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Selection of Sustainable Construction Method Using Analytical Hierarchy Process.

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اختيار افضل النظم الانشائية المستدامة باستخدام طريقه التحليل الهرمي

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KEYWORDS:
Sustainability assessment, Sustainable construction, Sustainability criteria, Construction methods, Analytical hierarchy process, Multi-criteria decision making

الملخص العربي:- البناء الإنشائي يلعب دورا هاما في التنمية المستدامة، تطبيق الاستدامة في أنظمة البناء من الأهمية الكافية للمساعدة في اختيار طريقة البناء المناسب في المباني الخرسانية خلال المراحل الأولية للمشروع. الهدف الرئيسي من هذا البحث هو تقديم معايير التقييم لتحقيق الاستدامة في أنظمة البناء بعد مراجعة الأبحاث السابقة. ولمعايير التقييم المستدامة بناء على سياسة ثلاثية المعايير ومتطلبات أصحاب المصلحة في المشاريع المختلفة بين طريقة البناء للأنظمة الإنشائية المسبقة الصنع وطريقة البناء المستخدمة في الموقع . تم تحديد ٣٣ معيار للأداء المستدام. وتنقسم معايير الاستدامة النهائية إلى ثلاث مجموعات عامة كمعايير وهي: (البيئية والاجماعية والاقتصادية) وكل مجموعة تتكون من المعايير الفرعية وتم تحديد الأوزان والقيم لكل معيار من الاستبيانات التي وزعت على الخبراء في هذا المجال ، وتم تقييم أهمية هذه المعايير بالنسبة للأخرى بناءا على نتيجة هذه الاستبيانات . تم استخدام تقنيات عملية التسلسل الهرمي التحليلية لتحديد أهمية هذه المعايير وتم شرح طريقة الاستخدام في البحث، ويوفر هذا البحث وسيلة جديدة لتحديد طريقة البناء الانشائي بناءا على معايير البناء المستدامة.

Abstract— **Building construction plays important role in sustainable development. Applying sustainability in building systems is important to assist with the selection of an appropriate construction method in concrete buildings during early project stages. The main objective of this research is presenting assessment criteria to investigate sustainability in building systems. Following a thorough literature review assessment criteria are made based on the triple bottom line and the requirements of different project stakeholders between prefabrication and on site construction method, a total of 33 sustainable performance criteria were identified. The final sustainability criteria are divided into three general groups as environmental, social and economic criteria and each group is consisting of sub-criteria. The table of criteria and weights and values from questionnaires of building experts to assess the relative importance of the criteria. The extended analytical hierarchy process techniques are used to prioritize the important for identified criteria. Illustrating the implementation of the model is given. The proposed model provides a new way to select a construction method.**

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I. INTRODUCTION

THE construction, fit-out, operation and demolition of buildings are significant factors that effect on the environment directly through material and energy consumption and the consequent pollution and waste and indirectly through the pressures on the infrastructures. In response to these impacts, there is growing demands among organizations to commit to the environmental to make construction activities more sustainable [1–3]. Attempts to improve social, economic, and environmental indicators have the attention to construction as one of the most active industries. Traditionally, researchers have focused on objectives, such as time, cost, safety, quality, and sustainability, to complete the project successfully with interfere by an external factor [4]. Recently, sustainability has increasingly become an important criteria to achieve a success to the projects [5]. Now sustainability set as a new project performance indicator, which expressed the terms of environment impacts, leading to the requirement to a better understanding of project sustainability and improve the performance of construction projects [6]. on-site construction methods have long been criticized for low productivity, poor quality and safety records, long construction time, and large quantities of waste in the industry [7]. Prefabrication is generally taking place at a specialized facility, with shortened construction time, lower overall construction cost, improved quality, enhanced durability, better architectural appearance, enhanced occupational health and safety, material conservation, less construction site waste, less environmental emissions, and reduction of energy and water consumption [8-10]. Prefabrication not always the better option than on-site construction method due to project type, project characteristics, available resources and available constrains like change orders, severe delays in production, substantial cost overruns, and constructability problems If not employed appropriately may be effected in the use of prefabrication. It is common for construction professionals to choose a construction method based on previous experience, which potentially misses an opportunity to apply a better construction method. Accordingly, there is a need to provide a decision-making tool that would stimulate the appropriate discussion of the suitability of prefabrication and other construction methods for concrete buildings The analytic hierarchy process (AHP) [11,12] is widely used for multi-criteria decision-making problems in real situations. Bahareh et al. [13] utilized the AHP as a multi criteria technique for sustainable assessment construction systems. AHP provides a framework for decision making to decide the final priority of different decision criteria. The proposed AHP uses as a pair-wise comparison scale for deriving the priorities of different selection criteria and sub-criteria. This connection will help stakeholders to a better understanding for the impact of different project conditions on the decision-making processes of construction professionals regarding the impact of construction method selection on project objectives, such as time, cost and environmental impacts. Although construction professionals often have many alternative construction methods from which to choose, we study impact of the alternatives on project objectives, some alternatives are often ignored during construction planning. We undertake this challenge, and in this paper, a solution is proposed as a response to this need.

II. ANALYTIC HIERARCHY PROCESS METHODOLOGY

AHP method is a multiple step analytical process of judgment, which designed to structure a decision process in a complex arrangement into a systematic hierarchical structure. It allows a set of complex issues that have an impact on an overall objective to be compared with the importance as the problem can be divided into several sub-problems that are organized according to hierarchical levels, where each level denotes a set of criteria or attributes related to each sub-problem [14]. The top level of the hierarchy denotes the goal or the objective of the problem and criteria is at second level, attributes are at third level, and decision alternatives are at fourth level in hierarchical structure or actions considered when achieving the goal.

Saaty [15-18] developed the following steps for applying the AHP:

1. Define the problem and determine its goal.
2. Structure the hierarchy from the top (the objectives from a decision-maker's viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level which usually contains the list of alternatives shown in Fig 1.

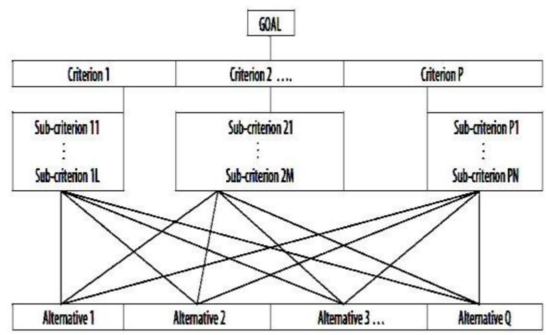

Fig. 1. Generic hierarchic structure

3. Construct a set of pair-wise comparison matrices (size n × n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table I. The pair-wise comparisons are done in terms of which element dominates the other.

TABLE I
PAIR-WISE COMPARISON SCALE FOR AHP PREFERENCES

Importance	Definition	Explanation
1	Equal importance of both elements	Two elements contribute equally
3	Moderate importance of one element over another	Experience and judgement favour one element over another
5	Strong importance of one element over another	An element is strongly favoured
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favoured by at least an order of magnitude
2,4,6,8	Intermediate values	Used to compromise between two judgements

4. There are n (n – n)/ 1 judgments required to develop the set of matrices in step 3. They are automatically assigned in

each pair-wise comparison.

5. Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy as shown in Table II.

TABLE II
PAIRWISE COMPARISONS TABLE

		Criteria			Geometric Mean	Criteria Weights
		A	B	C	$\left(\prod_{i=1}^{n} k_i\right)^{\frac{1}{n}}$	
Criteria	A	1	a/b	a/c	$A=\sqrt[3]{(1)\left(\frac{a}{b}\right)\left(\frac{a}{c}\right)}$	$W_A = (A \div T_w)$
	B	b/a	1	b/c	$B=\sqrt[3]{\left(\frac{b}{a}\right)(1)\left(\frac{b}{c}\right)}$	$W_B = (B \div T_w)$
	C	c/a	c/b	1	$C=\sqrt[3]{\left(\frac{c}{a}\right)\left(\frac{c}{b}\right)(1)}$	$W_C = (C \div T_w)$
					$T_w = \sum_{i=A,B,C} i$	

6. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue, lmax, to calculate the consistency index, CI as follows:

$$CI = \frac{(\lambda \max - n)}{(n-1)} \tag{1}$$

where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table III. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.

TABLE III
PAIR-WISE COMPARISON SCALE FOR AHP PREFERENCES

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	.58	.9	1.12	1.24	1.32	1.41	1.45	1.49

7. Steps 3±6 are performed for all levels in the hierarchy.
8. The rating of each alternative is multiplied by the weights of the su criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global ratings the AHP produces weight values for each alternative based on the judged importance of one alternative over another with respect to a common criterion as shown in Table IV.

TABLE IV
ALTERNATIVE SCORE CALCULATION

Criteria A		Alternatives			Geometric Mean	Alternative Score
		X	Y	Z	$\left(\prod_{i=1}^{n} k_i\right)^{\frac{1}{n}}$	
Alternatives	X	1	x/y	x/z	$X=\sqrt[3]{(1)\left(\frac{x}{y}\right)\left(\frac{x}{z}\right)}$	$S_X^A = (X \div T_s)$
	Y	y/x	1	y/z	$Y=\sqrt[3]{\left(\frac{y}{x}\right)(1)\left(\frac{y}{z}\right)}$	$S_Y^A = (Y \div T_s)$
	Z	z/x	z/y	1	$Z=\sqrt[3]{\left(\frac{z}{x}\right)\left(\frac{z}{y}\right)(1)}$	$S_Z^A = (Z \div T_s)$
					$T_s = \sum_{i=X,Y,Z} i$	

FOR FURTHER INFORMATION ABOUT AHP CAN BE FOUND IN SAATY [15-18].

III. DEVELOPMENT OF SUSTAINABLE ASSESSMENT CRITERIA

One of the main objectives of this paper is to develop a sustainable assessment criteria to stakeholders in the selection of sustainable building construction method in the projects. A wide scope review has been conducted between precast, pre stressed and on-site construction systems. In trying to develop a set of criteria, Pasquire et al. [19] recommended six factors of measurement when comparing prefabrication and traditional construction: cost, time, quality, health and safety, sustainability and site issues. Idrus and Newman [20] conducted a survey within construction industry to investigate the construction related factors influencing the choice of concrete floor systems: in situ, precast and hybrid construction. Ultimately, 12 factors were identified as being directly related to the construction process. Findings. The on-site construction method consists of cast in-place activities. It is characterized by labor intensive, resulting in poor safety, lengthy construction time and a large quantity of waste. The prefabrication method is featured by cleaner and tidier site environment, and the reduction of construction waste and time. In the research, assessment criteria for construction method selection should have the capability, there is a need to compare prefabrication and onsite construction method to be clearly implemented by the selected criteria. The comparisons were divided into three categories based on the sustainable triple bottom line the economic and environmental and social criteria. We take "construction time" under economic criteria as an example, and in prefabrication, factory fabrication and site preparation can occur at the same time, while on-site construction work procedures cannot start until the previous activity is completed. On the other hand, the following table set of guidelines has been developed between prefabrication, prestressed and on-site method on construction listed in Table 5 to aid the choice of criteria to assess the options under consideration. This study has investigated the most reliable and commonly used researches in the field of sustainable construction, which should enable the identification of the most applicable criteria to enabling the development of sustainable construction, with particular attention given to the sustainable development criteria, with the obvious similarities and differences having been identified to achieve the sustainability principles as an important aspect of the sustainable construction. Certain categories that are considered such as Economic disposal cost, maintenance cost and life cycle cost. In addition to the most important environmental categories such as material consumption and water consumptions evaluated by ripple bottom line. This integration aims to achieve superiority through a consideration of the most reliable criteria to reflect environmental performance to achieve the sustainable practices on the construction industry. This research identified 32 performance criteria based on the sustainable triple bottom line and requirements of different project stakeholders, consisting of 16 economic criteria, 7 social criteria, and 9 environmental criteria. All of the criteria were derived from a thorough related literature review and comparisons between prefabrication and on-site construction method. Table V shows the description for each criteria to assist the respondent with appropriate information before they make a decision.

TABLE V
SUSTAINABILITY FACTORS AFFECTING CONSTRUCTION METHODS

No	**Identified factors from literature**	**Comments**	**Selected factors for this study**	**Source**	**Description**
Economic sustainability criteria					
1	Construction times , completion date certain , minimise on site duration and minimise overall project duration	Merged	Construction times	[21-23]	Reduces construction time by minimizing duration for production,
2	Initial costs of construction and minimize construction cost	Merged	Initial construction costs	[21, 22]	The total cost considered the project life cycle, including site formation, construction, operation, maintenance cost and demolition cost.
3	Maintenance costs	Selected	Maintenance costs	[21]	Cost of building repair, maintenance and operation
4	Disposal costs	Selected	Disposal costs	[21]	Cost of building dismantling and waste treatment operation
5	Life cycle costs and minimize overall life cycle cost	Merged	Life cycle costs	[21-23]	Cost associated with building life cycle
6	The speed of return on investment	Selected	The speed of return on investment	[21]	Increases speed of return on loans or other investment
7	Flexibility and compatibility	Modified	Flexibility	[21, 24]	Allow adaptability and flexibility for changes in accommodating future trends or modification, which reduce cost
8	Loading capacity	Selected	Loading capacity	[21]	Able to support a higher load with a longer span (e.g. beam, column)
9	Integration of building services	Selected	Integration of building services	[21]	Provides simplicity in installation and user friendly (e.g.building automatic system, handicap facilities and centralise air conditioning system)
10	Lead-times	Selected	Lead-times	[21]	Provides extra duration for pre-construction phases (e.g.planning, designing, and material procurement)
11	Material costs	Selected	Material costs	[21]	Cost of materials (e.g. material delivery cost and storage)
12	Labor costs, labor	Merged	Labor costs	[21, 22]	Salaries were paid to human resources, such as general construction workers, plumbers, steel fixers, carpenters, masons, and bricklayers in time.
13	Constructability	Modified	Build ability	[21]	Provide ease for construction, simplification, dimension coordination and design integration for overall requirements
14	Integration of supply chain	Selected	Integration of supply chain	[21]	Smooth the flow of building materials and other resources from suppliers
15	Defects and damages	Selected	Defects and damages	[21]	Improves quality control, reduce failures in achieving specifications and limits damage to the products before final completion
16	Durability and achieving high quality	Merged	Durability	[21, 23]	Constructs highly durable buildings, which have a long usable life and cost effective

continued on the next page

TABLE V CONTINUED

No	Identified factors from literature	Comments	Selected factors for this study	Source	Description
			Social sustainability criteria		
17	Health of occupants, improved occupant health	Merged	Health of occupants	[21,24]	Refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.
18	Influence on job market	Selected	Influence on job market	[21]	Provides a stable job market which balances supply and demand
19	Physical space	Selected	Physical space	[21]	Provides larger space for engineering systems and potential occupants (e.g.physical spans, openings, and heights)
20	Aesthetic options	Selected	Aesthetic options	[21]	Improves artistic impact, appearance and offers more choices of decorative finishes (e.g. pattern, texture, and colour variations beside improving aesthetic values)
21	Workers health and safety , safety , reducing health & safety risks and health and safety during construction	Merged	Workers health and safety	[21-24]	Safety assessment conducted to identify any future safety risks to the public and project users and reduces risk of injuries, damages, death and chronic health risks for field workers in dangerous situations during construction
22	Labor availability	Selected	Labor availability	[21]	Reduces worker demand for on-site construction (e.g. labours, supervisors and other supervisory and site management personnel)
23	Community disturbance	Selected	Community disturbance	[21]	Reduces the adverse impact of construction activities to the occupants and the local community (e.g. construction noise, dust, light pollution and other pollutions)
			Environmental sustainability criteria		
24	Site disruption	Selected	Site disruption	[21]	Reduces disturbance and footprint of construction work on site area
25	Renewable contents	Selected	Renewable contents	[21]	Renewable materials such as bamboo, cork, fast-growing poplar, and wheat straw cabinetry, which are reproducible, were used.
26	Energy efficiency in building use	Selected	Energy efficiency in building use	[21]	Reduces the amount of energy use during the using of the building
27	Recyclable elements, increased material recycling	Merged	Recyclable elements	[21,24]	Building components, rubble, earth, concrete, steel and timber were reused
28	Material consumption and Reduced material waste	Merged	Material consumption	[21,24]	Reduces the amount of material used (e.g. natural resources use during design and construction phases)
29	Energy consumption in design and construction and reducing environmental impact during construction	Merged	Energy consumption in design and construction	[21,23]	Reduces the amount of energy use during the design and construction phases (e.g. electricity, petrol, diesel, and other fuels use)
30	Waste	Selected	Waste	[21]	Examinations of the waste generation at project construction and operation phases have been considered.
31	Pollution generation	Selected	Pollution generation	[21]	Reduces environmental emissions during construction phase (e.g. dust, CO_2, CO and other air pollution)
32	Water consumption	Selected	Water consumption	[21]	Reduces the amount of water usage throughout its life cycle
25	Renewable contents	Selected	Renewable contents	[21]	Renewable materials such as bamboo, cork, fast-growing poplar, and wheat straw cabinetry, which are reproducible, were used.
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IV. IMPLEMENTATION OF THE AHP SELECTION MODEL

In the following sections, the main steps of the method will be explained in detail.

Step 1. Define the main criteria and sub criteria for material selection to design the analytical hierarchy process structure. First the overall objective of the goal has been identified which was “selection of sustainable construction methods for building projects”. In selecting sustainable construction methods, a lot of criteria should be taken into account. All of the possible important criteria which could affect the sustainability of building constructions have been discussed with experts in the Construction sector. Also other selection studies in the literature were reviewed. By combining the determined criteria, the main criteria and the sub-criteria in the study were determined and validated. After the main criteria, sub criteria and alternatives were determined, the hierarchy of the material selection problem was structured. Fig.2 shows the structuring of the material selection problem hierarchy of four levels. The top level of the hierarchy represents the ultimate goal of the problem which is to choose a sustainable construction system options for the project. The goal is placed at the top of the hierarchy. The hierarchy descends from the more general criteria in the second level to sub-criteria in the three alternative options of construction systems (Pre stressed concrete (A), Precast concrete (B), In situ concrete (C)) at the bottom or fourth level. The general criteria level involved three major criteria: environmental social, economic and three alternative systems for the decision, and located them on the bottom level of the hierarchy.

Step 2. Questionnaires were designed and used to direct these experts to provide their comparison judgments using the relative scale measurement defined in Table 1. Comparisons were performed separately for each criterion in the hierarchy. Specific questionnaires for the four levels of the hierarchy were developed. By this interview process, all elements of each set will be performed a pairwise comparison to indicate with his or her preference for each criterion in pairs. In other words, this section will be analyzed through the use of the AHP method, these described criteria will be analyzed for the selection of sustainable options among the alternatives. The questionnaires facilitate the answering of pair-wise comparison questions. The preference of one measure over another was decided by the available research and the experience of the respondents.

First the respondents compared the main criteria with respect to the main goal then they compared the sub-criteria with respect to the main criteria. At the end, the respondents compared the alternative construction options with respect to each sub-criteria. The respondents used the variables to make the pair-wise comparisons. Then the priority weights of each main criteria, sub-criteria and alternative were calculated using AHP method. Calculating the weights of the main attributes, sub-attributes and alternatives. After the construction of the hierarchy, the different priority weights of each main criteria, sub criteria and alternatives were calculated using the AHP approach. The comparison of the importance of one main criteria, sub criteria and alternative over another were achieved by the help of the questionnaire. After calculation, the consistency ratio of each comparison matrix was found to be under 0.10. So we can conclude that the consistency of the pair-wise judgments in all matrices is acceptable. Then the priority weights of each main criteria, sub-criteria and alternative were calculated using AHP method.

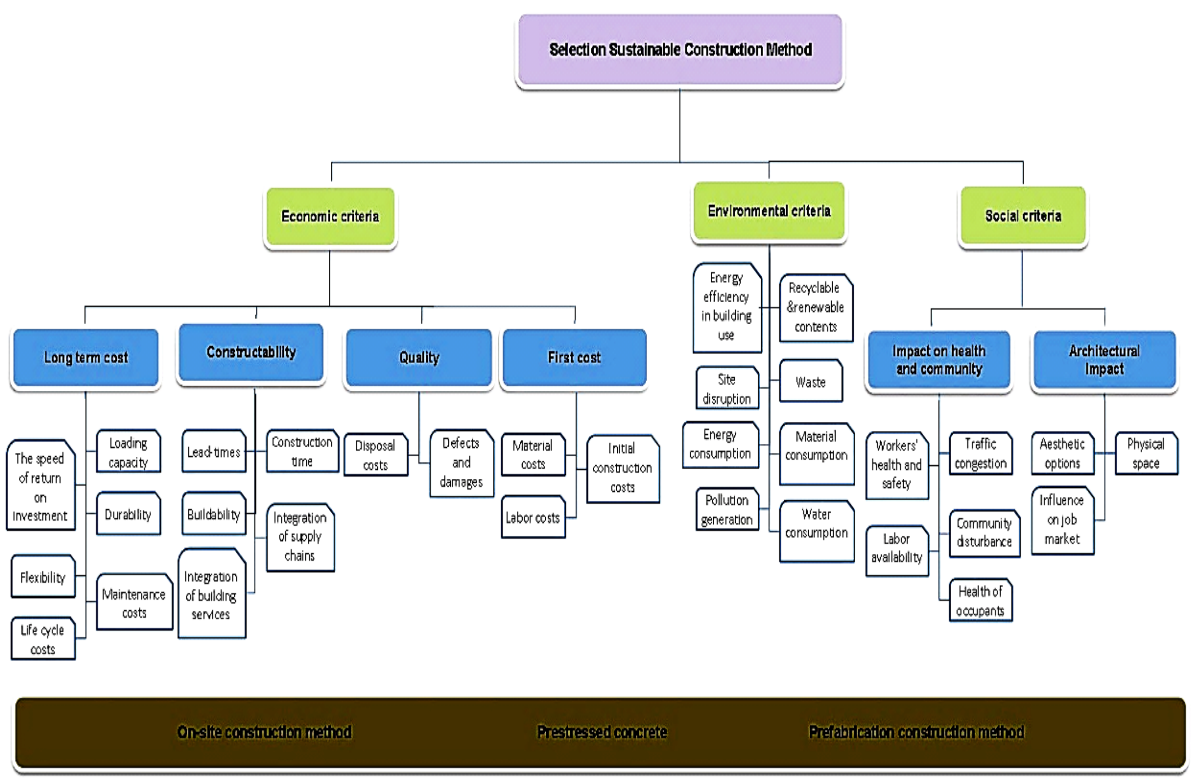

Fig. 2 conceptual model sustainability factors

TABLE VI
OVERALL PRIORITY WEIGHTS FOR THE THREE CONSTRUCTION SYSTEMS

Sustainability Criteria	Local weight (1)	Sub-criterion	Local weight(2)	Factors	Local weight(3)	Global weight(4)	Local weight(5)			Global weight(6)		
							(A)	(B)	(C)	(A)	(B)	(C)
Economic criteria	0.584	Long term cost	0.107	The speed of return on investment	٠.١١١	0.007	0.23	٠.٥٤	٠.٢٣	0.026	0.060	0.026
				Flexibility	٠.٠٤٢	0.003	0.132	٠.٦٣٥	٠.٣٦٥	0.040	0.027	0.015
				Life cycle costs	٠.٠٨١	0.005	0.0045	٠.٦٧٣	٠.٣٢٢٥	0.000	0.055	0.026
				Loading capacity	٠.٤٩٧	0.031	0.006	٠.٣٣٦	٠.٦٥٨	0.003	0.167	0.327
				Durability	٠.٢٠٧	0.013	0.35	٠.٣٢٥	٠.٣٢٥	0.072	0.067	0.067
				Maintenance costs	٠.٠٦٣	0.004	٠.٠٢٨	٠.٥٣٢	٠.٤٤	0.002	0.034	0.028
		Constructability	0.458	Lead-times	0.140	0.037	0.212	٠.١٣	٠.٦٥٨	0.030	0.018	0.092
				Buildability	0.236	0.063	0.183	0.563	٠.٢٥٤	0.043	0.133	0.060
				Integration of building services	0.095	0.025	0.026	٠.٧٤٢	٠.٢٣٢	0.002	0.070	0.022
				Construction time	0.489	0.131	0.044	٠.٦٣٥	٠.٣٢١	0.022	0.311	0.157
				Integration of supply chains	0.390	0.104	0.14	٠.٦٥	٠.٢١	0.055	0.254	0.082
		Quality	0.760	Disposal costs	0.357	0.158	0.292	٠.٥١٢	٠.١٩٦	0.104	0.183	0.070
				Defects and damages	0.643	0.285	0.071	٠.٥٦٤	٠.٣٦٥	0.046	0.363	0.235
		First cost	0.360	Material costs	0.259	0.054	0.133	٠.٦٣٢	٠.٢٣٥	0.034	0.164	0.061
				Labor costs	0.325	0.068	0.163	٠.٥١٢	٠.٣٢٥	0.053	0.166	0.106
				Initial construction costs	0.416	0.087	0.008	٠.٣٣٥	٠.٦٥٧	0.003	0.139	0.273
Environmental criteria	0.135	Environmental criteria	1	Energy efficiency in building use	0.313	0.042	0.3228	٠.٣١٢	٠.٣٦٥٢	0.101	0.098	0.114
				Recyclable& renewable contents	0.228	0.031	0.112	٠.٥٦٣	٠.٣٢٥	0.026	0.128	0.074
				Site disruption	0.133	٠.٠١٨	0.21	٠.٤٦٥	٠.٣٢٥	0.028	0.062	0.043
				Waste	0.117	٠.٠١٦	0.35	٠.٣٢٥	٠.٣٢٥	0.041	0.038	0.038
				Energy consumption	0.107	٠.٠١٤	0.22	٠.٥٣٥	٠.٢٤٥	0.024	0.057	0.026
				Material consumption	0.042	٠.٠٠٦	0.048	٠.٣٢	٠.٦٣٢	0.002	0.013	0.027
				Pollution generation	0.033	0.004	0.081	٠.٣٦٥	٠.٥٥٤	0.003	0.012	0.018
				Water consumption	0.027	0.004	0.072	٠.٦٣٥	٠.٢٩٣	0.002	0.017	0.008
Social criteria	0.281	Impact on health and community	0.569	Workers' health and safety	0.301	0.048	0.027	٠.٣٢١	٠.٦٥٢	0.008	0.097	0.196
				Traffic congestion	0.103	0.016	0.115	٠.٣٦٥	٠.٥٢	0.012	0.038	0.054
				Labor availability	0.216	0.035	0.015	٠.٥٥٣	٠.٤٣٢	0.003	0.119	0.093
				Community disturbance	0.129	0.021	0.395	٠.٣٥٣	٠.٢٥٢	0.051	0.046	0.033
				Health of occupants	0.251	0.040	0.319	٠.٣٥٦	٠.٣٢٥	0.080	0.089	0.082
		Architectural impact	0.430	Aesthetic options	0.456	0.055	0.028	٠.٣١٤	٠.٦٥٨	0.013	0.143	0.300
				Influence on job market	0.378	0.046	0.152	٠.٥٢١	٠.٣٢٧	0.057	0.197	0.124
				Physical space	0.166	0.020	0.21	٠.٤٦٥	٠.٣٢٥	0.035	0.077	0.054
Total	1.000						Overall priority			1.02	3.441	2.93

Local weight is derived from judgment with respect to a single criterion.

Global weight is derived from multiplication by the priority of the criterion.

Global weight (4) of the sub-criterion is obtained by multiplying the local weight (3) of the factors by the local weight (2) of the sub-criterion by the local weight (1) of the criterion.

Global weight (6) of the alternative is obtained by multiplying the local weight (5) of the alternative by the local weight (3) of the factors.

Step 3. Synthesizing the results. After computing the normalized priority weights for each pairwise comparison of the AHP hierarchy, the next phase is to synthesize the rating for each criterion. The normalized local priority weights of dimensions of sustainability were obtained and were combined together in order to obtain the global composite priority weights of all used in the third level of the AHP model. In order to shorten the solution process for the for construction selection, Microsoft Excel was used to determine the global priority weights of the alternatives based on the questionnaire. After deriving the local priorities for the criteria and the alternatives through pair-wise comparisons, the priorities of the criteria are calculated the overall priorities for the decision alternatives. As shown in Table VI, the sustainability index as calculated for the three construction systems alternatives was 1.02, 3.441 and 2.930 for options A, B and C respectively. In respect to the principle of a sustainability index the higher the sustainability index, the better the option, the ranking for the three options for the material alternatives is B>C>A. Option (B) turns out to be the most preferable material among the three materials, with an overall priority score of 3.441.

V. CONCLUSION

This paper discussed the development of assessment criteria, and of comparing building based on their sustainability for selection sustainable construction methods. Hence developing suitable systematic approaches and appropriate structured decision-making frameworks for sustainable building selection was considered in this research. Decision making for a sustainable construction alternative, while considering various criteria that influence selection, is difficult and this difficulty is further complicated not only when conflicting relationships exist between the criteria considered, but also when qualitative criteria are included. To deal with this difficulty effectively, review of the literature in the field of sustainability, combined with requirement of project stakeholders. A questionnaire survey was employed to obtain the perceived importance of the criteria. Following the results of the survey, the thirty-two criteria identified as being important components of selection factors. Analytical hierarchical process was used for assigning the weights to measure the relative importance of these criteria for a given material alternative. For this purpose, AHP used a simple pairwise comparisons to determine weights and ratings so that the analysis can concentrate on just two factors at one time. This process enables decision makers to solve the complicated, multi criteria problem. We proposed three alternatives construction system in this paper for a new building project. The ranking analysis presented reflects current industry emphasis on construction method selection in concrete buildings. Although the average rankings of social criteria and environmental criteria are not as high as economic criteria, the results showed that social awareness and environmental concerns were considered to be increasingly important when selecting construction methods. For example, defects and damages issues were rated with higher importance with 0.283 global importance weights and disposal cost, construction times and integration of supply chain rated as 0.158, 0.131 and 0.104 respectively. The result of the AHP method clearly shows that qualitative criteria have a significant impact on sustainability of building.

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