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A Strategy towards Sustainable Industrial Building Systems (IBS): The Case of Malaysia

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***Abstract*—Consistent with population growth, the demand for various products and services have increased. The necessity of meeting human needs while paying attention to the needs of future generations compels us to introduce and expand the concept of sustainable development in all areas. This concept is based on economic, environmental and social considerations. In recent decades, sustainable construction, as a new approach, is going to meet the basic needs of humanity toward sustainability in the construction industry. Thus, to conduct sustainable construction, the need for more sustainable methods in building systems is necessary. This study has been carried out to clarify ways of improving the implementation of IBS in terms of external macro-environment factors. The external environmental variables that affect the performance of a system consist of: Political, Economic, Social and Technological factors (PEST). Through the evaluation of a system with PEST analysis, its performance can be examined against other options with regard to the external environment. Therefore, this study is conducted by applying PEST analysis to compare the implementation of Conventional Building Systems and Industrial Building Systems (IBS) toward sustainable construction. The comparative table is developed according to PEST analysis based on the mean ranks obtained from interviews. The preference of IBS implementation has been established. The results show the need and importance of considering social factors to improve the development of IBS for sustainable construction.**

Keywords—Industrial Building System (IBS); Conventional Building System; Sustainable Construction; Malaysia; PEST analysis

I. INTRODUCTION

There are many buildings, offices, schools, shopping centers, hospitals, etc. built in different locations to supply any country's future plans. Construction has to support continuing population growth and economic development [1]. This huge demand for construction is associated with the challenges often faced with regards to productivity, efficiency, quality and delivery of work [2] . Moreover, the use of low technology methods and equipment, labor-intensive techniques and foreign unskilled workers, is still very common in the construction industry. On the other hand, there is a growing concern about the future, in the long-term, with regards to economic, environmental and social consequences [3]. Therefore, we cannot disregarded the importance of the construction industry to the three elements of sustainable development [1]. The relationship between sustainable development and the construction industry is undoubtedly evident, considering the fact that construction has a high economic significance and strong environmental and social impact [1]. According to Miyatake [4], achieving sustainable construction has to be appreciated and the industry must change the processes of creating built environments. This means the construction industry has to change the way in which all the activities of the building systems are undertaken.

A. *Sustainable Construction*

The concept of sustainable development emphasizes three dimensional principles which are the key attributes that supports the development of a sustainable society [5,6]. Social, economic and environmental dimensions are the triple bottom lines of sustainability. The identification of relevant issues of these three dimensions in any industry is critical in the development of sustainability [7]. In recent years sustainability has become an important and widely considered issue in the construction industry [8-10]. The term 'sustainable construction' is generally used to illustrate the application of sustainable development to the construction industry. Therefore, sustainable construction could be described as a division of sustainable development [11]. According to C. J. Kibert [12] the six principles of sustainable construction are: (1) to minimize resource consumption, (2) maximize resource reuse, (3) use renewable and recyclable resources, (4) protect the natural environment, (5) create a healthy and non-toxic environment and (6) pursue quality in creating the built environment.

B. *Building System*

A building system is a set of procedures which select or identify the design and construction of a building or structure. The building has always been regarded as one of the basic needs of humans and humans have used a variety of building systems at various ages. With regard to human needs and proportion to the advancement of technology, various industries have been undergoing changes and improvements. The construction industry and consequently the building systems are experiencing these changes. A building system process development is the only way to improve productivity and quality in building construction. In recent decades, in step with production industrialization, the construction industry has shifted from the conventional building systems to the industrial building systems.

C. Conventional Building System

The conventional building system is quite a handy method of construction. In this system, most activities in preparation for construction materials or components are carried out manually in the workshop. The procedures are based on manpower more than on machinery. There is a limited to an individual's use of engineering tools, installation and performance aids during the operation of construction. As a result the conventional building system is constantly associated with low quality and productivity, high workers' safety risk, and extreme dependence on labor. Consequently, a transition from conventional to a new building system that can cover these weaknesses is required.

D. Industrial Building System (IBS)

The IBS is an improved building system that is being introduced in the construction industry to achieve the target of faster completion with mass production of the building elements in places far from the final location of the building. The IBS seeks to tackle the weakness of and improved the current construction method. According to CIDB [13] "IBS is construction technique in which components are manufactured in a controlled environment(on or off site), transported, positioned and assembled into a structure with minimal additional site works." The main advantages of IBS construction method includes: the utilization of construction machinery, equipment, and materials; technology enhancement, increased flexibility, productivity, quality and safety of work; extension of pre-project planning and environmental friendly, saving in labor, time and cost [14-16]. Even with IBS's reasonable advantages and efficient implementation, it is facing some barriers such as negative perception and low popularity, readiness issues, cost and equipment, poor planning and regulations, lack of awareness and coordination among the relevant parties [17]. Since the construction industry is moving toward industrialization of the building system, a strategic plan is needed to cover the disadvantages of IBS and look at IBS as an answer to the housing shortage problem. The IBS must have a strategic plan to be able to choose appropriate goals and strategies.

Therefore this study was conducted by applying the PEST analysis to compare the implementation of Conventional Building Systems and Industrial Building Systems for sustainable construction. Furthermore this study was carried out to clarify ways of improving the implementation of IBS in terms of external macro-environment factors in the Malaysian construction industry. The variables in this study are the external environment variables that affect the performance of a system. The comparative table was developed according to PEST analysis based on the mean ranks, derived from interviews.

II. Methodology

The development and implementation of the strategies necessitates the understanding of the environment of a system which the strategies are going to be applied in. Political, Economic, Social and Technological factors are the external environment variables that affect the performance of a system. The PEST is the acronym for these factors. The PEST analysis can be used for evaluating market growth or decline, and as such the position, potential and direction of a business. By evaluating a system with PEST analysis, its performance can be examined against other options with regard to the external environment.

Political factors consist of government support, policies and regulations such as health and safety laws, employment and labor laws, environmental regulations and tax policy. Governmental decisions can influence and change other economic and societal issues. Economic factors refer to any aspect of the business and economic environment. Market value, target consumer, economic growth, interest rates, inflation and currency exchange rates are all the economic factors which can affect any decision making. Construction, operation, maintenance and transportation costs are involved in the performance of a system. Social factors refer to employee and consumer's needs and attitudes. Consumer's satisfaction and perception are the main factors responsible for the success of any new system. Social factors present social attitudes, interests and opinions. Technological factors can refer to technical development, innovation and limitations. New products and new processes are born from new technologies. Time and cost reduction, quality improvement, durability and flexibility are the effects of technology development and advancement. From the following, the PEST analysis is a useful tool for understanding and monitoring the external environment of any organization and system. It is able to examine the performance of the system against other options with regard to the external environment.

Considering increased building demand, it is necessary to develop an innovative and high speed construction method (Haron et al., 2005). By reason of higher cost and slow construction, the conventional construction method doesn't have sufficient capability to meet the demand (Agus, 1997). The conventional building system requires an excessive workforce. The rising cost of labor is an important factor in increasing the total cost of a building. In addition to that, the required quality cannot be achieved. Consequently, Malaysia is presently taking a hard look at IBS as an answer to the building demand problem. In spite of IBS advantages compared with that of the conventional method, the percentage of IBS usage is lower than expected the despite huge publicity campaign from the government [18]. This study is going to improve the implementation of IBS in the Malaysia construction industry. Therefore this study applies the PEST analysis by conducting a comparison of the implementation of the Conventional Building Systems and the Industrial Building Systems.

In the first stage, before starting the interview, the main Political, Economic, Social and Technical factors related to a building system are introduced from literature. The factors are categorized under 4 PEST obligations by content analysis. The definition of obligations weight according to PEST analysis for different building systems was done among six specialists and experts by the structured interview. According to Morse's statements there is an inverse relationship between the number of participants and the amount of useable data obtained from each participant. As a phenomenological study, six participants would be sufficient to achieve a large amount of data for each participant [19]. The comparative table was developed according to PEST analysis based on the mean ranks, achieved from interviews.

The transformation of linguistic terms to fuzzy numbers conversation scales tools is applied. The decision maker made use of linguistic five member weighting set [20 H, VH] to weight the criteria where VL=very low= (0, 0, 0, 3), L=low= (0,3,3,5), M=medium= (2,5,5,8), H=high= (5,7,7,10), VH= very high= (7,10,10,10) [21]. The study applied this scale to weight the obligations under two building systems. Linguistic weighting numbers (wij) were collected from each of the interviewee. The fuzzy weighted mean score ($\tilde{WMS}_i$) was calculated for each type of the building systems by (1).

$$\tilde{WMS}_i = \frac{\sum_{j=1}^{6} \tilde{W}_{ij}}{6} \quad (1)$$

where i is the index for type of the factors (Political, Environmental, Social, Technological) and j is the index for interviewees (j=1, 2, ..., 6).

In 2010 Sanayei, Farid Mousavi, & Yazdankhah [22] used normal fuzzy linguistic variables based on seven stages included VL=very low= (0, 0, 0.1, 0.2), L=Low= (0.1, 0.2, 0.2, 0.3), ML=Medium Low = (0.2, 0.3, 0.4, 0.5), M= Medium = (0.4, 0.5, 0.5, 0.6), MH= Medium High= (0.5, 0.6, 0.7, 0.8), H= High= (0.7, 0.8, 0.8, 0.9), VH=Very High= (0.8, 0.9, 1, 1). They used these linguistic rating scales for each of the alternatives. A seven member ranking set was used to rank the factors for each building system during the structured interview. Then the fuzzy ranking mean score ($\tilde{RMS}_{pz}$) were calculated by (2).

$$\tilde{RMS}_{pz} = \frac{\sum_{j=1}^{n} \tilde{R}_{pjz}}{6} \quad (2)$$

where the z is the index for the type of the building system (z= 1, 2, ..., n) and j is the index for interviewees (j=1, 2, ..., 6) and p is the index for detailed factors (p= 1, 2, ..., m). Then, the mean of the fuzzy ranking mean score ($\tilde{RMS}_{pz}$) under each obligation (Political, Environmental, Social, and Technological) multiply to fuzzy weighted mean score ($\tilde{WMS}_i$) to obtain the obligation ranking ($\tilde{OR}_{iz}$) (3). The results were defuzzified by the center of area (COA) method for each fuzzy number $\tilde{A} = (a,b,c,d)$ (4) to achieve weighted ranking for each of the building system under each of the obligations (Political, Environmental, Social, and Technological) in the PEST analysis. The policy index (PoI) for each building system can be calculated by summation of $d(\tilde{OR}_{iz})$ (5) and based on the policy index (PoI) for each building system, the new policy and strategy developed.

$$\tilde{OR}_{iz}(ObligationRanking) = \tilde{WMS}_i \times \left[\sum_{p=factors.under.i} \tilde{RMS}_{pz} \Big/ Number.of.factors.under.i \right] \quad (3)$$

$$d(\tilde{A}) = \frac{\int x.\mu_{\tilde{A}}(x)dx}{\int \mu_{\tilde{A}}(x)dx} = \frac{-ab+cd+\frac{1}{3}(d-c)^2-\frac{1}{3}(b-a)^2}{-a-b+c+d} \quad (4)$$

$$PoI_z = \sum_{i=1}^{4} d(\tilde{OR}_{iz}) \quad (5)$$

III. Results and Discussions

The interviews were conducted among six experts from the academic and governmental sectors of Malaysia. According to the method mentioned previously the results of the interviews are summarized and ranked as in the following steps.

A. *Achieving of the fuzzy weighted mean score ($\tilde{WMS}_i$)*

The fuzzy weighted mean score ($\tilde{WMS}_i$) which were calculated for all the linguistic weighting numbers (wij) were obtained from each of the interviewees according to the different building systems. Table I summarizes the weighting for obligation by the PEST analysis.

B. *Achieving of the fuzzy Ranking mean score ($\tilde{RMS}_{pz}$)*

The fuzzy rankings mean scores for each building system indexed by z under different factors were investigated and evaluated by fuzzy linguistic variables. Table II illustrate $\tilde{RMS}_{pz}$ which represents the mean scores for the rankings from the evaluators.

C. *Achieving of the Policy Index (PoI)*

To achieve the policy of developing building system, the numerical amount of the summarized ranking of each obligation $d(\tilde{OR}_{iz})$ should be achieved. This indicator helps the decision maker identify the source of strength and weakness of each system. Table III defines the defuzzified obligation ranking $d\left(\widetilde{OR}_{iz}\right)$ for each of the building systems. Moreover, the policy index for each of the system could be achieved from the summation of the ranking for the PEST obligation which is defined on table III.

TABLE I. SUMMERY OF THE WEIGHTING FOR OBLIGATIONS UNDER PEST ANALYSIS

R	Political				Economical				Social				Technological			
R1	7	10	10	10	7	10	10	10	5	7	7	10	7	10	10	10
R2	7	10	10	10	0	0	0	0	7	10	10	10	7	10	10	10
R3	7	10	10	10	7	10	10	10	7	10	10	10	0	0	0	0
R4	5	7	7	10	7	10	10	10	5	7	7	10	0	0	0	0
R5	7	10	10	10	0	0	0	0	5	7	7	10	7	10	10	10
R6	7	10	10	10	7	10	10	10	2	5	5	8	5	7	7	10
$\widetilde{WMS}_i$	6.67	9.5	9.5	10	4.67	6.67	6.67	6.67	5.17	7.67	7.67	9.67	4.33	6.17	6.17	6.67

TABLE II. FUZZY RANKING MEAN SCORES FOR FACTORS

			Conventional Building System				Industrial Building System			
Political	1	Government support	0.28	0.38	0.42	0.52	0.70	0.80	0.85	0.92
	2	Ecological/Environmental current legislation	0.25	0.35	0.40	0.50	0.63	0.73	0.77	0.87
	3	Health and Safety Laws	0.57	0.67	0.68	0.78	0.57	0.67	0.73	0.83
	4	Labour Law	0.40	0.50	0.55	0.65	0.52	0.62	0.68	0.78
Economical	5	Construction cost	0.60	0.70	0.75	0.85	0.52	0.62	0.68	0.78
	6	Maintenance cost	0.35	0.45	0.50	0.60	0.52	0.62	0.68	0.78
	7	Operating cost	0.43	0.53	0.57	0.67	0.45	0.55	0.60	0.70
	8	Transportation cost	0.40	0.50	0.55	0.65	0.57	0.67	0.73	0.83
	9	Long-term prospects for the economy Gross Domestic Product (GDP)	0.43	0.53	0.57	0.67	0.60	0.70	0.75	0.85
Social	10	Cultural aspects	0.60	0.70	0.75	0.85	0.38	0.48	0.52	0.62
	11	Living standards	0.38	0.48	0.52	0.62	0.43	0.53	0.57	0.67
	12	Lifestyle choices	0.57	0.67	0.73	0.83	0.43	0.53	0.57	0.67
	13	Perceived Image of the system	0.27	0.37	0.43	0.53	0.45	0.55	0.60	0.70
	14	Satisfactory of the system	0.45	0.55	0.60	0.70	0.43	0.53	0.57	0.67
	15	Employment Rate / Job growth	0.52	0.62	0.68	0.78	0.35	0.45	0.50	0.60
Technological	16	Construction easiness	0.30	0.40	0.45	0.55	0.63	0.73	0.77	0.87
	17	Flexibility with different environment	0.43	0.53	0.57	0.67	0.47	0.57	0.63	0.73
	18	Quality improvement	0.30	0.40	0.45	0.55	0.75	0.85	0.90	0.95
	19	Structural limitation	0.52	0.62	0.68	0.78	0.47	0.57	0.63	0.73
	20	Time	0.33	0.43	0.47	0.57	0.77	0.87	0.93	0.97

TABLE III. SUMMARY OF RANKING FOR PEST ANALYSIS

	Alternative Building System	Political	Economic	Social	Technological	Sum	Rank
1	Conventional Building System	4.45	3.49	4.20	2.96	15.10	2
2	Industrial Building System	6.52	4.07	4.18	4.33	19.09	1

IV. Conclusion

Sustainable development has become a critical issue in Malaysia. It is not achievable without sustainable construction. Malaysia needs to clarify her strategies for the building system so as to attain sustainable construction. The PEST analysis is a powerful tool that can be used to help analyze the external environment. The PEST analysis is applied to the building systems with regards to the conventional and industrial building systems. According to the results obtained, despite the better performance of the conventional method with regards to social concerns, IBS is the best ranked building system which can be utilized. IBS was considered the best in terms of its effectiveness in improving sustainable building systems in Malaysia. The development of IBS has more powerful impact with regards to political, economic and technical concerns, which make it a more effective solution for the country's construction industry. Since the social dimension has gained increased recognition as a fundamental component of sustainable development, to realize the government's ambition in moving towards a more sustainable IBS construction method, good practice in social features should be considered. Development of IBS in Malaysia need to be more concentrated toward social sustainability.

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