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Abstract: Labor constitutes a significant portion of the overall cost of a construction project, where labor productivity is often the main driver of the cost. Although studies on labor productivity factors exist, their frequency of occurrence in terms of their ranking remains unexplored. This study differs from other studies in the literature by introducing the frequency component to the productivity factors, a more realistic ranking of the factors by adjusting the importance by frequency (frequency adjusted importance index) and risk mapping of the factors. Moreover, this study is the first to apply risk mapping on labor productivity drivers. The aim of this paper is to identify the project factors affecting the labor productivity in construction projects and to rank these factors considering the perception of the industry on project performance. A literature review of past relevant studies was performed to identify and draft a list of factors affecting labor productivity in construction projects. Thirty-seven labor productivity factors were presented in a questionnaire to investigate the impact and frequency of their occurrence in construction projects. A 9-point scale structured questionnaire was constructed to measure the importance and the frequency of the factors and to evaluate the ranking for different categories. The frequency adjusted importance index (FAII), Spearman's rank correlation, and risk mapping were used to study and analyze the 105 completed responses. The participants rated the following factors as the five most significant labor productivity-influencing factors: (1) poor labor supervision, (2) delays in payments, (3) poor work environment, (4) lowly skilled labor, and (5) bad weather conditions.

1. Introduction

The construction industry plays a significant role in economic development [1], especially for developing nations [2]. It generates new job opportunities and offers solutions to address social, climate, and energy challenges. It has a direct connection with other sectors and, consequently, has a major impact on the GDP and, thus, economic development. Ref. [3] confirmed that the construction industry positively affects growth and that the establishment of the right institutions can further improve this growth. For example, the GDP of the United States from construction averaged about USD 630 billion from 2005 to 2019, and the GDP of the United Kingdom from construction averaged around GBP 23,884 million from 1990 to 2019. In addition, political decision-makers wield the construction sector as an important tool to boost the economic development process due to the positive relationship between per capita national income and construction demand as highlighted by [4].

Successful project management must strongly emphasize the efficient utilization of labor, material, and equipment in construction projects in order to deliver a successful project on time, within the

budget, and as per the defined quality standards. Construction is a labor-intensive industry [5], and labor productivity has a profound impact on construction management [6]. In most countries, labor cost in construction represents 30% to 50% of the overall cost of the project, which means that labor productivity is a prime contributor to the efficiency and the success of the operation.

Thus, it is crucial to investigate the different influences that affect labor productivity to minimize and eliminate the negative effects in order to improve productivity levels and, consequently, increase the chance of delivering the construction project successfully.

This paper aims to evaluate and rank the 37 labor productivity-influencing factors in construction projects by considering their frequency of occurrence on project performance, which has not been considered in the existing literature. By using the frequency adjusted importance index (FAII), one can easily differentiate between the commonly faced factors and the less frequently faced factors. Our model considers this important fact. The results of this study can be used by industry professionals to develop an extensive and deeper perception of the factors contributing to the efficiency of workers and the way construction managers can efficiently utilize the labor force.

2. Past Studies

Construction labor productivity is an important metric that provides feedback regarding industry-level trends and improvements [7]. Ref. [8] emphasized the fact that the construction industry employs laborers intensively. Consequently, labor productivity is extremely important for the delivery of successful construction projects.

Productivity is defined as a relative measure of labor efficiency, either good or bad, in comparison to an established base or norm according to The American Association of Cost Engineers, as mentioned by [9]. Ref. [10] defined productivity as the ratio between total outputs and total inputs expressed in dollars. Ref. [11] stated that one must compare actual productivity to optimal productivity. Optimal productivity is the highest sustainable productivity level that can be achieved under "good management" and "typical field conditions". Ref. [12] introduced a two-prong strategy for estimating optimal productivity in labor-intensive construction operations.

Ref. [13] evaluated and ranked the importance, frequency, and severity of project delay factors that affect construction labor productivity for Malaysian residential projects. The five most important factors identified by them were material shortage at the site; non-payment to suppliers, causing the stoppage of material delivery to the site; changes ordered by consultants; late issuance of construction drawing by consultants; and incapability of contractors' site management to organize site activities.

Ref. [14] invited a group of contractors in Qatar to fill in a questionnaire composed of 35 factors. They used the relative importance index (RII) to evaluate the different factors and were able to list the five most significant factors affecting labor in the construction industry: (1) skill of labor, (2) shortage of materials, (3) labor supervision, (4) shortage of experienced labor, and (5) communication between site management and the labor force. Ref. [15] circulated a questionnaire in the state of Kerala in India to identify the factors affecting construction labor productivity and their underlying relationships. Among the 44 factors considered, material unavailability was identified as the most critical factor affecting construction productivity.

Ref. [16] aimed to identify and rank, according to relative importance, the factors affecting labor productivity in building projects in Zimbabwe. Unavailability of materials, late payment of salaries and wages, suitability/adequacy of plants and equipment, supervisory incompetence, and lack of labor skills were highlighted as the five most influential factors.

Ref. [17] aimed to determine the perception, from the project manager's viewpoint, of the factors affecting construction productivity in Queensland, Australia. Three factors out of the 15 highest-ranking factors—rework, poor supervisor competency, and incomplete drawings—were identified as having a strong effect on construction productivity.

Ref. [18] invited 55 construction contractors involved in construction projects in Thailand to evaluate the factors influencing labor productivity. The five highest-ranking factors were absenteeism

of workers, labor skill and experience, financial shortage, inspection and instruction delay, and incomplete drawings.

Ref. [19] listed the most important factors affecting labor productivity in South Africa. The ten most important factors are the late issuance of drawings to the contractor, illegal strike action by the project labor force, delayed reply on RFI (request for information), late issuance of specifications to the contractor, civil unrest in the vicinity of the project, labor union strike (irrespective of union), delayed inspection by the consultant, management skills of the foreman, poor communication between site management and the labor force, and the complexity of the design (constructability).

Ref. [20] grouped 37 factors into five categories in order to study the labor productivity of Jordanian construction projects. The groups are labor, technical, project, financial, and material and equipment. Ref. [5] ranked factors affecting construction labor productivity in Yemen. The top five factors identified had the most significant effect on construction labor productivity in Yemen: (1) labor experience and skill, (2) availability of materials in the site, (3) leadership and efficiency of site management, (4) availability of materials in the market, and (5) the political and security situation.

Factors affecting productivity in the construction industry and their classification depend on the researchers' views. Ref. [21] identified 26 factors and grouped them into five major categories, namely project factors, manpower factors, management factors, technical factors, and external factors.

Ref. [22] mentioned that the factors affecting labor productivity in the construction industry have received significant attention from both academia and practitioners. Different studies have attempted to determine the most dominant factors in labor productivity. Ref. [22] listed the top 10 factors in each study and categorized them into three main groups: management, human, and external.

The risk map is a two-dimensioned matrix that classifies risks into three zones. The combined effects of their frequency and severity identifies the zone to which they belong. The matrix helps in classifying risks into one of multiple states of likelihood and consequence (minimal through unacceptable). The organizations use the thresholds to determine their risk levels.

Ref. [23] used a risk map to determine the risk zone for each cost overrun factor. The map is a five by five matrix with severity ranging from very low (VL) to very high (VH) on the horizontal axis and frequency with the same range on the vertical axis. Three zones were presented in the map to classify the risk as "high" (red), "moderate" (yellow), or "low" (green).

A comprehensive literature review was conducted by collecting and studying relevant research papers considering the various factors affecting labor productivity. These papers reported the top influencing factors and their classification groups. The author worked on revising all factors by eliminating the replicates, refining the statements, and sharing the updated list with professionals in the construction industry in order to evaluate the presented factors and finalize the list. Thus, a long list of 63 factors was shortened to come up with the following 37 factors influencing labor productivity in construction projects. The influencing factors and their relevant references are listed in Table 1.

Table 1. Factors affecting labor productivity in construction projects based on the literature study.

No.	Factor	Group	Reference
1	Inspection delays	Management	[14,16,18,19,24–26]
2	Poor labor supervision	Management	[14,24,25,27]
3	Unsuitability of storage location	Management	[14,15,24,26,28]
4	Crew size and composition	Management	[16,19,24,25,28,29]
5	Delay in payments	Management	[14,24–26]
6	Lack of periodical meetings	Management	[15,24,26]
7	Poor communication between project team	Management	[14–16,19,24,25,27,28,30,31]
8	Frequent change orders	Management	[18,24,25,29,32]

Table 1. *Cont*.

No.	Factor	Group	Reference
9	Higher ratio of subcontracted work	Management	[14,19,24,25]
10	Client's intervention	Management	[24,25]
11	Poor material/equipment management	Management	[15,16,18,19,26–28,33,34]
12	Excessive overtime	Management	[14,24–26]
13	Low employee satisfaction	Motivational	[26,30]
14	Poor work environment	Motivational	[27,30]
15	Lack of job security	Motivational	[27,30]
16	Lack of labor recognition programs	Motivational	[15,16,24,26]
17	Lack of training sessions	Motivational	[14,16,19,24,26,28]
18	Lowly skilled labor	Human	[27,30]
19	Lack of rest time(s) during the workday, fatigue	Human	[35]
20	Shortage of labor	Human	[19,36]
21	Labor absenteeism	Human	[16,18,19,26]
22	Poor communication with labor	Human	[14–16,19,24,25,30]
23	Delay in responding to "requests for information" (RFI)	Technical	[14,25]
24	Unclear technical specifications	Technical	[14,26]
25	Poor site logistics and management	Technical	[14–16,18,19,24,25,28,30,37]
26	Design errors and changes during construction	Technical	[15,25,28,36]
27	Poor construction methodology	Technical	[14,16,24–27,38]
28	Reworks	Technical	[16,30,36]
29	Not following the safety precautions and rules	Safety	[15,18,24–28]
30	Lack of safety officer on the construction site	Safety	[18,24,26,28]
31	High level of noise	Safety	[26,39]
32	Unsafe working conditions	Safety	[15,36]
33	Bad weather conditions	External	[15,16,19,25,28,30,40]
34	Unforeseen ground conditions	External	[25]
35	Delay in approvals by authorities	External	[25,28]
36	Frequent changes in regulations	External	[16,25,26]
37	Unstable local economy	External	[16,19]

3. Motivation for the Study

In the literature review, relevant studies were explored to identify the factors affecting labor productivity in construction projects. Moreover, the factors were categorized into groups as presented in Table 1. Although many studies discussed labor productivity [5,18–22,40–42], there is a gap in the literature when it comes to ranking labor productivity drivers considering their frequency of occurrence. The previous studies evaluating the labor productivity used only the level of importance without considering the frequency of occurrence of each factor. In addition, these studies did not apply

risk mapping to categorize the factors in different risk zones, which could assist the top management in construction projects to take serious actions to avoid/reduce the impact of the risky factors.

The main contribution of this paper to the existing body of knowledge is to investigate the labor productivity factors by introducing the frequency component to the productivity factors, which is a more realistic ranking of the factors by adjusting the importance according to the frequency (FAII). Studying frequency is important to evaluate the effect of that factor on the overall project performance. Researchers have studied the frequency component on various factors related to different topics, such as safety factors [43] and productivity factors in Indian construction [15]. However, this is the first study in the literature to study the FAII with labor productivity. Moreover, risk mapping has been applied as a tool to categorize influencing factors in other fields such as ranking of cost overrun factors [23]; however, to the best of the authors' knowledge, this is the first study to apply risk mapping on labor productivity drivers.

4. Methodology

A literature review of relevant studies from the past was performed to identify a list of factors affecting labor productivity in construction projects. This study composed a list of the 37 factors influencing labor productivity in construction projects based on a comprehensive literature study. A draft version of the questionnaire was shared with some professionals in the construction industry (project managers, construction managers, and project engineers) to take into account their opinion regarding the listed factors and questions. That step was taken to ensure that the factors are well-understood, the listed questions are realistic, and the questionnaire does not consume much time to be completed. After that, the final version of the questionnaire was disseminated to the target population on an online platform (Survey Monkey) in order to evaluate the importance and the frequency of occurrence of the different factors. This helped achieve the aim of identifying the top influencing factors that affect labor productivity in construction projects.

The questionnaire was composed of two sections: the respondent's general information and the evaluation of the factors influencing productivity. The first section aimed to obtain background information about the participants. It requested the respondent to fill in appropriate information related to his/her location, organization type, job designation, construction sector, and total years of work experience in the construction field. This section would help categorize the respondents into different groups for the purpose of comparison. The second section included the 37 productivity-influencing factors affecting construction projects. The respondent was requested to evaluate the "importance" (how much it affects the productivity level) and the "frequency" (how often the factor is considered) on a 9-point scale (1—very low importance/frequency and 9—very high importance/frequency) with the description shown in Table 2. Moreover, the respondent was asked to rate the importance of the different categories under which the various factors are classified.

Table 2. Impact and frequency rating scale.

Choice	1	2	3	4	5	6	7	8	9
Impact	No impact	←→	Moderate impact	←→	Strong impact	←→	Very strong impact	←→	Extreme impact
Frequency	Unlikely to happen	←→	May happen	←→	Likely to happen	←→	Very likely to happen	←→	Certain to happen

Since the study population is very large, data was collected through the convenience sampling technique by sending a questionnaire to professionals from different organizations and with different job designations, specializing in the construction industry. A total of 105 completed responses were received and analyzed using several statistical procedures, such as relative importance index, FAII,

Spearman's rank correlation, and risk mapping. Finally, recommendations for industry professionals were derived from the analyzed outcomes.

5. Internal Consistency of the Questionnaire

In order to identify the internal consistency of the questionnaire, Cronbach's alpha, a coefficient of reliability, was computed. The purpose of computing the Cronbach's alpha coefficient is to confirm that the criteria associated with the Likert scale actually measures the construct that was indeed intended to be measured, which is the importance and the frequency of factors affecting the productivity levels of laborers in the construction industry. Alpha measures the extent to which answers to survey questions correlate with each other, which means α estimates the proportion of variance that is systematic or consistent in a set of survey responses, as mentioned by [44]. The values range between 0 and 1, and a value of 0.7 is acceptable, and a value of 0.8 or higher indicates good internal consistency [45]. The formula for computing Cronbach's alpha coefficient is shown in Equation (1) as follows:

$$\alpha = \frac{N.\overline{C}}{\overline{v} + (N-1).\overline{C}} \tag{1}$$

where:

N = the number of items;
$\overline{C}$ = the average covariance between item pairs;
$\overline{v}$ = the average variance.

The SPSS, version 24 software was used to calculate the coefficient. The analysis resulted in a Cronbach coefficient of 0.94, which validates the internal consistency.

6. Frequency Adjusted Importance Index

The relative importance index (RII) was used to assess the importance of each productivity level attribute based on the scores derived from the questionnaire responses. The value of the RII ranges from zero to one, where a higher value indicates that the attribute is more significant compared to others.

In addition, the FAII was also computed to rank the productivity-influencing factors, considering the frequency of occurrence based on the respondents' views. Ref. [46] used RII and FAII to rank the critical factors behind construction delays in petrochemical projects in Saudi Arabia.

In order to calculate FAII, the relative importance index (RII) and the frequency index (FI) are estimated at the beginning using the following equations (Equations (2) and (3)) [47].

$$\text{RII}(\%) = \frac{\sum I}{A(N)} \times 100 \tag{2}$$

$$\text{FI}(\%) = \frac{\sum F}{A(N)} \times 100 \tag{3}$$

where,

I = weight given to importance by the respondent (1 to 9);
F = weight given to frequency by the respondents (1 to 9);
A = the highest weight (in this case is 9);
N = the total number of respondents.

FAII provides better ranking results since it reflects the effects of importance and frequency all together. This way, the effect of each factor on labor productivity is estimated more realistically. Using Equations (2) and (3), the frequency adjusted importance index will be calculated according to Equation (4) as follows [43].

$$\text{FAII}(\%) = (\text{RII}(\%) \times \text{FI}\%)/100 \tag{4}$$

7. Ranking Comparison amongst Respondents

Spearman's rank correlation coefficient is a non-parametric version of the Pearson product-moment correlation test that requires neither normality of the distribution nor homogeneity of the data. Spearman's correlation coefficient measures the strength and direction of association between two ranked variables rather than the strength and direction of the linear relationship between the two variables. Spearman's correlation assumes that data to be at least ordinal and the scores on one variable must be monotonically related to the other variable. Thus, Spearman's coefficient was used in this research to evaluate the correlation amongst numerous categories of respondents. Equation (5) below is used to calculate the coefficient value [16].

$$r = 1 - \left[\frac{6 \sum d^2}{n^3 - n} \right] \tag{5}$$

where,

r = Spearman rank correlation coefficient between two parties;
d = the difference between ranks assigned to factors;
n = the number of pairs of rank (equals the number of attributes, which is 37 in this research).

The correlation coefficient ranges from −1, which means a perfect negative relationship (disagreement), to +1, which means a perfect positive relationship (agreement).

8. Risk Mapping

The risk mapping matrix, shown in Figure 1, is a tool that, through a visual representation of each factor's average impact and frequency level in the data collected from the responses, helps express in which risk zone each productivity-influencing factor falls. The horizontal axis represents the frequency mean values (1–9), and the vertical axis represents the impact mean values (1–9).
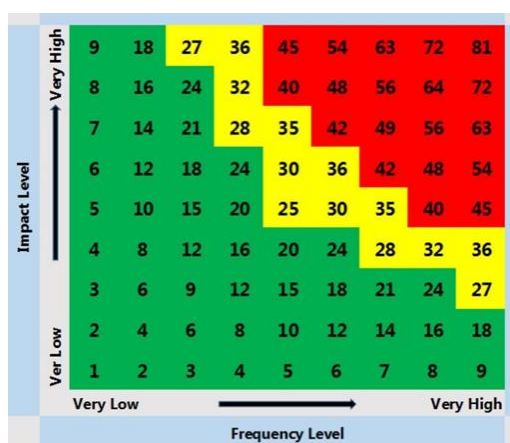

Figure 1. Risk mapping matrix.

The matrix is color-coded based on a series of thresholds. The organizations use the thresholds to determine their risk appetite. There is no universal system for determining the point at which the probability of risk changes. The organization will make a decision to take action regarding anything with a score higher than a specific number and accept anything lower as insignificant enough to be ignored.

The different zones of the risk matrix are defined as follows [48]:

(1)   Green zone with low-risk levels due to their low importance and frequency;
(2)   Yellow zone with risks that require a reasonable level of attention due to their moderate level of occurrence and importance;

(3)   Red zone with risks that require an immediate and high level of control due to their critical importance and frequency of occurrence.

The authors decided the limits of each zone by looking at past studies applying the risk mapping in other fields and by having discussions with academicians and professionals in the construction industry (senior project and construction managers) on how they consider the probability and the severity of each productivity-influencing factor. High-risk factors would have an impact times frequency (IF) value between 40 and 81, whereas low-risk factors would have an IF value between 1 and 24. The remaining factors would be considered as moderate risks.

9. Data Characteristics

Descriptive statistics are the basic measures used to describe survey data. They comprise summary descriptions of single variables and the associated survey sample. Frequency and percentage response distributions, measures of central tendency, and dispersion measures such as the range and standard deviation represent examples of descriptive statistics for survey data.

The respondents' profiles were based on organization type, job designation, construction sector, and their total experience in the construction field. These profiles are important to study how the different groups of respondents perceive different labor productivity factors.

Contractors with 44 responses (42%) represent the largest portion as shown in Table 3. Owners form 19% of the respondents. Consultants and sub-contractors constitute 15% and 10% of the responses, respectively.

Table 3. Respondent distribution by organization type.

Organization Type	Count	Percent
Owner	20	19
Contractor	44	41.9
Sub-contractor	11	10.5
Consultant	16	15.2
Academic Institution	8	7.6
Others	6	5.7

As shown in Table 4, project managers and project engineers form 33% and 22%, respectively, whereas construction managers make up 9% of the respondents.

Table 4. Respondent distribution by job designation.

Job Designation	Count	Percent
Owner	9	8.6
Project Manager	35	33.3
Construction Manager	9	8.6
Project Engineer	23	21.9
Site Superintendent	5	4.8
Academician	6	5.7
Others	18	17.1

Participants involved in building construction represent almost 56% of the responses, followed by those involved in infrastructure construction projects with 21% of responses, and industrial projects with 11% as shown in Table 5.

Table 5. Respondent distribution by construction sector.

Construction Sector	Count	Percent
Buildings	59	56.2
Infrastructure	22	21
Industrial	11	10.5
Others	13	12.4

It should be noted that others represent responses that were not available among the provided choices. Examples from the respondents' answers are given below. Organization type: BIM (Building Information Modelling) consultant, Supplier, Project Management. Job designation: Design Engineer, Site Engineer, Operations Manager, Program Control Manager, QA/QC (Quality Assurance/Quality Control) Manager, Technical Consultant, Head of Supervision. Construction Sector: MEP (Mechanical, Electrical and Plumbing), Maintenance and Operation, and so on.

According to the total years of work experience in construction, respondents were classified in the following four groups: less than 5 years, 6 to 10 years, 11 to 15 years, and more than 15 years as shown in Table 6. These groups' (less than 5 years, 6 to 10 years, 11 to 15 years, and more than 15 years) percentage levels are presented by 12%, 36%, 23%, and 29%, respectively.

Table 6. Respondent distribution by level of experience.

Experience	Count	Percent
Less than 5 years	13	12.4
5–10 years	38	36.2
11–15 years	24	22.9
Greater than 15 years	30	28.6

The respondents from different construction sectors, with different job designations, project types, and levels of experience were mainly based in Qatar, the United States, Japan, Turkey, Egypt, and Jordan. The majority of the respondents were construction engineers, project managers, project engineers, design engineers, and consultants.

Table 7 summarizes the demographics of the participants based on their organization type, job designation, construction sector, and experience level.

Table 7. Detailed demographics of participants.

	Category				
Organization Type	Contractor	Owner	Consultants	Sub-contractors	Others
	42%	19%	15%	10%	14%
Job Designation	Project Managers	Project Engineers	Construction Managers	Owners	Others
	33%	22%	9%	8%	28%
Construction Sector	Buildings	Infrastructure	Industrial	Others	
	56%	21%	11%	12%	
Experience Level	>15 Years	11–15 Years	5–10 Years	<5 Years	
	29%	23%	36%	12%	

The following sections present the data analysis using RII and FAII to rank the factors, Spearman's rank correlation, and risk mapping.

10. Data Analysis

Participants were asked to evaluate the importance of each of the 37 factors in order to assess its impact on labor productivity in construction projects. In addition, the frequency was rated in order to identify how often the factor is considered in construction projects.

This study used the collected data to compute RII, frequency index (FI), and FAII values for each productivity factor. Based on that, 37 influencing factors were ranked in ascending order, wherein a higher RII or FAII value indicates a higher importance level and vice versa.

Table 8 shows the RII, FI, and FAII values. The productivity factors were ranked using the FAII values based on all the completed responses.

Table 8. Relative importance index (RII), frequency index (FI), and frequency adjusted importance index (FAII) values and the rank of factors based on completed responses.

Factor	Code	RII	FI	FAII	FAII Rank
Poor labor supervision	MA	0.855	0.669	0.572	1
Delay in payments	MA	0.840	0.641	0.539	2
Poor work environment	MA	0.795	0.667	0.530	3
Lowly skilled labor	HU	0.782	0.670	0.524	4
Bad weather conditions	EX	0.790	0.639	0.505	5
Low employee satisfaction	MO	0.777	0.632	0.491	6
Design errors and changes during construction	TE	0.787	0.599	0.472	7
Reworks	TE	0.775	0.598	0.463	8
Poor site logistics and management	TE	0.759	0.610	0.462	9
Poor communication between project team	MA	0.790	0.575	0.454	10
Lack of training sessions	MO	0.733	0.619	0.454	11
Poor material/equipment management	MA	0.779	0.569	0.443	12
Frequent change orders	MA	0.741	0.574	0.425	13
Crew size and composition	MA	0.739	0.575	0.424	14
Lack of job security	MO	0.730	0.575	0.420	15
Delay in approvals by authorities	EX	0.728	0.575	0.418	16
Poor communication with labor	HU	0.752	0.556	0.418	17
Shortage of labor	HU	0.721	0.557	0.401	18
Poor construction methodology	TE	0.739	0.541	0.399	19
Unsafe working conditions	SA	0.754	0.529	0.399	20
Inspection delays	MA	0.716	0.551	0.395	21
Lack of rest time(s) during the workday, fatigue	HU	0.719	0.544	0.391	22
Excessive overtime	MA	0.713	0.546	0.389	23
Unclear technical specifications	TE	0.709	0.549	0.389	24
Delay in responding to "requests for information" (RFI)	TE	0.709	0.519	0.368	25
Higher ratio of subcontracted work	MA	0.642	0.566	0.364	26
Not following the safety precautions and rules	SA	0.677	0.534	0.362	27
High level of noise	SA	0.629	0.568	0.357	28
Lack of labor recognition programs	MO	0.626	0.550	0.345	29
Client's intervention	MA	0.683	0.492	0.336	30
Lack of periodical meetings	MA	0.650	0.511	0.332	31
Unforeseen ground conditions	EX	0.685	0.479	0.328	32
Unsuitability of storage location	MA	0.657	0.493	0.324	33
Unstable local economy	EX	0.705	0.438	0.309	34
Labor absenteeism	HU	0.656	0.470	0.308	35
Lack of safety officer on the construction site	SA	0.633	0.472	0.299	36
Frequent changes in regulations	EX	0.614	0.416	0.255	37

The different productivity factors were labeled with codes identifying the groups with which they were associated. MA, MO, HU, TE, SA, and EX codes represent management, motivational, human, technical, safety-related, and external factor categories, respectively.

The following tables (Tables 9–11) present the five most important factors as rated by owners, contractors, and participants with more than 15 years of experience in the construction industry, respectively.

Table 9. Top 5 FAII ranked factors by owners.

Code	Factor	FAII	FAII Rank
MA	Delay in payments	0.4779	1
MA	Poor labor supervision	0.4551	2
MO	Low employee satisfaction	0.4356	3
HU	Shortage of labor	0.4116	4
MA	Crew size and composition	0.4114	5

Table 10. Top 5 FAII ranked factors by contractors.

Code	Factor	FAII	FAII Rank
MA	Poor work environment	0.5928	1
MA	Delay in payments	0.5824	2
MA	Poor labor supervision	0.5776	3
HU	Lowly skilled labor	0.5737	4
EX	Bad weather conditions	0.5668	5

Table 11. Top 5 FAII ranked factors by participants with more than 15 years of experience.

Code	Factor (Greater than 15 Years of Experience)	FAII	FAII Rank
MA	Poor labor supervision	0.6507	1
MA	Delay in payments	0.5422	2
TE	Design errors and changes during construction	0.5055	3
MA	Poor work environment	0.4955	4
MA	Frequent change orders	0.4918	5

The top two factors in all lists are management related. This shows the impact of management on labor productivity. The top three overall factors appear in almost all lists. These are namely: (1) poor labor supervision (2), delays in payments, and (3) poor working environment. All these factors can be controlled with better project management. A detailed discussion on the top-ranked factors will be provided under Section 11.

Comparisons among construction sector (buildings, infrastructure, and industrial), organization type (owner, consultant, contractor, sub-contractor, and higher education), job designation (owner, project manager, project engineer), and experience level (5–10 years, 11–15 years, and >15 years) were made by calculating the relevant Spearman's rank correlation coefficients. All comparisons resulted in a value greater than 0.5, as shown in Table 12.

The analysis resulted in a high correlation between the contractors' and consultants' perceptions of the factors, with a correlation coefficient of 0.83. A similar high score of 0.80 exists between project managers and project engineers. A high level of correlation still exists between the contractors' and subcontractors' perceptions of the factors, with a correlation coefficient of 0.79.

Table 12. Spearman's correlation test results summary.

Construction Sector	Buildings	Infrastructure	Industrial		
Buildings	1	0.77	0.56		
Infrastructure		1	0.61		
Industrial			1		
Organization Type	**Owner**	**Consultant**	**Contractor**	**Sub-contractor**	**Higher Education**
Owner	1	0.66	0.60	0.65	0.50
Consultant		1	0.83	0.69	0.62
Contractor			1	0.79	0.60
Sub-contractor				1	0.54
Higher Education					1
Job Designation	**Owner**	**Project Manager**	**Project Engineer**		
Owner	1	0.54	0.50		
Project Manager		1	0.80		
Project Engineer			1		
Experience Level	**5–10 Years**	**11–15 Years**	**>15 Years**		
5–10 Years	1	0.75	0.71		
11–15 Years		1	0.60		
>15 Years			1		

A positive relationship with a correlation coefficient of 0.75 also exists among the respondents with 5 to 10 years of experience and the respondents with 11 to 15 years of experience in the construction field.

Comparing the scores of the professionals specializing in the building sector to the scores of those with wide experience in industrial projects resulted in a correlation coefficient of 0.56, which is the lowest correlation value in comparison with other correlation values.

Table 13 lists each factor's average impact and frequency level, the multiplication, and the risk zone based on all completed responses.

Table 13. Frequency and impact mean values (all responses).

Figure	Impact (Mean)	Frequency (Mean)	Impact X Frequency (IF)	Risk Zone
Inspection delays	6.448	4.962	31.99	Yellow
Poor labor supervision	7.695	6.019	46.32	Red
Unsuitability of storage location	5.914	4.438	26.25	Yellow
Crew size and composition	6.648	5.171	34.38	Yellow
Delay in payments	7.562	5.771	43.64	Red
Lack of periodical meetings	5.848	4.600	26.90	Yellow
Poor communication between project team	7.114	5.171	36.79	Yellow
Frequent change orders	6.667	5.162	34.41	Yellow
Higher ratio of subcontracted work	5.781	5.095	29.46	Yellow
Client's intervention	6.143	4.429	27.20	Yellow
Poor material/equipment management	7.010	5.124	35.92	Yellow
Excessive overtime	6.419	4.914	31.55	Yellow
Low employee satisfaction	6.990	5.686	39.75	Yellow
Poor work environment	7.152	6.000	42.91	Red
Lack of job security	6.571	5.171	33.98	Yellow
Lack of labor recognition programs	5.638	4.952	27.92	Yellow
Lack of training sessions	6.600	5.571	36.77	Yellow
Lowly skilled labor	7.038	6.029	42.43	Red
Lack of rest time(s) during the workday, fatigue	6.467	4.895	31.66	Yellow
Shortage of labor	6.486	5.010	32.49	Yellow

Table 13. *Cont.*

Figure	Impact (Mean)	Frequency (Mean)	Impact X Frequency (IF)	Risk Zone
Labor absenteeism	5.905	4.229	24.97	Green
Poor communication with labor	6.771	5.000	33.86	Yellow
Delay in responding to "requests for information" (RFI)	6.381	4.667	29.78	Yellow
Unclear technical specifications	6.381	4.943	31.54	Yellow
Poor site logistics and management	6.829	5.486	37.46	Yellow
Design errors and changes during construction	7.086	5.390	38.20	Yellow
Poor construction methodology	6.648	4.867	32.35	Yellow
Reworks	6.971	5.381	37.51	Yellow
Not following the safety precautions and rules	6.095	4.810	29.32	Yellow
Lack of safety officer on the construction site	5.695	4.248	24.19	Green
High level of noise	5.657	5.114	28.93	Yellow
Unsafe working conditions	6.790	4.762	32.34	Yellow
Bad weather conditions	7.114	5.752	40.92	Red
Unforeseen ground conditions	6.162	4.314	26.58	Yellow
Delay in approvals by authorities	6.552	5.171	33.89	Yellow
Frequent changes in regulations	5.524	3.743	20.67	Green
Unstable local economy	6.343	3.943	25.01	Yellow

Risk mapping may lead to better organization and management of projects as per different risk levels as calculated in the table above.

11. Discussion of Results

This study aimed to identify the most influential labor productivity factors affecting the construction industry. The factors evaluated in this study are of great importance, and their impacts should be taken into consideration. The participants rated the following factors as the five most significant labor productivity-influencing factors: (1) poor labor supervision; (2) delays in payments; (3) poor work environment; (4) lowly skilled labor; and (5) bad weather conditions. Factors 1 and 2 were common in the perception of groups such as owners, contractors, and highly experienced managers.

Labor supervision was ranked one of the top five significant factors by [14]. It is crucial for the utilization of productive input. Poor supervision will encourage workers to take unnecessary breaks, sit idle, and participate in useless tasks that waste time. Furthermore, direct labor supervision is essential in order to avoid defective work and non-compliance with the specifications, especially in the case of the non-highly skilled laborers.

Delay in payments [16], which comes in second place, has a prime impact on labor productivity. Moreover, payment delay was listed among the top 10 factors by many studies investigating labor productivity-influencing factors. Delay in payments influences every aspect of a construction project, interrupting the workflow. For example, delaying the wages of the workers will result in productivity losses since they will not be willing to perform the job in an efficient manner.

The work environment was listed among the influencing factors by [8,14]. A better work environment enables employees to work harder and more efficiently and effectively. Ambient temperature, lighting condition, ventilation, air quality, facilities on site such as restrooms, food, and rest areas are extremely important for labor productivity.

The authors of [18,20] considered the lowly-skilled labor factor in their research in Thailand and Jordan, respectively. The non-skilled labor force will consume more time to perform the job with larger room for mistakes and reworks. Consequently, employing lowly skilled workers will lead to lower job performance and increased cost.

In addition, bad weather conditions were highlighted as an important factor by the different studies [49] conducted among different regions and countries. Extremely hot summers and cold

winters will negatively affect the ability of a worker to perform. High levels of humidity and strong winds present a barrier to labor performance in construction projects.

In order to investigate how the different groups correlate, the Spearman's rank correlation test was performed, which resulted in a value greater than or equal to 0.5 for all comparisons, indicating a positive relationship and high correlation among the different groups. The comparison of contractors to consultants and project managers to project engineers resulted in the highest correlation coefficients of 0.83 and 0.80, respectively.

Contractors and sub-contractors have similar perceptions about the productivity-influencing factors. Both have ranked poor work environment, delay in payments, poor labor supervision, and lowly skilled laborers in their top five factors with minor differences in order. Moreover, poor site logistics and management, reworks, low employee satisfaction, and design errors and changes during construction are also common within the top ten factors.

Finally, risk mapping was used as a tool to determine the risk level of each influential factor and, consequently, to group the factors into three risk zones: red, yellow, and green zones. Poor labor supervision, delay in payments, poor work environment, lowly skilled laborers, and bad weather conditions fall into the red zone, representing the highest risk levels. However, labor absenteeism, lack of safety officer, and frequent changes in regulations fall into the green zone, representing the least risk factors.

12. Conclusions

This study aimed to recognize the most influential labor productivity factors affecting construction projects. A careful literature review, along with feedback of experts from the construction field, was used to curate a list of 37 productivity-influencing factors. A web-based questionnaire was developed to facilitate data collection and was shared with professionals from the construction field. A total of 105 respondents evaluated the importance of the factors, as well as the frequency of their occurrence.

The main contribution of this study to the existing body of knowledge is the investigation of these factors through the introduction of FAII and application of risk mapping on labor productivity drivers for the first time in comparison with the studies pertaining to the construction sector. FAII, Spearman's rank correlation, and risk mapping were used to rank the most significant factors and identify the correlation and agreement/disagreement level among the different groups of participants, such as owners, contractors, and sub-contractors.

Many recommendations can be specified to construction practitioners based on the study outcomes to avoid/reduce the impact of the presented productivity-influencing factors. During project execution, contractors have to properly plan the projects. For example, the employment of a capable construction manager is vital to the success of the project. The construction manager can implement efficient material procurement and site storage strategies to mitigate the risks involved with work interruptions and labor behavior. The construction manager can also maintain effective labor supervision criteria, display the required leadership on site, and organize and carry out practical working hours to enhance the productivity of the laborers.

The work environment directly affects the performance of the workers. The construction company has to secure the different facilities needed, such as clean restrooms and spacious rest and food areas. Moreover, the company should maintain proper ventilation and lighting conditions and control the contamination levels as much as possible. Additionally, enough scheduled breaks and a realistic number of working hours should be maintained.

Training the crew, especially construction supervisors, is extremely important in order to enhance productivity. Worker productivity would increase as soon as the new skill has been mastered, and the supervisors shall have an overall look at the job work process although not on a day-to-day basis. Consequently, the number of reworks due to faults during construction would be reduced. Moreover, instant supervision is extremely important to guarantee that all workers are performing the assigned tasks.

In addition, contractors and sub-contractors have to deliver their scheduled payroll on time by performing the work based on the contractual agreement in order to avoid disputes with the owners and avoid delayed payments.

Owners and consultants share almost the same top five productivity-influencing factors as ranked by the contractors and the sub-contractors above. Design errors and changes during construction, unclear technical specifications, client's intervention, frequent change orders, delays in responding to RFIs, and poor construction methodology are the most common factors listed by owners and consultants.

Before requesting for bids, owners should emphasize front-end planning, ensure that the project scope is fixed, and verify that the plan of execution is well prepared. Owners must be careful while introducing changes during project execution in order to avoid work disruption, which, in turn, causes significant productivity loss. Moreover, owners have to maintain the required cash flow to run the project without payment delays to the contractors, failing which delays the contractor's payment of wages to the workforce on site. Furthermore, the owner shall emphasize the selection of improved construction techniques, proper material management, and suitable construction methodology that would require fewer labor efforts and improve productivity.

Finally, the contractors, sub-contractors, owners, consultants, and all related project stakeholders are encouraged to investigate all productivity-influencing factors that are in their hands in order to avoid their negative impacts.

13. Limitations and Future Work

The questionnaire was shared with construction industry professionals from all over the world. They had two months to complete it. However, the completed responses were less in number than the number of communications made. In addition, the detailed technical aspects and definitions of labor productivity factors were not considered in this study.

The following recommendations can be considered in future studies in order to overcome the limitations of the present study and provide a better evaluation of the labor productivity factors influencing the construction industry.

1. Conduct face-to-face interviews with more professionals from the construction industry.
2. Distribute the questionnaire as much as possible among classified contractors and circulate the questionnaire among the related professional engineering communities all over the world in order to increase the number of respondents.
3. Modify the questionnaire and conduct the study to consider the perception of the highly skilled laborers and supervisors and investigate the difference in relation to the existing results.
4. Investigate more labor productivity-influencing factors belonging to the different groups mentioned in the study, including safety-related factors.
5. Consider detailed definitions and technical details for every factor mentioned in the current study in order to obtain more enhanced and accurate results.
6. Develop case studies and advanced models to investigate the labor productivity factors in detail.

Data Availability: All data, models, and code generated or used during the study are available from the corresponding author by request.

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