Jurnal Teknologi, 43(B) Dis. 2005: 1-11

BUILDING COST COMPARISON BETWEEN CONVENTIONAL AND FORMWORK SYSTEM

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Abstract. The Malaysian construction industry is undergoing a transitional change from an industry employing conventional technology to a more systematic and mechanised system. This new system is now known as the industrialised building system (IBS). This new method of construction can increase productivity and quality of work through the use of better construction machinery, equipment, materials, and extensive pre-project planning. This study is essential since there is no organised body, which can provide the necessary information on the building cost comparison between the conventional system and industrialised building system in Malaysia's construction industry. The study also addresses the building cost comparison of the conventional system and selected formwork system in the industrialised building system. It details out the building cost comparison between the conventional system and the formwork system and indicates which of the two is cheaper. The data were collected through questionnaire survey and case study, which involved institutional buildings. Through the statistical test 't-test', it is shown that there is a significant difference in cost saving for the conventional system as compared to the formwork system.

Keywords: Industrialised building system, formwork system, building cost comparison, 't-test'

Abstrak: Industri binaan di Malaysia kini menyusur ke alam perubahan iaitu daripada industri yang menggunakan teknologi tradisional kepada yang lebih sistematik yang melibatkan jentera. Kaedah baru ini juga dikenali sebagai sistem pembinaan bangunan berindustri. Kaedah baru binaan bangunan ini dapat meningkatkan produktiviti dan kualiti kerja menerusi penggunaan mesin, peralatan yang lebih baik, bahan binaan dan juga di peringkat perancangan projek. Kajian ini amat berguna memandangkan masih belum ada sebarang organisasi yang dapat menyediakan maklumat keperluan seperti perbezaan kos bangunan di antara sistem tradisional dengan sistem bangunan berindustri di dalam industri binaan di Malaysia. Kajian ini menerangkan tentang perbezaan kos bangunan di antara sistem tradisional dengan sistem bangunan berindustri yang terpilih iaitu kaedah acuan. Ia menyediakan maklumat perbezaan kos secara terperinci dengan menunjukkan penjimatan kos di antara kaedah binaan tradisional dengan kaedah acuan. Data telah dikumpul melalui kajian soal-selidik dan juga kajian kes bangunan institusi pengajian. Melalui kaedah ujian statistik '*t-test*', didapati terdapat perbezaan yang nyata dalam penjimatan kos antara kaedah binaan tradisional berbanding dengan kaedah acuan.

Kata kunci: Sistem pembinaan bangunan berindustri, kaedah acuan, perbandingan kos bangunan, ujian '*t-test*'

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1.0 INTRODUCTION

The Malaysian construction industry is undergoing a transitional change from an industry which employs conventional technologies to a more systematic and mechanised system which utilises the latest computer and communication technologies. This is vital for the future growth of the industry, given the trend towards global competition and the advent of the k-economy.

Industrialised Building System (IBS) has been introduced in Malaysia since the 60's by the application of pre-cast concrete in beam-column elements. Since the demand of building construction has increased rapidly, it is necessary to innovate the construction method, which speeds up the building construction process. Abdullah *et al.* [1] has listed various types of building systems currently available in Malaysia. Few definitions of industrialised building system are also given by various authors [2]. In general, IBS is a methodology which drives local construction industry towards the adoption of an integrated and encourages key players in the construction industry to produce and utilise pre-fabricated and mass production of the building at their work sites. This will help to enhance the efficiency of construction process, thus allowing a higher productivity, quality, time and cost saving.

The construction cost of a building using precast components should be assessed in its overall context. The traditional method of costing by material quantities with a fixed factor for labour cost can lead to incorrect estimation. For example, if labour usage is halved, this will more than compensate for a 10 percent material increase. More importantly, there is saving in time. Also, if properly designed and executed, precast method can lead to much better quality of work. The overall cost impact of precast construction, therefore, has to take all these factors into consideration. With the rising costs of labour and less assurance of dependable skilled manpower, the trend is that precast construction will become increasingly competitive as compared to cast-in-situ construction [3].

2.0 CLASSIFICATION OF INDUSTRIALISED BUILDING SYSTEM

2.1 Industrialisation

The Oxford English Dictionary (1991) defines industrialisation as "the process of industrialising or fact of being industrialised; also, the conversion of an organisation into an industry". However, industrialisation in this study means industrial methods employed, referring to especially, pre-fabrication, mechanisation, and standardisation. The meaning of pre-fabrication, according to the same dictionary is, "to manufacture, sections of building or similar structure, in a factory or yard prior to their assembly on a site". However, pre-fabrication in this study is the assembly of buildings or their components at a location other than the building site.

The types of construction methods range from a conventional construction method to fully pre-fabricated construction method. Generally, the construction methods are classified into four categories:

(i) Conventional construction method
(ii) Cast-in-situ method
(iii) Composite method
(iv) Fully pre-fabricated method

2.1.1 Conventional Construction Method

Conventional building method is defined as components of the building that are pre-fabricated on site through the processes of timber or plywood formwork installation, steel reinforcement, and cast in-situ. Conventional buildings are mostly built of reinforced concrete frames [4]. The traditional construction method uses wooden formwork. It is much more costly for construction which includes labour, raw material, transportation and low speed of construction time [5].

2.1.2 Cast-In-Situ Construction Method

This system is suitable for a country where unskilled labour is limited. There is no heavy machinery or high technology involved. The system is technically applicable to almost all types of building. Formwork is used as a mould where wet concrete is poured into a temporary system. The temporary system also acts as a temporary support for the structures. The objective of an in-situ method is to eliminate and reduce the traditional site-based trades like traditional timber formwork, brickwork, plastering and to reduce labour content. A carefully planned in-situ work can maximise the productivity, speed and accuracy of pre-fabricated construction. Cast in-situ method uses lightweight pre-fabricated formwork made of steel/fiberglass/aluminium that is easily erected and dismantled. The steel reinforcement is placed within the formwork as they are being erected and concrete is poured into the mould. When the concrete is set according to the required strength, the moulds are dismantled. The workers can be easily trained to erect the moulds and set the steel reinforcement. Its advantages over the traditional construction method include, low skill requirement, speedy construction, low maintenance, durable structure and less cost [5].

2.1.3 Composite Construction Method

The objectives of composite construction method (partially pre-fabricated) are to improve quality, reduce cost, and shorten construction time. The concept of partial industrialised system is derived from the composite nature of full industrialisation, and is used to describe a manufacturing or production strategy that selectively uses some industrialising aspects, while avoiding or postponing the use of others. The pre-

fabricated construction method is combined in such a manner that the features applied could be prominently demonstrated, especially composing various works such as temporary facilities, building frames, building finishes, and equipments [5].

2.1.4 Fully Pre-fabricated Construction Method

In this method of construction, all elements that can be standardised are pre-fabricated in the factory. Normally, this method would involve the assembly of precast elements such as floor slabs, in-filled walls, bathrooms, staircases, etc. into place for incorporation into the main units, columns and beams. This method of construction has reduced the amount of site labour involved in building operations and increased the productivity of the industry. Precast building systems can reduce the duration of a project if certain conditions are met [6].

The last three construction methods are considered as non-conventional construction methods. These types of construction are specifically aimed at increasing productivity and quality of work through the use of better construction machinery, equipment, technology and materials.

3.0 METHOD OF COST COMPARISON IN CONSTRUCTION INDUSTRY

During the past decade, a large number of studies on cost comparison has been carried out and published. In the existing studies, three principal approaches for comparing costs of building projects among countries can be distinguished [7 - 10]:

(i) Comparison of standardised identical buildings;
(ii) Comparison of standard buildings with local modifications; and
(iii) Comparison of functionally similar buildings.

3.1 Comparison of Standardised Identical Buildings

In this method, identical buildings work is priced on the basis of the same drawings and specifications. This is possible only in theory, largely as a result of national (or even regional) differences which exist in architecture, standards, availability of products, etc. The building and the costs will be comparable, but they are not necessarily representative.

3.2 Comparison of Standard Buildings with Local Modifications

Better representivity can be achieved when modifications for local circumstances, like building codes, standards, and specification levels, are taken into account.

3.3 Comparison of Functionally Similar Buildings

In this approach, typical, functionally similar buildings are compared, i.e building types which are representative. Not only locally divergent circumstances and quality-levels are taken into account, but also various performance and aesthetic criteria, which reflect typical client requirements or tenant expectations for a building in that sector. The buildings and the costs are representative, but not necessarily comparable. Arguably 'apples' are being compared with 'oranges' [11]. A meaningful comparison must take into account all relevant (time-dependant and quantity-dependant) cost components, classified as follows [12]:

(i) Labour;
  - Direct
  - Indirect

(ii) Materials
(iii) Investment
(iv) General expenses (site and plant)
(v) Transportation (for system construction only)
(vi) Overhead

As for this study, the method of cost comparison used is standardised identical buildings and functionally similar buildings while the unit is cost per gross floor area.

4.0 RESEARCH METHODOLOGY

Data was collected by using mail questionnaire. To strengthen the finding of the survey and to assist in providing information about building cost comparison study, a case study was also conducted. However, the major approach was using questionnaire, considering such factors on sample size, time, cost and efforts. Questionnaire method was chosen as the appropriate approach for this study since it can reach a large number of respondents in different locations of the country at a relatively lower cost, shorter time and less effort as compared to other data collection methods. The questionnaires were sent to general managers, project managers, technical executives, managing directors, and project directors of clients or developers, contractors, consultants and supplier. The questionnaires were mailed to the respondents, accompanied by a covering letter, a self-addressed and stamped envelope. The case study was conducted on building cost comparison of one unit 4-storey school building project carried out by Public Works Department, Malaysia [13], which uses conventional system and formwork system. Data gathered on the building cost of building systems in Malaysia was analysed using statistical t-test analysis.

5.0 RESULT AND DISCUSSION

5.1 Result and Discussion from Questionnaire Survey (First Stage)

Before the data is analysed from the point of view of building systems, it is important to look into the profile of respondents to establish the credibility of the data. Three important criteria of the respondents' background formed the basis of the study. These are academic discipline, current position and the relevant experiences in the construction industry. The nature of business of the respondents' company background is also considered in this study. The profile of respondents' company and their credibility were also undertaken to ensure relevancy of result.

5.1.1 Respondents' Background

5.1.1.1 Academic Discipline

Figure 1 shows the percentage of academic discipline of the respondents. 70 percent of the respondents are quantity surveyors, 15 percent are civil engineers, 13 percent are building engineers and 2 percent are architects.

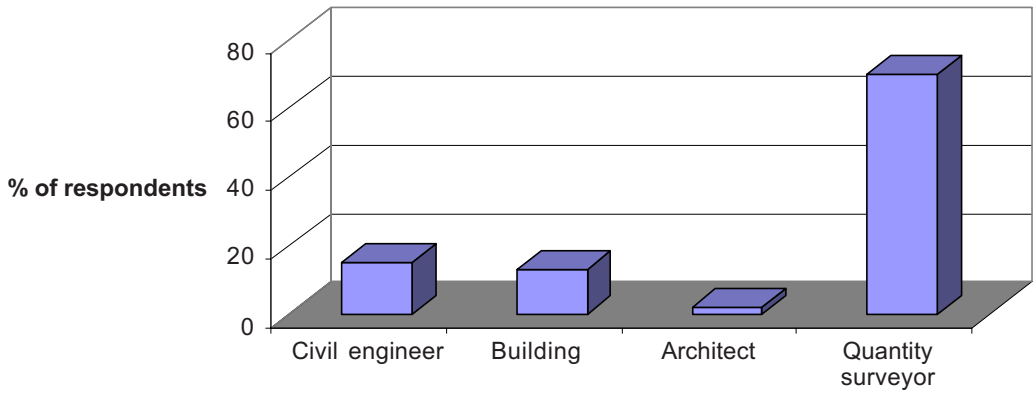

Figure 1 Academic discipline of the respondents

5.1.1.2 Respondents' Current Position

Figure 2 shows the percentage of the official status of the respondents. 34 percent of the respondents are executives, 23 percent are quantity surveyors and managing or executive directors, 11 percent are general managers, and 9 percent are project managers.

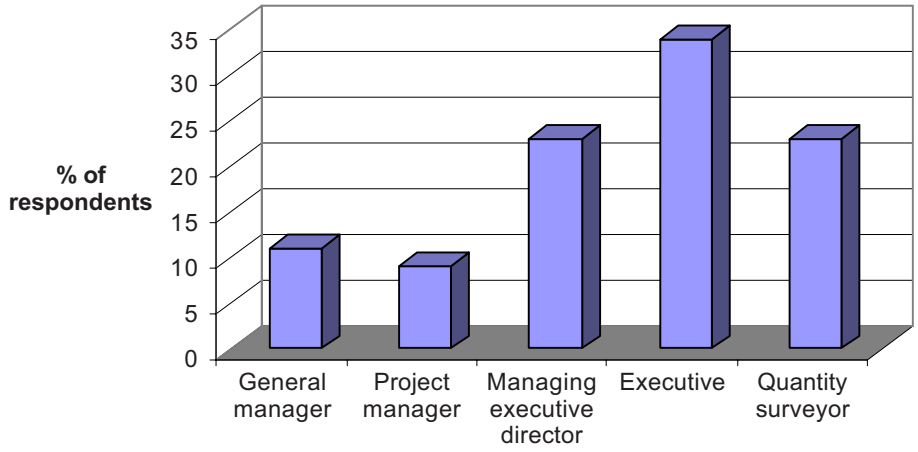

Figure 2 Respondents' current position

5.1.1.3 Length of Time in the Construction Industry

The number of years of prior experience in the construction industry for the respondents were found to vary ranging from 2 to 22 years. The median is 14 years, which provides a good spread of personal experience as in the sample.

5.1.2 Company

The responses were collected through mail questionnaires from total sample of 300 respondents. Of the 50 respondents, 45 percent were consultants, 37 percent were contractors, 16 percent were clients/developers, and 2 percent were suppliers, as shown in Figure 3.

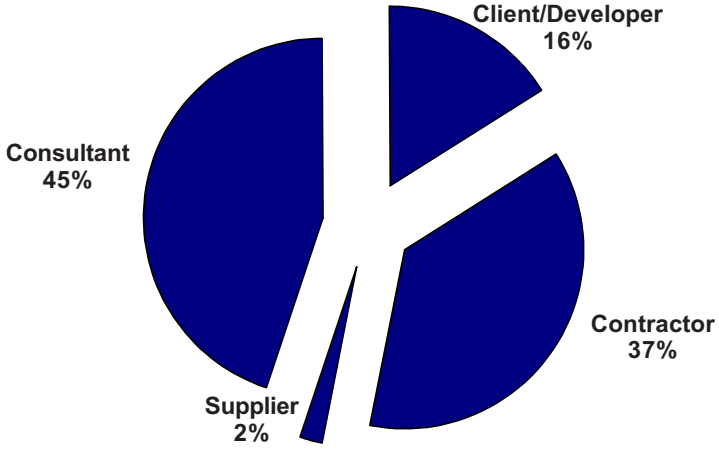

Figure 3 Nature of business

5.1.3 Building Cost Saving

Figure 4 shows building cost-saving in terms of percentage. Based on questionnaire survey, 42 percent of the respondents agreed that conventional construction method are the most cost effective, 25 percent agreed that composite construction method are the most cost effective, and 21 percent agreed that formwork system are the most cost effective. About 12 percent agreed that prefabricated construction method are the most cost effective.

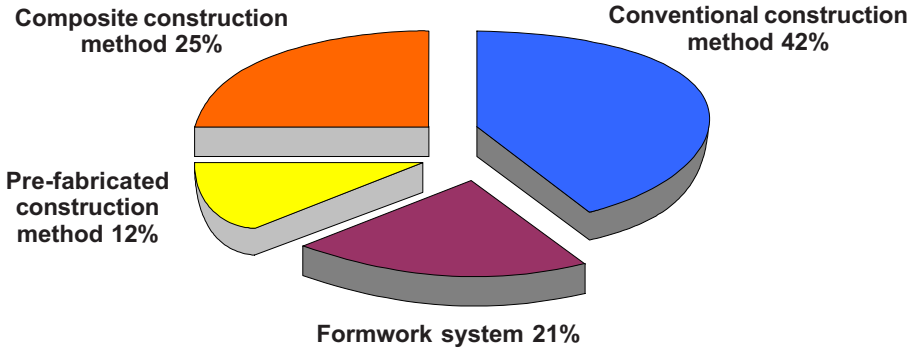

Figure 4 Building cost saving

The previous study showed clearly the advantages of using formwork system (cast in-situ). These include speed, quality and economics [5]. However, the results of the analysis revealed that the conventional construction method is more cost saving compared to the IBS method. According to the reasons given by the respondents, the conventional system is more cost saving as compared to formwork system, due to better negotiations and chances to get the most competitive tender price appropriate to the developer's budget. There is also flexibility in choosing alternative building materials at a lower cost. Hence, building cost can be reduced. The use of the IBS, on the other hand, is limited to a few manufacturers or specialised contractors. This situation contributed to the higher cost of building due to higher licensing cost, which tend to be monopolised by the higher price of the building panels or other building components.

5.2 Result and Discussion from the Case Study (Second Stage)

5.2.1 Formwork System Case Study

The selected industrialised building system case study is based on formwork system. The main objective is to study the cost comparison of a school building cost of one unit 4-storey (academic block) project carried out by Public Works Department, Malaysia, which used conventional system and formwork system. The conventional

and formwork system building cost data was obtained from the Elemental Cost Analysis (ECA) form. The formwork system is based on the combination of pre-fabrication and in-situ conventional construction, which features the utilisation of permanent concrete form elements instead of conventional timber formwork.

5.2.1.1 Cost Comparison

Table 1 shows the mean difference between one unit four storey school building of conventional and formwork system for 20 numbers of data. The mean cost of conventional system is RM432 per square metre, while for the formwork system, the mean cost is RM544 per square metre. Although the difference is RM112 per square metre, the total of the square metre for one unit 4-storey school building is about 2000 square metre. This shows that there is a wide difference in cost between IBS and the conventional system, the former being very expensive. For example, if the government plans to build 20 school buildings of the same IBS, this means the cost will be very high. Therefore, all efforts must be made to reduce this so as to ensure the future use of IBS method is feasible.

The t-test analysis is a statistical analysis to test the difference between two variables. The purpose is to show the significance level of the building cost comparison between one unit four storey school building using conventional system with that of IBS formwork system.

The present study used a two-tailed test and the underlying reason for choosing the two-tailed test over one-tailed test is to ensure that the result obtained is compatible. If only one-tailed test is used, then the result obtained might not be the same with that of a two-tailed test. If the result shows the difference between conventional and formwork system is not significant, then the study cannot conclude that formwork system is more expensive than the conventional system. Perhaps, the formwork system is only expensive for certain numbers of buildings based on 20 numbers of data available.

Table 1 Mean difference between one unit four storey school building of conventional and formwork system (IBS)

Paired samples statistics

		Mean	N	Std. deviation	Std. error mean
Pair	CONV	432.3940	20	73.4217	16.4176
1	IBS	544.4355	20	69.8597	15.6211

Table 2 shows the results of the t-test conducted using IBS (formwork system) and conventional methods. It has been found that there is a 0.000 (last column) or 100 percent confidence level. This confirms that the cost of building using formwork system

Table 2 Significant of difference between one unit four storey school building of conventional system and IBS (formwork system)

Paired samples test

		Paired differences					t	df	Sig (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference Lower	Upper			
Pair 1	CONV - IBS	-112.0415	79.8209	17.8485	-149.3988	-74.3988	-6.227	19	.000

method is more expensive compared to the conventional method. The means difference of RM112 per square metre also shows that formwork system is more expensive compared to the conventional system. The highest building cost difference per square metre is RM149 and the lowest difference is RM75 per square metre.

With reference to Table 1, the mean cost of conventional system is RM432 per square metre, whereas for the formwork system, the mean copy is RM544 per square metre. The difference is RM112 per square metre from 20 numbers of data. The results show that the difference is significant with a 100 percent confidence level. Therefore, the cost of conventional system is cheaper, compared to that of the formwork system. This finding is in coherence with the results already obtained in an earlier survey analysis.

6.0 CONCLUSIONS

According to the reasons given by the respondents, the conventional system is more cost saving as compared to the formwork system (IBS) since the former provides better negotiation chances so as to obtain the most competitive tender price appropriate to the developer's budget. There is also flexibility in choosing alternative building materials at lower cost. Therefore, building costs can be reduced. As for the IBS, these are limited to a few manufacturers or specialised contractors. This contributes to the higher cost of building since a higher licensing cost is levied on the IBS panel and they tend to be monopolised by the higher price of the building panel or other building components.

From the results of the case study, it can be concluded that the conventional construction system is more cost saving as compared to the formwork system (IBS). The case study results are also in coherence with the result from the survey analysis. Most of the organised body in the construction industry perceived that the building cost of IBS is cheaper compared to the cost of conventional system. However, the outcome of this study proved otherwise.

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