Key Performance Criteria Influencing the Selection of Construction Methods Used for the Fabrication of Building Components in the Middle East

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Abstract

There is a lack of an efficient systematic approach to the selection of appropriate construction methods for building projects. Not only various innovative methods are now available, but also established methods may often be adapted inappropriately, without recourse to the necessary scientific foundation of their efficiency. The result is that there is a low level of performance on building projects. This study examines how key performance criteria were used in the selection of construction methods on projects. The study employed an extant review of the literature, cross-section survey of construction managers of building projects and experts interview in the Middle East to identify and evaluate the influencing of the key performance criteria on selecting construction methods for building projects. It emerged from the Pearson Correlation Coefficient and Analytical Hierarchy Process analysis that key performance criteria consisting of time, quality, and cost have strong positive significant roles in the selection of construction methods used on building projects and that these selection criteria differed depending on the building components. The study concludes that the likelihood of a construction method being selected for use on projects in the Middle East depends on its ability to shorten the duration, improving the quality and reduce the cost of projects.

Keywords: analytical hierarchy process (AHP), building project, construction method, Middle East, Pearson correlation coefficient, performance criteria

1. Introduction

In the construction of buildings, there are common problems and challenges of a low level of productivity and efficiency. According to Wambeke et al. [1], 58% of building construction projects exceed the scheduled time, and 15 out of 20 projects exceed their original approved budgets. Kamali et al. [2] and Ren et al. [3] 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 [4] posited that the choice of construction method significantly impacts on 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 revolutionized and is experiencing changes, with the rapid growth of technology and the introduction of new building materials and modern construction methods [5]. Furthermore, the new generation of building regulations has been enacted to increase the efficiency and improve the quality of buildings and infrastructure [6]. As a result, construction managers, as decision makers, have to choose appropriate construction methods from those available. Therefore, to achieve construction project performance objectives, there is a need for adequate information and knowledge to help construction managers to make good choices of construction methods.

This research examines the selection of construction methods and materials on building projects in the Middle East by using the Pearson correlation coefficient (PCC) and the analytical hierarchy process (AHP) to determine the weight and influence of each key criterion. The PCC and AHP are also helpful to consider as the total weight of different construction methods used in the fabrication of selected building components. The AHP is an effective mathematical method used in solving multicriteria decision-making problems [7]. It has been applied to many decision-making problems related to construction management. However, AHP is unable to handle the inherent subjectivity and ambiguity associated with the mapping of an individual's perception to an exact number [8]. In this condition, the Pearson correlation coefficient (PCC) analysis is applied in verifying the AHP weight by measuring the relationship between the key criteria used in the selection and the level of use of each construction method.

The focus of the study is on the construction of buildings because these are the most common types of construction projects that make use of a wide variety of methods and components. With adequate knowledge and comprehensive data, the most suitable construction method, complementing the objectives, and condition of the project, can be selected.

2. Literature review

2.1. Overview of construction methods and key performance criteria

The construction method is a technical procedure to transform construction resources (materials, workforce, and equipment) into constructed products [9]. According to Haidar [10], the construction methods adopted affect the work activities and the work sequence. Construction planning and management techniques are without value if construction methodologies

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are not selected appropriately and if those selected are not optimal [11]. Each construction method has different specifications and aspects. Information such as cost, time, quality, ease of construction, and availability of method and skill is used by construction managers in the selection and use of appropriate construction methods on construction projects [12].

According to Monghasemi et al. [13], shorter time, lower cost, and higher quality are the primary project objectives which should be considered in the selection of construction methods. However, among these three primary factors, cost and quality are single dimension elements; this means that choosing the method with less cost, or with higher quality, will not guarantee or improve the other influencing factors. Time is a multidimensional element; choosing the method with a shorter construction time will reduce the labor cost and the error caused by labor [13, 14].

Ferrada and Serpell [15] posited that it is important to consider other parameters, such as the availability of materials in the market, the supply of a skilled workforce, ease of transportation, and ease of implementation; these all impact on the project objectives. The above suggests that selecting suitable construction methods depends on understanding the outcome of each method in relation to the final project outcome. Therefore, in this study, the impact and effect of each primary construction project performance criterion (cost, time, and quality), combined with ease of construction and the availability of method and skill, focus on six common components of buildings: the foundation, the frame of the structure, the roof, the wall, the flooring, and the façade. This effect applies to all buildings, regardless of their size and type.

The factor called “ease of construction” concerns the use of less intensive labor on construction sites to reduce the duration of construction and concomitant labor cost; however, the material cost of this method may be higher than those of more established construction methods [16].

2.2. Overview of the use of analytical hierarchy process and Pearson correlation coefficient in multicriteria decision analysis in selecting construction methods and materials

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It is a multicriteria decision-making approach [17]. In construction management, many decisions are made based on various criteria such as time, cost, and quality; thus, these decisions could be made by construction experts by assigning weights to the different criteria. It is important to determine the structure of the problem and explicitly evaluate the many criteria. The AHP method has been used in various areas of construction management. For instance, Sangiorgio et al. [18] measured the relative project performance among a set of criteria; Ng [19] evaluated environmental benefit of building designs using a weighting AHP; Hossaini et al. [20] assessed the lifecycle sustainability of a six-story wood frame and concrete frame buildings (respectively) in Vancouver; Wong and Li [21] analyzed the selection of intelligent building systems in Hong Kong; Pan [22] used a multi-criteria decision model to select the most suitable bridge construction method in China; Zayed et al. [23] evaluated the highway construction projects risks in China;

Shapira and Goldenberg [24] created an equipment selection model for construction projects; Al-Harbi [25] evaluated the problem of contractor prequalification; and Skibniewski and Chao [26] measured the technical and economic factors of the selection process of a tower crane in construction projects.

However, there is limited research undertaken involving the use of multicriteria models as a basis for the selection of construction methods using the key performance criteria. Reza et al. [27] used the AHP as a tool to assess the sustainability of floor systems in the city of Tehran. In a similar approach, Nadoushani et al. [28] utilized AHP to select façade systems for a building, based on criteria of sustainability. Hosseini et al. [29] used a simple scoring aggregation procedure, combined with the AHP method, to select the unsurpassed types of exterior walls to reconstruct in earthquake areas; Akadiri et al. [30] applied a multicriteria evaluation model for the selection of sustainable roofing materials for building projects in the United Kingdom. In all these studies, the AHP method was used for selecting only one component of the building, reflecting its particular characteristics. Even though AHP has been used for tackling multicriteria decision-making problems, it is required to validate the weight value of the criteria because of the discrete scale used in AHP, which cannot handle the uncertainty and ambiguity present in deciding the priorities of different attributes [31]. Therefore, the correlation coefficient analysis is commonly used in construction research to validate the research results and to measure the relationship between two random variables [32].

The Pearson correlation coefficient (PCC) has been used to determine and validate the relationship between different variables in construction projects, such as the relationship between total project cost and total material cost; between uncertainty factors and risk contingency value; between intelligence attributes of the Integrated Building Management Systems (IBMS) and the operational benefits; and between productivity and safety performance [21, 33–35].

3. Research objectives

The primary purpose of this study is to evaluate the key performance criteria influencing the selection of construction methods, which are currently being used on building projects in the Middle East and whether the selection criteria differ according to building components. According to Ferrada and Serpell [15], selecting appropriate construction methods based on their performance objectives is a contemporary topic in construction management that is progressing and expanding gradually. This technique involves evaluating, classifying, and suggesting the most appropriate construction method that best fits the project conditions [36]. There is limited research that examines the selection of construction methods for fabrication of different building components; most of the existing AHP models [27, 28, 30, 37] employ only one building component, such as the wall, the roof, or the floor. Therefore, this research examines the key performance criteria (time, cost, quality, ease of construction, and availability of method and skill) affecting the selection of 28 construction methods used in the fabrication of 6 building components, by employing multicriteria models as a basis for matching construction methods to performance criteria.

The novelty of this research is in the selection of construction methods for six different building components based on the five performance criteria, which are not only very complex issues due to involving a multi-criteria decision, but also some of these criteria may also influence some additional problems. Therefore, this research presents an AHP approach to determine the weight of the five key performance criteria in the selection of construction methods, for six main building components, and validates the key criteria weight of the construction method, through a PCC statistical analysis.

This approach is straightforward and provides the total weight value of the different performance criteria, which impacts on the selection of construction methods. It also provides a holistic overview of the most important criteria for construction managers and engineers, who are the decision makers on the building project.

4. Research method

The study made use of a sequential mixed-method research approach in evaluating the selection of construction methods currently adopted in the Middle East and in determining the contribution and relationship between the key performance criteria and the level of use of identified construction methods, differentiated by building components. First of all, the research identifies common construction methods that are currently employed on projects in the Middle East. To do this, the information on construction methods used was gathered and classified based on data obtained from construction industry experts. Secondly, the influence and significance of each performance criterion in selecting construction methods used on the building projects were obtained from the data collected from questionnaires. The questionnaires were completed by construction managers on 200 building projects in five countries, namely Iran, United Arab Emirates, Turkey, Egypt, and Qatar. The construction managers had different work experience and levels of education, as classified in **Tables 1** and **2**. Each questionnaire consisted of two parts:

Part 1 sought demographic information related to the construction manager.

Part 2 sought information concerning the construction methods and criteria used in the selection of each construction method used on the project.

The study also sought to know the perceptions of the construction managers regarding the performance in terms of cost, time, quality, ease of construction, and availability of the method/skill of the identified construction methods, on a scale of 1–3, where 3 = High, 2 = Moderate, and 1 = Low. If all respondents scored the performance of the construction method as 3, it was recorded as High (see **Table 4**); also when $2 < 3$, it was recorded as Moderate performance, while scores of less than 2 were classified as Low.

The data were also analyzed using descriptive and inferential statistics, consisting of the analytical hierarchy process (AHP) pair-wise comparison and the Pearson correlation coefficient (PCC) analysis. The AHP weight of each performance criterion and a total weight of available construction methods in the different building components were determined using Expert

Choice Version 11.5. To validate the AHP weight values and determine the extent of the relationship between the criteria used in the selection of the construction methods and the level of use of the construction methods on building projects, the Pearson correlation coefficient (PCC) analysis was conducted using IBM SPSS Statistics version 23. The most commonly used correlation coefficients in construction research are Spearman's rank correlation coefficient and the Pearson correlation coefficient [38]. The Pearson correlation coefficient is a measure of the strength of the linear dependence between random variables, while Spearman's rank correlation coefficient is a nonparametric measure of statistical dependence between two variables and is an indication of correlation between ranks of the values of random numbers instead of correlation between values [39]. Therefore, in this research, the Pearson correlation coefficient is preferred over the Spearman's rank correlation coefficient, since Pearson is the correlation between variates, while Spearman is the correlation between the ranks of the variates.

Tables 1 and **2** indicate that 81% of the respondents have more than 5 years of work experience in the construction industry and that 77% of respondents hold a university degree. The levels of education and work experience the respondent has in the construction sector are of relevance to the study because the higher the education level and work experience of the respondent the better the credibility and reliability of the information provided via questionnaires which focus on their knowledge of construction management and methods.

Reliability in quantitative research indicates that the scores received from the respondents are consistent and stable over time; reliability is often assessed through reliability coefficients [40]. In order to check that the collected data and scores were reliable, a statistical analysis was made of the reliability and internal consistency of the data. These data had been provided by the 200 respondents on the key project performance criteria, which influenced the selection of construction methods for projects. To do this, the Cronbach's alpha coefficient of each criterion and the internal consistency ratio of the overall influencing criteria were calculated. The values of Cronbach's alpha that are commonly used to determine the internal reliability, consistency, and co-variation among variables related to the measurement of each construct often range from 0 to 1 [41]. The results of the test showed that dependency among the five identified criteria was equal to 0.838, which indicates a high reliability and internal consistency of data collected across the five criteria. Also, Cronbach's alpha coefficients of each

Years of experience	Individual percentage					Overall percentage (%)
	Iran (%)	UAE (%)	Turkey (%)	Egypt (%)	Qatar (%)	
<5	18	16	20	23	17	19
6–10	34	38	32	33	36	35
11–15	28	24	25	23	29	26
16–20	9	13	14	11	10	11
>20	11	9	9	10	8	9

Source: Researcher's field survey.

Table 1. Respondents' work experience.

Level of education	Individual Percentage					Overall percentage (%)
	Iran (%)	UAE (%)	Turkey (%)	Egypt (%)	Qatar (%)	
Vocational degree	19	24	25	26	23	23
Bachelor degree	54	55	57	62	60	58
Postgraduate degree	27	21	18	12	17	19

Source: Researcher's field survey.

Table 2. Respondents' education level.

	Cronbach's alpha
Cost	0.829
Time	0.783
Quality	0.762
Ease of construction	0.768
Availability of method and skill	0.868

Table 3. Cronbach's alpha coefficient of each influencing criterion.

criterion were greater than 0.7, which indicate sufficient reliability and internal consistency of the data collected for each criterion, as illustrated in **Table 3**.

5. Data presentation and analysis

This research evaluates five criteria (cost, time, quality, ease of construction, and availability of method/skill), which influence the selection of construction methods on building projects. **Table 4** summarizes and evaluates the types of construction methods used, distributed by the number of projects, and the perceived performance attributes of each construction method.

Table 4 indicates the characteristics of each construction method, in terms of technology, three primary factors (cost, time, and quality) and two combinational influential factors (ease of construction and availability of method and skill), which influence the selection of construction methods on building projects. Each method was evaluated based on the technology utilized in two categories of the conventional method and modern innovative method. Furthermore, the cost (material cost and labor cost) [42], time (construction duration), quality, ease of construction, and availability of method and skill of each method are evaluated in three classes, namely low, moderate, and high.

It can be seen from **Table 4** that the common construction methods used in the foundation, structure, roofing, wall, façade, and flooring of the projects studied are steel formwork, concrete framed structure, steel decking, Leca blocks, composite façade, and laminate flooring, respectively. However, **Table 4** also shows that the construction methods with a perceived

Method	Number of projects	Technology	Cost	Time	Quality	Ease of construction	Availability of method and skill	Overall performance
Foundation								
Steel formwork	106	Innovative	High (85)	High (100)	High (80)	High (50)	High (20)	High
Brick formwork	54	Conventional	Low (50)	Low (40)	Low (8)	Low (45)	High (25)	Low
Wood formwork	22	Conventional	Low (5)	Moderate (5)	Low (2)	Moderate (20)	High (15)	Moderate
Cement hollow block (CHB) formwork	18	Conventional	Moderate (15)	Low (18)	Moderate (10)	Low (5)	High (5)	Moderate
Structure								
Concrete frame structure	88	Conventional	Low (85)	Low (65)	Moderate (80)	Low (25)	High (30)	Moderate
Bolted steel frame structure	56	Conventional	Moderate (45)	Moderate (55)	Moderate (40)	Moderate (50)	Moderate (15)	Moderate
Welded steel frame structure	45	Conventional	Moderate (35)	Moderate (44)	Moderate (30)	Low (30)	High (20)	Moderate
Light steel frame structure (LSF)	11	Innovative	High (5)	High (10)	High (6)	High (11)	Low (0)	High
Roofing								
Steel decking	76	Innovative	High (65)	High (75)	High (70)	High (30)	High (25)	High
Reinforced concrete slab (one/two way)	33	Conventional	High (0)	Low (0)	Low (10)	Low (5)	High (30)	Low
Polystyrene inter-Joist	29	Conventional	Low (20)	High (25)	Moderate (10)	High (10)	High (5)	High
Hollow core	26	Conventional	Moderate (15)	Moderate (25)	Moderate (20)	Moderate (10)	High (5)	Moderate
Double tee	22	Innovative	Low (20)	High (15)	High (15)	High (10)	Moderate (5)	Moderate
Cobiax	14	Innovative	Moderate (10)	Moderate (12)	Moderate (10)	Moderate (5)	Moderate (0)	Moderate

Method	Number of projects	Technology	Cost	Time	Quality	Ease of construction	Availability of method and skill	Overall performance
Wall								
Leca block	90	Innovative	Moderate (75)	High (75)	High (85)	High (45)	Moderate (35)	High
Autoclaved aerated concrete (AAC) block	58	Innovative	Moderate (45)	Moderate (50)	High (55)	High (35)	Moderate (20)	High
Clay hollow blocks	30	Conventional	Low (30)	Low (15)	Low (10)	Low (25)	High (10)	Moderate
Silica block	16	Innovative	High (10)	High (10)	High (15)	High (9)	Moderate (0)	High
Cement hollow blocks	6	Conventional	Moderate (0)	Low (0)	Moderate (0)	Low (5)	High (6)	Moderate
Façade								
Composite façade	81	Conventional	Moderate (80)	Moderate (76)	Moderate (60)	Moderate (40)	High (10)	Moderate
Stone façade	56	Conventional	Moderate (20)	Low (15)	Moderate (55)	Low (5)	High (30)	Moderate
Steel façade	24	Innovative	High (5)	High (22)	High (20)	High (10)	High (0)	Moderate
Brick façade	21	Conventional	Low (15)	Low (10)	Moderate (10)	Low (20)	High (15)	Moderate
Glass façade	18	Innovative	High (5)	High (17)	High (15)	High (5)	High (5)	Moderate
Flooring								
Laminate flooring	78	Innovative	Low (75)	High (78)	High (60)	High (65)	High (20)	High
Ceramic flooring	64	Conventional	Moderate (30)	Moderate (50)	Moderate (60)	Moderate (30)	High (25)	Moderate
Stone flooring	42	Conventional	High (10)	Low (20)	Moderate (40)	Low (15)	Moderate (25)	Moderate
Parquet flooring	16	Conventional	High (0)	Low (10)	High (15)	Moderate (15)	High (0)	Moderate

Table 4. Distribution of construction methods by perceived performance attributes.

high overall performance are steel formwork, light steel frame structure (LSF), steel decking, polystyrene inter-joist, Leca block, autoclaved aerated concrete (AAC) block, silica block, and laminate flooring. By comparison, the low performing construction methods are brick formwork and reinforced concrete slab (one/two way).

Figures 1–5 show the distribution of the five key performance criteria used by the construction managers in the selection of each construction method.

It can be seen from **Figures 1–5** that from a ranking perspective, the performance criteria with the most influence on the selection of the construction methods studied are time, quality, cost, ease of construction, and availability of method and skill, respectively.

5.1. Influence of identified criteria on selection of construction methods

The study sought to know from the construction managers, the key criteria responsible for the choice of construction methods used on their projects. The influence and rank of each criterion in the selection of construction methods used in the fabrication of different components of the examined building projects are analyzed and presented in **Table 5**.

Table 5 shows that from a ranking perspective, in the foundation, structures, and roofing, the primary criterion influencing the choice of the construction method employed is time. However, in the other components consisting of the wall, flooring, and façade, quality is the key criterion influencing the selection of the construction methods used. **Table 5** also shows the overall level of influence and rank of the criteria used in the selection of construction

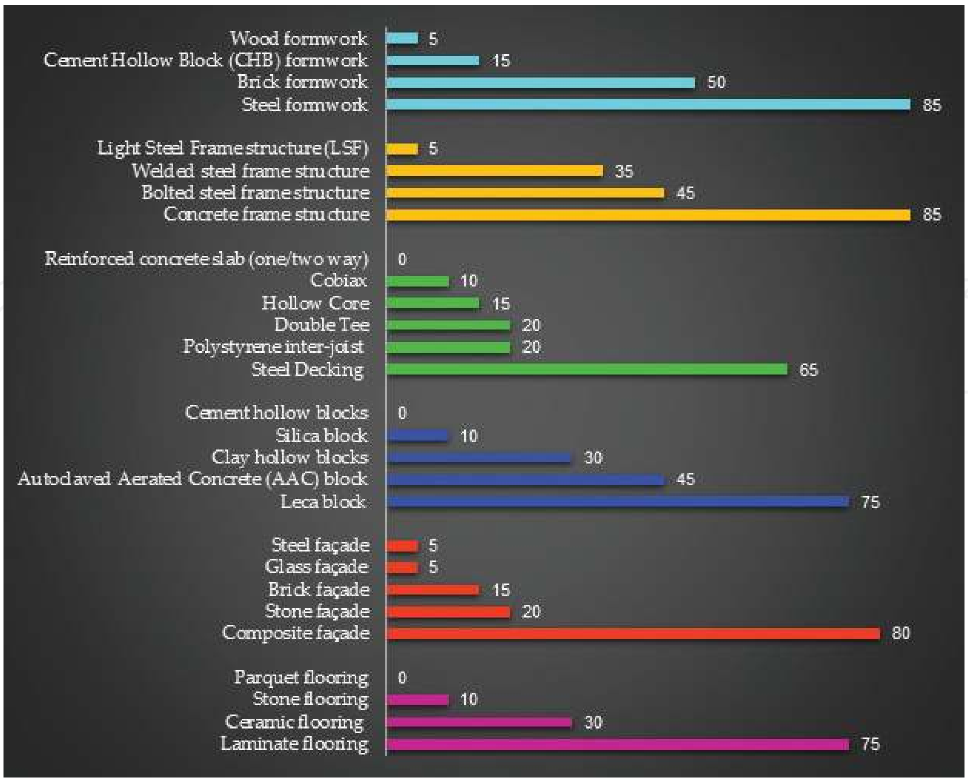

Figure 1. Distribution of cost as key performance in the selection of construction methods by construction managers.

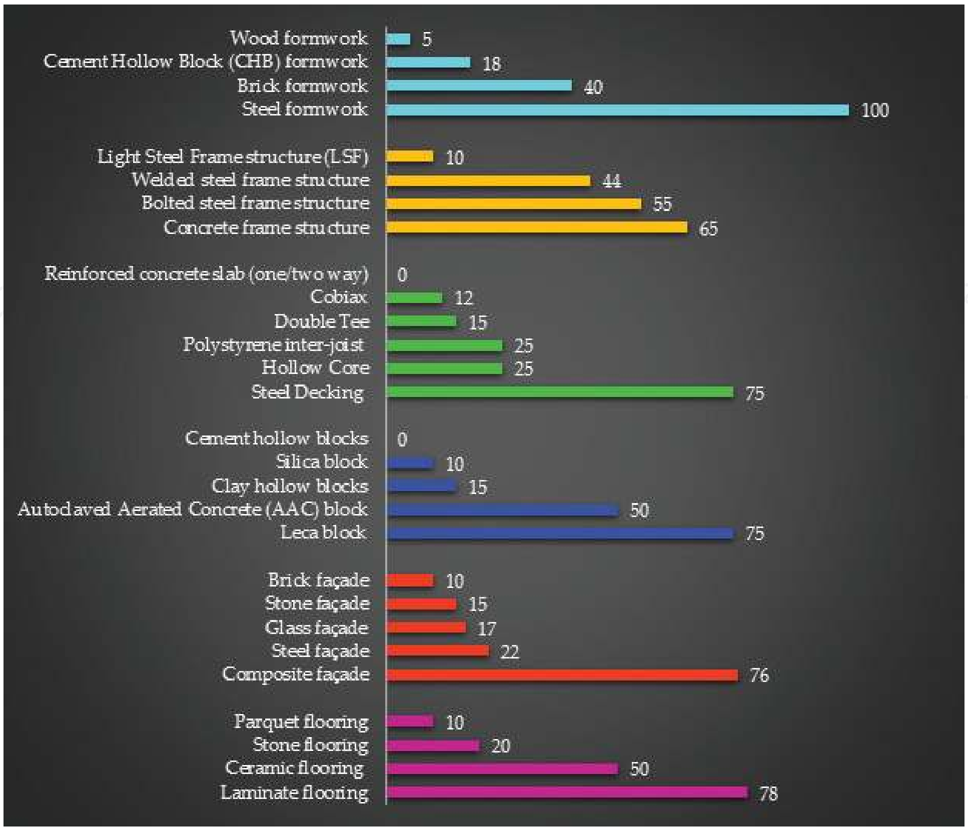

Figure 2. Distribution of time as key performance in the selection of construction methods by construction managers.

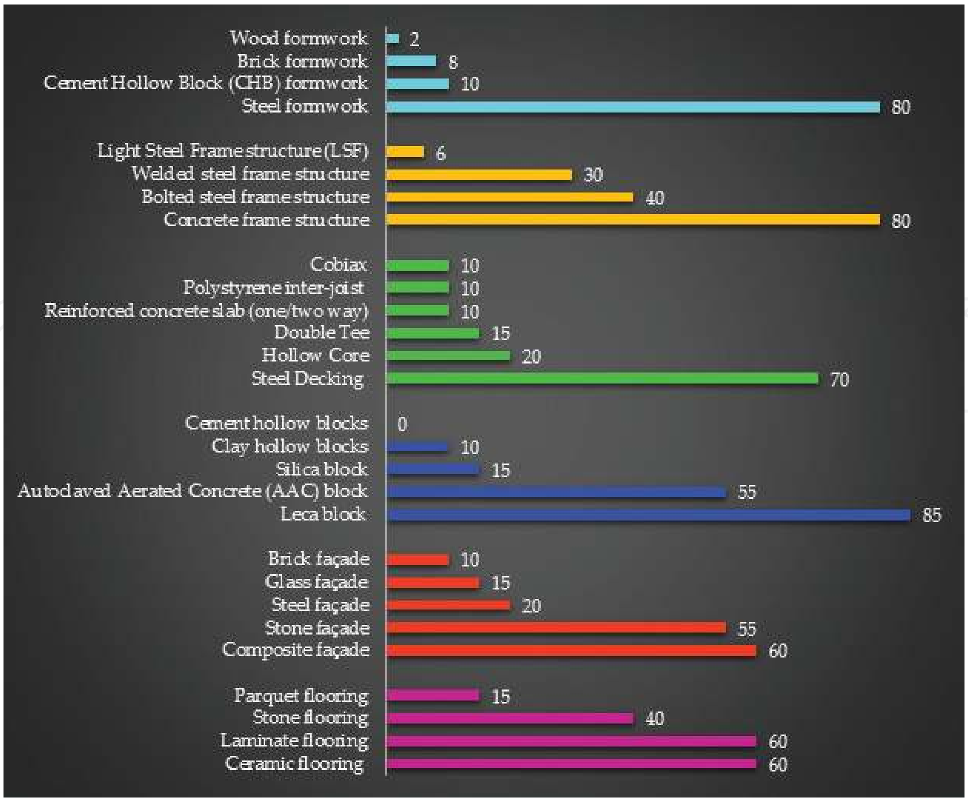

Figure 3. Distribution of quality as key performance in the selection of construction methods by construction managers.

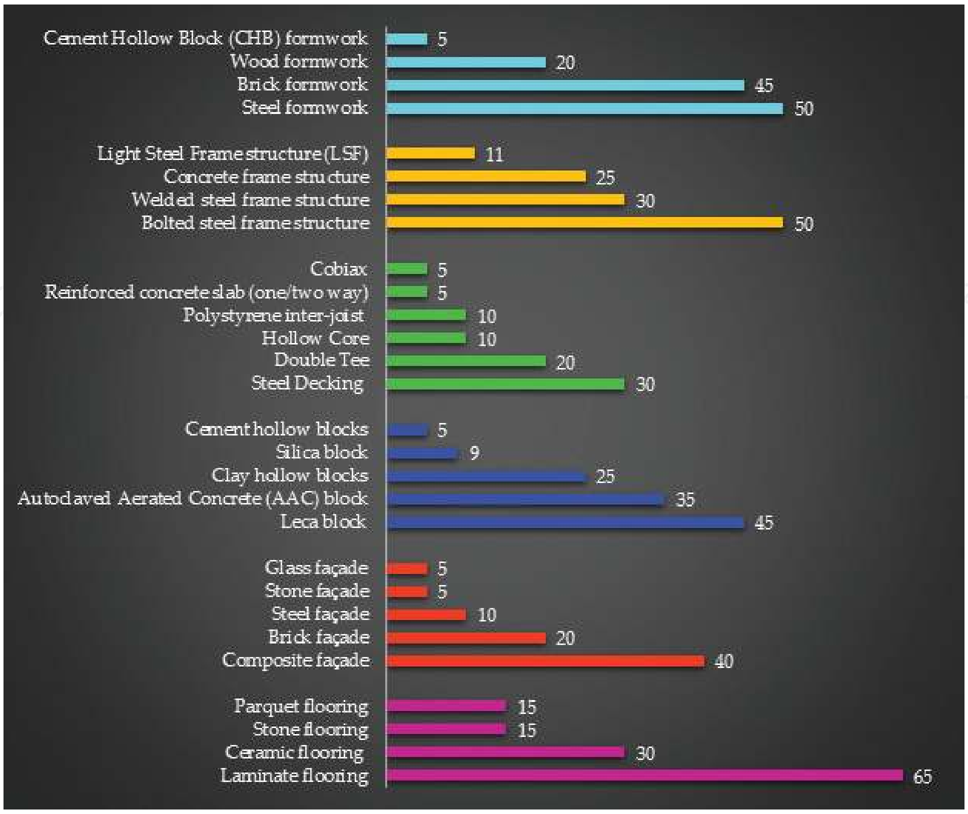

Figure 4. Distribution of ease of construction as key performance in the selection of construction methods by construction managers.

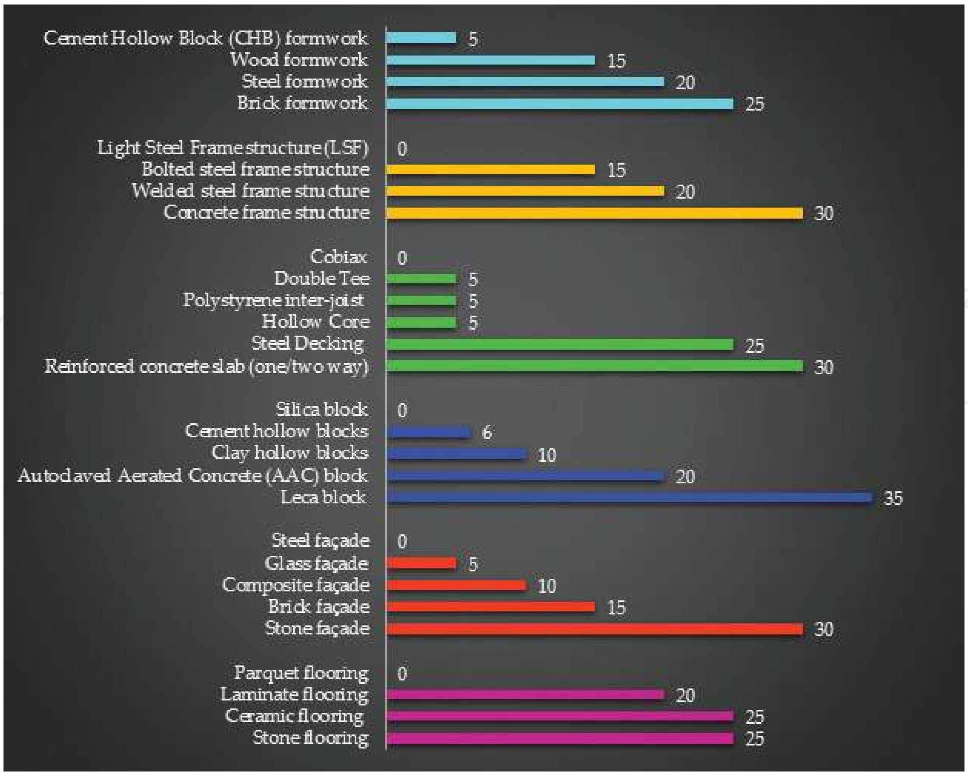

Figure 5. Distribution of availability of method and skill as key performance in the selection of construction methods by construction managers.

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	Foundation	Rank	Structure	Rank	Roofing	Rank	Wall	Rank	Façade	Rank	Floor	Rank	Overall	Rank
Cost	27.0	1	25.5	1	26.8	1	22.6	3	24.6	2	24.8	3	25.2	1
Time	25.7	2	25.0	2	22.9	3	24.1	2	17.9	4	22.1	1	23.0	3
Quality	16.6	4	22.9	3	23.8	2	24.8	1	27.2	1	28.3	1	23.9	2
Ease of construction	19.9	3	17.0	4	14.1	4	17.9	4	19.4	2	14.2	4	17.2	4
Availability of method and skill	10.8	5	9.5	5	12.4	5	10.7	5	10.9	5	10.6	5	10.8	5

Table 5. Level of influence and rank of the criteria used in the selection of construction methods, distributed by building projects.

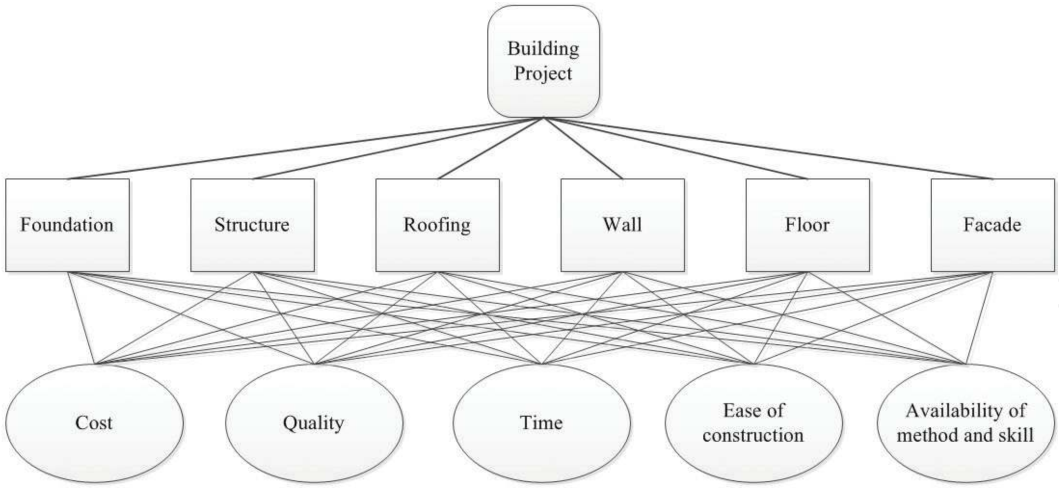

Figure 6. AHP model of the criteria influencing the selection of construction methods within building projects.

methods based on the data collected. **Table 5** indicates that time (25.2%) is the primary criterion that is most frequently used by construction managers in the selection of construction methods on building projects in the Middle East, followed by quality (23.9%), cost (23.0%), and ease of construction (17.2%), while the least used criterion is the availability of method and skill (10.8%).

5.2. Prioritizing the criteria used in the selection of construction methods used within building projects

The AHP model shown in **Figure 6** was developed to evaluate the importance of the different criteria used in the selection of construction methods (within the building components of the projects). Pairwise comparisons included cost, time, quality, ease of construction, and availability of method and skills, as shown in **Figure 6**.

The responses of construction experts, obtained in the pairwise comparisons, were used as inputs to determine the ranking of the selection criteria by each respondent. **Table 6** shows the weight and rank of the criteria used in the selection of construction methods within each building component studied, along with the inconsistency ratio in each component of construction, within the building project, from the AHP paired comparison matrix.

Table 6 shows that the inconsistency ratios of each component are less than 0.10 [43], which indicates the sufficient consistency in each matrix; therefore, all generated eigenvectors are considered. As shown in **Table 6**, it can be deduced that the construction method selection criteria weighting is in the following order at each stage:

1. Foundation time with weight value of 44.54% is more important than the other factors (cost (29.72%), quality (14.69%), ease of construction (7.31%), and availability of method and skill (3.74%)) in selecting foundation methods;
2. Structure cost with a weight value of 41.27% is the most important factor, followed by quality (24.19%), time (20.22%), availability of method and skill (10.39%), and ease of construction (3.92%), respectively;

3. Roofing quality with a weight value of 39.61% is the most important factor, followed by time and cost with weight values of 23.9 and 22.42%, ease of construction (8.21%), and availability of method and skills (5.86%);

4. Wall time and cost with weight values of 39.08 and 34.03% respectively, are the most important factors in selecting the wall methods, followed by quality (13.40%), ease of construction (7.25%), and availability of method and skill (6.25%);

5. Façade quality with a weight value of 42.45% has a significant role in the selection of the façade construction method, followed by cost (27.28%), time (17.72%), ease of construction (8.36%), and availability of method and skill (4.19%); and

6. Flooring quality with a weight value of 37.61% and time with a weight value of 32.1% have a more important influence on the selection of a flooring method, followed by cost (14.21%), ease of construction (9.84%), and availability of method and skill (6.24%).

From a ranking perspective, the expert construction managers rated the key performance criteria (weight value) according to their importance in the selection of construction methods on building projects.

Table 7 presents the overall weight value and rank of each criterion used in the selection of construction methods, based on the AHP paired comparison matrix.

As shown in **Table 7**, the inconsistency ratio is less than 0.10, and time (29.60%) is the most important criterion used in the selection of construction methods in building projects, followed by quality (28.66%), cost (28.16%), and ease of construction (7.48%), and the least important is the availability of method and skill (6.11%). It is therefore anticipated that construction methods will be selected based on the criterion of time before other considerations.

5.3. Relationship between the level of use of the construction methods and selection criteria

To validate the calculated AHP weight value of each criterion in the previous section, the association between the criteria used in the selection of the construction methods and the level of use of the construction methods on building projects is determined, using the Pearson correlation coefficient (PCC). The results of the correlation coefficients are shown in **Table 8**.

Table 8 shows that there are positive significant relationships between the criteria used in the selection of construction methods identified by the respondents, and the level of use of the construction methods, in six different building components. This indicates that as the value of the criterion used in the selection of a construction method increases, the influence of using that construction method is likely to increase and vice-versa. Touran [44] proposed following convenient system to quantify the correlation coefficients: weak 0.15; moderate 0.45; and strong 0.80. For instance, time (0.983) and cost (0.978) have a strong positive significant relationship on the selection of foundation methods, which means that an increase in the value of time and cost of a construction method (shorter duration and cheaper product) will result in an increase in the possibility of using the method and vice-versa. **Table 6** shows that quality is the most significant criterion when selecting construction methods for roofing and that all criteria are

	Foundation	Rank	Structure	Rank	Roofing	Rank	Wall	Rank	Façade	Rank	Floor	Rank
Cost	29.72	2	41.27	1	22.42	3	34.03	2	27.28	2	14.21	3
Time	44.54	1	20.22	3	23.90	2	29.08	1	17.72	3	32.10	2
Quality	14.69	4	24.19	2	39.61	1	13.40	3	42.45	1	37.61	1
Ease of construction	7.31	3	3.92	5	8.21	4	7.25	4	8.36	4	9.84	4
Availability of method and skill	3.74	5	10.39	4	5.86	5	6.25	5	4.19	5	6.24	5
Inconsistency ratio	0.06		0.07		0.02		0.02		0.04		0.04	

Table 6. Weight value and rank of the criteria used in the selection of construction methods within each component of building projects.

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	Weight value (%)	Inconsistency ratio	Rank
Cost	29.60		1
Time	28.66		2
Quality	28.16	0.04	3
Ease of construction	7.48		4
Availability of method and skill	6.11		5

Table 7. Weight and rank of criteria used in the selection of construction methods on building projects.

	Foundation	Structure	Roofing	Wall	Façade	Floor
Cost	0.978*	0.994*	0.875*	0.992**	0.902*	0.903
Time	0.983*	0.961*	0.879*	0.993**	0.814	0.953*
Quality	0.921	0.986*	0.940**	0.978**	0.960**	0.974*
Ease of construction	0.873	0.436	0.779	0.970**	0.658	0.840
Availability of method and skill	0.614	0.949	0.687	0.965**	0.390	0.734

*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

Table 8. Correlation between criteria used in the selection and level of use of the construction methods within different building components.

significant when considering construction methods for the wall components. Also, **Table 8** presents the overall association between each criterion used in the selection of construction methods and the level of use of the construction method within the sample population.

As shown in **Table 8**, time (0.933) is the most associated criterion used in the selection of construction methods within the building projects studied followed by quality (0.932) and cost (0.931). These three factors have a strong positive significant relationship with the level of use of construction methods within the building projects assessed, while the ease of construction (0.771) and availability of method and skill (0.723) have a moderate positive significant relationship with the construction methods used within the building projects.

6. Discussion of findings

The main objectives of this study were to assess the criteria influencing the selection of construction methods used in building projects and whether selection criteria differed according to building components. The collected data from expert surveys and 200 building projects were analyzed using AHP and Pearson correlation coefficient to determine the rank and weight value of each selection criterion, as well as the relationship between the criteria and

Stage	Rank	Level of influence		AHP		Correlation coefficient	
		Factor	%	Factor	Weight value	Factor	Dependency
Foundation	1st	Time	27.0	Time	44.54	Time	0.983*
	2nd	Cost	25.7	Cost	29.72	Cost	0.978*
Structure	1st	Time	25.5	Cost	41.27	Cost	0.994*
	2nd	Cost	25	Quality	24.19	Quality	0.986*
Roofing	1st	Time	26.8	Quality	39.61	Quality	0.940**
	2nd	Quality	23.8	Time	23.9	Time	0.879*
Wall	1st	Quality	24.8	Time	39.08	Time	0.993**
	2nd	Cost	24.1	Cost	34.03	Cost	0.992**
Façade	1st	Quality	28.3	Quality	27.28	Quality	0.960**
	2nd	Cost	22.1	Cost	42.45	Cost	0.902*
Flooring	1st	Quality	27.2	Quality	37.61	Quality	0.974*
	2nd	Time	24.6	Time	32.1	Time	0.953*

*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

Table 9. 1st and 2nd criteria used in the selection of construction methods in each stage of building projects.

the level of use of the construction methods within different components of building projects. Triangulating the results of the three analysis tests, as shown in **Table 9**, reveals that the AHP weight values and Pearson correlation coefficients correspond to each other in all the different stages of the building projects considered. However, the discrepancy between results in some stages (level of influence of criteria in selecting the construction method to AHP weight values and Pearson correlation coefficients) demonstrated that some of the project managers selected improper and inappropriate construction methods that were neither complement project objectives nor optimal methods. For instance, the construction method employed by project managers studied at the roofing stage was not the optimal method, due to a mismatch in the ranking of quality and time factors. In addition, construction methods selected for use in the structure and wall stages were improper and inappropriate.

The total weight value of different construction methods was achieved using perceived performance attributes of construction methods and AHP weight value of criteria in six building components. The total weight value assists decision makers in identifying the best suitable construction methods with the highest total weight value in each building component. To facilitate the comparison between construction methods within each component of building projects, the cluster bar chart of the total value of six building components was plotted in **Figure 7**.

Figure 7 shows that the best construction methods with the highest total weight value at each stage of building projects are steel framework in foundation stage with total weight value of 300, light steel frame structure (LSF) in structure stage with total weight value of 289.61, steel decking in roofing stage with total weight value of 300, Leca block in wall stage with total

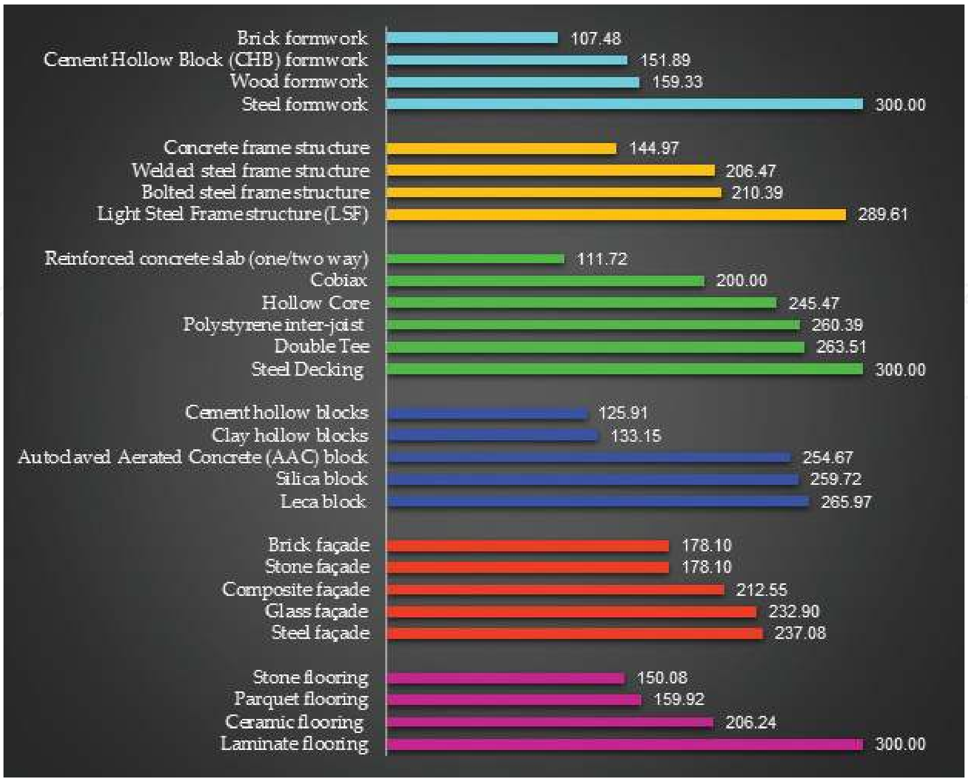

Figure 7. Total weight value of construction methods within each component of building projects.

weight value of 265.97, steel façade in the façade stage with total weight value of 237.08, and laminate flooring in the flooring stage with total weight value of 300.

The comparison between the distribution of construction methods and the total weight value of construction methods reveals that majority of the responding construction managers were not able to determine and select the best construction methods for different building components. It can be deduced that only 53% of construction managers have implemented the best construction method in the foundation stage, 5.5% in the structure stage, 38% in the roofing stage, 45% in the wall stage, 12% in the façade stage, and 39% in the flooring stage.

Table 10 shows the data analysis summary obtained from **Tables 5, 6**, and **8**, on the level of use of the criteria in the selection of construction methods, AHP weight value, and PCC relationship of each selection criterion to methods used in the overall stage of the building projects examined.

Cross-comparison of the PCC dependency results between criteria used in the selection and level of use of the construction methods (**Table 8**), with the AHP weight value of the criteria in the selection of each component of building, and the overall AHP weight value (**Tables 6** and **7**), validates the determined AHP weight values (See **Table 10**).

As demonstrated in **Table 10**, it emerged from the study that the results of three analysis tests established that the most important factor in the selection of construction methods is time, or duration of construction, with the highest level of use in the selection of construction methods, a weight value of 29.60% and a strong positive significant dependency to construction methods

	Level of influence	Rank	AHP weight value	Rank	PCC dependency	Rank
Time	25.2	1	29.6	1	0.933**	1
Quality	23.9	2	28.66	2	0.932**	2
Cost	23.0	3	28.16	3	0.931**	3
Ease of construction	17.2	4	7.48	4	0.771**	4
Availability of method and skill	10.8	5	6.11	5	0.723**	5

**Correlation is significant at the 0.01 level (two-tailed).

Table 10. Data analysis summary.

used. It can be inferred from this finding that adopting a process that has a shorter duration has two impacts on the project; first, it reduces the duration of the project, thereby decreasing the cost of the project by reducing the cost of labor equivalent to amended time [13, 14].

The second most important factor seen from **Table 10** is that quality highly influences the selection of construction methods, with a weight value of 28.66% and a strong positive significant dependency to construction method. It can be deduced that quality is the second priority of construction managers when selecting building materials and construction methods. Conversely, the new generation of building regulations and codes tends to increase the quality of buildings [6]; therefore, choosing poor quality methods and materials could lead to additional cost and time, due to failure to meet these building regulations, or owners' expectations.

Furthermore, the study found that the third factor influencing the selection of construction methods is cost, with a weight value of 28.16% and also a strong positive significant dependency to construction method (see **Table 10**). Unlike time, the cost is a single dimension element, and choosing the method or material with less cost will not guarantee or improve the other influencing factors [13]. For instance, cement hollow block (CHB) is cheaper than Leca block, but the construction time is longer and the implementation process is more difficult because the method uses more labor in the construction process and construction of the CHB wall would increase the overall cost of the project due to higher labor costs [42].

The fourth important factor influencing the selection of construction methods is the Ease of construction, with a weight value of 7.48% and moderate positive significant dependency to construction methods used. Finally, the factor with the least priority is the availability of methods and skills, with a weight value of 6.11% and also a moderate positive significant dependency on construction methods used. The data obtained provide evidence of the adequate supply of all methods and expertise in the construction market of the Middle East.

The findings of the study are consistent with those of previous studies by Noorzai et al. [45] and Monghasemi et al. [13], who acknowledge that the most important effective criterion for the selection of construction methods in building projects is time, followed by quality and cost, among other factors; Lam et al. [46] indicates that in order to enhance productivity and efficiency of building projects, a shorter time and higher quality methods, such as precast or prefabricated systems, should be employed in the construction stage of projects.

The above analysis evaluated the importance, significance, and priority of each criterion that influences the selection of construction methods in selected components of building projects and highlighted that the selection criterion differs in line with the different building components. This knowledge helps decision makers like construction managers and engineers to identify the importance (weight value) of each key performance criterion (time, cost, quality, ease of construction, and availability of method and skill) and best available construction method (total weight value) in different stages of building projects. They are then enabled to make proper decisions and select appropriate methods accordingly.

Selecting appropriate construction methods based on these priorities plays a significant role in achieving the project objectives and enhancing productivity and successful project delivery [47]. The other advantage of this knowledge is that building material manufacturers could use this guideline as a tool in the production of innovative technologies and modern construction methods for each component, according to the priority of the criterion used in its selection, so as to improve the productivity, efficiency, and quality of building projects.

7. Conclusion

The lack of an efficient systematic approach to the selection of appropriate construction methods for building projects necessitates a critical examination of the various construction methods currently available to identify the criteria used in their selection and their weight and to enable the optimum performance, success, and sustainability of building projects. Therefore, this study examines how key performance criteria were used in the selection of construction methods on projects and whether these selection criteria differed across different building components toward making recommendations for improving the selection of appropriate construction methods on projects. To achieve this objective, the study employed an AHP (structured mathematical) model and PCC (statistical) analysis to aggregate and compare relative weight values of different construction methods in six major building components, based on their performance criteria in construction projects completed in the Middle East.

The study found that 47% of construction managers had employed improper and inappropriate methods in the foundation stage, 94.5% in the structure stage, 62% in the roofing stage, 55% in the wall stage, 88% in the façade stage, and 61% in the flooring stage despite the availability of new equipment and facilities, innovative technologies, and modern construction methods in the Middle East.

The results of the AHP model and PCC analysis revealed that the most important criteria for the selection of construction methods and also the best component for each stage of a building project were steel framework in the foundation, light steel frame structure (LSF) in the structure, steel decking also in the roofing, Leca block in the wall, steel façade in the façade, and laminate in the flooring.

The study established the positive significant role and impact of time and quality performance criteria in the selection of construction methods. Based on the findings, it was concluded that the capacity of a method of construction to shorten the time span for the process (29.60%) and facilitate a higher quality of building (28.66%) rendered it more likely to be used on building projects.

To achieve project objectives, enhance productivity, and successful project delivery, building components that are suitably aligned to these criteria should be selected by project decision makers, while construction materials producers need to align their products to fit these criteria.

Finding the most suitable and sustainable construction methods for building components will accomplish a sustainable building, as is required in the Middle East and other developing countries. The detailed analysis and results of prioritizing the affecting factors from this research should be used as a platform and benchmark for future studies. Also, this platform should be utilized for evaluating the level of efficiency of building processes and as a guideline for improving the effectiveness of building processes by selecting optimum construction methods that are aligned to project objectives and targets.

It is possible to extend the straightforward and flexible model developed here to other construction methods and ultimately to the whole building project. The model criteria can also be modified, depending on the scope or focus of the study. Not only it is the proposed systematic approach applicable to different construction projects, but also it is useful globally to improve standards of construction, thereby benefiting communities and ensuring safer, sturdier, and more sustainable buildings.

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