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RESEARCH ARTICLE

Factors Affecting Construction Productivity for Steel Rebar Work in Hot Climate Country

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Abstract:

Introduction:

Construction industry is increasingly emphasizing productivity due to its effect on key performance indicators such as schedule, budget, and quality of work. This study aims to identify and rank the factors affecting the productivity of steel rebar work in construction projects in a hot climate. Among the activities involved in structural reinforced concrete work, fabricating and placing reinforced steel on a construction site is considered the most labor-intensive, outdoor, and time-consuming.

Methods:

In this paper, an intensive qualitative literature review is conducted to identify the factors affecting the productivity of steel rebar work in concrete construction. Initially, forty factors were identified from the literature affecting the productivity of steel rebar work in Saudi Arabia. Final list of thirty-seven factors was used in the questionnaire survey. The identical nature and core content of these factors are clustered and grouped into five categories: technical, labor, management, external, and financial. As part of this study, fifty contractors working in the Saudi Arabian construction industry are recruited to participate and complete a structured pilot study questionnaire.

Results:

The results of the questionnaire are weighted using the pairwise comparison method and then ranked based on the Analytic Hierarchy Process technique. The analysis of the thirty-seven factors results in a top ten list of the leading factors that directly impact the productivity of steel rebar work in concrete construction projects in Saudi Arabia. These factors are (1) humidity, (2) delay of salary, (3) sandstorms, (4) payment delay by client, (5) labor's low wage, (6) lack of financial incentives, (7) labor work experience and skills, (8) completeness of drawings, (9) poor labor relations, and (10) labor absenteeism. The general trend in these studies is that the factors tend to vary from jurisdiction to jurisdiction, from one construction project to another, and are directly related to the zone or country of construction.

Conclusion:

These findings benefit stakeholders working in the concrete construction industry in Saudi Arabia, particularly project managers, project planners, cost estimators, and civil design and site engineers working on construction projects.

Keywords: Productivity factors, Steel rebar, Concrete housing, Analytic hierarchy process, Ranking, Construction.

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1. INTRODUCTION

The construction sector in Saudi Arabia has witnessed an unprecedented boom over the past decade and has attracted leading construction enterprises from around the world. Furthermore, the construction sector was one of the largest recipients of annual government investment [1]. To fulfil the core objectives of Vision 2030, the Saudi Ministry of Housing announced in 2017 that one million housing units will be constructed by the year 2030 [2]. In this regard, a comprehensive study conducted by Al-Emad (2016) [3] revealed that government authorities in Saudi Arabia face a serious problem of prolonged and repetitive delays in housing projects overall. However, the norm states that the construction process is subjected to many variables and unpredictable factors, where each project presents a unique case. One of the most important variables is productivity [3]. In Saudi Arabia, construction productivity is typically estimated based on the United States or global standard employment rate. Moreover,

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contractors continue to use a standardized method of estimating productivity that is not accurate. This may lead to an unrealistic construction scheduling and cost estimate, as in the construction industry, labor cost is estimated to account for 30 to 50% of the total cost of construction projects [4]. Moreover, the Saudi construction industry is governed by many different factors such as local workers, legal policies, local economic conditions, weather, and culture differences that should be considered.

The literature indicates that there are many studies conducted to investigate the factors affecting labor productivity in the construction industry in Saudi Arabia. The literature also reveals that there is a lack of research in determining the factors affecting the productivity of steel rebar work in particular. Jarkas (2010) [5] pointed out that fabricating and placing reinforced steel is considered the most labor-intensive and time-consuming of the activities involved in concrete work. The main goal of the research presented in this paper is thus to identify and then assess the critical factors that have a negative impact on the productivity of steel rebar work in concrete construction projects in Saudi Arabia. To achieve this objective, a pilot questionnaire was administered to construction experts in order to identify and rank the factors affecting the productivity of steel rebar work. The collected data were analysed by implementing the Analytic Hierarchy Process (AHP) technique, with the questionnaire results to highlight the important factors that influence the site productivity of steel rebar work. It should be noted that the findings can be utilized to measure the importance of these factors compared to one another and to improve the productivity of steel rebar work. Moreover, the results of this research will help in identifying misconceptions and bridging the gap between different construction stakeholders regarding factors that would improve construction productivity and help in addressing the problems encountered at construction sites.

The significance of the study can be summarised as follow: (1) the identified factors affecting labor productivity of steel rebar may be used as an index for measuring the efficiency of production in Saudi Arabia, (2) it can also serve to measure the status of economic growth and related production from industrial and corporate perspectives in Saudi Arabia; and (3) it can assist project planners, schedulers, and cost estimators in preparing realistic project planning and scheduling.

This paper is structured and organized into six sections. In section 2, a review of the relevant literature on labor productivity and how it relates to steel rebar work is presented. In addition, the factors affecting productivity in Saudi Arabia are highlighted in order to create a pool of factors. The notable differences between construction productivity in Saudi Arabia and other countries are also reviewed. In section 3, the general methodology implemented in this paper is defined. Section 4 details the proposed framework and describes AHP explored to the approach adopted in this study. In section 5, the results are summarized and discussed, while the main conclusions are outlined in section 6.

2. LITERATURE REVIEW

Labor productivity data is crucial information when estimating cost and scheduling the work required for a construction project. Mohamed and Srinavin (2005) [6] presented a simulation of the effect of the thermal environmental factors on labor productivity and developed a new regression model that can reflect the correlation and interdependence between the thermal comfort index and labor productivity. They concluded that air temperature affects the thermal environmental variable acting on labor productivity. Ezeldin and Sharara (2006) [7] developed a neural network model capable of predicting the productivity of structural form assembly, steel rebar installation, and concrete pouring activities while incorporating both quantitative and qualitative factors. The final questionnaire form capturing the critical factors that impact the overall productivity of steel rebar work included structural elements, steel quantity, crew size, supervision, labor experience, overtime, activity complexity, construction material accessibility, and weather conditions.

Jang *et al*. (2011) [8] conducted a study to identify the top direct and indirect factors affecting labor productivity for reinforced concrete construction projects. Other studies have shown that most factors affecting labor productivity, in general, vary depending on the jurisdiction. For example, Jarkas and Bitar (2012) [9] asserted that the most influential factor affecting labor productivity in Kuwait was the degree of simplicity of the specifications, while another study by Jarkas *et al*. (2014) [10] concluded that the most influential factor in Qatar was the skill of labor. Other leading factors affecting productivity in different jurisdictions, such as the lack of timely delivery of construction materials, payment delays, the competence of project managers, the amount of rework, lack of financial incentive scheme, labor experience, and labor skills, have been identified in various studies. These studies were conducted in India by Thomas and Sudhakumar (2013) [11], Kuwait by Jarkas and Radosavljevic (2013) [12], Lithuania by Gudienė *et al*. (2013) [13], Palestine by Mahamid (2013) [14], Qatar by Jarkas *et al*. (2014) [10], Egypt by El-Gohary *et al*. (2013) [15], and Bahrain by Jarkas (2015) [16], respectively.

Alsaleh (1995) [17] identified the major challenge facing the construction industry in Saudi Arabia to be low labor productivity. He described the causes of project delays in construction as deficiencies in planning, communication, availability of materials and tools, and effectiveness of supervision. Mahamid *et al*. (2013) [18] identified the critical factors impacting labor productivity in Saudi Arabian public construction projects from the general contractor's perspective, focusing on the factors related to steel rebar work. Mahamid *et al*. (2013) [18] surveyed 41 contractors working on public construction projects, identifying the critical factors and ranking them based on their severity scale. Their analysis indicated that the top ten critical factors impacting labor productivity are the absence of labor with relevant work experience, lack of communication and coordination, a gap between labor and management, payments lag on the part of the client, inefficient work schedule, rework, labor's minimum wage, contractor financial difficulties, and inadequate site management.

Mistry *et al*. (2015) [19] identified the critical factors influencing the labor productivity of the building construction

sector in India. They developed a questionnaire where the participants ranked the identified factors according to the AHP ranking scale. They conducted a detailed literature review in which they identified forty different factors. These factors were grouped and clustered together to form seven main clusters: technical, labor, materials, equipment, external and environmental, safety, and quality. They further analysed these factors and concluded that labor productivity is affected by ten important factors related to the building construction sector in India. These factors are quality assurance, high working elevations, repetitive rework, absence of material, equipment availability, inadequate labor skill, and payment lag. In a similar study, Sherekaret *et al*. (2016) [20] identified thirty-five critical factors affecting labor productivity of the residential construction sector in India. These factors were grouped into eight clusters: psychological, skills, external, capital, endurance, schedule and effort, supervision and leadership, and safety. They conducted their analyses using the multi-criteria decision analysis AHP method. Their results showed that the three critical factors influencing the labor productivity of small-to-medium construction projects are remuneration, drug use by labor, and contravention of safety standards, whereas in large construction projects the critical factors were identified to be job satisfaction, level of training, and work planning schedule.

Alaghbari *et al*. (2017) [21] identified and ranked the critical factors influencing construction labor productivity in Yemen. Their questionnaire included fifty-two factors categorized into four main clusters: manpower, management, technical and technological, and external. They adopted a methodology similar to the one developed by Kazaz *et al*. (2016) [22], which utilizes the relative importance index (RII) as an indicator to identify and rank the relative factors. They identified the top five critical factors impacting construction labor productivity in Yemen: labor qualifications and skills, access to raw materials, site management expertise, and political and security. Durdyev *et al*. (2018) [23] addressed the critical factors affecting labor productivity in the Malaysian construction sector, using the structural equation modelling technique to analyse the collected information from a survey administered to 185 participants from both the government and the construction sector. Their final model adopted twenty-nine attributes distributed among six labor productivity factors: project control, manpower, budgeting, external, project, and resources. The results of their study confirmed the importance of project control experience level and manpower quality in improving labor productivity.

Khaleel and Nassar (2018) [24] identified and analysed the critical factors affecting labor productivity in construction projects in Iraq, organizing them into seven groups: manpower, management, motivation, site supervisors, site safety, project schedule and budget, and work resources. Their questionnaire results identified the main factors affecting labor productivity as material availability, weather conditions, holidays, number of working groups, crew experience and age, and revisions to technical drawings and material specifications during the design and execution phases. In a recent study by Rad *et al*. (2018) [25], they investigated the critical factors influencing construction labor productivity in Iran. They analysed and validated the collected datasets using the AHP and Structural Equation Model (SEM) techniques. They compared the outputs from both the AHP and SEM techniques and concluded that labor characteristics and tools and equipment are the two top-ranked among the six factors under consideration in their study.

Most of these previous studies have investigated the different critical factors influencing labor productivity in different countries. The general trend in these studies is that the factors tend to vary from jurisdiction to jurisdiction, from one construction project to another, and are directly related to the zone or country of construction. A review of these previous studies also shows that the AHP method and the relative importance index are the most widely used techniques for productivity assessment, as shown in Table **1**.

Table 1. Initial Identified Factors affecting the productivity of construction projects in Saudi Arabia.

No.	FaCtors Affecting the Productivity of Construction Projects In Saudi Arabia	Refs.	Brief Description
Management-related Factors			**Factors related directly to management activities that can be controlled**
01.	Clarity of technical specifications	(Jarkas and Bitar, 2012) [9]	
02.	Extent of variation/change orders during execution	(Jarkas and Bitar, 2012) [9]	
03.	Lack of labor supervision	(Jarkas and Bitar, 2012) [9]	
04.	Proportion of work subcontracted	(Jarkas and Bitar, 2012) [9]	
05.	Crow size	Interviews	
06.	Utilization of traditional construction methods	(Jarkas *et al*., 2012) [12]	
07.	Poor layout of job site	(Jarkas *et al*., 2012) [12]	
08.	Inexperienced site manager	(Jarkas *et al*., 2012) [12]	
09.	Lack of Job enrichment	(Jarkas *et al*., 2015) [16]	
10.	Working overtime	(Jarkas, 2015) [16]	
11.	Unrealistic design schedules imposed on designers	(Enshassi *et al*., 2007) [26]	
12.	Unavailability of tools	(Enshassi *et al*., 2007) [26]	
13.	Payment delay	(Hiyassat *et al*., 2016) [27]	
14.	Construction method	(Enshassi *et al*., 2007) [26]	
15.	Availability of materials in the site	(Enshassi *et al*., 2007) [26]	

(Table 1) contd.....

No.	FaCtors Affecting the Productivity of Construction Projects In Saudi Arabia	Refs.	Brief Description
16.	Required equipment required for work on the project	(Jarkas and Bitar, 2012) [9]	
17.	The quality of materials used in the project	(Jarkas and Bitar, 2012) [9]	
18.	Insufficient places for eating and relaxation	(Dai *et al*., 2005) [28]	
19.	Method of employment (using direct work system)	(Dai *et al*., 2005) [28]	
20.	Lack of monetary incentive for good performance	(Jarkas, 2015) [16]	
21.	Lack of providing labor with transportation	(Jarkas, 2015) [16]	
22.	Working at heights	(Ghoddousi and Hosseini, 2012) [29]	
23.	Provided services on site (*e.g*., water and electricity)	(Jarkas, 2015) [16]	
24.	Ongoing corrective actions by the project engineer	Interviews	
25.	Repetitive management process during construction	Interviews	
26.	Delay in responding to requests for information	(Jarkas *et al*., 2015) [30]	
Labor-related factors			Category includes factors that are directly related to labor
27.	Nationality of labor	Interviews	
28.	Lack of feeling of achievement	(Hiyassat *et al*., 2016) [27]	
29.	Lack of dependence on equipment	(Jarkas *et al*., 2015) [30]	
30.	Age of workers	(Hiyassat *et al*., 2016) [27]	
31.	Physical fatigue	(Hiyassat *et al*., 2016) [27]	
32.	Younger workers' lack of motivation	(Jarkas, 2015) [16]	
33.	Delays due to absenteeism of other workers	(Jarkas, 2015) [16]	
Technology-related factors			Category includes factors that are directly related to the project's technical part, which can be controlled by owners and contractors
34.	Coordination level among various design disciplines	(Jarkas and Bitar, 2012) [9]	
35.	Quality of drawings	(Hiyassat *et al*., 2016) [27]	
36.	Clarity of instructions and communication on site	(Jarkas and Bitar, 2012) [9]	
37.	Rework due to modifications in drawings and/or specifications	(Jarkas *et al*., 2012) [12]	
38.	Inspection delay	(Dai *et al*., 2005) [28]	
External-related factors			Category includes factors that are out of control of stakeholder of project
39.	Market conditions (*e.g*., escalation of prices and inflation)	(Jarkas and Bitar, 2012) [9]	
40.	Accidents	(Ghoddousi and Hosseini, 2012) [29]	

A few researchers have conducted studies to determine the critical factors influencing construction productivity in Saudi Arabia. For example, Mahamid *et al*. (2013) [18] identified the critical factors impacting productivity in municipal road construction projects in Saudi Arabia from the general contractor's perspective. Alsaleh (1995) [17], meanwhile, presented a study addressing the major challenges facing the construction industry in Saudi Arabia, which are directly related to low labor productivity. Hence, this study is conducted to bridge the gaps of previous work and is focused on identifying and ranking the factors affecting the productivity of steel rebar work in concrete construction projects in Saudi Arabia since it is considered the most labor-intensive and time-consuming work. Table **1**. summarizes the findings of previous studies conducted in identifying the most important factors affecting labor productivity, while Table **2**, summarizes the findings of previous studies conducted in identifying the most important factors affecting labor productivity in last ten years.

Table 2. Summary of previous studies.

Country	Researchers	Years	Most Important Factors	Analysed Use
Iraq	Tareq and Yasser	2018 [24]	Availability Material	SPSS and EXCEL packages
Iran	Kiyanoosh and Kim	2018 [25]	Lack of required tools and/or equipment	AHP and SEM
Indian	Saurav *et al*.	2018 [31]	Planning and scheduling	relative importance index (RII)
Yemen	Wael *et al*.	2017 [21]	Labor's experience and skills	relative importance index (RII)
Pune	Vishal and Mahesh	2016 [20]	Remuneration	Analytic Hierarchy Process (AHP)
UK	Shamil Naoum	2016 [32]	Ineffective project planning	relative importance index (RII)
India	Rajen *et al*.	2015 [33]	Quality inspection Delay Working	Analytic Hierarchy Process (AHP)
Bahrain	Jarkas *et al*.	2015 [16]	Labor skills	relative importance index (RII)
Lithuania	Gudiene *et al*.	2014 [34]	Clear and realistic goals	Analytic Hierarchy Process (AHP)
Egypt	El Gohary and Aziz	2014 [15]	Labor experience and skills	relative importance index (RII)
Qatar	Jarkas *et al*.	2014 [10]	Lack of financial incentive scheme	relative importance index (RII)

(Table 2) contd.....

Country	Researchers	Years	Most Important Factors	Analysed Use
KSA	Ibrahim *et al*.	2013 [18]	Lack of labor experience	relative importance index (RII)
Palestine	Mahamid	2013 [14]	Rework and weather changes were rated as the least important factors.	importance index (II)
Kuwait	Jarkas and Radosavljevic	2013 [12]	Payment delay	relative importance index (RII)
Qatar	Jarkas *et al*.	2012 [35]	Skill of labor	relative importance index (RII)

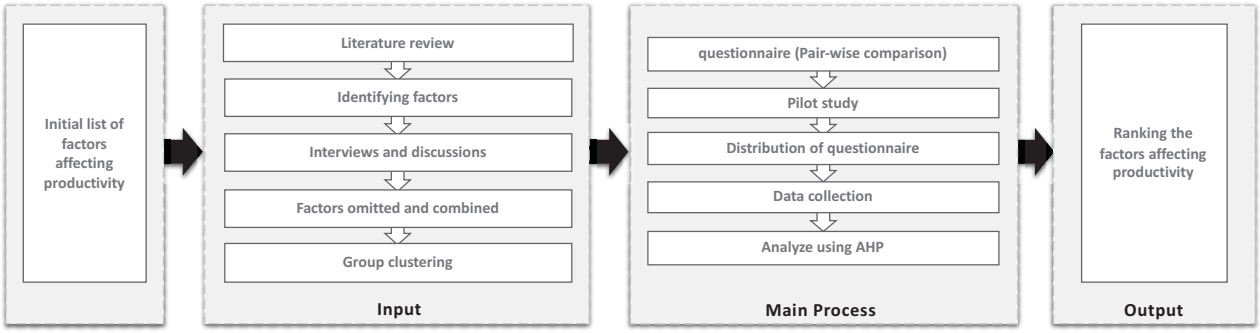

Fig. (1). Methodology flowchart.

The previous studies, individually or collectively, do not consider the factors affecting the productivity of steel rebar work. Those studies investigated the factors impacting labor productivity in general, and they did not focus on steel rebar work. In addition, the assessment of the current practice in estimating the productivity of steel rebar work in Saudi Arabian indicates that contractors apply inaccurate methodology, which can lead to unrealistic project scheduling and cost estimates. Therefore, the main purpose of this study is to identify and rank the factors affecting productivity of such activity. This can assist contractors in estimating production rate more accurately, which consequently will help in estimating such activity and project duration more accurately. In addition, identifying such factors can help project planner and estimator in assigning time and cost contingency values. The research is limited on measuring the productivity of concrete steel fixing tasks for slabs, walls, and columns in housing projects. This study will investigate the labor output of steel fixers in residential buildings.

3. METHODOLOGY

This research adopted four phases methodology to evaluate the critical factors affecting the productivity of steel rebar works in construction projects in Saudi Arabia. An overview of the methodology is shown in Fig. (**1**).

To identify the critical factors affecting the labor productivity of steel rebar work in KSA, a comprehensive literature review was conducted, followed by discussions with experts and stakeholders involved in the Saudi Arabian construction industry. Based on expert opinion, some factors were excluded from the analysis phase, while other factors that were deemed to be similar in purpose and to have the same core context were combined and some factors that were unique to the Saudi market, such as labor culture which means the culture of the country in which they lived before working. A final list of thirty-seven factors was organized into five groups, as shown in Fig. (**2**). The final list was then distributed to local experts in construction to evaluate the content of these factors and to observe their feedback.

The questionnaire for the present study was prepared in the structure of a pairwise comparison using Saaty's 1-9 scale, as shown in Table **3**. The questionnaire was reviewed by 5 project managers who are specialists and professionals in construction engineering. As shown in Fig. (**3**), respondents recommend adding examples of how to complete the questionnaire to ensure its readability, accuracy, and comprehensiveness. The questionnaire, it should be noted, was developed to target experienced engineers and senior management who work in construction firms. The 75 targeted participants include 10% project managers, 26% construction managers, 56% site engineers, and 8% foreman, each with at least 5 years' experience in construction. Then, 15 responses were eliminated based on an incomplete submitted questionnaire, and 10 responses were excluded due to the consistency ratio (*CI*) of more than 0.1, which is not acceptable as per AHP methodology.

Table 3. Saaty's scale of importance intensities.

9	Extreme Important
8	Very Strong to Extreme Important
7	Very Strong Important
6	Strong to Very Strong Important

(Table 3) contd.....

5	Strong Important
4	Moderate to Strong Important
3	Moderate Important
2	Low Important
1	Equally Important

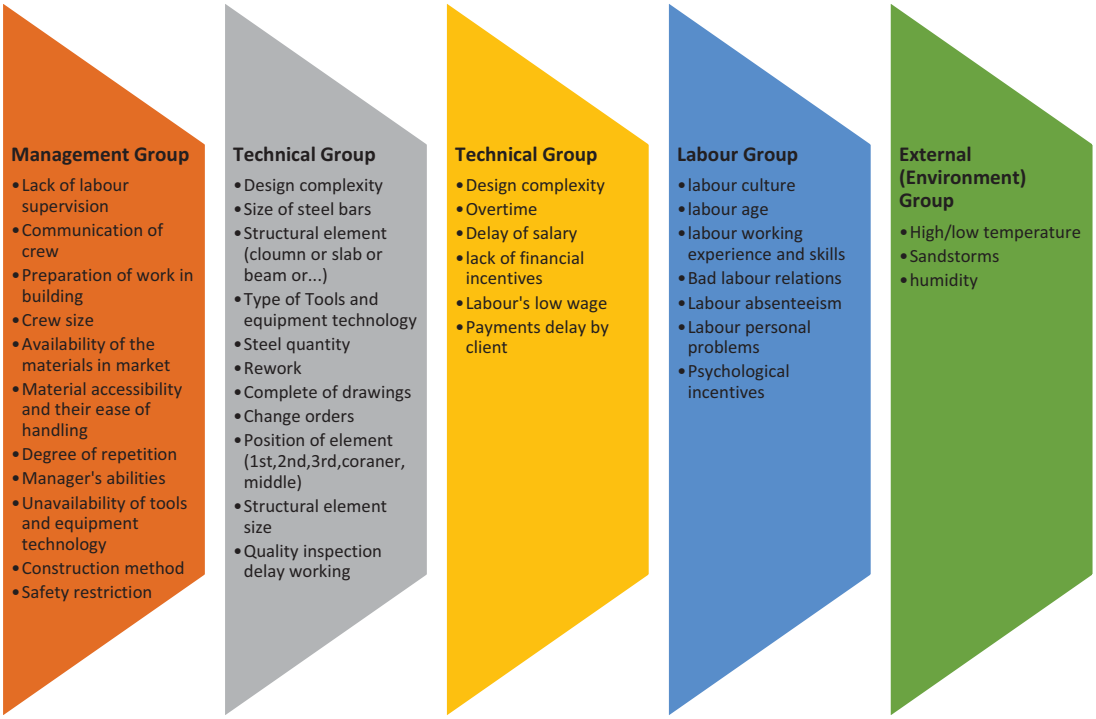

Fig. (2). Categorization of the factors affecting the productivity of steel rebar works.

Based on the scale (1-9):

A B

9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9

The above choice means: A is moderately affected more than B

A C

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

The above choice means: A is extremely affected compared to C

A D

9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9

The above choice means: D is very strongly affected compared to A

Fig. (3). Example for questionnaire format of (Pair wise comparison).

4. ANALYTIC HIERARCHY PROCESS

The AHP method was developed by Saaty (1980) [36] to find solutions to a variety of multi-criterion decision problems according to the relative weights assigned to each of the criteria. AHP, it should be noted, is a scoring model that depends on subjective experts' assessments of each criterion as an input, which is converted to a numerical value used in the process of evaluating a given alternative.

Johnson (1980) [37] explained in detail the four steps that the AHP method follows to solve a decision-making problem with multiple inputs and alternatives, as represented in Fig. (**4**).

Step 1: Establish the problem decision hierarchy by segmenting the main problem into a sequential hierarchy of interrelated and intercorrelated decision key elements as illustrated in Fig. (**4**)

Step 2: Gather the input data by conducting the pairwise comparisons of the key decision elements where experts compare the factors in pairwise comparison matrices in each level using the nine-point scale shown in Table **1**,

Step 3: Utilize the "eigenvalue" method to calculate the relative importance weights of key decision elements,

Step 4: Aggregate the relative importance weights of the key decision elements to output multiple alternatives.

4.1. Calculating the weights and testing the consistency for each level

This step is to find the relative priorities of criteria or alternatives implied by these comparisons. The relative priorities are worked out using the theory of eigenvector. The consistency check should be done at each stage of the selection process, as shown in Fig. (**5**).

Construct a set of pair wise comparison matrices (size n x n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement. The pair-wise comparisons are made in terms of which element dominates the other, as shown in Fig. (**6**).

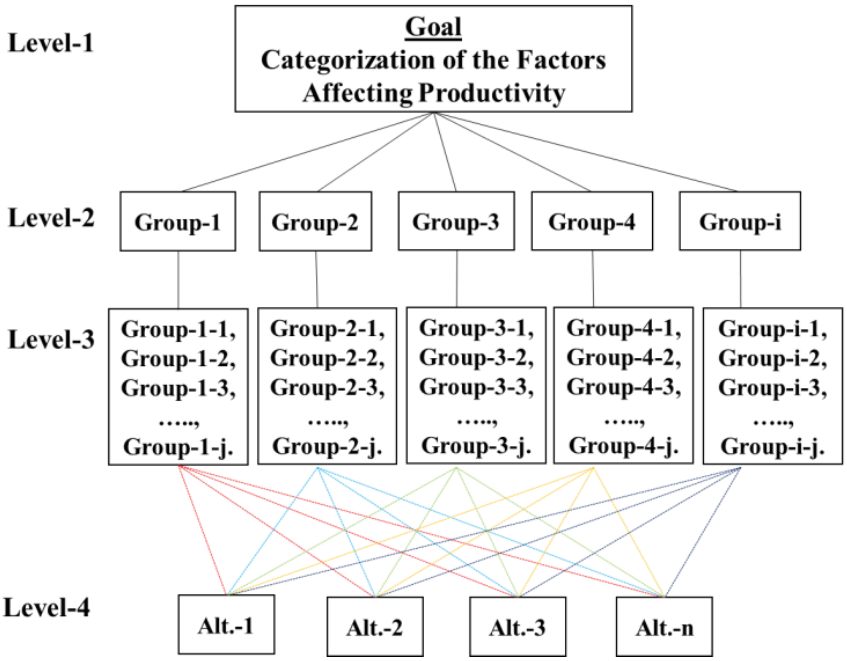

Fig. (4). AHP Decision hierarchy schema

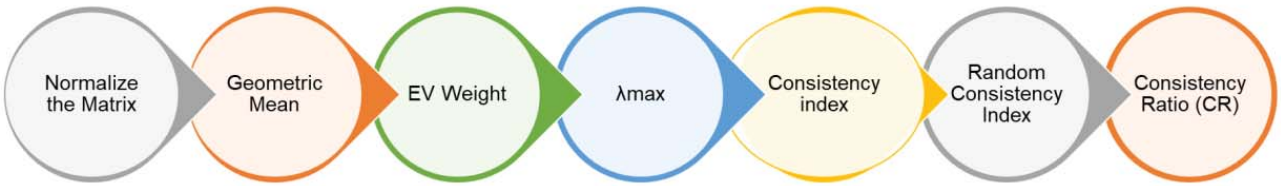

Fig. (5). AHP Process description.

Labour Group								
	Number of Factors	1	2	3	4	5	6	7
Number of Factors	SELCTION Labour Factors	labour culture	labour age	labour working experience and skills	Bad labour relations	Labour absenteeism	Labour personal problems	Psychological incentives
1	labour culture	1.00	2.00	0.33	0.33	2.00	0.33	0.33
2	labour age	0.50	1.00	0.17	0.17	1.00	0.17	0.17
3	labour working experience and skills	3.00	6.00	1.00	1.00	6.00	1.00	1.00
4	Bad labour relations	3.00	6.00	1.00	1.00	6.00	1.00	1.00
5	Labour absenteeism	0.50	1.00	0.17	0.17	1.00	0.17	0.17
6	Labour personal problems	3.00	6.00	1.00	1.00	6.00	1.00	1.00
7	Psychological incentives	3.00	6.00	1.00	1.00	6.00	1.00	1.00

Fig. (6). Pairwise comparison matrix.

To evaluate the consistency of the obtained result, three components are needed from the analysis, namely Consistency index (CI), Random consistency Index (RI), and Consistency ratio (CR). Following techniques are used to determine the above said elements of calculation. Where M×M is the matrix size.

Weights are calculated from the comparison matrices. After putting the values in each cell of the matrix, the first step would sum up the value of the columns. Then the summations of values of the columns would be equated, after that, each column summation is divided by the total sum of the columns to find the weights of the criteria/ factors.

This step calculates the CR as a way of measuring the consistency of the judgments. To perform this step, the first consistency index is calculated as per Equation **1**:

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

where λ_{max} is the maximum eigenvalue of the expert's judgment matrix and *n* is the size of the pairwise comparison matrix.

The random consistency index (RI) is computed using Equation **2**:

$$RI = 1.98\frac{n-2}{n} \quad (2)$$

The consistency ratio is obtained using Equation 3:

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

CR is acceptable if it is less than 0.1 and thus is considered consistent.

5. RESULTS AND DISCUSSION

A hierarchically structured model for the critical factors that impact the labor productivity of steel rebar work was constructed in terms of the main factors and sub-factors. From this model, the questionnaire was designed accordingly to determine the relative importance weight of each factor listed in the problem hierarchy. Construction experts performed pairwise comparisons to judge which factor is more critical to labor productivity by specifying the importance degree on a scale between 1 (Equally Important) and 9 (Extreme Important). Fifty participants completed the questionnaire, and the collected data were analysed using the AHP method described above. The results can be understood as the top-most groups of factors affecting labor productivity in steel rebar work and are detailed in the following sections.

5.1. Ranking Clusters of Factors Affecting Labor Productivity

The results shown in Table **4** demonstrate the ranking of productivity factors in terms of weight index. The management cluster is ranked first with the highest weight score of 21.89%. It is followed by the technical cluster, ranked second with a weighted score of 21.24%, and the financial cluster, ranked third with a weighted score of 21.19%. The external cluster is ranked fourth with an overall weight score of 18.33%, and the labor cluster is ranked last with an overall weight score of 17.35%. It can be noted from the results that the first three clusters have very similar results, and this is due to their relatively equal importance in determining the productivity of steel rebar work. Classifying the factors as such in this study is very helpful and indicates the importance of these clusters since their relative weight values were too close to all others.

Table 4. Groups of factors affecting labor productivity.

List of Clusters	Ranking	Weight (%)
Management Cluster	1	21.89%
Technical Cluster	2	21.24%
Financial Cluster	3	21.19%
External (Environment) Cluster	4	18.33%
Labor Cluster	5	17.35%

5.1.1. Management Factors Cluster

The weight indices and rankings of the 11 factors categorized under the management cluster are shown in Table **5**. Manager's abilities were the highest ranked in this cluster, with a weight of 12.01%, followed by safety restrictions with a weight of 11.88%, whereas the lack of labor supervision was ranked lowest with a weight of 4.19%. The result indicates that managers' abilities play a major role in supporting labor productivity by giving salaries on time, incentives, and personal motivation to labors.

5.1.2. Technical Factors Cluster

The weight indices and ranks of the 11 factors classified under the technical cluster are shown in Table **6**. Completeness of drawings was the highest ranked factor within this cluster with a weight of 17.30%, followed by delay due to quality inspection with a weight of 12.41%. Design complexity was the lowest ranked factor within this cluster, with a weight of 4.68%. The result indicates that incomplete design and drawings is a vital reason for delaying the work and affecting productivity when work details are not clear for labor.

5.1.3. Labor Factors Cluster

The weight indices and ranks of the 7 factors classified under the labor cluster are shown in Table **7**, where the labor work experience and skills was the highest ranking factor with a weight of 21.22%, followed by poor labor relations and labor absenteeism with weights of 17.96% and 17.53%, respectively. Labor culture was ranked lowest among the factors in this cluster, with a weight of 7.34%. The result indicates that steel rebar work is complicated and requires a long time, reflecting the need for labor with a high level of skills and experience.

Table 5. Management factors affecting labor productivity.

List of Factors	Ranking	Weight (%)
Manager's abilities	1	12.01%
Safety restrictions	2	11.88%
Unavailability of tools and equipment technology	3	11.28%
Availability of materials in the market	4	10.70%
Construction method	5	9.55%
Communication of crew	6	9.33%
Degree of repetition	7	8.77%
Crew size	8	7.89%
Material accessibility and their ease of handling	9	7.87%
Preparation of work in building	10	6.54%
Lack of labor supervision	11	4.19%

Table 6. Technical factors affecting labor productivity.

List of Factors	Ranking	Weight (%)
Completeness of drawings	1	17.30%
Delay due to quality inspection	2	12.41%
Rework	3	11.89%
Change orders	4	11.30%
Type of tools and equipment technology	5	8.74%
Structural element size	6	7.98%
Position of element	7	7.97%
Structural element	8	6.85%
Steel quantity	9	5.81%
Size of steel bars	10	5.07%
Design complexity	11	4.68%

Table 7. Labor factors affecting labor productivity.

List of Factors	Ranking	Weight (%)
Labor work experience and skills	1	21.22%
Poor labor relations	2	17.96%
Labor absenteeism	3	17.53%
Labor personal problems	4	13.72%
Psychological incentives	5	12.07%
Labor age	6	10.17%
Labor culture	7	7.34%

5.1.4. Financial Factors Cluster

The weight indices and ranks of the 5 factors classified under the financial cluster are shown in Table **8**, where delay of salary was the highest ranking factor in this cluster with a weight of 34%, followed by payment delay by the client with a weight of 21.24%. Overtime was ranked the lowest among the factors in this cluster, with a weight of 6.77%. The result indicates that delaying the salary for any reason could lead to a negative social impact on labor, which consequently will affect labor performance and work productivity. Increasing the wages will improve the social life of labor and will have a positive impact on productivity.

5.1.5. External (environment) Factors Cluster

The weight indices and ranks of the 3 factors classified under the external cluster are shown in Table **9**, where humidity was ranked highest among the factors in this cluster with a weight of 48%, followed by sandstorms with a weight of 37%. High/low temperature was ranked lowest among the factors in this cluster, with a weight of 15%. The result indicates that the weather condition plays a major role on productivity, especially the humidity and dust. This is due to the extreme hot-humid weather in the coastal cities in the east and west of Saudi Arabia. The productivity will increase if some steel rebar work can be prefabricated indoors in a well-conditioned environment.

5.2. Reliability Analysis of Responses

The reliability analysis is conducted from the early stage of data analysis. 25 responses were excluded due to incompleteness and low consistency level in order to achieve high reliability level. Cronbach's alpha equation is also applied in this study to conduct the reliability analysis of the experts' responses. This reliability coefficient can examine the reliability or the internal consistency of a psychometric test score for a sample of examinees. The coefficient value explains how well a set of variables can measure a single uni-dimensional latent construct. Cronbach's alpha represents the ratio of the true variance to the total variance of measurement and is a function of a number of observations, covariance, and variance. The Cronbach's alpha is computed using the following formula:

$$C\alpha = \frac{n}{n-1}\left(1 - \frac{\Sigma Vi}{\overline{V}}\right) \quad \textbf{(4)}$$

where:

$\overline{V}$ = sum of variance of overall points

Vi = variance of values for each point

n = number of points

The coefficient of Cronbach's alpha has a scale value that ranges from 0 - 1. The higher the score, the more reliable the data is. According to the previous studies, the acceptable reliability range varied between 0.70 and 1.0. A commonly accepted rule of thumb for describing internal consistency using Cronbach's alpha is presented in Table **10** .

Table 8. Financial factors affecting labor productivity.

List of Factors	Ranking	Weight (%)
Delay of salary	1	34.39%
Payment delay by the client	2	21.24%
Labor's low wage	3	19.43%
Lack of financial incentives	4	18.18%
Overtime	5	6.77%

Table 9. External factors affecting labor productivity.

List of Factors	Ranking	Weight (%)
Humidity	1	48%
Sandstorms	2	37%
High/low temperature	3	15%

Table 10. Accepted rule of thumb for internal consistency (Alshamrani, 2012).

Cronbach's Alpha (α)	Internal consistency
α ≥ .9	Excellent reliability
.9 > α ≥ .8	Good reliability
.8 > α ≥ .7	Acceptable reliability
.7 > α ≥ .6	Questionable reliability
.6 > α ≥ .5	Poor reliability

For example, the result of the reliability analysis of technical factors shows that the data has acceptable reliability according to Cronbach's Alpha (0.711), as presented in Table **11** . This value represents the highest resulted coefficient, including all factors. Eliminating any factor from the analysis will lower the reliability level by reducing the coefficient ratio of Cronbach's Alpha, as shown in Table **12** . This reliability result indicates that including all factors is very significant in this study.

5.2.1. ToP Ten Factors Affecting Construction Productivity

Among the 37 critical factors surveyed, the top ten factors affecting construction productivity in Saudi Arabia were identified, as shown in Table **13**. These top ten factors were found to represent almost 50% of the overall weight of all factors combined, and they are mainly related to external and finical groups. (Fig. **7**) shows all thirty-seven factors that have an effect on labor productivity, organized into five groups showing the weight for each one.

Table 11. Resulted cronbach's alpha value.

Cases		N	%	Cronbach's Alpha	Based on Standardized Items	N Of Items
	Valid	**11**	**100%**			
	Excluded	0	0%	0.71	0.74	44
	Total	11	100%			

Table 12. Expected Cronbach's Alpha if any single response is eliminated

Factors	Cronbach Alpha	Std. Alpha	G6(smc)	Average R
All factors	0.7115	0.7399	0.9998	0.2055
Q1 excluded	0.7105	0.7269	0.9919	0.2102
Q2 excluded	0.6874	0.7149	0.902	0.2005
Q3 excluded	0.6864	0.7283	0.8768	0.2114
Q4 excluded	0.6886	0.7226	0.8701	0.2066
Q5 excluded	0.6882	0.709	0.9171	0.1959
Q6 excluded	0.6764	0.7113	0.8392	0.1977
Q7 excluded	0.6773	0.7088	0.8426	0.1957
Q8 excluded	0.7084	0.7249	0.8229	0.2086
Q9 excluded	0.6966	0.7314	0.8932	0.214
Q10 excluded	0.6762	0.7121	0.8972	0.1983
Q11 excluded	0.7068	0.7394	0.8453	0.2211

Table 13. Top ten factors affecting labor productivity.

List of Factors	Ranking	Factors (%)	Group
Humidity	1	8.8%	External Group
Delays in salary	2	7.3%	Financial Group
Sandstorms	3	6.8%	External Group
Payment delay by the client	4	4.5%	Financial Group
Labor's low wage	5	4.1%	Financial Group
Lack of financial incentives	6	3.9%	Financial Group
Labor work experience and skills	7	3.7%	Labor Group
Completeness of drawings	8	3.7%	Technical Group
Poor labor relations	9	3.1%	Labor Group
Labor absenteeism	10	3.0%	Labor Group

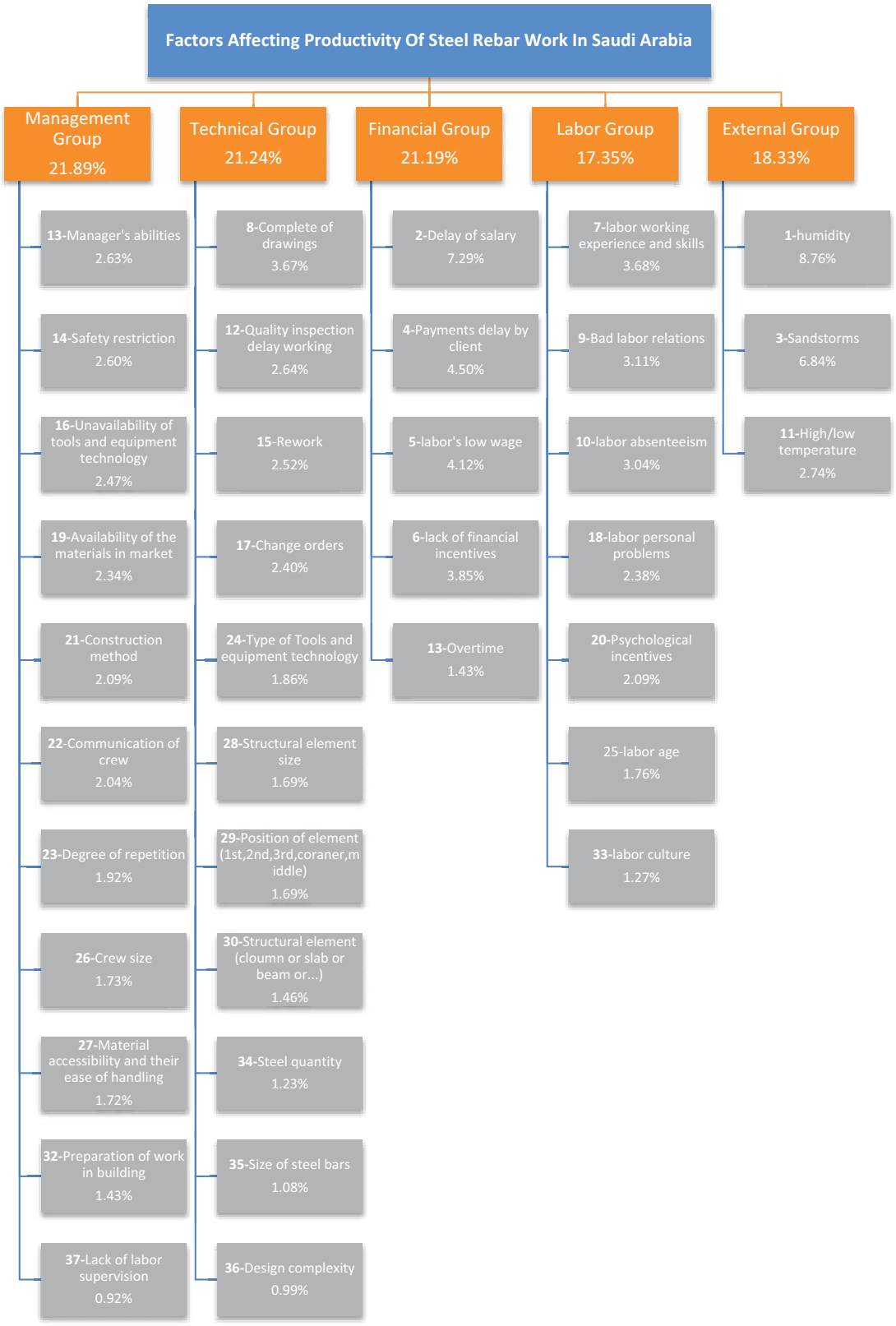

Fig. (7). Overall ranking of factors affecting the productivity of steel rebar work in Saudi Arabia.

As shown in Table **9**, the humidity and sandstorm factors from the external group are ranked first and third among the top ten factors. These findings are in keeping with the results of studies conducted in Iran, the United States, New Zealand, Qatar, India, and Bahrain [16] that have underscored the important influence of weather conditions on labor

productivity. As it has an arid climate, the weather in Saudi Arabia can be described as extremely hot in summer, from April to October, and relatively cold in winter, with weather conditions becoming much more extreme between June and September. The temperature reaches 50 °C with humidity above 90% in some regions, making outside working conditions difficult. As a result, the Saudi Arabian government has banned outdoor work in all construction sites between the hours of 12:00 pm and 3:00 pm from 15 July to 15 September of each year. The weather conditions in Saudi Arabia also include frequent dust storms, causing coughing, eye irritation, and in some severe cases, asthma. Working under such extreme heat, high humidity, and sandstorms reduces labor productivity and efficiency in Saudi Arabia.

Delays in salary, payment delays on the part of the client, and labor's low wage are among the primary critical factors that have an impact on the labor productivity of steel rebar work, while the delays in salary factor are ranked second among the top 10 factors. This factor is affected by global economic conditions and is directly related to fluctuations in oil prices, where oil companies represent 50% of the contracting companies in Saudi Arabia and are facing difficulty in paying the salaries of their workers as a result of the global recession since 2016. Moreover, the lack of labor supervision is ranked last among the investigated factors. However, other researchers have stressed the importance of supervision as a determinant of overall labor productivity in the United States, Uganda, Palestine, New Zealand, Bahrain, Qatar, Egypt, and Kuwait [16]. This may indicate that the quality and consistency of supervision of steel rebar work is in its best condition in Saudi Arabia.

The overall results indicate that manufacturing of some steel rebar works in a well-conditioned environment will improve productivity since the weather is proved in this study to play a major role on labors' productivity in Saudi Arabia. In addition, financial status is very important to improve their social life, consequently improving their psychosocial comfort and performance at work. Increasing the wages of laborers who are working in the steel rebar works is highly recommended since the nature of such a job requires high skilful and experienced labor

CONCLUSION

This study was conducted in order to identify and rank the critical factors influencing the construction productivity of steel rebar work in Saudi Arabia. Thirty-seven critical factors were mined and then categorized into five clusters: management, technical, financial, external, and labor factors. The top ten factors that have an impact on the construction productivity of steel rebar work in Saudi Arabia were found to be humidity, delays in salary, sandstorms, payment delays on the part of the client, labor's low wage, lack of financial incentives, labor work experience and skills, completeness of drawings, poor labor relations, and labor absenteeism. Two of the top three were weather-related factors unique to Saudi Arabia. The management cluster was ranked first among the five clusters. It can also be noted that, among the top 10 factors, four factors were from the financial cluster, three from the labor cluster, two from the external cluster, and one from the technical cluster, while the management cluster had no factors in the top 10 which does not match the ranking of previous study. As a result, there must be a unique Saudi standard for construction productivity in Saudi Arabia as it is not possible to apply construction productivity based on the US or worldwide standard employment rate. The AHP method proved usefuln for quantitative analysis and for finding the interrelation and correlations between different factors. The study covers factors affecting the productivity of steel rebar work in Saudi Arabia. The findings of this study will contribute to improving steel rebar work in the concrete construction sector in Saudi Arabia by informing the stakeholders of the respective impacts of the various factors influencing the labor productivity of rebar work. This study is restricted to examining the variables influencing the productivity of steel rebar work in Saudi Arabian building projects, which are constrained to particular weather conditions. Future studies could investigate the productivity rate of other types of work under different weather conditions. Furthermore, future works could model the relationships of productivity factors by applying different modelling techniques.

LIST OF ABBREVIATIONS

AHP	=	Analytic Hierarchy Process
CI	=	Consistency index
CR	=	Consistency Ratio
	=	

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The authors confirm that the data supporting the findings of this study are available within the manuscript.

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CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

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