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Project cost control using five dimensions building information modelling

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ABSTRACT
Correctness level of data is the key of the construction industry success. Today, there is a novel wide-spread tool in construction sector which is building information modelling (BIM). BIM assists as a collective intelligence supply for data about a service and improves closeness among distinct stakeholder concerned in a project. The usual problems confronted by construction sector are cost increasing and schedule delays. BIM will certainly assist to reduce these circumstances. This article used a case study to show how the applying of BIM systems on a full construction project life cycle cost can decrease project budgets and enhance project time. Moreover, it is going to focus on integrating the traditional 4D BIM (project schedule) and the cost of every project item to form 5D BIM. This will simplify several cost associated actions such as controlling the construction project cost. At the end of this study, it is found out that the variance between planned costs and actual costs decreased from 12% to 5% when 5D BIM is used instead of traditional methods. Therefore, accurate cost estimates and clash finding are the useful outcomes of 5D BIM.

KEYWORDS
Construction projects; cost control; building information modelling; top management-5D

Introduction

In order to improve the productivity of construction industry, novel technologies must be followed. Luckily, novel technique can improve this procedure and one of these important technologies is building information modelling (BIM). By gathering and controlling project data as records, BIM resolutions can summarize and provide information through manners that are suitable for the project top management team operating that information. Because the data are gathered as records, data variations that happen repeatedly through plan can be raised and controlled by the software during the construction project (Kulkarni and Mhetar 2017; Tahir 2018). The application of BIM permits for important swap of data by all participants involved in the construction project: clients, designers, consultants and contractors (Shrivastava and Chini 2012).

On the other hand, BIM has several benefits that can be very useful for the project team. BIM can be a beneficial tool during the project life cycle. The construction benefits contain, but not constrained to: modelling of design, organization among sections, modelling of construction arrangements and extraction of quantities data from models. The project records usually located at the construction site but the BIM permits every one of the project team to understand the correlation between various construction activities in one location. With collecting this info in one model every project member is able to imagine each component which helps for more perfect estimating and effective communication and to overcome the clash detection. Timely organization between project team members has effective influence on the project's duration and cost. The capability to imagine the relations between each project activities before the construction initiation allows timely ordering of materials. With the help of these data, shop manufacture of tools and the location of every trade's work activity could prevent conflicting with that of the other activities and finally decrease projects cost and improve efficiency (Elhag et al. 2005; Darren Olsen 2017).

The effect of BIM experience times on the understanding of its potential values was studied and the consequences of this study appeared that BIM experience was an important issue in the achievement of these values (Ahankoob et al. 2019). The 4D BIM is constructed when the component of time is inserted to the 3D BIM by forming a connection with the 3D BIM and the critical path of the project. This can be created by merging 3D BIM with scheduling software (Turkan and Bosche 2013). The 4D BIM is an effective technique to the BIM procedure because it recognizes conflict among construction items. 4D BIM is applied to recognize flow of project activities and relations between tools. The 4D BIM can also be helpful for investigating various construction circumstances and establishing the best effective arrangement of work and by this data the project manager and his management team could find whether the project is on schedule or ahead of schedule or the project is behind schedule (Bansal 2010; Dang and Bargstädt 2015). Despite the fact that the current BIM is extremely effective in keeping logical jobs such as scheduling and conflict finding, it is incomplete in data extraction and cost assessing (Zhang and El-Gohary 2020).

At present, precision of cost assessments and cost control are inclusive problems that obstacle finishing building projects effectively. A set of determinations were aimed to form methods about traditional project cost control. However, it reflected only measurable aspects without taking into account the qualitative aspects such as 'time importance for owner, scheduling ability for contractor, purchasing systems, clash detections, cost – time relationship and market states involving degree of project activity' (Elchaig et al. 2005). Consequently, researchers are determined to advance a further combined model to merge the standards.

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To disable this challenge, many researchers examined issues of cost overrun and the causes that affect the cost estimates. Ghazal and Hammad (2020) formed a model that forecasts project cost overrun by means of an appropriate information method and cost overrun issues. The limitation of this research is that the existing information did not involve all the issues needed to completely characterize the projects. Another paper recognized causes affecting the correctness of cost assessments for projects in Pakistan. Relatively fewer data are obtained from these developing countries (Arif et al. 2015). Khanzadi et al. (2020) found that project cost decrease can be gained from using BIM in the construction phase of the projects. Moreover, it was deduced that project organization, clash finding, are the influences of using BIM in the construction industry. Mostafa et al. (2020) recognized the chances and obstructions of combining BIM in the construction industry. The study outcomes showed that using BIM reduces the project mistakes.

In this research, the 5D BIM is formed when the component cost is added to 4D BIM in order to control the data stored in the BIM to extract data and transmission these data into both construction control and estimation of project costs. So when any changes arise, these estimations can be renewed at the moment based on data developed from the BIM. There are several techniques to associate model quantities to assessing methods, but each organization establishes which techniques enhance them the top based on its method of work and estimations plans. So today it is a require of the projects to integrate BIM tool with both elements time & cost control factors in order to improve all project deliverables.

Problem statement

Timely and correct view of real cost aids construction project team to consider suitable helpful proceedings that would reduce cost overrun in an appropriate way. As project develops, the procedure of construction controlling becomes more complicated due to the enormous quantity of data that demands to be determined and examined (Metkari 2004; Goedert and Meadati 2008).

An efficient control technique should involve a method of records to include the considerable groups of information related to the various project sections. Therefore, creating an integrated imagined cost assessment and control forms would be an essential development in the topic of the building control.

Aim and objectives

The principal aim of this article is to carry a case study of applying BIM to aid construction project cost management. The objectives of this research are to: (i) study the advantages of applying BIM for project cost control; (ii) present a tool that integrates the traditional 4D BIM and the cost of every project item to supply project team with a model called 5D BIM; (iii) compute the difference between actual project cost and traditional way planned cost estimation (4D BIM); (vi) compute the difference between actual project cost and planned cost estimate obtained by 5D BIM; and (vii) finally, compare the traditional cost estimation with 5D BIM-based cost estimation.

Building information modelling advantages and challenges

BIM has a very wide usage field as it is very advantageous. Listing its pros, BIM validates lower expenses as well as higher safety rates especially in development sites so less risks and more securities. Moreover, it allows better communication between the team members resulting in an improved teamwork and enhanced collaboration. BIM allows monitoring the changes, visualizing the project during the planning stage and detecting any clashes effectively. In addition, it affords superior sequencing and scheduling. Not only does it provide improved structures but it also improves the work productivity and prefabrication. Alongside this, it lowers the entire duration of the project. Additional advantage is cost evaluation based on 5D BIM that related to the paper study. The period-spending efforts related to cost estimation are simply computerized with the aid of Building Information Model Software for example the Revit that allows project team to focus on the highest item of value that includes identifying project parts. Other researches declare that, the companies that use BIM have delivered confident evaluations for their investments (Nguyen and Dang 2018; Borrmann et al. 2018; Dinga et al. 2019). The benefit of 5D BIM can minimize project cost, decrease insurance cost and reduce possibility of claims. On the other hand, an efficient study of the construction project at the initial phase reduces the quantity of unused resources and the labour costs due to miscommunication. Then again, 5D BIM produces imaginings of information that can be monitored by the construction project team and presented on a monitor (Dinga et al. 2019).

Although there are many advantages of BIM, its usage is still limited due to the following obstacles. One of the BIM challenges is its need to technology as hardware, software and network. Moreover, the process itself needs a challenging product and service infrastructure, a good leadership and various human resources. In addition, the surrounding culture is counted as a challenge as BIM needs good innovation and management. Not only does it need a good market place, but it also requires good take care of the clients and their demands. Finally, their preparatory contractual and regulatory policies are considered other challenges.

Methodology

In order to use the 5D BIM, and compare between it and the traditional cost control method, there are multiple steps to be followed which are shown in Figure 1. First, prepare 3D BIM by means of Revit software for assumed construction project with specifics then estimate the quantity and cost for various elements from 3D BIM using this software. Subsequently, set these data in a Microsoft Excel page for advance usage and organize schedule for project items using Microsoft Project. By means of Nevis Software, combine both the Microsoft Project Schedule and Cost information for each activity from excel page then get the modelled vision of construction building in terms of schedule and cost as 4D BIM and 5D BIM. Thenceforth, supply the real records of project using Microsoft Excel to Nevis Software to find the difference of schedule and cost to follow the dangerous region for cost variance by simulation. Finally, Gather the data of quantities and cost elements with conventional way from office to validate the variance with regard to 5D BIM.

Case study

It is required in the studied project; an efficient control technique involves a method of records to include the considerable groups of information related with the various project sections.

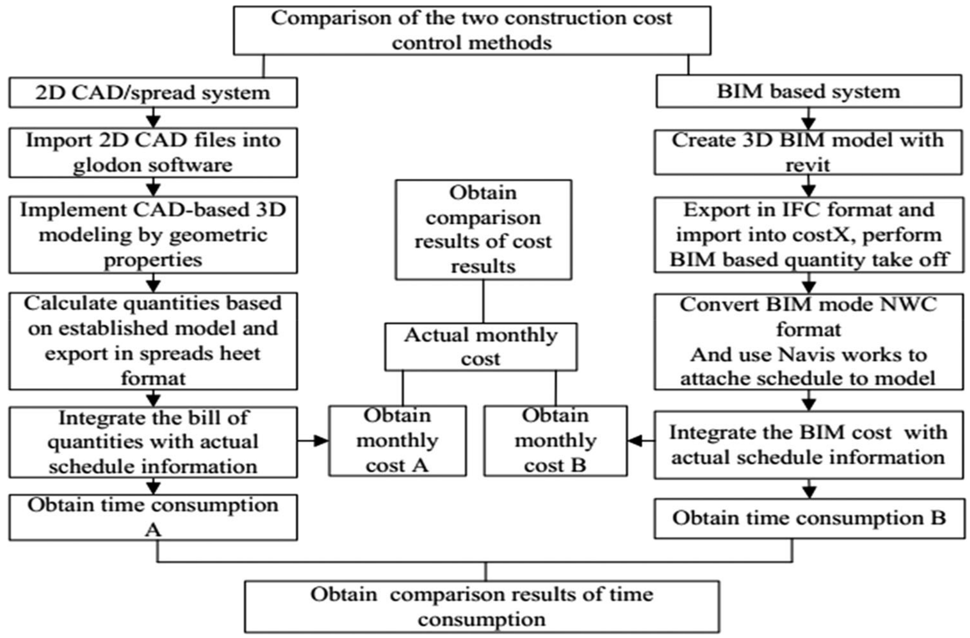

Figure 1. Comparisons between the traditional cost control method and 5D building information model.

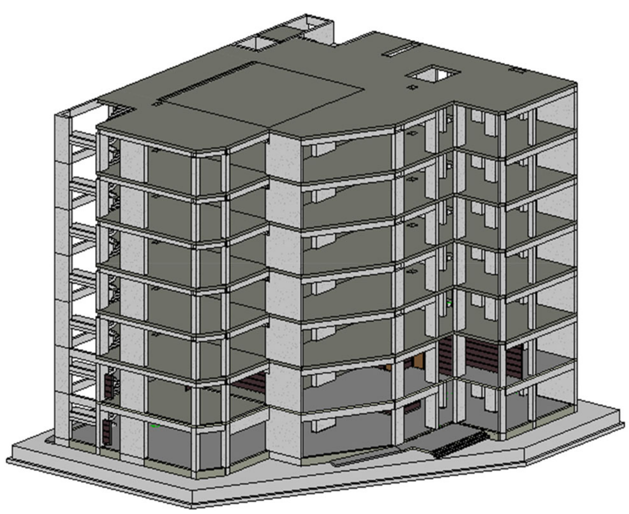

Figure 2. Administrative building using structure modelling.

For research work, a real case study project was presented to apply the new technique on it. The project is located in the new administrative capital of Egypt. It is the Administrative Building of Universities of Canada in Egypt. The building of the project has an area of 750 m^2 and consists of seven stories as shown in Figure 2. The Structure system consists of raft with variable depth, huge core, many shear walls and flat slab system. For the finishing process a lot of materials were used started with ordinary dry mix products to granite, gladding and curtain walls. Owing to the importance of the project, all the construction processes were continuous at all the 7 d of the week with a rate of 24 h/d. The top management of the project was consisted of high qualified engineers in order to complete the project within the planned required time and cost.

For creation of Structural BIM, complete structural sketches are suggested as shown in Figure 2. With the aid of Revit 2015 Software, and other existing data such as the used matter and cost of particular resources, etc., the paradigm was finished.

Quantities and cost by BIM

All the building element describes are transmitted to Excel sheets. Some elements such as soil and floor slabs are selected for the research from BIM and those elements only are compared to the real cost. The cost of the soil, first-floor slab and typical floor slabs are presented in Table 1 (cost estimate using traditional methods) and in Table 2 (cost estimate using 5 BIM). Many project elements are ignored because the difference between traditional cost and 5 BIM cost is negligible. With help of 2D drawings and site scheduling the estimated cost is taken for the comparison as shown in Table 1 and this cost is named as (COST 1 = $4,123,996). The estimated cost using 5D BIM as shown in Table 2 is named as (COST 2 = $4,398,930). Actual cost (COST 3 = $4,618,876) of all the elements needed is gathered from the project. By using earned value analysis, the differences are computed as follow:

$$\text{Variance 1} = \text{COST 1} - \text{COST 3} = 494,880 = 11.87\%$$
$$\text{Variance 2} = \text{COST 2} - \text{COST 3} = 219,946 = 4.76\%$$

So after calculations it's clear that: The variance between actual cost and estimated cost by 5D BIM is less than the variance between actual cost and estimated cost by traditional method.

Discussions

This article examined if 5D BIM can minimize the project cost, insurance cost and possibility of claims through a real case study project. It has been proved that 5D BIM has enormous ability to enhance the construction cost estimation by reducing the difference between the planned and actual cost of the project as shown in Table 2. It showed how using 5D BIM technology is very useful for project cost control. 5D BIM forms accurate Bill of Quantities by means of a particular technique to maintain the consistency of cost information.

On the other hand, more cost effectiveness can be reached when clash discovery and project organization are brought to light. In this context, combinations of construction, electrical and mechanical models identify any clashes before happening to

Table 1. Cost estimate using traditional methods.

No.	Element	Length	Width	Height	Volume	Estimated unit cost	Total estimated cost
Soil scheduling							
1	Autocad	11	10.9	0.3	35.97	220.00	7913.40
2	Autocad	7.5	5.3	0.3	11.93	220.00	2623.50
3	Autocad	15	18.6	0.3	83.70	220.00	18,414.00
4	Autocad	17.5	9.3	0.3	48.83	220.00	10,741.50
Total estimated cost for soil							**39,692.40**
Slab on grade scheduling							
1	Autocad	12	11.9	0.15	21.42	1500.00	32,130.00
2	Autocad	8.5	6.3	0.15	8.03	1500.00	12,048.75
3	Autocad	16	19.6	0.15	47.04	1500.00	70,560.00
4	Autocad	18.5	10.3	0.15	28.58	1500.00	42,873.75
Total estimated cost for slab on grade							**157,612.50**
First floor slabs scheduling							
1	Slab 140 mm	9.4	5.8	0.14	7.63	2900.00	22,135.12
2	Slab 150 mm	362.44		0.15	54.37	3000.00	163,098.00
3	slab 270 mm	78.98		0.27	21.32	3500.00	74,636.10
4	Slab 350 mm	135.54		0.35	47.44	4000.00	189,756.00
Total estimated cost for first floor slabs							**449,625.22**
Typical floor slabs scheduling							
1	Slab 140 mm	9.4	5.8	0.14	7.63	2900.00	22,135.12
2	Slab 250 mm	445.6		0.25	111.40	3300.00	36,7620.00
3	Slab 350 mm	135.54		0.35	47.44	4000.00	189,756.00
Total estimated cost for typical floor slabs							**579,511.12**
Total estimated cost for six typical floor slabs							**3,477,066.72**
Total estimated cost for the concrete slabs and soil replacement							**4,123,996.84**

Bold value signifies the sum of the costs of each part in the traditional methods.

Table 2. Cost estimate using 5 BIM.

Family and type	**Level**	**Thickness (mm)**	**Perimeter (mm)**	**Area (m^2)**	**Volume ($m^{3)}$)**	**Unit price**	**Total cost**
00-Soil level							
Floor: soil_300	00-Soil level	300	218,922.842	639.461	191.838	$220.00	$42,204.40
Floor: slab on grade_150	00-Soil level	150	192,701.16	703.811	105.572	$1500.00	$158,357.56
A01-first floor							
Floor: concrete slab 150 mm thickness	A01-first floor	150	269,046.267	389.489	58.274	$3000.00	$174,821.45
Floor: concrete slab 140 mm thickness	A01-first floor	140	45,717.642	59.344	8.308	$2900.00	$24,093.48
Floor: concrete slab 350 mm thickness	A01-first floor	350	48,049.326	142.82	49.987	$4000.00	$199,947.36
Floor: concrete slab 270 mm thickness	A01-first floor	270	38,268.931	85.202	23.005	$3500.00	$80,515.78
A02-second floor							
Floor: concrete slab 140 mm thickness	A02-second floor	140	45,717.642	59.344	8.308	$2900.00	$24,093.48
Floor: concrete slab 350 mm thickness	A02-second floor	350	48,049.326	142.82	49.987	$4000.00	$199,947.36
Floor: concrete slab 250 mm thickness	A02-second floor	250	231,021.083	473.711	118.428	$3300.00	$390,811.91
A03-third floor							
Floor: concrete slab 140 mm thickness	A03-third floor	140	44,717.642	52.984	7.418	$2900.00	$21511.53
Floor: concrete slab 350 mm thickness	A03-third floor	350	49,049.326	149.179	52.213	$4000.00	$208850.66
Floor: concrete slab 250 mm thickness	A03-third floor	250	233,621.083	473.291	118.323	$3300.00	$390465.41
A04-Fourth Floor							
Floor: concrete slab 140 mm thickness	A04-fourth floor	140	44,717.642	52.984	7.418	$2900.00	$21,511.53
Floor: concrete slab 350 mm thickness	A04-fourth floor	350	49,049.326	149.179	52.213	$4000.00	$208,850.66
Floor: concrete slab 250 mm thickness	A04-fourth floor	250	233,621.083	473.291	118.323	$3300.00	$390,465.41
A05-fifth floor							
Floor: concrete slab 140 mm thickness	A05-fifth floor	140	44,717.642	52.984	7.418	$2900.00	$21,511.53
Floor: concrete slab 350 mm thickness	A05-fifth floor	350	49,049.326	149.179	52.213	$4000.00	$208,850.66
Floor: concrete slab 250 mm thickness	A05-fifth floor	250	233,621.083	473.291	118.323	$3300.00	$390,465.41
A06-sixth floor							
Floor: concrete slab 140 mm thickness	A06-sixth floor	140	44,717.642	52.984	7.418	$2900.00	$21,511.53
Floor: concrete slab 350 mm thickness	A06-sixth floor	350	49,049.326	149.179	52.213	$4000.00	$208,850.66
Floor: concrete slab 250 mm thickness	A06-sixth floor	250	233,621.083	473.291	118.323	$3300.00	$390,465.41
A07-seventh floor							
Floor: concrete slab 140 mm thickness	A07-seventh floor	140	44,717.642	52.984	7.418	$2900.00	$21,511.53
Floor: concrete slab 350 mm thickness	A07-seventh floor	350	49,049.326	149.179	52.213	$4000.00	$208,850.66
Floor: concrete slab 250 mm thickness	A07-seventh floor	250	233,621.083	473.291	118.323	$3300.00	$390,465.41
Grand total: 24					**1503.472**		**$4,398,930.78**

Bold value signifies the sum of the costs of all parts using 5 BIM.

minimize the mistakes, improve accuracy and raise plan valuation. In addition, the advantages of using 5D BIM involve rapid preparation time, better communication, precise estimating and constructability development. Moreover, the combination of project time with cost decreases the project delivery time and improves the relation between the contractor and suppliers. Therefore, the 5D BIM can be used through preparation and execution stages of the project.

Conclusion and future research

This article presented a 5D BIM (project cost estimation), compared it with the traditional method 4D BIM (project time). It also obtained the advantages of using 5D BIM in the construction project. These advantages comprise quick actual estimate and design and correct 3D BIM imagining with various design visions. Not only does it improve communication, but it also enhances 4D BIM scheduling. The improved model contains combination of 4D and 5D BIM of time and cost information, connects this information to BIM elements and gives project stakeholders all necessary data for up-to-date decision making. In this context, when project elements are created within a BIM technique, these elements can be created digitally and the data about them can be distributed over the life-cycle of the project. Consequently, key stakeholders can create up-to-date decisions on the construction of the project elements.

On the other hand, the research examined if 5D BIM can decrease project cost assess throughout a case study. This case study focuses on joining 4D BIM and 5D BIM and verifies that all costs have been allocated accurately to all elements. Furthermore, the case study outcomes showed that the 4D and 5D BIM combination gives the contractor the chance to decrease the gap between the planned cost and the actual cost, so the model aids the project team in the cost control. Therefore, the developing 5D BIM with cost estimate procedure is extremely much useful than a conventional method through the construction cycle. This model reduces costly reworks and identifies design faults quicker compared to the usual models; therefore, the use of 5D BIM can apply within the construction life cycle, from initiation stage to closing, and even reconstructing.

More researches are concentrated on developing an automated cost control technique for construction projects. This is where 6D BIM appears in. 6D BIM contains the data to force the well business results. This information might contain records on the producer of an element, its fixing day, needed repairs and describes in what way the component should be constructed and worked for ideal operation. 6D BIM presents an agreed method of generalizing data. This technique actually derives into its specific in permitting project team to pre-arrange repairs items in advance and forms applying contours over the duration of the project. Finally creating a model using 6D BIM is a very useful tool that will help us a lot in both estimating and controlling of project costs also to predict any obstacle that may occur in the future. So in the future studies, 6D BIM is applied to finish the project before you even build one single brick.

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