Vol. 8. No. 4. 2019

Contents available at:

www.crdeepjournal.org

International Journal of Basic and Applied Sciences (ISSN: 2277-1921)

Full Length Research Paper

Integration of Building Information Modeling with Value Engineering in Construction Industry-Case Study

Ayman Hussein Taher[1*]; Ibrahim Abd EL Rashid[2] and Emad ElSaid Elbeltagi[3]

[1]*Research Scholar, Department of Structural Engineering, Faculty of Engineering, Ain Shams University, Egypt.*
[2]*Professor, Department of Structural Engineering, Faculty of Engineering, Ain Shams University, Egypt.*
[3]*Professor, Department of Structural Engineering, Faculty of Engineering, Mansoura University, Egypt.*

ARTICLE INFORMATION

Corresponding Author:
Ayman Hussein Taher

Article history:
Received: 29-07-2019
Accepted: 02-08-2019
Revised: 11-08-2019
Published: 16-08-2019

Key words:
Construction industry, BIM, VE, Scheduling, Cost estimation, Creativity, VE workshop

ABSTRACT

The construction industry in developing countries plays an important role in supporting, developing the infrastructure, contributing to social and economic growth. Thus, there is a need to increase the efficiency of the construction industry through increased use of technology. Building information modeling (BIM) is the digital representation of the physical and functional properties of the elements of the facilities. By integrating project information into 3D, which allows visualizing project parts compatible with time and cost. Value Engineering (VE) is a systematic effort to improve the project in terms of improving the life-cycle cost. It is a process to identify and eliminate unnecessary costs while ensuring quality, reliability and performance during design and construction. The integration of BIM with VE helps to develop, understand project elements and work to identify suitable alternatives for design. The focus is on the most important pillars of VE, which is to reduce unnecessary costs without affecting the functionality required for project elements. This paper introduces a case study project to illustrate the effect of using BIM along with VE in the design by developing a BIM model for design based on Value Engineering to integrate building objectives using a computational platform to automate the time and cost dimensions of creating a 5D model of alternatives. This research proved that the application of BIM on the VE achieved a reduction of the total cost of the project "between" 31% to 48% without change in the functional properties of the structural elements.

Introduction

The construction industry is one of the important industries which have a contributing role towards social and economic growth, especially for developing countries. This is an industry of complex nature because of its many chronic problems like time overrun (70% of projects), cost overrun (average 14% of contract cost), and waste generation (approximately 10% of material cost) (Hussein et al., 2013). For nearly 60 years, the construction industry in the Middle East is growing and thriving through the construction of social, economic, environmental projects, and provides a range of innovative projects and developments that help building strong foundations for the future by contributing to city planning and growth (Middle East Handbook, 2016).

BIM is the digital representation of the physical and functional characteristics of the facility (NBIMS, 2007). BIM is one of the most promising developments in the construction (AEC) industries. BIM is beginning to change the way buildings look, the way they function, and the ways in which they are built. With BIM technology, an accurate virtual model of a building is constructed digitally. When completed, the computer - generated model contains precise geometry and relevant data needed to support the construction, and procurement activities needed to realize the building. BIM also facilitates a more integrated design and construction process that results in better quality buildings at lower cost and reduced project duration and is a new approach to design, construction, and facility management (Eastman et al., 2011; Smith and Tardif, 2009).

Value Engineering (VE) is a systematic effort to improve the project in terms of improving the life -cycle cost. It is a process of identifying, eliminating unnecessary costs while ensuring that the quality, reliability and performance during design and construction as well as at various stages of the project life are in line with the goal of increasing the net value (Mostafaeipour et al., 2001). VE is a technique oriented to analyze the functions of an item or process to determine "best value", or the best relationship between worth and cost. "Best value" is represented by process that consistently performs the required purpose and has the lowest life-cycle cost (AtabayandGalipogullari,2013).VE is concerned with achieving a given function at minimum cost; it is based on the assumption that function is an objective characteristic, which is waiting to be identified. Furthermore, it is assumed that all feasible design alternatives provide the same level of functional performance (Layaraja and Eqyaabal, 2015).

The integration between BIM and VE is to use the BIM model to support visualization to help users visualize different project design alternatives. Evaluation and selection of a suitable alternative design through the 3D BIM model will have the constructability and coordination, 4D Scheduling and 5D costs planning consequently (Ranjbaran, 2013) which helps to develop the maximum number of alternatives in order to deliver the functions cost-effectively through the following:

1- Develop the listing of creative ideas for alternative ways to performing each function selected.
2- Provide optimal solutions among the available solutions to the necessary functions within the project at a lesser cost.
3- Develops a wide range of possible alternatives to perform the function to improve the value of the project.

Literature review

A. Building Information Modeling (BIM)

The concept of BIM is a popular buzzword used by software developers to describe the capabilities that their products offer (Eastman et al., 2011). A BIM is an information-rich digital model with a central repositorydatabase for all building components. The structure is represented in a 3D form that shows all its differentcharacteristics, such as dimension, location, texture, operating, maintenance procedures software (Azhar et al., 2008). BIM is the parametric modeling for a building, allows construction stakeholders to design and construct buildings virtually. BIM solutions enable architects, and engineers to more accurately visualize, helps decision-making, design, analyze, explore and sequence through visual representation of information (AGC, 2005). BIM creates a model with a limitless information; if can be 3D, 4D (integrating time) or 5D (including cost) – right up to 'nD' (a term that covers any other information) (Tarar, 2012). Upon completion of the simulations, these computerized models and accurate data are used to support the construction, manufacturing and procurement activities through which the building is realized (Eastman et al., 2011).BIM offering a host of benefits from increased efficiency, accuracy, speed, coordination, consistency, energy analysis, project cost reduction etc., (Table 1) to various stakeholders from owners to architects, engineers, contractors and others (Mandhar and Meenakshi, 2013).

Table 1: Different benefits of BIM (NZIA, 2014)

Benefits of BIM	Key Benefits
Coordination	Models show the spatial relationships of building. Reduce errors in the documentation.
Communication	3D models/images representation of the parts of a building. BIM improves communication between all stakeholders of the project.
Data management	Generates graphical representations of building elements. Modelling software manages data associated with each element of the building. Any design changes entered to the building model is automatically updated. Reports produced at any time reflects the current state of the model. Being digital, BIM data can be easily stored and transmitted, and rapidly searched, and filtered, as required.
Analysis and simulation	Data associated with the model can be used for: Quantity take-off and costing. Simulation of various aspects of the proposed building's behavior.
Improved productivity during construction	BIM improves construction quality, improves on-site safety, shortens construction programs and reduces costs by allowing: Better planning of site activities Quicker and more accurate set out prefabrication off site as building elements can be modelled, documented Possible linkage to computer-controlled machinery using digital model files.
Better information for Facilities Management	Data generated during design and construction can be readily passed on to Facility Managers to assist them in operating and maintaining buildings more effectively.

Current BIM modeling can function to Multi-dimensional of works (Fig. 1) such as 4D, 5D, 6D and 7D (Aouad et al., 2006).

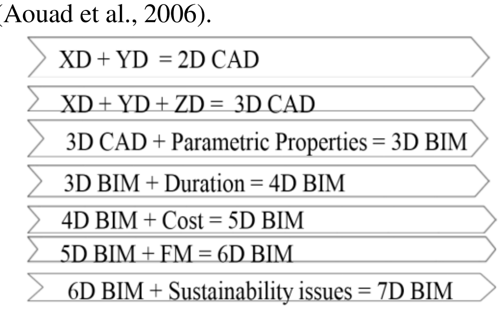


Fig 1: BIM dimensions (RICS, 2014)

B. Value Engineering (VE)

VE is a technique oriented to analyze the functions of an item or process to determine "best value", or the best relationship between worth and cost. "Best value" is represented by process that consistently performs the required purpose and has the lowest life-cycle cost (Atabay and Galipogullari, 2013). The combination of VE and BIM is a powerful management technique that gives an accurate estimation of costs and time. To support the VE analysis BIM is applied, allowing 5D presentations of project's alternatives to automate data extraction and to facilitate visualization capabilities (Ranjbaran, 2013).

VE uses a systematic methodology (job plan) to analyze a product or service in order to develop the maximum number of alternatives in order to achieve cost-effectively deliver the functions. The methodology has been developed for VE Job Plan consists different phases. Applying VE results in potential savings as shown in (Fig.2) (Heralova,2016). There are numerous benefits of value engineering. The most important of these benefits include:

- Isolation of design deficiencies.
- Cost reductions.
- Elimination of the unnecessary functions.
- Alignment of the project team and stakeholders.
- Introduction of innovation in project or product.
- Documentation of the process and results.
- Quality improvements.
- Paradigm shifts of project participants and stakeholders (Fisher, 1999).

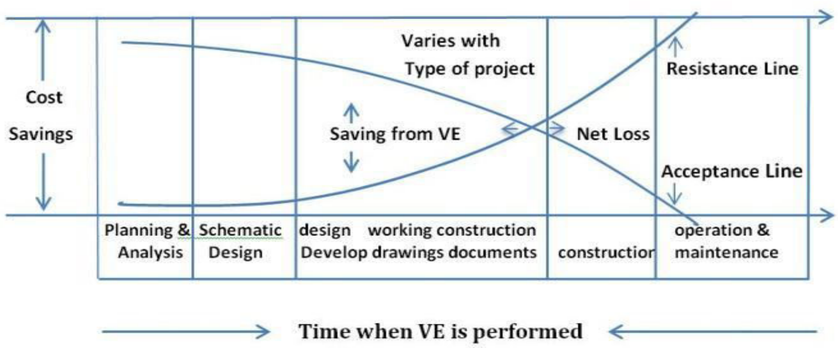


Fig 2: Potential savings from VE applications *(Heralova, 2016)*

Research methodology

This study aims to investigate the effect of integrating BIM with VE through integrating project information into 3D model, which allows visualizing project parts compatible with 4D and 5D. The integration of BIM with VE helps to develop, understand project elements and work to identify suitable alternatives for design (Fig 3).

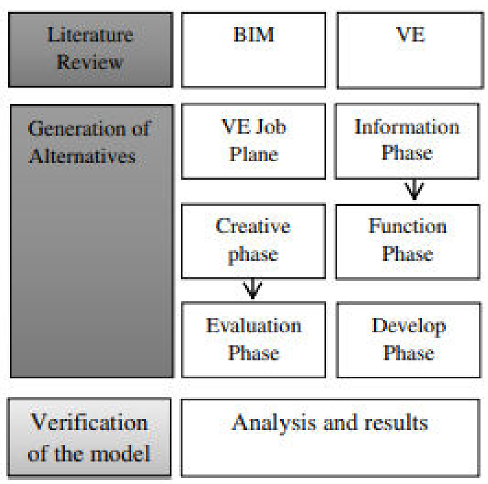


Fig 3: Frame work development for this paper

Value engineering study

The VE study comprises the following phase.

A. Pre-Workshop Phase

At this stage, the project background is explained in addition to the design information and information required for the study.

B. Workshop Stage

This phase is the essence of the VE technique. The purpose of the workshop is to provide maximum alternatives to achieve the appropriate design. The workshop phase involves the job plan steps and functional analysis as follows.

1. Information phase

At this stage, the value is analyzed by reviewing project design, objectives and initial cost information. It is therefore essential to detail the work of concrete and quantities for the elements under study. The information phase ends with the proposal to create an alternative to the design of the ceiling structure project.

Table 2: Project Information

Location	The project is located in Aden city/Yemen.
Total Area	8400 m3.
Project components:	The project will be divided into three phases and consists of four floors.
Project schedule	Two and a half years.
Project cost	The total estimated cost of the proposed project is about $4,200.000.

Fig 4: Project perspective

2. Function analysis phase

In this research, the functions of structural elements were identified to assist in the study of VE to generate design alternatives. The basic functions are identified for each alternative (Table 3). The cost is determined by comparing several alternatives that meet the basic functions of ceiling design. After determining the functions, it is necessary to clarify the scope of study by creating a Function Analysis System Technique (FAST) diagram (Fig 5).

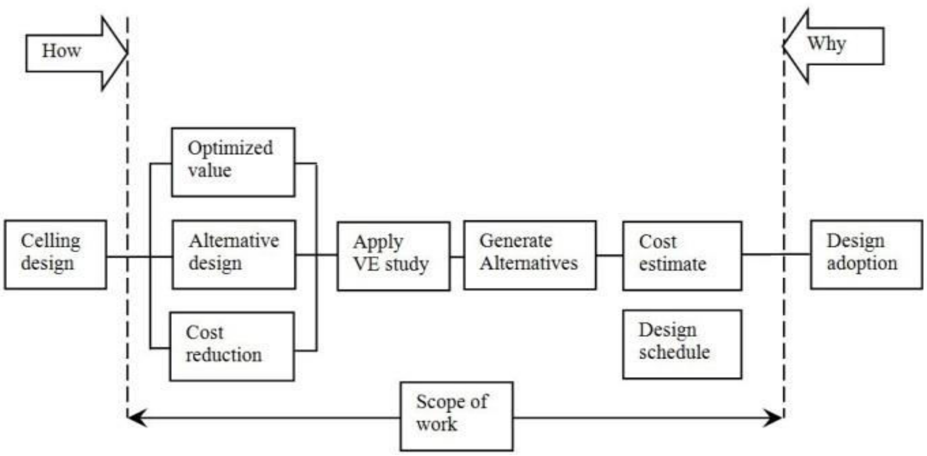


Fig 5: FAST diagram of the ceiling design

Table 3: Proposal for the alternatives slab design

Cost= design value, worth=VE target						
	Function					
Component	Verb	Noun	Kind	Cost ($)	Worth ($)	Value index
Standard foundation	Supports	Load	Basic	635714	575582.2	1.10
Deep Beam	Provide	Support	Basic	130012	03328.06	1.25
Ceiling	Provide	Cover	Basic	415940	369537.7	1.12

3. Creative phase

In the creative phase, the integration of the BIM and VE helps to contain all the information required for the alternatives. Through developing alternative methods that are more cost-effective for achieving the basic function. The 3D model of the VE team provides a specific feature that is directly related to items, assemblies and create visual takeoff diagram. So that it gives a more visualization of all design elements for alternatives. Development of an alternative evaluation framework relied on the 3D-BIM field to enable, store, edit and manage component data for design part. Quantity takeoff process could be automated for alternatives and provide better coordination and quality of design, such as classifications of structural elements, Family, Volume, and Reference level. In this case three alternatives were created to design the ceiling structure.

Alternative design 1: Flat slab

The preliminary alternative design of ceiling was the flat slab (Fig 8), which consists of marginal beam with slab thickness 20 cm. A flat slab is a reinforced concrete slab supported directly by concrete columns without the use of beams (Fig 9).

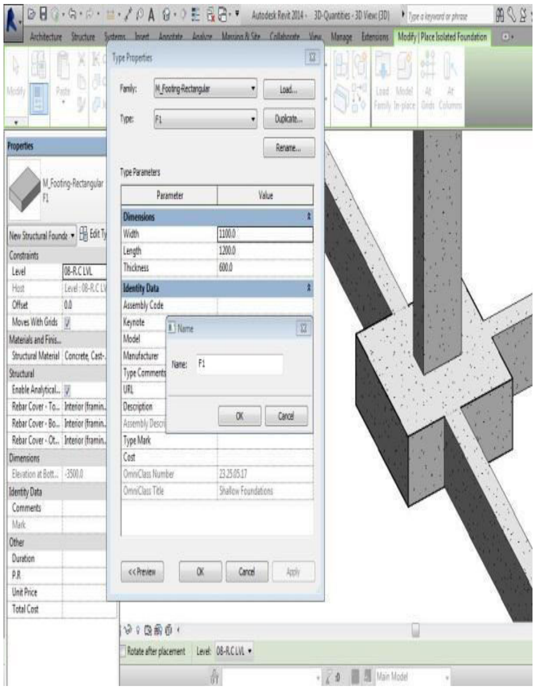
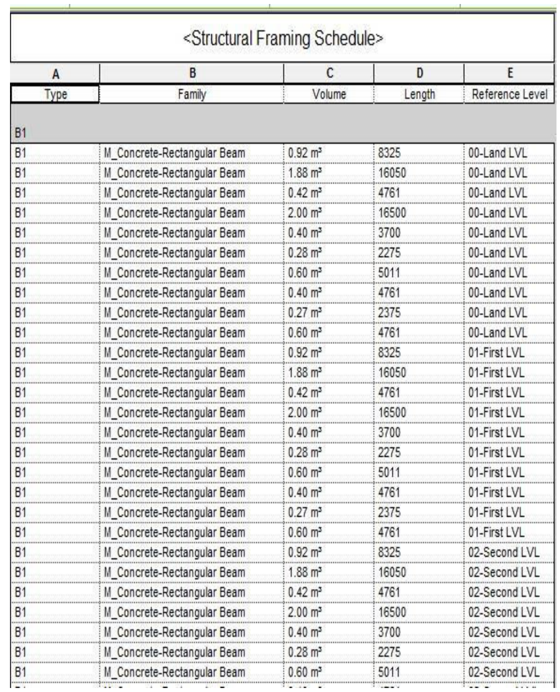


Fig 6: Properties Defined in Revit for design components



<Structural Framing Schedule>

A	B	C	D	E
Type	Family	Volume	Length	Reference Level
B1				
B1	M_Concrete-Rectangular Beam	0.92 m³	8325	00-Land LVL
B1	M_Concrete-Rectangular Beam	1.88 m³	16050	00-Land LVL
B1	M_Concrete-Rectangular Beam	0.42 m³	4761	00-Land LVL
B1	M_Concrete-Rectangular Beam	2.00 m³	16500	00-Land LVL
B1	M_Concrete-Rectangular Beam	0.40 m³	3700	00-Land LVL
B1	M_Concrete-Rectangular Beam	0.28 m³	2275	00-Land LVL
B1	M_Concrete-Rectangular Beam	0.60 m³	5011	00-Land LVL
B1	M_Concrete-Rectangular Beam	0.40 m³	4761	00-Land LVL
B1	M_Concrete-Rectangular Beam	0.27 m³	2375	00-Land LVL
B1	M_Concrete-Rectangular Beam	0.60 m³	4761	00-Land LVL
B1	M_Concrete-Rectangular Beam	0.92 m³	8325	01-First LVL
B1	M_Concrete-Rectangular Beam	1.88 m³	16050	01-First LVL
B1	M_Concrete-Rectangular Beam	0.42 m³	4761	01-First LVL
B1	M_Concrete-Rectangular Beam	2.00 m³	16500	01-First LVL
B1	M_Concrete-Rectangular Beam	0.40 m³	3700	01-First LVL
B1	M_Concrete-Rectangular Beam	0.28 m³	2275	01-First LVL
B1	M_Concrete-Rectangular Beam	0.60 m³	5011	01-First LVL
B1	M_Concrete-Rectangular Beam	0.40 m³	4761	01-First LVL
B1	M_Concrete-Rectangular Beam	0.27 m³	2375	01-First LVL
B1	M_Concrete-Rectangular Beam	0.60 m³	4761	01-First LVL
B1	M_Concrete-Rectangular Beam	0.92 m³	8325	02-Second LVL
B1	M_Concrete-Rectangular Beam	1.88 m³	16050	02-Second LVL
B1	M_Concrete-Rectangular Beam	0.42 m³	4761	02-Second LVL
B1	M_Concrete-Rectangular Beam	2.00 m³	16500	02-Second LVL
B1	M_Concrete-Rectangular Beam	0.40 m³	3700	02-Second LVL
B1	M_Concrete-Rectangular Beam	0.28 m³	2275	02-Second LVL
B1	M_Concrete-Rectangular Beam	0.60 m³	5011	02-Second LVL

Fig 7: Quantity takeoff table

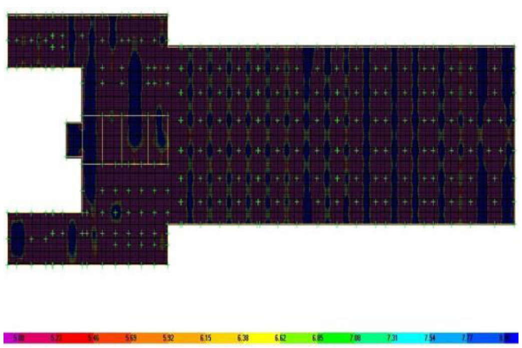


Fig 8: Distribution of the moments in the flat slab from the SAP model

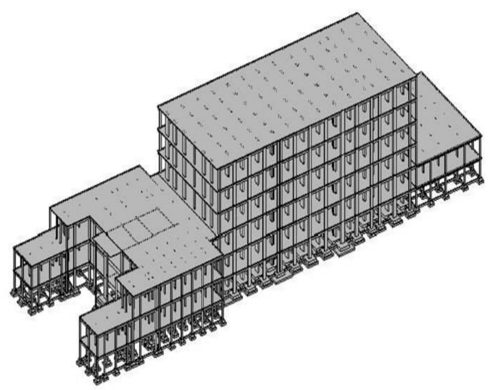


Fig 9: Flat slab BIM model

Alternative design 2: Post tension slab

The secondary alternative design of ceiling was the post tension slab (Fig. 10), which consists of slab thickness 25cm. A post tension slab is a reinforced concrete slab supported directly by concrete columns without the use of beams (Fig. 11).

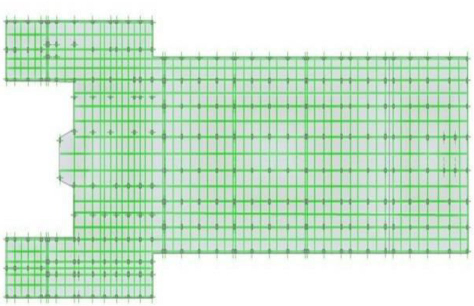


Fig 10: Post tension tendons layout in horizontal and vertical directions

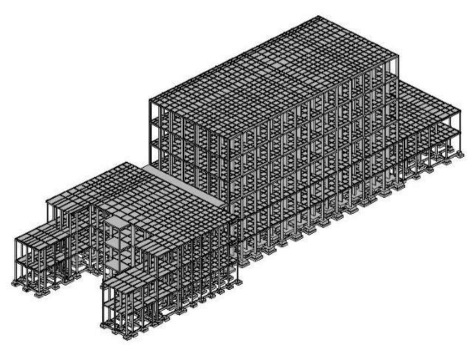


Fig 11: Post tension BIM model

Alternative design 3: Hollow Block slab

The third alternative design of ceiling was the hollow block slab (Fig. 12), which consists of blocks (20 * 40* 25) cm with ribbed Slabs 30cm thick. In this type of slab are used hidden beams. A concrete slab with a small thickness of 5cm was used. This slab is based on a group of ribbed, either in one direction or both. These rib width 10 cm and height of 30 cm (Fig. 13).

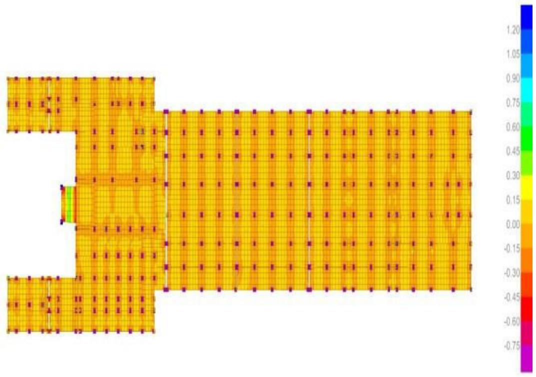


Fig 12: Distribution of the principal moments for safe model

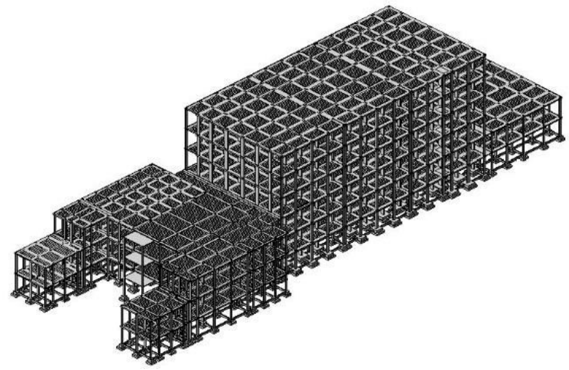


Fig 13: Hollow block slab BIM model

4. Evaluation Phase

Evaluation Phase relied on two main criteria through the 3D BIM model; 4D scheduling and 5D cost estimateon creating multiple alternatives for ceiling design. 4D BIM is a dynamic simulation tool for analyzing different times of activity. The planning process illustrates the workflow of the project scheduling by using the Gantt chart in Primavera (Fig 14).

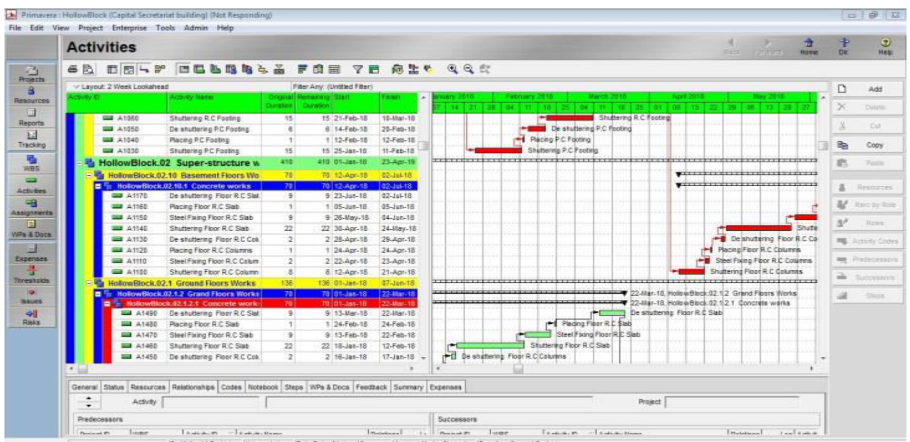
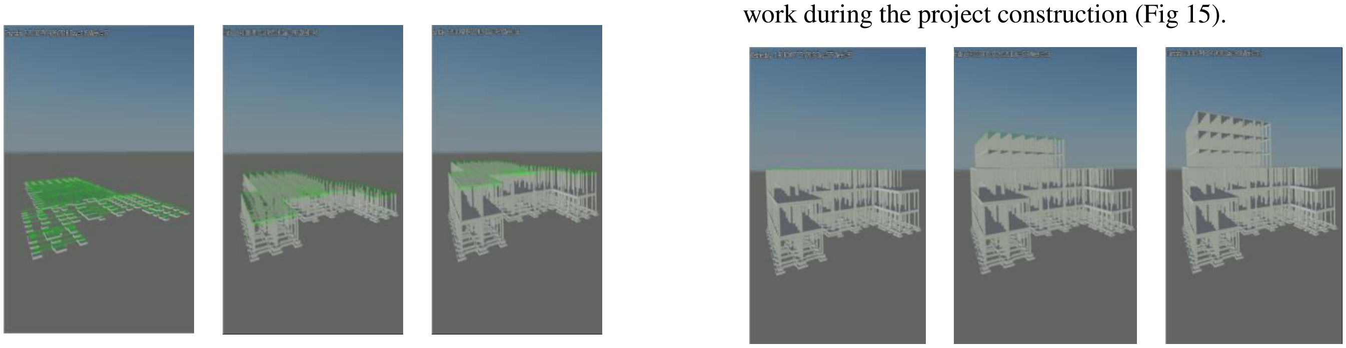


Fig 14: Planned Schedule

Project scheduling is based on the total amount of the project quantities and on the production rate of various construction crews. With the import of the table created by Primavera, the BIM platform allows the design schedule.

Use the Navisworks program to create a visual representation of time by providing a 3D virtual simulation of the project. The 4D model helps to integrate the 3D and the time dimension to show the impact on the cost of the project. It represents a virtual environment linked to the activities and show time sequence of work during the project construction (Fig 15).



Week 17 Week 42 Week 66 Week 83 Week 106 Week 117

Fig 15: Sequence of construction with time.

5D BIM allows 3D visualization compatible with the cost and time of each alternative. The cost of the design was estimated through the quantity take-off of extracted from the BIM model. The generation of cost estimates for the design alternatives is performed using the unit price for different element. So that the total quantity of the element can be multiplied by the total price. A parameter is added to link costs and time in the BIM schedule. Cost and time data are entered manually when multiple items are added in the BIM fields. Thus, producing quantity take-off, cost data and time automatically. The 5D model is used in the design phase according to the design needs of alternatives to be used to achieve project item costs. In the BIM model, the design schedule activities are combined to develop the 5D model. To compare different alternatives and make the best decision, helps the5D model to showing planned work sequence with the time and cash flow.

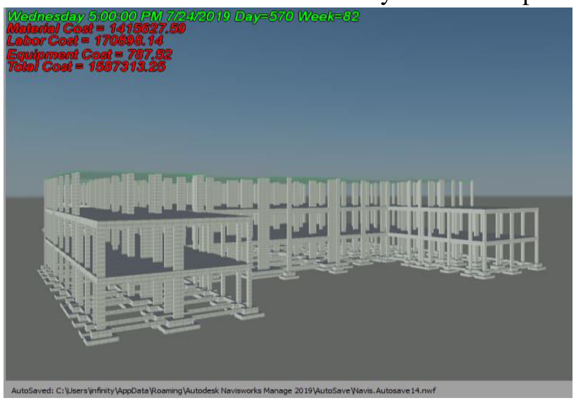


Fig 16: Shows the cost for week 82 and 117 in the BIM model

The design alternatives were evaluation as follows:

Flat slab
It was found that the idea of slab is economically inappropriate. Flat slab construction offers considerable flexibility in horizontal service, which can easily change the internal partition walls to accommodate changes in the use of the structure.

Post tension slab
The idea of this slab was found to provide material, labor cost and time less than the flat slab. Post tension slab allows more architectural freedom: Larger column free spaces providing more flexibility and elegant appearance of slender ceiling use.

Hollow Block slab
It was found that the idea of slab is economically designed. In large spans, the design needs a large slab thickness, which increases the weight of the slab. This method is used to remove part of the non-working concrete in the tension area, which reduces the own weight of slab.

5. Development phase
The study of VE suggested many ideas for generating an economical alternative to design. A cost analysis comparison was made between the three alternatives.

Table 4. Cost estimate for alternatives

No	Type of work	Item	Cost ($)		
			Flat Slab	Post Tension	Hollow Block
1	Sub-structures work	Soil works	$37,692.4	$37,692.4	$39,089.8
		Concrete works	$476,046.1	384,585.3	$234,271.4
		Insulation works	$18,136	$14,300	$11,066.6
2	Super-structure works	Reinforced concrete columns	$794,911.7	$751,559	$511,723.1
		Reinforced Concrete- Slab	$1,557,611	$1,198,646	$1,347,086
		Stairs	$19,030.3	$19,030.3	$19,030.3
	Total cost		$2,903,428	$2,405,813	$2,162,267

The result shows that the use of the Hollow block achieves a better cost saving. The use of the Hollow block slab will reduce the total cost of the initial design of the project by 48%.

Analysis and Results
The study relied on time and cost criteria in choosing the best design alternative. From the case study, the visualization capabilities in the 3D BIM assisted the VE analysis process in the creative phase to generate alternatives. The 5D BIM helped to analyze the time of each alternative and find the relationship between the costs of design elements. A simple comparison of the cost and time-generating alternatives is made to determine the best alternative to the design.

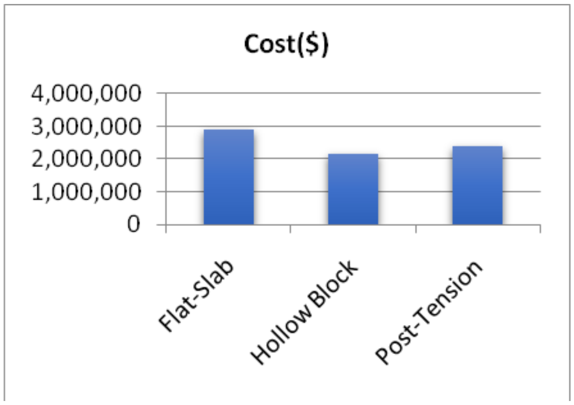


Fig 17: Alternative cost

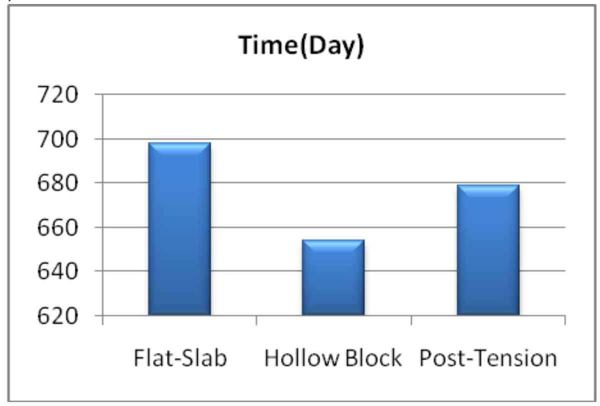


Fig 18: Alternative Time

Conclusion

The study proved that the analysis ofVE based on BIM is a powerful tool to solve the costs not required in the design. The integration between BIM on VE supports the visualization capabilities of creative phase to help study value engineering to visualize different alternatives to project design. Comparing alternatives through in this research relied on two main criteria through the 3D BIM model; scheduling 4D and cost estimate 5D. In the VE study, the Hollow Block slab was found to be cost-appropriate. The estimated total cost of the proposed design is about $2,162,267 The total time of this alternative design is estimated at six hundred and fifty- four days. The second arrangement of the alternative design of the ceiling was the post tension slab. The estimated total cost of the proposed design is approximately $2,405,813 and the total time is seven hundred and seventy-nine days. The flat slab is not economically suitable. Where the total cost of design is approximately $2,903,428 and the total time is eight hundred and fourteen days. The results of the study showed that the application of BIM on the VE achieved a reduction of the total cost of the project “between” 31% to 48% without change in the functional properties of the structural elements.

References

AGC, Associated General Contract. (2005). The Contractor’s Guide to BIM, 1st Edition, American of Associated General Contractors, Las Vegas, USA.

Aouad, G., Wu, S., and Lee, A. (2006). N Dimensional Modeling Technology. Past, Present, and Future. Journal of Computing in Civil Engineering, 20: 151-15.

Atabay, S., and Galipogullari, N. (2013). Application of Value Engineering in Construction Projects. Journal of Traffic and Transportation Engineering, 1: 39-48.

Azhar, S., Hein, M., and Sketo, B. (2008). Building Information Modeling (BIM) Benefits, Risks and Challenges. Proceedings of the 43rd ASC National Annual Conference, pages 1-11, Alabama. USA.

Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2011). BIM Handbook: A guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. John Wiley & Sons. Inc, USA.

Fisher, J. M. (1999). The Modification of Value Engineering for Application in the Petrochemical Industry. Master Thesis, Civil Engineering Department, University of Calgary, Canada.

Heralova, R. S. (2016). Possibility of Using Value Engineering in Highway Projects. Creative Construction Conference, 25–28 June, Czech Technical University in Prague, Czech Republic.

Hussein, J. M., Abdul Rahman, I., and Memon, A.H. (2013). The Way Forward in Sustainable Construction: Issues and Challenges. International Journal of Advances in Applied Sciences, 2(1):15-24.

Layaraja, K., and Eqyaabal, M. (2015). Value Engineering in Construction. Indian Journal of Science and Technology, 8 (32): 974-981.Mandhar, Manish., and Mandhar, Meenakshi. (2013). Integrating BIM in Architectural Education. International Journal of Architecture, 1(1): 1-20.

Middle East Handbook. (2016). Property and Construction Handbook, 2016 Edition. Middle East Construction Survey, UAE.

Mostafaeipour, A., Roy, N., Hosseininasab, H., Emam, M., and Bordbar, G. (2011). Value Engineering Analysis Appraisal for Farm Management: A Case Study of Pistachio Farms. South African Journal of Industrial Engineering, 22(2):204-215.

National Building Information Modeling Standard, NBIMS. (2007). National Institute of Building Sciences, Facilities Information Council, National BIM Standard, USA.

New Zealand Institute of Architects, NZIA. (2014). New Zealand BIM Handbook: A guide to enabling BIM on building projects. Building and Construction Productivity Partnership, New Zealand.

Ranjbaran, Y. (2013). Integrated Computational Model in Support of Value Engineering, Master Thesis, Building, Civil and Environmental Engineering department, Concordia University, Canada.

RICS. (2014). International BIM implementation guide, 1st edition, Royal Institution of Chartered Surveyors, UK.

Smith, D., and Tardif, M. (2009). Building Information Modeling: A Strategic Implementation Guide for Architects. Engineers, Constructors, and Real Estate Asset Manage. John Wiley & Sons, Inc, New Jersey, USA.

Tarar, D. T. (2012). Impact Of 4D Modeling on Construction Planning Process. Master Thesis, Civil and Environmental Engineering department, Chalmers University of Technology, Swede.