessary information for any project before construction (Xiao & Noble, 2014). Thus, the information represented by BIM models is very useful and can be analysed to optimise the design, planning and construction processes (Azhar, 2011). Moreover, according to Bryde et al. (2013), BIM is an appropriate tool for project managers and should be considered by project managers as a way to help manage construction projects. However, BIM as an alternative technology in Malaysia needs to be studied to provide proof that it can satisfy the industry's need in improving cost and time control. It is also important to further investigate how cost and time control can be improved upon using BIM technology.

Project Time Control

Project time control is the process of monitoring the status of project activities, which include updating the project progress and managing changes to the schedule baseline to achieve the plan (PMI, 2013). This process is beneficial as it provides the means to recognise deviation from the actual plan in order to take corrective and preventive measures to reduce risk. The duration of time it takes for the execution of a project is, most of the time, very important to the parties involved (Dalu, 2012). However, project delays are common globally, especially in developing and underdeveloped countries (Nassar et al., 2005).

Project time control process. The process of project time control involves three main parameters, which are input, tools and techniques and output (PMI, 2013). The input are project management plans, the project schedule, work performance data, the project calendar and organisation process assets. The tools and techniques used in project time control are performance reviews, project management software, resource optimisation techniques, modelling techniques, leads and lags, schedule compression and use of scheduling tools (Masrom et al., 2015), while the output that is expected from these processes are work performance information, schedule forecasts, change request, project management plan updates, project document updates and the organisational process assets updates (Yun et al., 2016).

Project Cost Control

According to Dalu (2012), project cost control is a vital ingredient for a successful project. Project cost control is the process of monitoring the status of the project by updating the project costs and managing changes to the cost baseline. This provides means for the recognition of variance from the plan so as to take corrective actions and reduce risk (PMI, 2013). This, therefore, means that corrective action needs to be taken by personnel who incur cost in all companies irrespective of their size.

Project cost control process. Similar to time control, the process for project cost control involves three main parameters, which are input, tools and techniques and output. The process and its parameters for input are project management plan, project funding requirements, work performance data and organisational process assets. The tools and techniques comprise earned value management (EVM), forecasting, to-complete performance index (TCPI), performance reviews, project management software and reserve analysis, while the output process and its parameters include work performance information, cost forecast, change request, project management plan updates, project document updates and organisational process updates (PMI, 2013).

Causes of Delay and Cost Overrun in Construction Projects

However, even with the vast integrated knowledge areas in project management, delay and cost overrun are the most common issues in construction projects (Francois, 2016). Thus, it is significant to note that the degree of success of a project is defined within the triangle of scope, time and cost. As such, it is important to look at the causes of these delays and cost overrun in projects. In this regard, delay is generally acknowledged as the most common, costly, complex and risky problem encountered in construction projects.

Previous research conducted has shown that project delays are common and costly, making it an important study to know the causes of these problems for effective project management (Frimpong et al., 2003; Koushki & Kartam, 2004; Koushki et al., 2005; Abdullah & Tawie, 2006; Abdul-Muhid, 2006; Ramanathan et al., 2012). As a result of the overriding importance of time for both the owner (in terms of performance) and the contractor (in terms of money), delays are undoubtedly the source of frequent disputes and claims leading to lawsuits. Delays occur in most construction projects; the magnitude of these delays varies considerably from project to project (Alaghbari et al., 2007; Enshassi et al., 2009).

Chan et al. (1997) stated that poor site management and supervision, unforeseen ground conditions, delays in making decisions by the project team and changes in scope caused by initiated and necessary variations of work by the project sponsors are the main causes of cost and time overrun in Hong Kong. In Jordan, Al-Momani (2000) examined 130 government projects and stated that changes that were initiated by the designers, weather, client requirement, late deliveries, site condition and economic conditions were the main causes of delay in construction projects.

According to Frimpong et al. (2003), in Ghana, material procurement, escalation of material prices, poor contractor management, poor technical performance and difficulties arising from agencies' monthly payment are the major causes of delay and cost overrun in the construction of groundwater projects. In Hong Kong, the major cause of delays and cost overrun were identified to be the poor management of sites, unforeseen ground conditions, change orders and poor decision making (Chan & Kumaraswamy, 1997, 2002). Furthermore, according to Odeh and Battaineh (2002), from the viewpoint of contractors and consultants in the construction industry, owner interference, inadequate contractor experience, finance and payment, labour productivity, slow decision making, improper planning and subcontractors are the major causes of delay in construction projects.

Hsieh et al. (2004) conducted a study on 90 metropolitan projects in Taiwan, and identified planning and design as the major cause of change orders in the projects leading to delay and cost overrun, while Sambasivan et al. (2007) stated that predominantly, delays are caused as a result of changes in design, poor planning and labour productivity. Moreover, in a study conducted by Kaliba et al. (2009), other prime causes of delay and cost overrun are client organisations delaying in making payment, modification of contracts, economic hardship, procurement materials, design changes, staffing issues, lack or unavailability of working equipment, poor supervision, mistakes during construction, poor site coordination, specification changes and labour.

Abd El-Razek et al. (2008) conducted a survey on the causes of delay and cost overrun and found that financial problems experienced during construction by contractors, owners delaying payment to contractors, changes in design by clients or their agents during construction and the lack of use of professional construction and contractual management were the main causes of delay and cost overrun. In addition, research by Le-Hoai et al. (2008) on the causes of delay in Vietnam compared with those of other countries showed that in Vietnam, lack of experience, loose deadlines, poor cost estimates, design inefficiencies, labour incompetence, government-related issues and financial problems were the main causes of delay, whereas in Thailand, the main causes of delay were poor design, resource and labour shortages, poor project planning, inefficient contractor management, financial difficulties and change orders (Toor & Ogunlana, 2008).

Delay and cost overrun do occur internally and are generated by the sponsors, design team, contractors and consultants. At the same time, they could be externally caused through late material supply, government policies or weather conditions (Ahmed et al., 2003). Olawale and Sun (2010) reported change in design as the most significant cause of poor time and cost control from the practitioner's point of view. The five main causes of delay in construction projects according to Alinaitwe et al. (2013) comprise scope change, payment delays, high cost of capital, poor monitoring and control and political insecurity and instability. Inadequate experience by the contractor, poor project planning, site management and change orders were among the 15 main causes of delay in Turkey according to Gündüz et al. (2012).

Samarghandi et al. (2016) conducted a study on the reasons for delay and cost overrun in construction projects in Iran and developed a statistical model that categorised delay factors into four main categories. The categories include owners' defect, contractors' defect, consultants' defect and government laws, regulations and other general defects. Delay factors such as shortage of materials, change orders, delay in payment of suppliers, poor management of site and late submission of drawings are the main causes of delay (Abdul Kadir et al., 2005; Ramanathan et al., 2012). Alaghbari et al. (2007) conducted a study on the causes of delay and ranked them. The researcher found that financial problems and coordination problems were the two most important factors causing delay in construction projects in Malaysia.

Similarly, Sambasivan and Soon (2007) conducted research using a questionnaire to describe the 10 main causes of delay in Malaysian construction projects and found that they included poor site management, late payment, labour supply, improper planning, lack of experience, problems with subcontractors and shortage of materials. Al-Tmeemy et al. (2012) listed several causes of delay in Malaysia that included labour productivity, slow decision making, inflation, material delivery and insufficient equipment. Shehu et al. (2014) also stated that contract delays were predominantly caused by the contractors, while the other factors were associated with finance. Ahmed et al. (2003) and Al-aghbari (2005) in their separate research classified the factors causing delay and cost overrun in Malaysian construction projects into four categories, which are contractor's responsibility, consultant's responsibility, owner's responsibility and external factors.

The causes of delay and cost overrun are summarised in Table 1 below.

Table 1
Causes of delay and cost overrun

Causes of Delay and Cost Overrun	Sources
Scope change, payment delays, high cost of capital, poor monitoring and control and political insecurity and instability	Alinaitwe et al. (2013)
Client organisations delay in payment, modification of contracts, economic hardship, procurement materials, design changes, staffing issues, lack or unavailability of working equipment, poor supervision, mistakes during construction, poor site coordination, specification changes and labour disputes	Kaliba et al. (2009); Samarghandi et al. (2016); Olawale and Sun (2010)
Inadequate experience of the contractor, poor project planning, site management and change orders	Gündüz et al. (2012)
Designers, weather, client requirement, late deliveries, site condition and economic conditions	Al-Momani (2000)
Material procurement, escalation of material prices, poor contract management, poor technical performance, difficulties arising from agencies' monthly payment	Frimpong et al. (2003)

Table 1 *(continue)*

Owner interference, inadequate contractor experience, finance and payment, labour productivity, slow decision making, improper planning and subcontractors	Odeh and Battaineh (2002)
Poor planning and design	Hsieh et al. (2004)
Changes in design, poor planning and labour productivity.	Sambasivan et al. (2007)
Poor site management and supervision, unforeseen ground conditions, slow rate of making decisions by the project team, changes in scope of work by the project sponsors	Chan et al. (1997); Chan and Kumaraswamy (1997, 2002)
Financial difficulty during construction by contractor, owners delaying payment to contractors, changes in design by clients or their agents during construction, lack of use of professional construction and contractual management	Abd El-Razek et al. (2008)
Lack of experience, loose deadlines, poor cost estimates, design inefficiencies, labour incompetence, government-related issues and financial issues	Le-Hoai et al. (2008)
Poor design, resource and labour shortages, poor project planning, inefficient contractor management, financial difficulties and change orders	Toor and Ogunlana (2008)
Late material supplies, government policies, weather conditions	Ahmed et al. (2003)
Shortage of materials, change orders, delay in payment to suppliers, poor management of site and late submission of drawings	Abdul Kadir et al., 2005; Ramanathan et al., 2012
Financial issues and coordination	Alaghbari et al. (2007); Shehu et al. (2014)
Poor site management, late payment, labour supply, improper planning, lack of experience, problems with subcontractors and shortage of materials	Sambasivan and Soon (2007)
Low labour productivity, slow decision making, inflation, material delivery and insufficient equipment	Al-Tmeemy et al. (2012)
Adherence to outdated/old construction methods, lack of knowledge about different defined execution models, poor contract management by consultants, governmental inefficiencies, mistakes in technical documents, delays in producing design documents, delays in reviewing and approval of design documents by consultant and client	Odeh and Battaineh, (2002); Faridi and El-Sayegh, (2006); Assaf and Al-Hejji, (2006).

From the review above, one can conclude that the cause of delay and cost overrun have eaten deep into the industry and have given the construction industry a bad image for decades. Unfortunately, such causes keep recurring even with the advancement in technology and rigorous research done to solve or minimise their recurrence. It is believed that the application of BIM will solve these issues as it integrates all the major stakeholders from different disciplines in a project when making and taking decisions.

Concept of Building Information Model (BIM)

The contractor's guide to Building Information Modelling (BIM) describes it as a process of developing and implementing computer-generated models to combine the design, planning, construction and operation of a facility. In this light, Masood et al. (2014) defined BIM as a 3D digital representation of a facility with essential components and characteristics made up of intelligent building components. It is a means and practice of virtual design construction throughout the facility life-cycle that serves as a platform for knowledge and data sharing for communication between stakeholders (Eadie et al., 2015). While Olatunji et al. (2010) defined it as a representation of the combination of fairly revolutionary ideals for design technology, it portrays the geometry, geographic information spatial relationships, quantities and characteristics of building elements, material inventories, cost estimates and schedule of performance.

BIM is basically a 3D digital representation of a facility. The model can be used to express the entire facility life-cycle. The model is data rich because of the quantity of material involved, its properties can be easily obtained and the scope of work required can easily be defined and isolated from the model (Smith & Edgar, 2008). Contract documents, drawings, procurement details, specifications and other construction documents can easily be interrelated using the model (Bazjanac, 2006; Khemlani, 2007). Thus, a series of techniques that enable the practice and processes of construction and virtual designs through the project's life-cycle is the main concept of BIM (Zhang, 2012).

The BIM industry working group (BIWG) (2011) defined the levels of BIM from 0-3. Level 0 refers to the unmanaged CAD, Level 1 is the managed CAD, while Level 2 is the managed 3D of the different disciplines. The third level is a fully-open process and data integration system enabled by web services compliant with emerging Industry Foundation Class/International Framework for Dictionaries (IFC/IFD) standards managed by a collaborative model server.

BIM tools. A lot of tools have been developed as a result of the spread of the concept of BIM in achieving its perspectives. These tools are used to manage construction projects, most of which are designed for specific purposes to meet the need of users, while a few are designed for multiple functions and information collection. The type of tool to be used depends on the purpose, user and stage in which it will be used. BIM tools enable 3D modelling and the management of information. The use of these tools makes BIM a unified system that interacts with all its parts. The table below shows some known BIM tools, their manufacturers and their functions.

Table 2
Building information model tool

Manufacturer	Tool	Function
AutoDesk	Navisworks	To manage 3D model-based design and clash detection
Bentley	Bentley Navigator	Dynamic coordination between models and disciplines
Vico Software	Vico Office	Analysis of various 3D models for coordination, scheduling and estimating
Gehry Technologies	Digital Project Suit	Full-featured suite: For design, review and information management
Tekla	Tekla Structures	3D structural modelling and detailing
Solibri	Solibri Model Checker	For quality assurance/quality control (QA/QC)
Synchro Ltd.	Synchro Professional	Scheduling of systems and planning simulations

Applications of BIM in Project Management

The potential of the application of BIM in the management of construction projects is similar to the Project Management Body of Knowledge (PMBOK); hence, it is an important tool for effective and efficient project management as it integrates stakeholders (Rokooei, 2015). BIM as a promising technology facilitates project management and the possibility of integrating building models and products, giving it high potential for management of project life-cycles (Gourlis & Kovacic, 2016) as it can be used throughout a project's life-cycle. It helps in understanding the project needs by the owner. It is also used for analysis, design and development of the project by the design team. The contractor also makes use of it in managing the construction phase, as well as in decommissioning, maintenance and operation carried out by the facility manager (Grilo & Jardim-Goncalves, 2010).

BIM is regarded as a great visualisation tool as it provides 3D virtual representation of the facility (Zhang, 2012). This is the reason why in recent times, researchers and practitioners in the industry have been using it as an alternative means of interdisciplinary information sharing; it enables users to have an idea of the functional and physical characteristics of the facility in 3D visualisation. Walk-through, rendering and sequence of the model can be provided by the project manager during project bidding for ease of communication with interested contractors. An outlook of the project, when completed, is provided through visualisation of the model using BIM techniques, which solve the issues of having to combine the different 2D views of the proposed project to create a 3D view (Mohandes et al., 2015). The virtual models enhance collaboration and communication as it can be shown to the owner and designers during meetings. The sequence of the construction work and planning can be based upon the utility of the model component. The virtual models, which are cost effective, allow the contractor and the design team to work on the constructability analysis of the building, thereby reducing risk and potential design errors and saving time (Azhar et al., 2008).

Value for money can be improved through the use of BIM, as was shown through research conducted by Li et al. (2014). The evidence provided to justify their finding was from the Shanghai Disaster Recovery Centre project, which showed a potential benefit of optimised construction activities through cost-orientated activities. Moreover, BIM reduces waste and also optimises efficiency throughout the project life-cycle as it supports integrated project delivery through a collaborative process (Glick & Guggemos, 2009).

Lavy et al. (2014) conducted research using a case study of the Solibri Model Checker (SMC), and it was found out that maintainability of the facility could be checked during the design phase (i.e. using BIM), which will reduce the cost of maintenance during a project's life-cycle. This is possible as the 3D model offers facility managers the opportunity to anticipate maintenance accessibility problems and ways to resolve them.

Lu et al. (2014) conducted a study on the cost benefit of implementing BIM by comparing two projects i.e. one using BIM and the other, conventional methods. It was found that the implementation of BIM saved cost by about 7% per square metre for the project. At the construction stage, it decreased the cost per square metre of the gross floor area by 8.61% when compared to the conventional designed and built project. According to Lu et al. (2016), cash flow analysis can be automated and simplified through 3D modelling design by linking cost and schedule information (i.e. 5D BIM); this saves more time and cost compared with using the traditional method, which is time consuming. On the contrary, Masood et al. (2014) stated that BIM has very low impact on cost reduction, time and human resource in Pakistan's construction industry.

According to Underwood (2009), BIM presents a non-redundant model of the project's life-cycle information to streamline its processes, which solves the problem of redundancy when using conventional methods. Improvement in quality of design, construction and minimising rework during construction are the three most important merits of using BIM. This was the perception of AEC professionals in Pakistan's construction industry (Masood et al., 2014).

The applications of BIM in project management are summarised in Table 3.

Table 3
Building information model applications

Application of BIM	Source
Quality compliance management	Chen and Luo (2014)
Reduction in Information Exchange (IE) waste	Dubler et al. (2010)
Improvement in the accessibility of facility management data	Kassem et al. (2015); Liu (2010); Meadati et al. (2010)
Sustainability of project design and building performance	Wong and Fan (2013)
Clash detection and coordination	Azhar et al. (2008); Foster (2008); Young et al. (2009); Arayici et al. (2011); Lahdou and Zetterman (2011)
Automated safety checking platform	Zhang and Gao (2013)
Constructability analysis	Foster (2008)
Visualisation and sequencing of activities	Tulke and Hanff (2007); Wilson and Koehn (2000); Ding et al. (2014)
Cost estimation of material and quantities	Azhar et al. (2008); Hergunsel (2011); Sabol (2008)
Integration of key stakeholders	Foster (2008)
Optimisation of prefabricated construction components	Hergunsel (2011); Winberg and Dahlqvist (2010)
Risk assessment of design component of facility for prevention through design	Kamardeen (2010)
Scope clarification	Bryde et al. (2013)

Table 3 shows that all the applications and the benefits from the applications of BIM are geared towards minimising construction cost and time spent on projects. This has shown that the use of BIM in the management of construction projects has great impact on project time and cost. Initial cost for the implementation of BIM might cost much, but it will increase the profitability of the company in the long run. The applications of BIM such as clash detection, quantity take-off, design and visualisation play an important role in the management of construction projects. The most common causes of delay and cost overrun arise from poor designs, inaccurate estimates, mistakes and errors during construction due to clashes in designs. These issues can be minimised as there are reported benefits in the application of BIM that solve these issues by researchers.

CONCLUSION

The review highlighted the main causes of delay and cost overrun in the construction industry. It is generally acknowledged that the end result of delays and cost overrun is costly and risky, leading to many disputes and claims that end in lawsuits. Most of the causes of delay and cost overrun as stated by previous researchers can be classified into four categories. These are contractor's responsibility, consultant's responsibility, owner's responsibility and external factors. It is believed that the evolution of the Building Information Model (BIM) will be able to increase efficiency and quality of output in the construction industry by eliminating these causes of delay and cost overrun. The application of BIM and the potential benefits of its application were also reviewed. The benefits from using these applications are expected to minimise delay and cost overrun as they provide solutions for the main causes of delay and cost overrun such as estimation, clash detection, integration and many more.

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