Factors Affecting Speed of Industrialized Building System (IBS) Projects in Malaysia

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Abstract:

This study attempts to identify the factors affect the speed of IBS and the probability level to select either IBS or conventional method. A questionnaire was distributed in order to collect the data. It consists of 6 main factors namely: high productivity of structural elements, using of moulds, using of new equipments and technology, workers skills and experience, equipments and mechanical plants used, and the materials used. The level of importance of the categories was measured and ranked in terms of relative importance weights. Logit linear analysis was used to choose either using IBS or Non-IBS (conventional system) in term of speed. In addition, it was used to test and compare the affecting of different speed factors on the probability to choose the construction methods. The finding of this study was found that the high productivity of structural elements is the main factor. Using of moulds factor, and using of new techniques and technology factor were the second important factors affecting the speed of industrialized building system in construction projects in Malaysia. This paper suggests possible improvements that could be made in order to reduce the delays and increase the productivity in the construction building industry.

Keywords: speed, IBS, high productivity, mould, logit linear, Malaysia

Introduction

Malaysia is presently taking a hard look at IBS as an answer to the housing shortage problem. The main advantages of using IBS according to a report published by the Malaysian Ministry for Local Government and Housing (Ministry 1997), are speed of construction, quality, and economic advantage, all of which are required to meet such a large demand for housing (Badir, 2002).

Between years 1995 to 2020, Malaysia will need a total of 8,850,554 houses, including 4,964,560 units of new housing to cater for increase in population during this period. Unfortunately, only 1,382,917 units were constructed in the 6th (1991-1995) and 7th (1996-2000) Malaysia Plan. In addition, not more than 800,000 units were constructed in the 8th Malaysia Plan (2000-2005). That is, on average 900,000 units to be built for every 5 years (Malaysia Plan).

It is clear that unless a drastic change of policy pertaining to population growth is adopted, or some new solution for this increase housing demand is implemented, the housing problem is expected to continue for years to come (Chen, 2000). While the problem of housing grows more acute, Malaysia is struggling to meet its own housing needs by increasing application of advanced technology. The conventional construction method, due to the slow pace of construction and higher cost, is not able to meet the demand (Agus, 1997)

There are many types of IBSs existing in Malaysia; formwork, precast load-bearing wall panel, precast frame, precast floor and hollow core slab, sandwich, block panel, and steel frame. These IBSs represent most of the IBSs that exit worldwide. Quality, speed of construction, and cost savings are the main advantages of these systems. These factors are very important in implementing the Seventh Malaysia plan. The main disadvantages of the IBSs in Malaysia are that they are highly capital intensive and there is a need for experts at the construction site for some of them. The main reason to recommend the use of IBSs in Malaysia is that the raw materials used in the IBSs have to be produced locally in order to overcome the shortages that are being faced by the IBSs construction industry (Badir, 2002)

IBS has been proposed in many writings as the solution for this increasing housing demand due to its advantages such as the shorter construction time, saving in labor cost, material saving, better quality control, immunity to weather changes and the cost factor among the advantages of IBS. However, there should be given more attention to the improvement of the advantages of IBS system, especially the shorter construction time. Therefore, the contribution will be employed to the improving of the speed and cost control advantages

The specific objective of the study is to identify the significant factors affect the speed of Industrialized Building System (IBS) and the probability of clients choosing between IBS and conventional method.

Literature Review

The types of construction methods range from a conventional construction method to fully prefabricated construction method. In general, the construction methods can be classified into four categories; conventional method, composite method, cast in situ method, and full prefabricated method.

Conventional Building System

Conventional building system defined as a system of current practice usually using in-situ concreting with temporary wooden formwork. Andres and Smith (1998) defined that conventional building system is based on its principal, which the components of the building are 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.

In the conventional construction method (reinforced concrete frames and brick as infill), beam, column, wall, and roof are cast in situ using timber formworks while steel reinforcement is fabricated on site. This method of construction is labour intensive and involves three separate trades, namely, steel bending, formwork fabrication, and concreting. Skilled carpenters, plasterers, and brick workers are also involved in this method. The process can be hampered by bad weather and unfavourable site conditions (Badir, 2002).

Classification of Industrialized Building System

Building systems may be classified according to: type of sponsorship, method of production, degree of prefabrication and site mechanization utilized, structural type, materials, weight and methods of assembling structural elements, application to different building types, flexibility of design, and their varying permutations. The most significant differences between different building systems relate to their structural types. These include cross wall construction, storey height plank construction, framed structures, box-shell construction, composite systems, and box construction (Leon, 1971). Majzub (1997) presented the typical classifications of Industrialized Construction and divide these systems fewer than three generic system figures; frame or post and beam systems, panel system, and box or modular systems.

Warszawski, (1999) mentioned that building systems can be classified in different ways, depending on the particular interest of their users or producers. A frequent basis for such classification is the construction technology. In this manner four major groups can be distinguished; timber, steel, cast in situ concrete, and precast concrete as their main structural.

Advantages and disadvantages of conventional and IBS in Malaysia

In Malaysia the advantages of conventional system as compared to IBS are cost saving and easy to transport. The higher costs of IBS are due to higher cost of the panels or structures and higher cost in transportation of the panels or structures. The advantages of IBS compared to conventional system are labour saving and speed of construction. Therefore, the overall construction cost can be reduced through labors-saving and speed of construction. (Haron, 2002)

The quality, speed of construction, and cost saving are given the main emphases in the building construction industry in Malaysia. The savings in labor cost and the savings in material cost are also the major advantages of the Malaysian IBS's. The control in using materials, such as steel, sand, and timber, will result in substantial savings on the overall cost of the project (Badir, 2002).

(Din, 1994) mentioned that the industrialized building generally has the following advantages in terms of time saving:

- Saving of time and materials involved in the erection of scaffoldings.
- Shorter construction time as a result of well planned and coordinated sequence of construction.
- Not affected by weather condition as building components are manufactured in the factory, and there is no on-site concreting.

The disadvantages of the conventional system as compared to IBS are shortage of raw material and difficult in erection. On the other hand, the disadvantages of IBS as compared to conventional are the need of skilled labour, heavy equipment, and expensive cost of plant / factory. These factors also contribute to the higher cost of IBS as compared to conventional system (Haron, 2002).

The benefits and limitations of industrialized building systems (IBS)

Warszawski, (1999) mentioned the benefits of IBS as the following:

1. Saving in manual labor onsite (up to 40-50% of the input in conventional construction), especially in skilled trades such as formwork, masonry, plastering, painting, carpentry, tiling, and pipe laying (electrical and water supply).
2. Faster construction process, that is, earlier completion of building projects.
3. Higher quality of components attainable through careful choice of materials, use of better production tools - in batching and casting – and strict quality control.

Warszawski, (1999) and Alaghbari, (2005) presented that development or selection of and industrialized system must always consider the following aspects:

1. Physical performance: stability, strength, thermal and acoustic requirements, fire resistance, maintainability, and insulation.
2. Architectural design: aesthetics, functionality, versatility, and flexibility.
3. Technology: selection of materials, production methods, and connecting, jointing, and finishing techniques.
4. Management: planning and coordination of production, transportation, and erection, and quality control.
5. Economics (forecasting of demand): its scope and characteristics and the selection of the most profitable method and optimal location and size of the production plant in accordance with this demand.
6. Marketing: advertising, sales engineering and effective contracting for projects.

Methodology

The questionnaire includes several sections to provide sufficient information for the study. It was divided into few sections namely, respondent background, company information, project information, speed factors and so forth. Personal information of the respondent section includes academic qualification, working experience in construction building projects, job status and so forth. Subsequently other parts gathered the information on building system and its different properties. At the end it focused on the factors affecting the speed of IBS and so forth. Most of the questions were closed type and designed for qualitative information. The codes were provided beside the questions so that respondent and enumerator could communicate in a convenient way.

Population and Sampling Size

The sample was restricted to the building system companies. The respondents were contractors, consultant, Developers, subcontractors, Engineers, and architects who involved in building system construction projects. A total of 450 questionnaires were distributed by post and 78 samples were collected from the survey. The sample was selected randomly. Simple Random Sampling procedure employed to choose sample.

From these 78 numbers of sampling, only 29 samples (37 %) were contractors, 31 samples (40 %) were consultants, and 18 samples (23%) were developers and from governments boards.

Ranking the Significant Factors Influence Speed of IBS

The respondents identify variables that they perceived as likely to contribute to factors influence speed of IBS in construction building projects by responding to a scale from 1 (very important) to 4 (non-important). The four rating Likert Scale is, 1 = very important, 2= important, 3 = some or less important, and 4 = non-important. This scale was chosen to avoid the neutral answers which do not provide answer on very important or non-important with the statements. Mean score (MS) of each factor was calculated by using the following formula (Chan and Kumaraswamy, 1996), (Lew, 2002), (Alaghbari, 2005) and (Alaghbari, 2007):

$$MS = \left(4 - \frac{\sum (f \times s)}{N}\right)(1 \leq MS \leq 4) \quad \ldots\ldots\ldots\ldots (1)$$

Where is;

MS = Mean score

f = frequency of responses to each rating (1 – 4)

s = score given to each factor by the respondents and ranges form 1 to 4.

N = total number of responses concerning that factor (78).

Logit log linear analysis

The logit log linear analysis procedure analyzes the relationship (or response) variables and independent (or explanatory) variables. The dependent variables are always categorical while the independent variables can be categorical (factors). The logarithm of the odds of the dependent variables is expressed as linear combinations of parameters. A multinomial distribution is automatically assumed.

Limited dependent variable models provide sufficient information about the choice preference. This study was designed to investigate, based on prevailing situation in the construction world of Malaysia, which factors influence the speed of IBS. The model provided significant information to find out the factors significantly related to the preference of building construction method by the users. The dependent variable of the model was dichotomous. It was quantitative in nature. It had two values such (1 and zero). When the study considers the choice of IBS the value was assigned as IBS = (1) or (0) for Conventional Method. There were different studies conducted using logit model to determine choice preference. Begum (1998) in her comparative study on awareness credit accessibility used logit model to show the probability of credit accessibility based on the qualitative information. Log-logit model is suggested for the qualitative information by Gujarati (1995). As the study was used qualitative information more than the quantitative information the model for the analysis would use log form of the logit equation. The dependent variable of the model was the choice preference of IBS and the independent variables were factors affecting the speed of IBS. The model was selected because of its ability to deal with a dichotomous dependent variable. The model can be represented as follows:

$$P_i = E(Y = 1 | X_i) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x1 + \beta_2 x2 + \beta_3 x3 + \beta_4 x4 + \beta_5 x5)}} \quad \text{........ (2)}$$

Where P_i is a probability to choice IBS that $Y_i = 1, x_1, x_2, ...x_n$ are independent variables while $\beta_1, \beta_2, ...\beta_5$ are coefficients to be estimated corresponding to logistic function. For ease of exposition, the equation (2) can be rewritten as:

$$P_i = \frac{1}{1 + e^{-Z_i}} \quad \text{........ (3)}$$

Where $Z_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5$

The equation (2) represents what is known as the (cumulative) logistic distribution function (Gujarati, 1995). It is easy to verify that as Z_i ranges from (-∞) to (+∞,) P_i ranges between 0 and 1 and that P_i is nonlinearly related to $Z_i(i.e., x_i)$. The functional form of the logit model is as follows:

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 x1 + \beta_2 x2 + \beta_3 x3 + \beta_4 x4 + \beta_5 x5 + \mu \quad \text{.........} (4)$$

In this study Logit linear analysis was employed to find out the significant quantitative variable of the construction methods and the probability level of choosing between Industrialized Building System (IBS) and other methods (Non-IBS). The dependent variable of the model was the construction method (IBS) or (Non-IBS) and the independent variables were the factors affecting the speed of IBS. These factors are skills and experience, high productivity of structural elements (in-situ or off-situ), the equipment and mechanical plants used, using of mould (type, size, and number of unit needs), the material used (type, availability….) and using of new techniques and technology (computer and robot in design manufacturing). The functional form of the model was as follows:

$$Y\ (Construction\ Methods) = f\ (Factors\ affected\ the\ speed\ of\ IBS\ .....n) + e \quad \text{......} (5)$$

Result and Discussion

Industrialized Building system (IBS) has been proposed due to the shorter construction time, saving in labor cost, material saving, better quality control, immunity to weather changes and the cost factor among the advantages of IBS. Shorter construction time offered by IBS seems to be the panacea for housing demand in Malaysia and it is proven successful in many countries, (Lian, 2002).

Significant Factors Affecting Speed of Industrialized Building System

Table (I) presents the result of analysis of the items on the respondent's opinion toward the significant factors affecting the speed of industrialized building system IBS. The six variables were ranked according to their order of mean value criterion.

Table (I): Ranking the Factors Affect Speed of IBS

Items	Mean Score	Standard Deviation	Ranking
High productivity of structural elements (In-situ or off-situ)	1.53	0.80	1
Moulds (type, shape, size, and number of units needs)	1.68	0.75	2
Using new techniques and technology (computer and robot in design manufacturing)	1.68	0.80	2

Skill and Experience	1.71	0.79	3
The equipments and mechanical plants used	1.87	0.75	4
The materials used (type, availability…)	1.90	0.80	5

The High productivity of structural elements (In-situ or off-situ) is the most significant factor that affects the speed of IBS compared with other systems. IBS gives the highest productivity in the construction industry includes the industrialized process by which components of building are conceived, planned, fabricated, transported, and erected on site, Junid (1986).

The second significant factor affecting the speed of IBS compared with other system are "using of moulds" factor and "using of new techniques and technology" factor such us using computer and robot in design manufacturing. Both of these factors have the same ranking (second ranking), with the mean value of 1.68. According to Alaghbari, 2005; Koo, 2000; Omar, 2000; Engletrik, 2000; Trikha, 1999; Karim and Adeep, 1993; Chew, 1986; and Din, 1984 mentioned one of the benefit of industrialized building system IBS is greater speed of construction than the conventional method may be due to "using of moulds" and "using of new techniques and technology" factors. Consequently, it will save in labor cost. More than 85% of the respondents agreed that "using of moulds" is very important factor resulting in the speeding up of IBS, whereas more than 80% of them agreed that IBS is very fast due to the "using of new techniques and technology" factor.

Meanwhile, "skill and experience" statement was the third significant factor affecting the speed of IBS system. "The equipments and mechanical plants used" factor was fourth. Even though for the respondents, both of the questions showed to be very important for the speed of IBS, but it is not as important as the "High productivity of structural elements" factor, and "using of moulds" factor, "using new techniques and technology" factor.

Finally, the "materials used" factor is the fifth and last significant factor affecting the speed of industrialized building system IBS. This shows that this factor is the least important of the previous ones in affecting the speed of IBS according to the respondents.

Logit Linear Analysis: Respondents Preference for Choosing the IBS

This part analyses the preferences of respondents in choosing between IBS system and non-IBS system in the construction projects. Logistic regression was used to test these hypotheses because this is a useful means of both summarizing the results of categorical data analysis and comparing the effects of different factors on the dependent variable (Kim *et al.,* 1995).

The factors that have association with the reason of choosing IBS in term of speed were determined. These factors are “skill and experience”, “high productivity of structural elements (in-situ or off-situ)”, “the equipment and mechanical plants used”, “using of mould”, “the material used”, and “using of new techniques and technology”. On the assumption that IBS is known-better compare with non IBS, we expect, with other thing equal, that the mentioned above variables would be positively correlated to the willingness to take industrialized building system IBS as the construction method. In the context of voting model, this suggests a positive relationship between all the variables mentioned above and the probability of a choosing IBS vote.

The logit estimation results can be used to test the above hypothesis. In the logistic regression analysis, the construction methods are the dichotomous variable with answers of "IBS " or "not IBS" to indicate whether or not the construction methods of projects studied give different results in terms of the reason for choosing the construction methods. The statistical properties for the maximum likelihood estimator are established for “large” samples (asymptotically). This means that the asymptotic t statistic has an approximate normal distribution in “large” sample (Pindyck and Rubinfeld, 1998).

After the analysis, it was found that only four variables were found to give a significant effect choosing the construction methods. These variables are “high productivity of structural elements”, “using of mould”, “the material used”, and “using of new techniques and technology”.

The positive estimated coefficient on “high productivity of structural elements” factor suggests that an increase in “high productivity of structural elements” factor gives a higher probability to choose industrialized building system IBS. The null hypothesis test that the “high productivity of structural elements” factor coefficient is zero against the alternative hypothesis that the “high productivity of structural elements” coefficient is positive has a t-statistic with 0.015 probabilities. The calculated test statistic exceeds the critical value of 1% level and therefore the null hypothesis is rejected in favor of the alternative.

The “using of mould” factor was included to allow for the possibility that because using mould determine the speed of IBS. The using of mould (formwork system) variable will increase the opportunity of choosing industrialized building system IBS. The result shows that the estimated coefficient was positively significant at 10% level. This implies that we reject null hypothesis state that using of mould does not increase the probability of taking IBS. If the use of mould were increases then the respondents would like to choose IBS because with the use of mould the use of IBS will be more advantageous.

Table (II): The Estimate Result of Logit Model of Respondents Preference

Variable	Coefficient	Standard Error	b/St.Er	P Value
Constant	0.176263731	0.89023536	0.197996776	0.84
Skill and Experience	0.442036673	0.38142654	1.158903816	0.367
High productivity of structural elements	0.914322127	0.34589561	2.643347012	**0.0157*** **
The equipments and mechanical plants used	-0.536415221	0.41788789	-1.283634281	0.199
Mould (type, size, and number of units needs)	0.801829311	0.39162009	2.047467257	**0.06948** **
The material used (type, availability...)	-0.889908124	0.3966399	-2.243617256	**0.02168** **
Using new technique and technology	1.010521489	37107600	2.72322E-08	**0.01734*** **

1. *Log–Likelihood Function = –47.82*
2. *Restricted Log–Likelihood = -51.47*
3. *Chi squared 7.30*
4. *Probability 0.29*
5. *Hosmer-Lemeshow chi-squared 11.47*
6. *P-value 0.17*

(**) Indicates significant at level 5% because t critical value is 1.960.
(***)Indicates significant at level 1%

According to Singh and Huat (2003), the mention of industrialized building systems leads to thinking of the manufacture of pre-fabricated elements in reinforced concrete and pre-stressed concrete for industrial, civil and artisan building application. Based on this reason, the material used was also included in the analysis of logit model. "Material used" factor was found the significantly positive estimated coefficient on the material used. This implies that the materials used give a higher probability of choosing IBS vote. The null hypothesis test for the material used coefficient is (zero) against the alternative hypothesis that the "material used" coefficient is positive has a t-statistic of 2.48 and therefore, the calculated test statistic exceeds the critical value and hence the null hypothesis is rejected in favour of the alternative. This result confirms the development of the IBS especially in Malaysia, since one of the recent researches concerning IBS is the importance of material site for the IBS system such as the study by Singh and Huat (2003), Taly (2003), Mukherjee and Arwikar (2003), and Ahmad, et al. (2003).

"Using of new techniques and technology" is another factor that was found to significantly increase the probability of choosing the construction method of IBS in Malaysia. This finding confirms with the study by Warszawski (1999) and Lew, et al. (2003) mentioned that building system defines as a set of interrelated elements that act together to enable the designated performance of a building. It may include various procedures including technological and managerial for the production and assembling of these elements for this purpose. This implies that using of new technique and technology gives a higher probability of choosing IBS vote. The null hypothesis test that "using of new technique and technology" coefficient is zero against the alternative hypothesis that "using of new technique and technology" coefficient is positive has a t-statistic of 2.48 and therefore, the calculated test statistic exceeds the critical value and hence the null hypothesis is rejected in favor of the alternative.

Other variables included in this logit model analysis are "skill and experience". However, the coefficient of those variables was insignificant, as expected. Another variable that included in the model is "the equipment and mechanical plants used" was also insignificant. This means that these variables do not enter in the model of respondent's preferences for choosing construction method. The estimate results are presented in Table (II).

Conclusion

Moreover, the advantage of Industrialized Building system (IBS) in construction projects in term of the speed is also being analyzed in this study. Based on the six factors that influence the speed of IBS methods, the high productivity of structural elements (In-situ or off-situ) is the most significant factor. Using "Moulds (type, shape, size, and number of units needs)" and "using new techniques and technology (computer and robot in design manufacturing)" are also considered significant factors for the speed of IBS. However, "skill and experience", "the equipments and mechanical plants used", "the materials used (type, availability…)" are not as important as the previous factors.

This finding is further supported by the result of the preferences analyses of choosing between the use of IBS and non-IBS (conventional system) in the construction projects. Logit model analysis shows only four variables that give a significant effect on the changes of choice the construction methods. These variables are "high productivity of structural elements (in-situ or off-situ)", "using of mould", "the material used" and "using new techniques and technology". The positive estimated coefficients of those variables imply that an increase in the value of its variables gives a higher probability to choose IBS.

Recommendation

Based on the findings and discussions of the study, hence the following recommendation is required: Since high productivity is the major factor that affects the speed of IBS, a research should be focused on innovation techniques that improve the productivity of building system industry.

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