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ECONOMIC COMPARISON OF INDUSTRIALIZED BUILDING SYSTEM AND CONVENTIONAL CONSTRUCTION SYSTEM USING BUILDING INFORMATION MODELING

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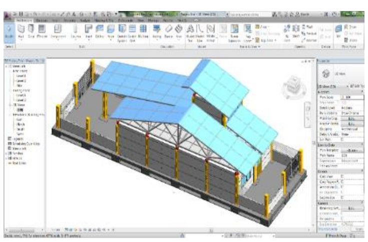
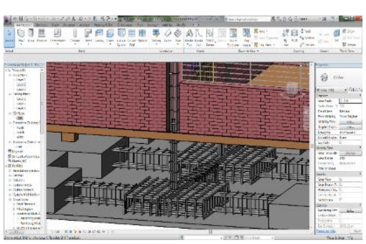
Graphical abstract





Abstract

The new construction method known as Industrialized Building System (IBS) offers several benefits compared to the Conventional Building System (CBS); however, IBS is perceived by most of the practitioners to be an expensive method for being utilized in construction industry. Whilst relatively numerous studies have been carried out on the subject of IBS and CBS methods, there has not been any exploiting building information modeling (BIM) as a useful tool to calculate quantities, time, and cost needed to construct building with each of the two aforementioned methods. The aim of this paper is to calculate cost of two similar buildings (one is constructed with IBS method and other one with CBS method) and compare them in terms of economy based on a chosen case study and same initial investment. To this end, the construction cost of buildings is calculated using BIM software, namely Revit Architecture and Navisworks Manage for modeling the chosen case study and estimating construction cost, respectively. The findings indicated that IBS was not economic in low investment of company; however, with investment on more than 100 units of IBS, this method was shown more economical compared to CBS method. In addition, the initial investment on IBS method could be returned when more than 200 units of IBS were implemented in the projects.

Keywords: Industrial building system, building information modeling, Cost estimation

Abstrak

Kaedah pembinaan baru yang dikenali sebagai Sistem Binaan Berindustri (IBS) mempunyai lebih manfaat berbanding Sistem Konvensional Bangunan (CBS). Walaupun kajian terhadap kaedah IBS dan CBS telah sering di lakukan, eksploitasi maklumat pemodelan bangunan bermaklumat (BIM) sebagai alat untuk mengira kuantiti, masa, dan kos pembinaan tidak berkembang. Tujuan penyelidikan ini adalah untuk mengira kos dua bangunan yang serupa tetapi menggunakan dua kaedah pembinaan yang berbeza (kaedah pembinaan IBS dan keadah pembinaan CBS). Keduanya di bandingkan dari segi pengiraan kos sebenar semasa pembinaan, termasuk pelaburan awal untuk aktiviti pembuatan dan pembinaan. Untuk tujuan ini, kos pembinaan bangunan telah dikira dengan menggunakan perisian BIM (Revit Architecture dan Navisworks Manage) dalam mengira kos sebenar pembinaan setiap satu kaedah pembinaan. Dapatan kajian menunjukkan bahawa IBS tidak ekonomi jika keupayaan pelaburan syarikat pembinaan adalah rendah atau kecil. Walau bagaimanapun, jika syarikat membina lebih dari 100 unit rumah IBS, kaedah pembinaan IBS adalah lebih menjimatkan berbanding dengan kaedah pembinaan CBS. Di samping itu, pelaburan awal pada kaedah pembinaan IBS dapat dikembalikan sepenuhnya jika melebihi 200 unit IBS dilaksanakan dalam apa juga projek pembinaan perumahan.

Kata Kunci: Sistem bangunan perindustrian, membina model maklumat, anggaran kos

1.0 INTRODUCTION

Nowadays, construction industry is considered to be a key program for promoting the economy growth in both developing and developed countries [1]. Its development goes back to the age of the industrial revolution in 18th century. Since that time, many attempts have been increasingly made to systemize the construction methods with current technologies. Recently, the construction technology has experienced various challenges, and new methods have emerged to replace the conventional ones [2]. Based on the history of construction industry and the utilization of simple methods and materials, its growing tendency is through fabrication of advanced machineries and equipment, manufacture of the universal construction materials, new installation methods, and construction steps throughout the life cycle of projects [3].In In the early 1960's, the new construction methods arrived in Malaysia and gradually changed the construction industry from the traditional methods to Industrialized Building System (IBS) [4].

According to the IBS Roadmap 2003-2010 in Construction Industry Development Board (CIDB, 2003), IBS is a construction system wherein components are manufactured off site (i.e., in a factory) and assembled into a structure with the minimum on-site work. This system includes the whole pre-fabricated parts of a building (e.g., wall, floor slab, beam, column, and staircase), which are manufactured in a completely controlled condition. Many researchers believe that IBS has shifted construction from traditional to systematic methods in a way to decrease the waste of resources and enhance the value for end users.

As mentioned in the previous studies, several benefits can be delivered through the application of IBS, including environmental friendliness, cost savings, less construction time, flexibility, saving in labor, optimized use of material, higher quality and better finishes, less impact of weather on construction operation and increase site neatness and safety [2,3,5,6,7,8]. Shen *et al.* [9], mentioned that the main goal of any construction challenge is to assure fiscal affordability towards stakeholders and clients, job opportunities, competitiveness and maintain the needs of future generations. This may undoubtedly be accomplished through adding IBS in the project. However, IBS benefits the environment; it assures a considerable profit to the stakeholders and clients. There is a potential for IBS users to benefit from IBS in terms of long-term income and expenditure reduction [2]. Yee [10] emphasized that IBS is very cost beneficial due to the lower cost of materials. There is a study conducted in Malaysia that compared the results of a case study and a questionnaire survey in terms of cost comparison between IBS and CBS [11]. They concluded that, many professionals believe that CBS is more cost saving even if considering all the benefits of IBS. Shamsuddin *et al*. [2], conducted a study to compare the costs of using IBS and CBS methods using questionnaire and statistical analysis. They found that IBS is cost saving in terms of material and labor. Lachimpadi *et al*. [12] stated that IBS can be very cost beneficial in terms of Waste Management. In their study, all the data only obtained from construction waste over a 3-year period. Bari *et al*. [5], used qualitative and quantitative analysis and concluded that long-term costs can be reduced even if the initial cost is higher through IBS method.

As mentioned above, numerous studies have been conducted on the subject of CBS and IBS methods; however, no research has utilized BIM as a helpful tool for the calculation of cost, materials, and time required for constructing each of the two above-mentioned methods. This paper highlights several benefits involved of using BIM in IBS method. The present research aims at comparing IBS and CBS to confirm that the use of IBS has positive influence on financial profitability of construction projects. It focuses on a single-story building in Malaysia designed by UTM inventor with IBS method in the area of 200 m2. Additionally, there is another similar plan built with CBS method.

In the company of information revolution occurred in the middle of the 20th century, computer started playing an important role in the improvement of the construction industry in terms of administration, construction, and design. Additionally, it is capable of removing numerous construction limitations. Computer has provided technologies such as Building Information Modeling (BIM) that initially provides the owners with better vision and more accurate perception towards the project features [13, 14]. Furthermore, it reduces the cost of project and avoids reworking since digital information is easily exchangeable [15].

1.1 Comparison between IBS and CBS

IBS represents 70% of total building constructions in some European countries like Finland. IBS facilitates an efficient and rapid site assembly and improves the construction quality. In Japan, the building industry has promoted the most advanced manufacturing approaches in construction processes. Manufacturing processes in construction take the advantages of automation and robotics. At the same time, the quality of off-site manufacturing in German building industry has improved, and a better value is provided together with a significant flexibility and variety in design. Moreover, IBS has aided the developers to realize the strict standards of quality control that are imposed by local authorities.

Additionally, off-site production greatly reduces the construction cost at site compared to the traditional methods. It considerably decreases redundant activities and some wastes, which are considered as two of the most important challenges in construction sites. These two factors are deemed to be as non-value adding activities that account for 30 to 35% of the construction cost of a project. Wastages and redundant activities include extra workers at the site about 16% of worker's cost[2]; material wastages around 2.5% of construction cost[16];need-to-do rectification works at approximately 5% of project value [17]; theft and destruction of properties around 1.5% of production cost; redundant activities of workers almost 5% of construction cost; check and inspection of the construction process roughly 1% of production cost; and safety and health nearly 6% of construction cost[18].

1.2 Project Cost Estimate

To organize and control information, estimators are able to prepare work breakdown structure (WBS) through dividing a given project into different cost centers. The majority of complex projects use WBS for achieving greater information control on a project. To develop the estimating process, the quantity of the cost centers should be estimated. This quantification process is called quantity takeoff. In conventional methods, to count the number of each drawing item, estimators carry out the test on 2-D drawing design [12]. Afterwards, estimators sum up their count into WBS and price out the quantities.

In the cost estimating process, there are two major elements: quantity takeoff and pricing. Quantity takeoff is one of the primary and cost-effective applications for Automatic BIM [19]. Quantities extracted from BIM can be presented in a cost database or excel file. Note that the model does not release the price; therefore, there is a need for certain expertise to analyze the material components and their installation methods. In cases where the price of a particular activity is not determined, the elements should be broken by the estimator. For instance, in the activities related to the concrete pour, the model might comprise the details of the rebar, formwork, wire mesh, concrete, and so on.

2.0 RESEARCH METHODOLOGY

BIM is considered as one of the most promising developments in the Architecture, Engineering and Construction (AEC) industries [20, 21]. Using BIM, construction projects can be simulated in a virtual environment and a perfect virtual model of a building can be digitally generated. The computer-constructed model consists of accurate geometry and data required for supporting the whole activities in the construction, fabrication, and procurement, which are needed to realize a building.

The National BIM Standard defines BIM as "a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition." BIM is the process and practice of virtually designing and constructing a building throughout its life cycle [22]. Using this platform, project participants can share their knowledge and communicate with each other.

3D modeling is a developing method of three dimensional displaying mathematically the objects' surface using special software. In addition, it can demonstrate a 2D model of objects through 3D rendering. Models are created both manually and automatically. 3D solid models are applied to not only 3D solid graphics but also most of the computer games, including the 3D solid models as spites. 3D solid model is employed in different industries such as movie industry for producing animations, medical industry for the creation of 3D solid model's organs, and so on.

4D BIM has various applications in building construction, including the visualization of the project construction, scheduling, and the management of the supply chain, risk, and cost, the improvement of construction projects, the implementation of the collaborative projects, the participation in the supply chain, and producing the components [23]. In 4D BIM, the new dimension of 'time' is added to 3D CAD (solid modeling). 4D BIM is aimed to expand the technology in a way to help the construction delivery teams and maintain the demands for construction industry [24].

5D BIM connects the 3D model to the time schedule and cost information of the project. Using 5D BIM, the process of construction activities as well as the cost of the project and the project time can be visualized for the owners, managers, contractors, and designers. This method improves the quality of the projects' management and their delivery in different size and complexity [25].

2.1 Research Framework

The framework used in this paper is presented in Figure 1. The initial step is collecting data from reliable sources such as Malaysian rules and market conditions, reasonable assumptions based on the previous experiences and Malaysian Public Work Department (JKR) price list. JKR is the federal government department in Malaysia under Ministry of Works of Malaysia (WOM) that is responsible for construction and maintenance of public infrastructure in Malaysia. The next step is to model the selected case study located at Universiti Teknologi Malaysia (UTM). It includes two types of plans; one is for IBS method and the other one for CBS method. The aforementioned plans have been drawn in Revit Architecture 2013 including different components such as foundation, beams, exterior and interior walls, columns, and so on.

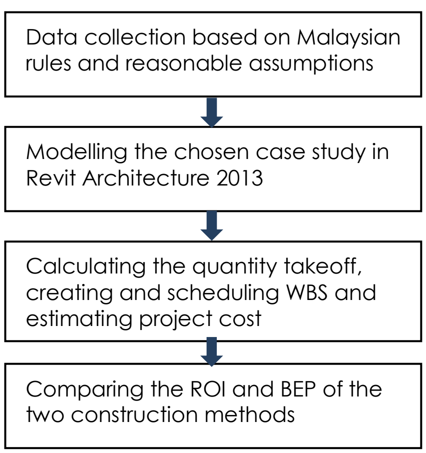


Figure 1 Research Framework

In the third step, the 3D models are exported to Navisworks Manage 2014 separately, and the construction cost of each building is calculated based on different specifications identified regarding each component. Next, quantity takeoff is done for all parts of the building designed on the 3D model by inserting into the Quantification Workbook. Finally, the results are exported to the Microsoft Excel software to obtain reports from quantity of materials used in the building. Step 4 presents the WBS of the projects created in the Navisworks Manage software in order to estimate 5D and 4D based on quantities obtained from the third step. In the 5th step, different benefits of prefabrication method which positively affect onsite construction process and lead to a reduction in some value or non-value costs related to the construction site are extracted from the past research as waste costs. This is shown as the percentage of the total construction cost and added to the total cost of the conventional construction method as the extra costs in order to achieve the rate of these effects on the reduction of cost difference between two methods.

Finally, the effect of time on comparison of two construction methods is evaluated for multi-story buildings in different volumes based on the same value of initial investment and time. To this end, the Microsoft Excel Software is employed using the visual graph based on the Break-Even Point (BEP) analysis, return on investment (ROI), and profitability of each project.

3.0 DATA COLLECTION

The following considerations have been collected from the Malaysian policies; all unit costs are collected from JKR and CIDB price list, and also some assumptions are needed for calculation based on the past researches and experiences.

- It is assumed that the distance of soil mobilization to the contractor's source or construction site is about 10 km.
- To encourage practitioners to be involved more in IBS, an exemption in the form of tax levy (0.125% of project cost) is taken into account by the Malaysian government for those projects that achieve a minimum of 50% of the IBS score in the construction of residential buildings. Thus, this reduction rate is used for construction cost of IBS project in this study [26].
- It is assumed that the number of units per level is five, and the construction cost is invariant in every level of the buildings.
- Sale of 30% of units before the projects' finish-time is expected for both methods. Moreover, monthly sale has been assumed five units.
- Industry interest rate and Building unit price is considered to be 12% and $ 693.5 respectively.

3.1 Estimating the Cost of Constructing Two Buildings (IBS and Conventional)

Figures 2-3 illustrates the case study, including IBS and CBS, which has been modeled by Revit Architecture 2013. In the next step, the construction cost of each building was calculated using the Navisworks Manage software. After importing separately the 3D models into Navisworks Manage, as Figure 4 shown, all building materials used in buildings were defined with details related to each component in the Resource Catalog.

Afterward, the identified materials were allocated to the relevant groups. For example, there were different materials identified for Footing in the Foundation named as rebar 20, steel box, wood form and concrete as shown. Finally, as it can be seen in Table 1 and Table 3, quantity takeoff was automatically taken for all parts of the building designed on the 3D model.

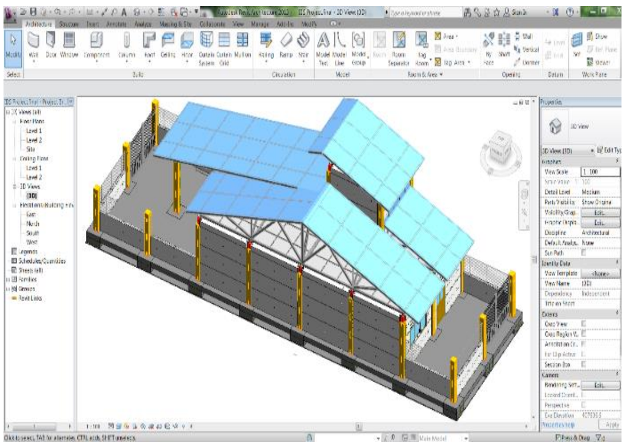


Figure 2 3D Model of the IBS project

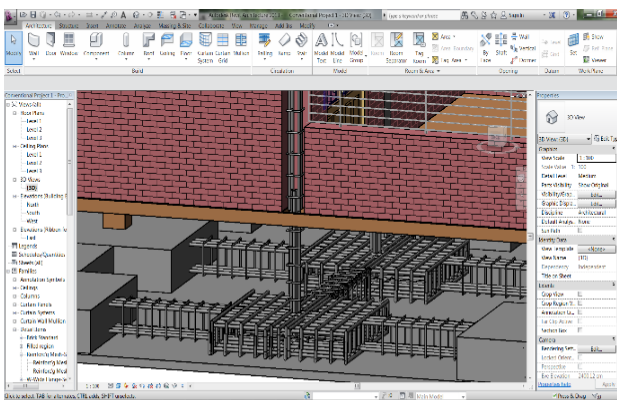


Figure 3 3D Model of Structural Details in the CBS Project

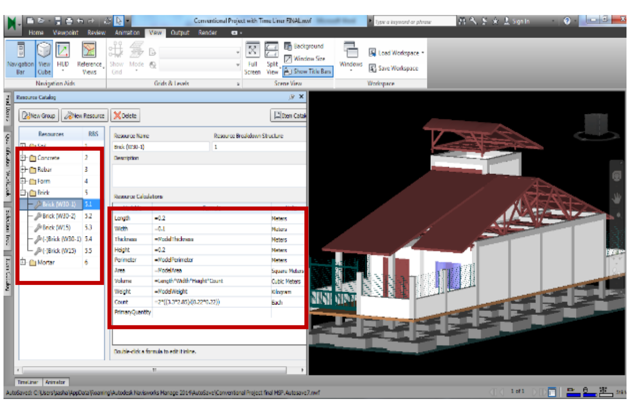


Figure 4 Identification of Materials in Navisworks Manage 2014

3.2 Financial Impacts of IBS Benefits

Despite the high cost of constructing a building with IBS method, this method offers numerous benefits leading to a decrease in the cost discrepancy between the aforementioned two mentioned methods. In this regard, prefabrication method reduces significantly the construction activities on site; therefore, unnecessary activities and resource wastages are decreased throughout the project. According to other studies, this reduction rate is about 70 % of building construction [11].

3.2.1 Material Wastage

According to the literature, at least 10 % of materials in the construction site is wasted due to some reasons such as design and documentaries, material procurement and management, site management practices, site supervision, and environmental conditions. This leads to an increase in total construction cost of building. A study conducted by Begum *et al*. [16], at an IBS construction project site in Malaysia showed that there is a potential to reuse and recycle around 73% of construction wastages.

3.2.2 Rectification Works

It is a common problem in construction sites because of poorly controlling and checking and non-conformance during production, which results in rework to repair the surface. Normally, around 5% of the value of each project considers for rectification works [16]; however, this amount might change based on the characteristics of each project.

3.2.3 Problems in Relation to Workers

Approximately 5% of the construction cost is wasted due to redundant activities that can be eliminated without affecting the final product. These activities include reworking, waiting, and wasted time. Worker's cost is about 4% of total project cost, and Jaillon *et al*. [18] proved that a cost saving of 16% in labor requirement on-site are achievable while using IBS method.

3.2.4 Stealing Problem and Destruction of Property

Theft is an unexpected occurrence in construction sites, which causes no value-adding cost for projects. This cost is about 1.5% of construction cost in conventional projects, which is about 1% more than this amount in IBS projects.

3.2.5 Level of Health and Safety

The construction projects allocate a part of their direct costs to safety and health. This cost includes work-related injuries and illnesses and also safety of workplace against the possible events during the construction process. This amount is roughly 6.5% of construction cost, and this rate in conventional projects is near 4 % more than IBS projects.

3.2.6 The Inspection of Construction Process

This item is the most costly part in conventional projects in comparison with IBS projects because all building components are constructed on-site, and it takes definitely more time to check and supervise the construction process. According to previous studies conducted on this issue, this amount is about 4.5% of construction cost, and it is around two times more than this amount in IBS projects [27].

Table 1 IBS Quantity Takeoff (Exported file from Navisworks Manage to Excel)

Group / Item		Resource	Count (No)	Area (M^2)	Volume (M^3)	Weight (KG)
Excavation		Soil			569.8	
Smoothing & Leveling		Soil		335.2		
Compaction		Soil			259.2	
Lean Concrete		Concrete			25.8	
		Wood Form		7.4		
Foundation	**Footing**	R20 (F)				6,398.8
		Steel Box	24			
		Wood Form		190.1		
		Concrete			103.7	
		Connection	24			
	Top Foundation	R20-1				3,199.4
		R20-2				3,153
		Wood Form		51.5		
		Concrete			127.7	
Column		3.3*0.3*0.3	21			
		2.2*0.3*0.3	7			
Beam		3.3*0.3*0.3	29			
Wall (Panel)		3.3*0.9*0.1	113			

4.0 RESULTS AND DISCUSSION

4.1 Quantity Takeoff

WBS of the projects was created in Navisworks Manage 2014 in order to estimate 4D and 5D of projects in the construction phase. Required activities for construction of every part of building were listed based on their priorities and types of relationships with preceding and succeeding activities. Additionally, the unit price for each activity has been taken from the updated JKR price list consisting of all resources such as machineries, labors, and materials. As it can be seen in Figure 5, there is a significant difference between the construction's cost of CBS and IBS method (the total cost for the conventional project is $62392, while for the IBS one, this is $88012). Obviously, these results confirm the findings of previous studies, indicating that IBS technique is more expensive than the CBS. A comparison clearly shows that the significant difference corresponds to the activities that are done through industrialized method, such as the construction of foundation, columns, beams, walls, and ceiling. For instance, the construction cost of the foundation in IBS method is about 1.2 times more than that of the conventional one. This difference is generally due to the kind of connection between column and foundation, which leads to change in the design of footing in IBS method.

When it comes to components such as columns, beams, and ceiling, the construction and installation cost of columns, beams, and ceiling in IBS project are about two times more than the same components in CBS on site. Additionally, the construction cost of walls using bricks and plasters as in the conventional method is less than half of the fabrication and installation of walls in IBS.

4.2 Financial Aspects of IBS Benefits during Construction

As it can be seen in Table 2, there is extra cost on the construction site when a building is constructed using the conventional method compared to prefabrication method. The total extra cost is considered as the advantage of off-site production in IBS and must be added to conventional project as the additional percentage of construction cost.

Table 2 IBS benefits and cost saving amounts

IBS Benefit	IBS Cost Saving
Material wastage	2200
Rectification work	2511
Worker	400
Destruction of property and Theft	623
Health and safety	2807
Inspection of Construction Process	1403
Rework	6176
Total	16120

Table 3 CBS Quantity Takeoff (Exported file from Navisworks Manage to Excel)

Group / Item		Resource	Count (No)	Area (M^2)	Volume (M^3)	Weight (KG)
Excavation		Soil			569.8	
Smoothing & Leveling		Soil		335.2		
Compaction		Soil			483.6	
Lean Concrete		Concrete			25.8	
		Wood Form		7.4		
Foundation	**Footing**	Concrete			58.1	
		R20 (F)				5007.7
		R20 (CL Root)				996.9
		Wood Form		93.6		
	Pedestal	Concrete			2.4	
		R20 (P)				695.5
		R10 (P)				85.2
		Wood Form		31.7		
	Ribbon FND	R20 (Ribbon)-1				2390.9
		R20 (Ribbon)-2				2202.5
		Concrete			14.8	
		R10 (Rib Stirrup)				279.0
		Wood Form		55.5		
Column	**Column 11**	Concrete			6.2	
		R10 (CL)-1				173.9
		R20 (CL)-1				1359.2
	Column 12	Concrete			1.4	
		R10 (CL)-2				37.3
		R20 (CL)-2				304.3
Beam	**Beam 1**	Concrete			8.1	
		R10 (Beam)-1				207.0
		R20 (Beam)-1				1810.3
	Beam 2	Concrete			1.3	
		R10 (Beam)-2				33.1
		R20 (Beam)-2				324.6
Wall		Brick	7970			
		Mortar				5152.5

Name	Total Cost ($)
New Data Source (Root)	
Conventional Project	
START	
Foundation	31603.5
Column	3986.8
Beam	4468.8
Walls	3908.8
Roofing & Stair	12258
M & E Works	3000
Doors and Windows	854.8
Yard and Access	1406.5
Building Finishes	905.2
FINISH	62392

Name	Total Cost ($)
New Data Source (Root)	
IBS Project	
START	
Foundation	40778.3
Installation of Pre-cast Components	
IBS Column Installation	7903.2
IBS Interior Wall	1558.0
IBS Exterior Wall	3895.2
IBS Beam Installation	8887.0
Roofing & Stair	18824.2
M & E Works	3000.0
Doors and Windows	854.8
Yard and Access	1406.5
Building Finishes	905.2
FINISH	88012

Figure 5 Top: Construction Cost of CBS Project. Bottom: Construction Cost of IBS Project

4.3 Construction Time Reduction in IBS Method

In this section, the effect of time in IBS method is estimated and compared with CBS method for a single-story and multi-story project with different volumes based on the two different scenarios. This comparison is made using the graph based on the Break-Even analysis, ROI, and profitability of same projects and industry.

In order to consider the benefit of time saving in using IBS method, two different scenarios have been considered; first, the owner starts a new project after finishing the construction; second, the owner is not interested to invest in another construction project. In the first scenario, a same profit is considered for the next project, and in the second scenario, due to lack of interest in investment in another construction project, the industry interest rate (12%) is considered as the benefit time reduction in IBS method.

In the first step, projects duration for different volumes has been estimated based on coincident construction activities in different stories. Table 4, shows the time discrepancy estimated for two projects, one constructed with CBS and the other one with IBS methods, have been calculated. For instance, 60 units of a building constructed with CBS method have been compared with 50 units constructed with IBS. This comparison is practicable due to the same initial investment assumed for the two construction methods.

The obtained results indicated that the project built with IBS method is completed sooner than that with the CBS method. It is believed that there can be counted several advantages for finishing a project on time such as avoidance of the encounter with the increase of inflation, worker's wages, or claiming for reward. The possibility of demobilizing and using the machineries and equipment to commence a new project is considered as another advantage of finishing on time or sooner than the project's pre-defined time. In this research, it is assumed that at the time when IBS project is completed and the site is handed over, the company engaged in another contract and started a new project based on obtained profit of selling out the units of the first IBS project. On the other hand, the operation of the project with CBS method has not been completed yet. As such, the economic comparison of two construction methods can be rationalized in this regard.

Although the criterion of economic comparison is based on almost same investment in both projects as mentioned in the project considerations, the number of units in IBS method is definitely less than CBS due to the differences in their construction cost with each other, as illustrated in Table 5.

Table 4 Estimated Time Table based on Projects' Volume

N	IBS duration	N	CBS duration	Rate of time difference (%)
1	71	**1**	112	36.6%
100	935	**120**	1680	44.3%
200	1535	**235**	2830	45.8%

Table 5 The Number of Units in the Two Methods based on Initial Investment

Investment Value ($ million)	Unit Numbers	
	IBS	CBS
8.77-9	100	120
17.46-17.57	200	235

4.4 Break-Even Analysis and Return on Investment (ROI)

The BEP is determined in the point where sales are equal to the total cost of project (or net income = 0); it was specified in both methods considering units sale; whereas ROI occurs when sales equal two times of the total project cost. The two construction methods were economically compared with each other considering the increase of units in multi-stories projects and based on the Break Even analysis and ROI using respective graphs. In terms of time benefit of IBS project, there are two scenarios that considered in this study.

Figure 7 and Table 6 show that the profit obtained from CBS projects is more than IBS project due to less initial investment. Moreover, ROI in the conventional method is 18.2 % higher than the industrial one. In addition, discrepancy between the BEP times in the two projects is not enough for a new investment on IBS method (41 days). Therefore, the IBS project cannot be economical compared to the CBS project. Additionally, ROI in the second scenario as indicated in Figure 7 and Table 6, is also lower than CBS method.

Figure 8 shows a trend similar to the previous condition of the project. However, the IBS project was remarkably finished sooner than the CBS project along with an increase of investment. It was found that time difference between BEP of two projects was nearly two times of this period. As a result, in the scenario 1, new IBS project constructed with profit made from the first project enhanced ROI of IBS method up to 89.5%; however, this amount is 75.2% in the second scenario. Table 7 indicates that this amount was more than the percentage resulted from the conventional method and reached the final profit nearly five months sooner than the other method. Therefore, investment on at least 100 units with IBS method can be more economical compared to the same investment on CBS method.

Finally, as shown in Figure 9, the initial investment on IBS method was almost entirely returned when invested on 200 units (40-story building) while this rate was still less than 90 % in CBS method. The interesting thing in the findings from Table 8, is that three IBS projects have been constructed in scenario 1, and achieved their final profit before the CBS project reached its total profit due to the long duration of the CBS project. In this case, the ROI in scenario 2 is lower than scenario 1.

Figure 6 depicts the upward trend of ROI in IBS method in comparison with CBS method showing the effect of time on the form of new investment.

5.0 CONCLUSION

This paper evaluated some benefits of IBS regarding the construction phase of a single-story building. Primary data were collected from the Malaysian government policies and past experiences. The purpose of this study was to calculate the cost estimation and compare the mentioned case study constructed with Industrialized Building System (IBS) and Conventional Building System (CBS). The following conclusion can be drawn based on the findings of the study:

- This study showed that building construction in IBS method is more expensive compared to the conventional method. The main reason for the cost differences between the two methods is directly related to the industrialized process of IBS components. The high expenditure must be paid to purchase the mechanization tools, transport, and assemble the prefabricated components at the construction site.
- In spite of great prefabrication expense, numerous benefits can be realized by using IBS method throughout the life cycle of the project, particularly in construction stage. IBS has many positive impacts on cost and quality of the project; as a result, there is a reasonable reduction of cost in comparison with CBS. This reduction is approximately 26% of construction cost, which is the incremental rate of construction cost in CBS due to much more amounts of wastes on the construction site in comparison with manufacturing method. Most of the wastes in CBS method include material wastage, rectification works, problems in relation to workers, stealing problem and destruction of property, level of health and safety, the inspection of the construction process.
- Two scenarios have been considered in this paper; first, the owner starts a new project after finishing the construction; second, the owner is not interested to invest in another construction project. In the first scenario, IBS method could not be economical in low initial investment compared to CBS method due to lower ROI. The increase in initial investment, results in considerable difference in projects' finish-time to the extent that the new IBS project(s) has/have the chance to start. The findings indicated that IBS was not economic in low investment of company; however, with investment on more than 100 units, IBS method can be more economical compared to CBS one. Furthermore, the initial investment on IBS method was returned when more than 200 units were implemented in the projects.
- In the second scenario, it is proved that the investor of the project cannot benefit from using IBS in low investment. Investing in a project including the construction of around more than 200 units, results in benefit for the investor. Findings also indicate that, the higher the investment using IBS methods, the more profitable is the project.

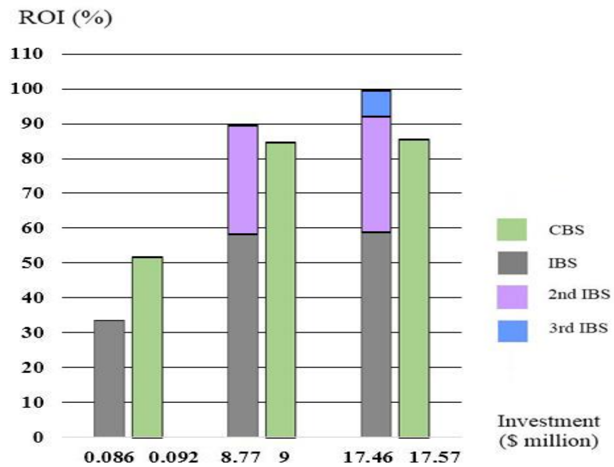


Figure 6 The Effect of time on the form of Investment on ROI

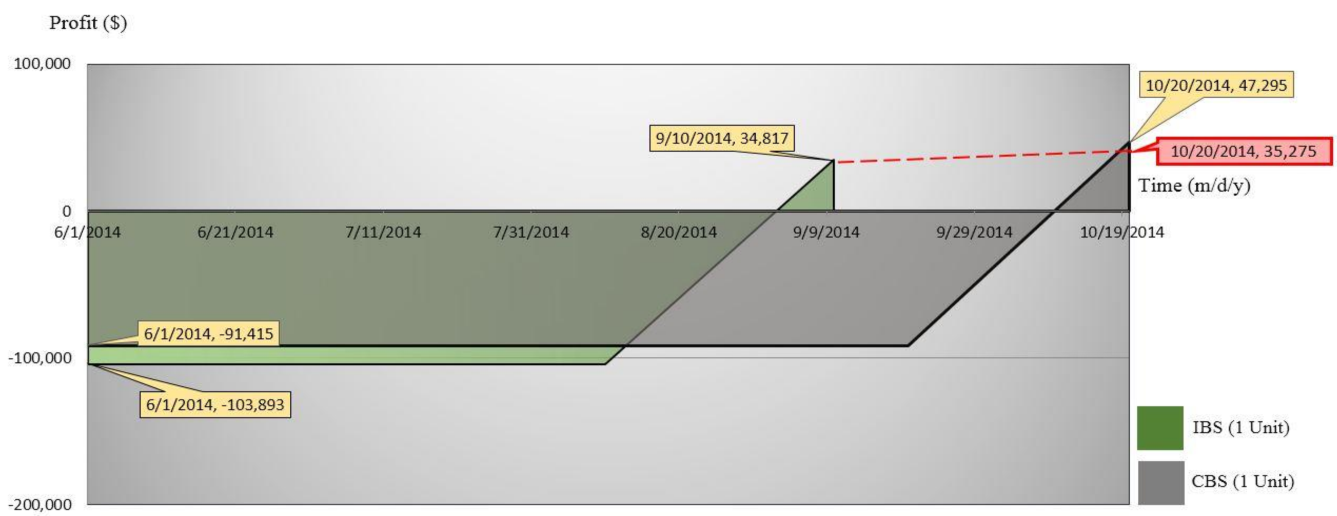


Figure 7 Economic comparison based on one-unit project. The effect of time reduction in scenario 2 is highlighted in red color

Table 6 Cost-Profit Chart based on Units Number (N)

Method		N	Sales ($)	Fixed Cost ($)	Variable Cost ($)	Total Cost ($)	Net Income ($)	ROI (Accumulative %)
IBS	Scenario 1	1	138,710	16,981	86,912	103,893	34,817	33.5
	Scenario 2	1	138,710	16,981	86,912	103,893	35275	33.9
CBS		1	138,710	16,981	74,434	91,415	47,295	51.7

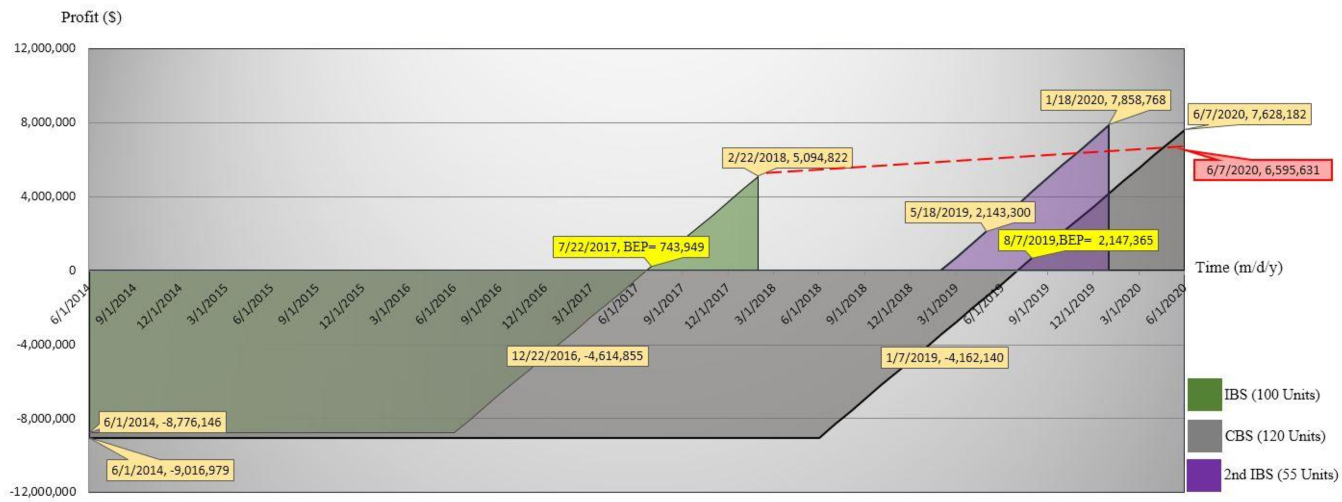


Figure 8 Economic comparison based on $8.77-9 million Initial Investment. *The effect of time reduction in scenario 2 is highlighted in red color*

Table 7 Cost-Profit Chart based on Units Number (N)

Method		N	Sales ($)	Fixed Cost ($)	Variable Cost ($)	Total Cost ($)	Net Income ($)	ROI (Accumulative) (%)
IBS	Scenario 1	100	13,870,968	84,903	8,691,242	8,776,146	5,094,822	58.1%
	Total	155	21,500,000	169,806	13,471,425	8,776,146	7,858,768	89.5%
	Scenario 2	100	13,870,968	84,903	8,691,242	8,776,146	6,595,631	75.2%
CBS		120	16,645,161	84,903	8,932,076	9,016,979	7,628,182	84.6%

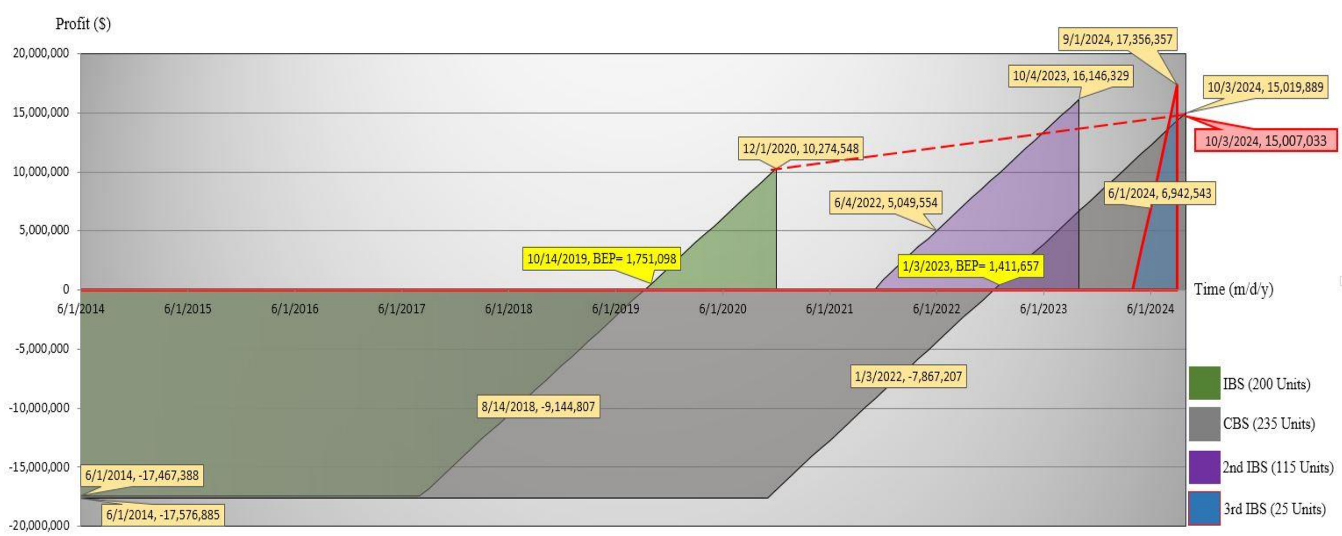


Figure 9 Economic comparison based on $17.46-17.57 million Initial Investment. *The effect of time reduction in scenario 2 is highlighted in red color*

Table 8 Cost- Profit Chart based on Units Number (N)

Method		N	Sales ($)	Fixed Cost ($)	Variable Cost ($)	Total Cost ($)	Net Income ($)	ROI (Accumulative) (%)
IBS	Scenario 1	200	27,741,935	84,903	17,382,485	17,467,388	10,274,548	58.8%
	Total	340	47,161,290	254,709	29,550,225	17,467,388	17,356,357	99.4%
	Scenario 2	200	27,741,935	84,903	17,382,485	17,467,388	15,007,033	83.9%
CBS		235	32,596,774	84,903	17,491,982	17,576,885	15,019,889	85.5%

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