Selection of Method in Construction Industry by using Analytical Hierarchy Process (AHP)

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Abstract Method in construction industry is very important in construction industry. The type of method used in construction may affect the quality of the project. Three distinct method that will be explore in this paper are traditional method, design and build and industrial building system (IBS). The traditional procurement method, known for its separate entity by the client, architect and contractor. The architect will responsible for design work, while contractor will responsible for construction work. Meanwhile, the design and build, whereby the contractor accepts responsibility for some or all of the design finally the IBS is when the construction built using pre-fabricated components. This paper aiming in identifying the criteria and suitability for selecting different kind of construction delivery method in construction by using the multi-criteria decision making (MCDM) namely the Analytical Hierarchy Process (AHP) method. Results provides some empirical finding which contractor for Grade 7 is suitable employing the industrial building system(IBS) method while the traditional method is appropriately for the Grade 1 contractor.

1. Section heading

The choice of the appropriate method in a construction project is indeed an important decision and is a major factor that greatly influences the productivity and efficiency of the construction project in addition to the large impact aspect given by the method of construction on productivity, quality, and cost [1]. The method of construction is generally known as one of the ways in which it is used to alter the raw material and is exhibited in a product form [2]. Rendering to [3], any sophisticated programming and management of a system that was introduced in the construction project, it will be worthless if the method of construction used does not giving any optimal impact in terms of time, cost, quality and safety. Construction professionals including engineers, (structural or mechanical) expertise was needed during the early stage of a project. Choosing the wise construction method largely crucial during the progressive delivery of a construction developments which often deeds as an actual obstacle to expending the expertise and acquaintance of all project companions meritoriously in the design and inception of the project [4]. In addition, extensive attitude, perception and commanding divergences amidst single project and project groups causing an isolating between design stage and development project growth. Remarkable differences of design and build contract if compare to traditional method is that the clients will have lacking in command and power when comes to the design issues and resist for any major modification. Henceforth, the contractor need to responsible for both design and construction of the project. This causing some clients and contractor having less interest on the leverages offered by design and build method. On the other hand, for the traditional method, client will assign different parties such as architect to performed design work. Reflecting to the issue, within

Malaysia context, the number of projects procured under design and build method decreasing from March 2012 to March 2014 [5]. In similar vein, prior to finish the project in timely manner, associated risk that arise from the verdict made by the contractor for design and construction work should cover by a liability. This is extremely contrast to traditional method, which risk appear from the design stage will fully responsible by the architect [6]. Most small contractors still choose to adopt conventional systems or traditional methods as they are familiar with the facilities offered by conventional systems compared to IBS technology. They argue that the IBS system is more suitable to be applied to large-scale construction projects. [6]. Among the constraints and challenges identified in implementing IBS for construction projects are the financial problems and constraints faced by small contractors who have made it difficult for them to build a manufacturing plant that is in desperate need of high and demanding capital investment. Detrimental the issues, lacking of knowledge and expertise owned by civil engineers in Malaysia in use of the structure analysis for the pre-fabricated design are among obstacles identified by prior study[6]. Given so many choices of methods available in the industry, thus this study is conducted in identifying and analysing within the three method using a systematic decision making tools namely the AHP. This paper will aid construction practitioners that are focussing within the contractor scope in evaluating the feasibility within the conventional, design and build or industrialised building system.

2. Literature Review

Construction industry player has been widely practiced globally and locally in a traditional method (TM). Therefore, the process of the installation of the timber or plywood formwork and steel reinforcement for the building at site is by fabricating components that called as a conventional method [7]. On the other hand, in conventional method have two parts. For the first part is structural system that the frame is in cast in-situ such as column, slab and beam. Hence, cast in-situ process is going into four action which are install the steel reinforcement bar, erection of the timber of formwork and scaffolding, using of pouring fresh concrete and disassemble of formwork and scaffolding [8]. Design and Build (D & B) procurement method of delivery are recognized as the ultimate substitute for most of public and private projects in many countries [9]. D & B is seen as one of the alternative procurement approaches that promote a single entity or consortium that takes sole responsibility for the project, couple with the fixed pricing offer [10]. The popularity of the D&B procurement system was driven by the separation of the design phase from the construction team project [9]. The point is due to the fact that construction projects require a more integrated design and build (D&B) process moreover on-time project delivery by having a privilege consortium entity that only takes on the sole responsibility of the particular project. The D & B system became popular and referred to in Malaysia beginning in the 1980s and 1990s where the Public Works Department (PWD) played their main role. Typical in the D & B project implementation process is the end user who initially identified the project and applied for a budget. Industrialized Building System (IBS) is a construction system built using pre-fabricated components. Component assemblies are systematically made using sophisticated machines, mould systems and mechanical equipment. These components are made out of the construction site (off-site) and upon completion of the manufacture, will be sent to the construction site for installation. IBS is characterize as a construction system where each component is manufactured in a factory or a construction plant or outside of the construction site, then placed and installed into the building structure by requiring only minimal additional site work [9]. The progress of this system is seen as very economical, reducing construction time while reducing construction workers.

3. Research Methods

This study that aiming in identifying the best method to adopt within the Malaysia's contractor scope. In determining which method works best for each contractor, multi-criteria decision making (MCDM), AHP tools are used to assist and facilitate construction practitioners in making quick decisions. AHP was first introduced by Professor Saaty in the 1980s [10], and many studies especially in the field of

construction management adopt this method. Among them include [11-13]. For the context of this study, hierarchical and alternative structures are built first as shown in **Figure 1** below.

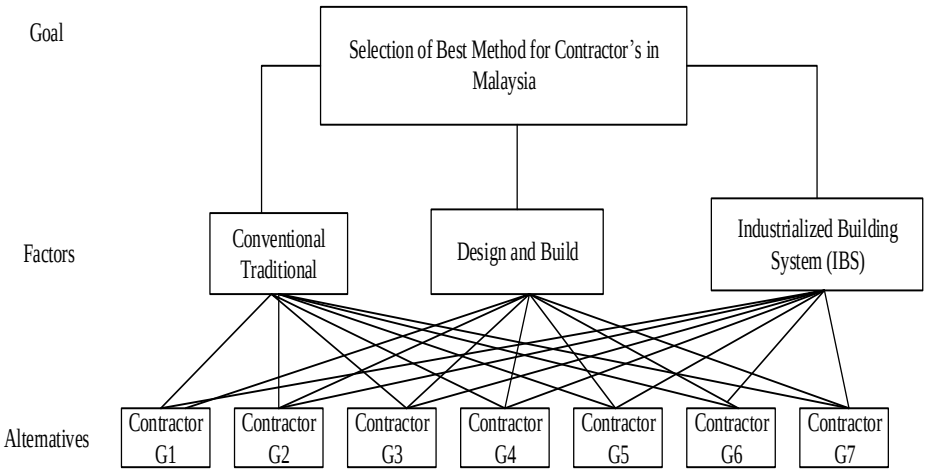

Figure 1. Decision Hierarchy Structure

AHP requires a hierarchy structures to develop first that composed of the goal, factor and optionally any alternatives within the context of the goal. On the other hand, the methods adopted in this study is presented in flowchart diagram shown in **Figure 2.** Uniquely, the AHP method employing the pair-wise questionnaire with nine (9) linguistic scale. The pairwise questionnaire distributed to all local and active construction practitioners. Upon getting their feedback, screening made for any unattended question and if there are any, will revert back to the respondent. Once confirmed, the analysis begin and all the data converted to square matrix form, normalizing the data and finally the data being validate by checking the respondent judgement consistencies and inconsistencies.

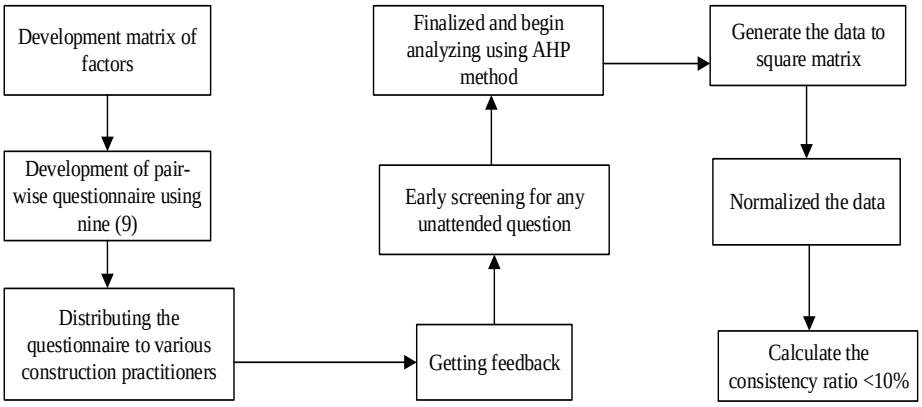

Figure 2. Research Methos Flowchart

In the AHP method all judgements are recorded in a matrix of pairwise comparisons $A = (a_{ij})_{n\times n}$ in which the dimension of matrix n means that we compared n parameters. The element of the matrix a_{ij} denotes a pairwise comparison of parameter *i* with parameter *j*, we gave the inverse comparison (comparing parameter *j* with parameter *i*). So the reciprocal value:

$$a_{ij} = 1/a_{ij} \qquad (1)$$

We can employ the eigenvector method to derive the parameter weights from the matrix of pairwise comparisons *A*, which means that we must solve the equation:

$$Aw = \lambda_{max} w \quad (2)$$

where λ_{max} is the maximal eigenvalue of matrix *A*. For every matrix of pairwise comparisons *A* we must also calculate the consistency ratio, which measures the level of inconsistency between pairwise comparisons:

$$CR = \frac{CI}{RI} \quad (3)$$

where $CI = \frac{\lambda_{\max - \mathrm{n}}}{\mathrm{n}-1}$ is the consistency index, *n* is the size of matrix *A* and *RI* is the average consistency index. We assumed that if $CR \leq 0.10$, then the inconsistency level of matrix *A* is still acceptable.

In the case of group decision making where m is the number of decision makers, we aggregate the individual judgments into one joint judgment ${a_{ij}}^{group}$ applying the geometric mean method:

$${a_{ij}}^{group} = \sqrt[m]{\prod_{k=1}^{m} {a_{ij}}^{k}} \quad (4)$$

Where ${a_{ij}}^{k}$, $k = 1, ..., m$ are the individual judgements of *m* decision makers. [14] Addressed that the geometric mean method Equation (4) is the only appropriate method for aggregating individual judgments into group judgments as it satisfies some necessary axiomatic conditions like preserving reciprocity. For the analysis to be reliable, the acquired data is require a consistency ratio of less than 10% or ($CR \leq 0.1$). On the other hand, a systematic software program namely the 'Expert Choice' is further utilized during the data analysis process. The Expert Choice software is a multi-objective decision support tool based on the Analytic Hierarchy Process (AHP), a mathematical theory first developed at the Wharton School of the University of Pennsylvania by one of Expert Choice's founders. The AHP is a powerful and comprehensive methodology designed to facilitate sound decision making by using both empirical data as well as subjective judgments of the decision-maker(s) [15]. The AHP assists with the decision making process by providing decision-makers with a structure to organize and evaluate the importance of various objectives and the preferences of alternative solutions to a decision [15]. Following are the steps proposed by [15] in AHP and Expert Choice :

- Brainstorm and structure a decision problem as a hierarchical model.
- Set the type and mode of pair wise comparisons or data grid functions.
- Group enable the model.
- Import data to Expert Choice from external databases.
- If applicable, pair wise compare the alternatives for their preference with respect to the objectives, or assess them using one of the following: ratings or step functions, utility curves, or entering priorities directly.
- Pair wise compare the objectives and sub-objectives for their importance to the decision.
- Synthesize to determine the best alternative.
- Perform sensitivity analysis.

4. Results and Discussion

4.1. Demographic Respondent Analysis

This section is explanatory from **Figure 3.** To **Figure 6.** Figure 3. Illustrates the respondents by gender. From the total 30 responses received, 21 responses (70%) received from male and 9 responses (30%) received from female. Figure 4 below shows the composition of respondents by profession. From the total 30 responses received, 8 responses (29%) received from site engineer and designer, 8 responses (28%) from engineer and 4 responses (14%) received from site engineer. On the other hand, figure 5 illustrates the respondent experiences in construction industry. From the total 30 responses received, 13 responses (44%) received from less than 5 years experiences, 6 responses (20%) received from the 5-10 years experiences, 7 responses (23%) received from the 11-15 years experiences and 4

responses (13%) received from more than 15 years. While figure 6 depicts the organization of the company. It shown that, 4 responses (13%) received from the government (public authority), 4 responses (14%) received from the consultant and 22 responses (73%) from the contractor.

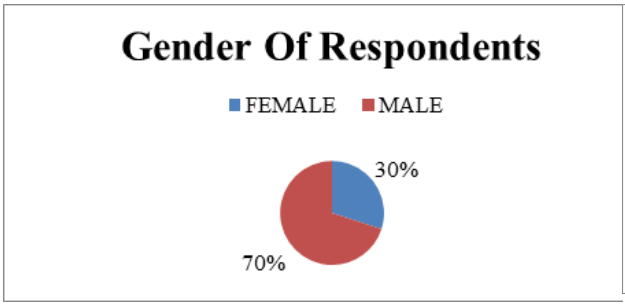

Figure 3. Respondent's by Gender

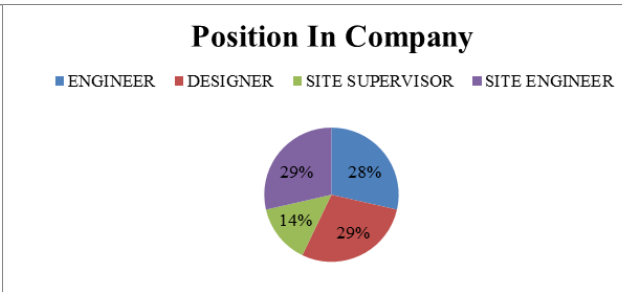

Figure 4. Respondent's Position

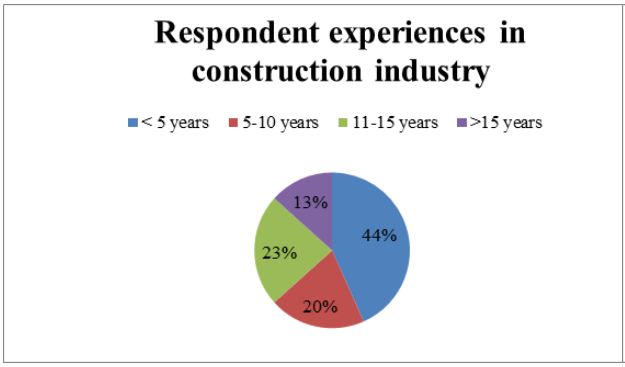

Figure 5. Respondent's Experiences

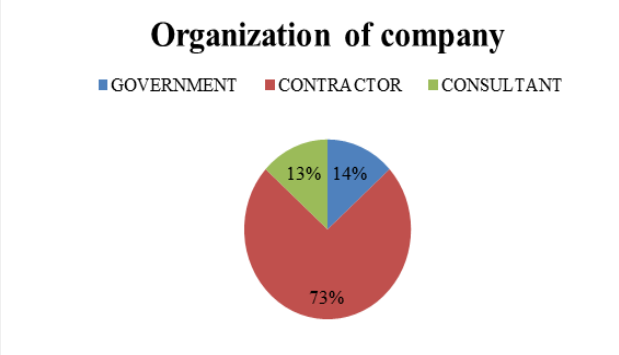

Figure 6. Organization of the company

4.2. AHP Results and Discussion

Figure 7 below depicts the results on the prioritization of the selection for construction method derived upon analysis using the 'Expert Choice' program.

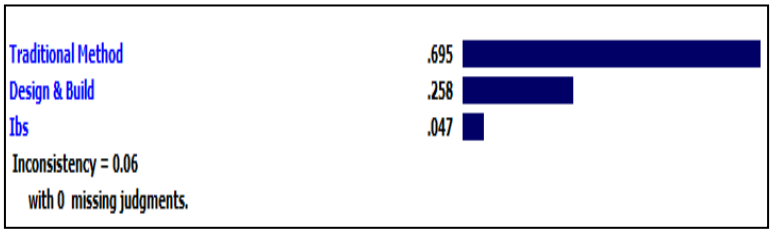

Figure 7. Priorities of selection of construction method

Apparently, the results achieved inconsistencies at 0.06 less than 0.10 (10%) as per recommendation by [10], [16]. Analysis of AHP analysis shows that contractors are more likely to choose conventional building systems rather than D&B and IBS. This is in line with current thinking that contractors prefer to choose conventional building systems. Results shows that traditional method weighted the most prioritized at 0.695 rather than proposing D&B weighted at 0.258 and IBS system weighted at 0.047. A possible explanation for this might due to shuffle of building system from conventional to IBS is not motivated by financial constraint borne by the contractor. Additionally, for decades, most contractors have been disclosed and educated in conventional building systems coupled with the large number of foreign workers employed inexpensively in Malaysia [17].

The delay in IBS implementation and acceptance in the construction industry in Malaysia is largely driven by the lack of knowledge of IBS in the industry. In addition, the lack of exposure to IBS technology has contributed to the structure analysis and design of the poorly installed components in the manufacturing plant [18]. It further leads to problems when assembling the components resulting to difficulty prior to fitting the installation process [19]. According to [20] many small contractors are in hesitant to embrace IBS system and choose to remain employed the conventional method. The rationale of this lies in the fact that, contractors are formerly adapted with the conventional system and they presume that the available technology system are appropriate and suitable for them in handling with small scale projects. In similar vein, among the constraints and challenges identified in implementing IBS for construction projects are the financial problems and constraints faced by small contractors who have made it difficult for them to build a manufacturing plant that is in desperate need of high and demanding capital investment. Eventually, it was also reported some contractors in Malaysia is affected from poor efficiency and financial performance to commit in IBS [21]. **Figure 8** below illustrates the sensitivity analysis of each construction method with respect to the alternatives i.e. the grade of contractors. From the figure, observable remark can be made that contractor G7 dominates in embracing the IBS technology and design and build rather than the conventional method. Thus, it can be presume that with the higher financial capabilities borne by the contractor (G7), the higher their willingness to adopt new technology than the conventional method. Additionally, low-grade contractors (G1), their level of readiness to adopt the latest technology is also relatively low. This can be seen from the diagram where G1 contractors embrace more on conventional methods rather than design and built and IBS.

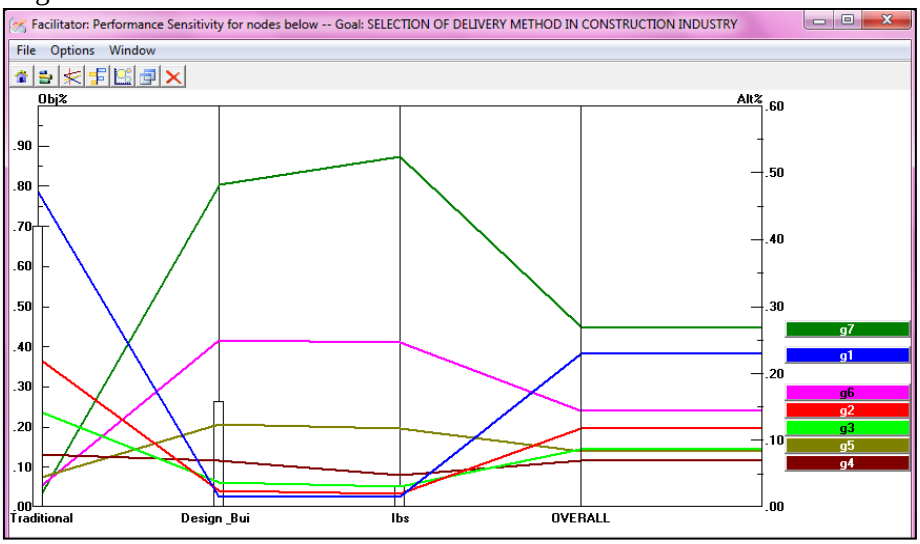

Figure 8. Sensitivity Analysis of Alternatives with respect to the goal

5. Conclusion

Based on the overall result, the conclusion drawn as follows. First, the traditional method is captured the most prioritized ranking for the method used in construction industry is due to the fact that traditional procurement method is the project's client and have full influences toward the overall process of the project. This also contributes to the increase on quality and functionality of the project. Other than that, best quality of project is guarantee when the building contract attached with the bill of qualities and project specification. Traditional procurement method is hassle-free type of procurement while in develop any project. The effect of variation may reduce the number of contract conflict. In addition, it having balanced allocation of risk between project's client and contractor compare to design and build method. It also known as tried procurement method because it have been tested in the long term period and is a very familiar procurement method. On the other hand, for the design and build method cost factors are key factors that need to be addressed in the design and build contract.

However, other factors such as duration, team reputation and quality should still be considered. The basis in making the decision for awarding the contract is based on the lowest bid provided by the contractor. However, the consideration of other criteria's should also be taken into account, this due to the fact that cost factors is commonly dynamic in nature. The selection of best value provides consideration of both cost factors and other subjective factors such as project management, quality control, and team reputation. These factors has gain popularity among project contracting building team due to its ability to consider all relevant factors affecting the design proposal's. It can be concluded that, in determining the best method selection, cost factors need to be in line with other subjective factors such as project management, quality control, and project team reputation. These subjective factors are always taken into consideration by the project team because of its ability to consider all the factors associated with design proposals. As a driver to the movement in activating IBS involvement in the construction industry, the government should implement IBS-related forums periodically. In addition, academics and industry practitioners can also actively cooperate in the form of information and experience sharing, the development of new techniques and advice on the promotion and implementation of IBS. Finally, an online portal may also be available to disseminate information on IBS internationally, such as products produced and processes related to IBS.

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