Determination of fundamental criteria in the selection of a construction system

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Abstract. There is a lack of an efficient systematic approach to the selection of appropriate construction methods for modern building systems. Identifying key criteria is necessary to help decision-makers in implementing the principles of this process. The present article was conduct for the same purpose. In this article, after reviewing of the literature, we found that construction experts' opinions did not consider until now. Thus, we considered the opinion of experts in the field of the construction industry (Technical and executive specialists of the Afghanistan's Ministry of Urban Development and Housing, Technical and executive specialists of the Kabul Municipality and Omran Houlding Group). For identifying key criteria, "64" criteria have been extracted that affect the selection of modern building systems and are classified into "six" economic, qualitative, social, environmental, executive and technical groups. A comprehensive study conducted through the distribution of questionnaires. The collected data were analysed using SPSS statistical software; the main criteria ranked by using "Friedman's statistical test". Based on the results of statistical tests, 18 criteria were determined and ranked as fundamental criteria. Therefore, paying attention to these criteria for the selection of appropriate construction methods for modern building systems can help experts in the country of Afghanistan.

1 Introduction

The new methods of the building is a relatively new term that used to reflect the technical advances in housing forecasting. Kamali et al. [1] and Ren et al. [2] found that different construction methods influence project performance in various ways and impact on the productivity of construction projects; deficient methods decrease the productivity of projects. Furthermore, Forbes and Ahmed [3] posited that the choice of construction method significantly affects the cost, time, and quality of buildings, and adopting inappropriate methods increases the cost and duration of projects, as well as decreasing the quality and lifespan of buildings. Currently, the construction industry has been revolutionize and is experiencing changes, with the rapid growth of technology and the introduction of new building materials and modern construction methods, Harris and McCaffer [4]. Furthermore, the new generation of building regulations enacted to increase

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the efficiency and improve the quality of buildings and infrastructure, Youssef et al. [5]. As a result, construction managers, as decision-makers, have to choose appropriate construction methods from those available. Therefore, to achieve construction project performance, there is a need for adequate information and knowledge to help construction managers to make good choices of construction methods.

In this article, we found, that construction experts' opinions did not consider currently. Thus we considered the opinion of “Technical and executive specialists of the Afghanistan’s Ministry of Urban Development and Housing”, “Technical and executive specialists of the Kabul Municipality” and “Omran Houlding Group” experts in the field of the construction industry, which the organizational profile of the experts is listed on the website of those organizations. For identifying key criteria, “64” criteria have been extracted that affect the selection of modern building systems and are classified into “six” economic, qualitative, social, environmental, executive and technical groups. A comprehensive study conducted through the distribution of questionnaires.

The focus of the article is on the determination of fundamental criteria because the selection of appropriate construction methods for modern building systems can help experts in Afghanistan country.

2 Relevant works

Choosing the most appropriate method is to construct a decisive factor in achieving optimal results and high productivity. Despite this, in many cases, this activity done without the necessary consideration and inadequate study of the available options, Fakhri et al [6]. This situation can have consequences such as lack of performance in the use of resources, inappropriate use of technologies, lack of attention to the most effective option for the work and absence of reuse of previous project experience, Youssef et al [7]. Also, the selection method is a multi-criteria decision-making process, Golabchi et al [8] and it is necessary to consider decision-makers of different factors in the relevant project (such as environmental features, access to force, etc.), our goals (reduce costs, more safety, etc.) Specify and finally choose a suitable method, Lovell [9]. This requires the use of a process in which experts and project team members apply their experience to choose the most effective way [10]. "Ferrada" & "Serpell" [11] examined the different decision criteria used in the literature during the design and construction process of a project to select the most appropriate construction method. These criteria include time, cost, quality, risk, resource availability, production rate, environment, site features, security, method of construction, maintenance, etc. Chen et al [12] identified four sustainable performance measures based on the requirements of various project stakeholders. The results of this study show that social awareness and environmental concerns are very important in choosing the construction method. Also, based on the results of factor analysis of these criteria to seven dimensions, namely, economic factors: The long-term cost, manufacturing capability, in the research "Pan et. Al" [13], More than 50 criteria decision to select the construction systems developed to be the groups of cost, time, quality, health and safety, sustainability, process, procurement, and legal acceptance and regulation and classified according to the results. In order to cost, time and quality were dominant in the selection process on other criteria. In order to obtain a comprehensive view of the criteria affecting the selection of new methods of construction projects, in the present study, comprehensive research conducted on the criteria presented in related research. In table, 1, 64 the identified criteria reported along with their sources. These criteria determined by a study of relevant research, along with inputs, revisions, and changes made by experts of Afghanistan’s construction industry, and based on the opinions of experts in the country's manufacturing industry in six groups of economists, qualitative, social, environmental, executive and technical and logistics.

Table 1. Evaluation criteria for new building systems.

Criteria	No.	Sub-criteria	Source
Economical	1	Initial system construction Cost	Tam et al. (2007) [14]
	2	Design costs	Song et al. (2005) [15]
	3	Cost of the life cycle	Soetanto et al. (2004) [16]
	4	Maintenance costs	Nelms et al. (2007) [17]
	5	Structure value	Chen et al. (2010) [18]
	6	Return on investment speed	Chen et al. (2010) [19] Abd Hamid and Mohamad Kamar (2011) [20]
	7	Cost of materials and materials	Blismas and Wakefield
	8	Labor costs	(2007) [20]
	9	Impact on the cost of interface systems (ceilings, walls, etc.)	Blismas and Wakefield
	10	Impact on the costs of related items (required changes to the site, scaffolding, elevator, etc.)	(2007) [20]
	11	Cost-certainty	Pan et al (2012) [13]
	12	Construction time	Balali et al. (2014) [13]
	13	Delivery times	Pan et al (2012) [13]
	14	Uncertainty of time	Pan et al (2012) [13]
Qualitative	15	Compliance with construction regulations	Pan et al(2012) [13]
	16	Building Control in the construction process	Pan et al (2012) [13]
	17	Defects (in delivery)	Chen et al. (2010) [10] Pan et al (2012) [13]
	18	Satisfaction and hire customers to design	Pan et al (2012) [13]
	19	flexibility (adaptability)	Pan et al (2012) [13]
	20	Structural resistance	Ferrada and Serpell (2014) [11]
	21	Seismic resistance	Ferrada and Serpell (2014) [11]
	22	Resistance against fire	Balali et al (2014) [21]
	23	The possibility of retrofitting in the future	Balali et al (2014) [21]
	24	Performance of building lifecycle	Pan et al (2012) [13]
	25	Durability	Chen et al. (2010) [10]
Social	26	Safety and Health Concerns for Workers	Chen et al. (2010) [10] Chen et al. (2010) [18]
	27	Residents' health (indoor air quality)	Pan et al(2012) [13]
	28	Impact on the labor market	Chen et al. (2010) [10]
	29	Physical space	Chen et al. (2010) [10]
	30	Beauty Options	Chen et al. (2010) [10]
Environmental	31	Energy consumption in design and construction	Chen et al. (2010) [10] Tam et al. (2007) [14]
	32	Consumption of materials	Chen et al. (2010) [16]

Criteria	No.	Sub-criteria	Source
	33	Waste production	Chen et al. (2010) [10] Pan et al (2012) [13]
	34	Production of pollution	Chen et al. (2010) [10] Chen et al. (2010) [18]
	35	Energy efficiency when using the building	Chen et al. (2010) [10] Chen et al. (2010) [18]
	36	Recyclability in the industry	Jaillon and Poon (2008) [22]
	37	Adaptation to climatic and environmental conditions	Chen et al. (2010) [10] Chen et al. (2010) [18]
Executive and Technical	38	Design repeatability and standardization	Gibb and Isack (2001)[23] Song et al. (2005) [15] Pan et al (2012) [13] Chen et al. (2010) [18]
	39	Executable (build)	Chen et al. (2010) [10]
	40	Ease of implementation	Balali et al (2014) [21]
	41	Design flexibility	Gibb and Isack (2001) [23]
	42	Use in future projects	Pan et al (2012) [13]
	43	Height limitation	Pan et al (2012) [13]
	44	Structural Weight	Ferrada and Serpell (2014) [11]
	45	production capacity	Pan et al(2012) [16]
Procurement / logistics	46	Supply chain (transfer from the factory to site and inside the site, warehouse, etc.)	Chen et al. (2010) [10] Abd Hamid and
	47	Ease of site coordination (e.g., mechanic and Electric)	Hamid & Kamar (2011) [24]
	48	Planning and honesty to site	Pan et al (2012) [13]
	49	Building Services Integration	Pan et al (2012) [13]
	50	The availability of local localization companies	Pan et al (2012) [13]
	51	Qualified workers	Chen et al. (2010) [10]
	52	Availability of equipment for installation and commissioning	Chen et al. (2010) [18]
	53	Required Force	Ferrada and Serpell (2014) [11]
	54	System Market Availability	Pan et al (2012) [13]
	55	Previous manufacturer Experience	Pan et al (2012) [13]
	56	Manufacturer/vendor competence and capability	Pan et al (2012) [13]
	57	Contractual risk	Pan et al (2012) [13]
	58	Depending on specific machines	Balali et al (2014) [21]
	59	The space required to build structures	Youssef et al (2005) [5]
	60	Execution expertise, and the need for expert workforce	Soetanto
	61	Country record	et al. (2007) [18]
	62	Fit into the architecture of the country	

Criteria	No.	Sub-criteria	Source
	63	Seasonal and seasonal restrictions on system use	Pan et al (2012) [13]
	64	Permission and Restriction of Transportation and Pre-Elements (Delivery Logistics)	Pan et al (2012) [13]

3 Research method

The present study was conduct in descriptive-survey research. The required data is collected through a literature review related to the subject and field studies. The statistical population of the present study is experts and decision-makers, including consultants and contractors of contractor companies and active consultant engineering in the field of building industry located in Kabul City. According to the wider population, the size of the appropriate statistical sample for this study based on Cochran's sampling formula, which was 96 to determine the sample size in unlimited communities. The required data obtained from distributed questionnaires among the samples. To determine the criteria for critical selection in the evaluation of new construction systems from among 64 identified criteria and their ranking, a questionnaire with a range of five “Likert options” developed and the experts asked to determine the importance of each criterion by choosing the appropriate option. Both experts of all ranges of experience confirmed the questionnaire’s validity. The Cronbach's alpha confirmed by the questionnaire to assess its reliability using SPSS software (0.903) and since it was more than (0.7). The collected data analyzed through questionnaires using descriptive and inferential statistic tools. In order to determine the criteria of critical selection from the initial criteria, the parametric T-student and “Wilcoxon non-parametric tests” used in SPSS software at a 5% error level. “Friedman statistical test” used to evaluate the final ranking criteria.

4 Research findings

Descriptive analysis of demographic characteristics of respondents showed that more than 50% of them have work experience more than 10 years in the construction of new construction systems and more than 60% of respondents have postgraduate and doctoral education. In the inferential analysis, the statistical hypothesis associated with each criterion of the questionnaire defined in the same way: “These criteria for selecting the most appropriate method of buildings in the country are very important, and it is considered as fundamental criteria”. Considering that in the questionnaire with experts and professors, the scale of five “Likert” options used, the Test Value for measuring assumptions equals four considered. First, the data need to be test for normality or non-normality. For this purpose, the “Kolmogorov-Smirnov test” (K-S) is used. Then, the t-student parametric test used to test the hypotheses if the hypothesis not rejected; otherwise, the Wilcoxon nonparametric test is used. The Null hypothesis of these tests defined as the mean (for the parametric test) or the median (for the nonparametric test) is bigger or equal than "4". If the value of the "P test" is more than the intended error level (0.05), then criteria accepted as a fundamental and effective criterion in selecting the most appropriate method of building in the country. The results of the normal data analysis using the "K-S" test showed that, except three criteria for maintenance costs, physical space and ease of site coordination, other criteria did not follow the normal distribution (P-value <=0.05) and it is necessary to check their critical use of nonparametric tests. In order to summarize the paper, the test results "K-S" have not reported. In Tables 2 and 3, the results of the "Wilcoxon" single-sample test and one-sample "T-Test" were reported. Critical selection criteria highlighted in these tables. As we can see, 18 criteria selected as critical criteria for assessing and selecting new construction systems with experts and experts in the country.

Table 2. One-sample "T-test" results for data with normal distribution.

Criteria	No.	Sub-Criteria	Mean	SD	T-Value	P-Value
Economic	4	Maintenance costs	2.99	1.395	-7.09	0
Social	29	Physical space	2.979	1.407	-7.08	0
Procurement / Logistic	47	Ease of site coordination	3.01	1.41	-6.87	0

Table 3. One-sample "Wilcoxon test" results for non-normal data.

Criteria	No.	Sub-Criteria	Wilcoxon statistic	P-Value	Estimated Median
Economical	1	Initial system construction Cost	1400	0.002	3.5
	2	Design costs	1120	0.018	4
	3	Cost of life cycle	184.5	0	3
	5	Structure value	336	0	3
	6	Return on investment speed	936	0	3
	7	Cost of materials	3465	1	5
	8	Labor costs	1764	0.989	4.5
	9	Impact on the cost of interface systems (ceilings, walls, etc.)	480	0	3
	10	Impact on the costs of related items (required changes to the site, scaffolding, elevator, etc.)	1313.5	0.002	3.5
	11	Cost-certainty	575	0	3.5
	12	Construction time	2520	1	4.5
	13	Delivery times	344	0	3
	14	Uncertainty of time	480	0	3
Quantitative	15	Compliance with construction regulations	2537	0.961	4
	16	Building Control in the construction process	147	0	3
	17	Defects (in delivery)	1188	0.006	4
	18	Satisfaction and hire customers design	841	0.021	4
	19	flexibility (adaptability and adaptability)	1037	0.043	4
	20	Structural resistance	2814	0.996	4.5
	21	Seismic resistance	3394.5	1	5
	22	Resistance against fire	1419	0.978	4
	23	The possibility of	966	0	3.5

Criteria	No.	Sub-Criteria	Wilcoxon statistic	P-Value	Estimated Median
		retrofitting in the future			
	24	Performance of building lifecycle	144	0	3.5
	25	Durability	2848	0.999	4.5
Social	26	Safety and Health Concerns for Workers	1171.5	0.007	4
	27	Residents' health (indoor air quality)	1650	0.014	4
	28	Impact on the labor market	51	0	3
	30	Beauty Options	211.5	0	3.5
Environmental	31	Energy consumption in design and construction	2251.5	0.969	4
	32	Consumption of materials	782	0	3
	33	Waste production	1548	0.807	4
	34	Production of pollution	1924	0.928	4
	35	Energy efficiency when using the building	1138.5	0	3.5
	36	Recyclability in the industry	1120	0	3.5
	37	Adaptation to climatic and environmental conditions	1512	0.032	4
Executive and Technical	38	Design repeatability and standardization	900	0	3
	39	Executable (build)	2937	0.999	4.5
	40	Ease of implementation	3036	1	4.5
	41	Design flexibility	1206	0	3.5
	42	Use in future projects	476	0	3.5
	43	Height limitation	660	0.988	4
	44	Structural Weight	1435	0.914	4
	45	production capacity	1120	0.027	4
Procurement / Logistic	46	Supply chain (transfer from the factory to site and inside the site, warehouse, etc.)	1040	0.031	4
	48	Planning and honesty to site	783	0.029	4
	49	Building Services Integration	423	0	3
	50	The availability of local localization companies	2866.5	0.999	4.5

Criteria	No.	Sub-Criteria	Wilcoxon statistic	P-Value	Estimated Median
	51	Qualified workers	198	0	3
	52	Availability of equipment for installation and commissioning	2610	0.999	4.5
	53	Required Force	52.5	0	3
	54	System Market Availability	1105	0.002	3.5
	55	Previous manufacturer Experience	200	0	3.5
	56	Manufacturer/vendor competence and capability	1239.5	0.016	4
	57	Contractual risk	575	0.004	3.5
	58	Depending on specific machines	157.5	0	3
	59	The space required to build structures	112.5	0	3
	60	Execution expertise, and the need for expert workforce	3412.5	1	5
	61	Country record	423	0.002	3.5
	62	Fit into the architecture of the country	1258	0.029	4
	63	Seasonal and seasonal restrictions on system use	627	0.003	3.5
	64	Permission and Restriction of Transportation and Pre-Elements (Delivery Logistics)	0	0	3.5

Finally, in order to complete the study, 18 basic criteria affecting the selection of new construction systems compared with the "Friedman statistical test". The results of this test reported in tables “4” and “5”. Since the significance level of the test statistic is less than (0.05), there is a significant difference between these criteria and therefore the ranking is significant. “Figure 1” shows the final ranking of fundamental criteria in selecting new methods of building projects.

Table 4. The “Friedman test” results for significant evaluation of criteria differences.

Chi-Square	85.877
Degrees of Freedom	17
Significance (sig.)	0.000

Table 5. The Friedman test results for ranking criteria.

Rating	Friedman average rating	Criteria
1	11.42	Cost and material

Rating	Friedman average rating	Criteria
13	8.84	Labor cost
4	10.17	Construction time
11	9.12	Compliance with construction regulations
8	9.81	Structural resistance
3	10.81	Seismic resistance
15	8.39	Resistance against fire
7	9.85	Durability
12	9.07	Energy consumption in design and manufacture
17	8.11	Waste production
14	8.8	Pollution production
5	10.01	Executive capability
6	9.91	Ease of execution
18	8.01	Height limit
16	8.21	Structure weight
9	9.79	The availability of local localization companies
10	9.66	Availability of equipment for installation and commissioning
2	11.03	Expertise implemented, and requires expert force

The Friedman test results for ranking criteria reported in "Tables 5".

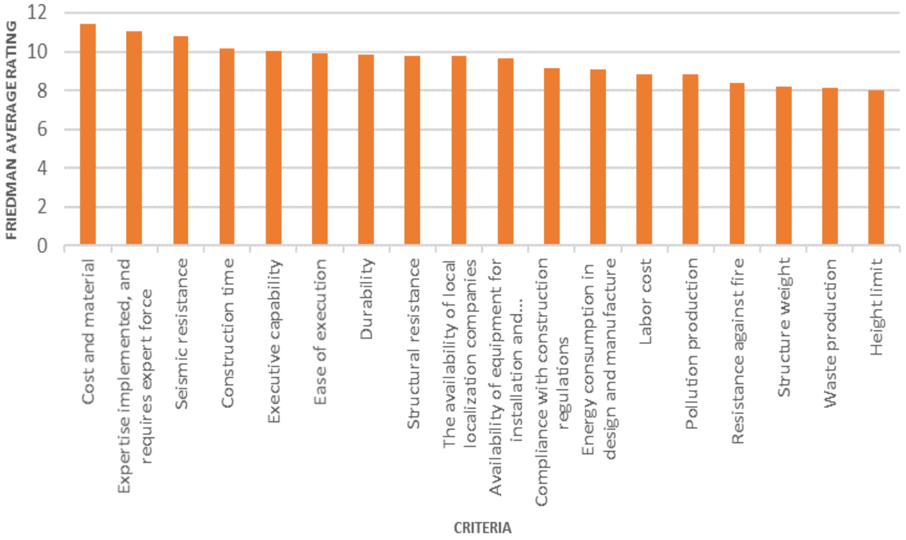

Fig. 1. The final ranking of fundamental criteria in the selection of new methods of construction projects.

The final ranking of fundamental criteria in selecting new methods of building projects shows in "Figure 1".

7 Conclusion

In this study, the criteria of critical selection for the use of new construction systems in the country's manufacturing industry identified, evaluated and ranked. Based on the findings of the study, among 18 critical criteria identified, the cost of materials and materials, expertise in implementation, the need for human resources specialist and seismic resistance, according to the technical expert's opinion in the country's manufacturing industry, they have the first rank to the third rank. Therefore, paying attention to these criteria for the selection of appropriate construction methods for modern building systems can help experts in the country. Finally, it suggested that in future research, a more comprehensive study conducted to consider the views of other experts and experts in the country's manufacturing industry. Further studies suggest to be compare the new building systems with the help of multi-criteria decision-making techniques and considering the developed criteria in this study.

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