

Development of a Safety Performance Index for Construction Projects in Nigeria

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Abstract: The identification of factors can contribute to creating awareness and/or improving safety performance is germane in safety performance index construction as well as developing a safety performance index for the Nigerian construction projects. A questionnaire survey was conducted among construction experts to identify the relative importance of these indicators. The study collects data from 238 contractors. The collected data include information on worker factors, environmental factors, and organizational factors. Statistical analyses were carried out to develop the proposed safety performance index. The study reveals the most important safety performance factors. Among these are the lack of historical factors, natural environment, incentives factors and effective project budget plan, and safety training. Moreover, the developed index can be used as an effective tool to evaluate the expected safety performance of any construction project in Nigeria.

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1. Introduction

Safety is defined as a relative freedom from danger, risk, or threat of harm, injury, or loss of personnel and/or property, whether caused deliberately or by accident. In this research, safety means try to prevent the danger, accidents, harm, and injury to the person involved in construction activities. Safety at work is a complex phenomenon, and the subject of safety attitudes and safety performance in the construction industry is even more so [29]. Construction sites itself is commonly known as the most hazardous workplace. The construction industry is still based on labour intensive, while working environments are often changing and include several different parties. Thus, construction industry became the most crucial industry in the need of effective safety measures and safety management system in the effort to achieve better safety performance [19]. Research shows that the major causes of accidents are related to the unique nature of the industry, human behavior, difficult work site conditions, and poor safety management, which result in unsafe work methods, equipment and procedures [1]. The main force behind any construction site is the man power. Without safety, the risks and hazards at a very dangerous place like this can get people injured, hurt or even killed. This can cause any construction increasing cost, reducing productivity, and site delays [29]. Scholars (e.g. [11,20,39,52,53]) have stressed the importance of improving safety to reduce occupational accidents.

2. Literature Review

According to European Process Safety Centre, Basic safety management include important elements

such as politics, organization, management practices, procedures, monitoring and auditing [22]. The majority of studies contained Safety Elements reported that many of the Safety Elements are more general in nature and tend to not be easily measured, such as: safety policy, safety organization, inspecting hazardous conditions, plant and equipment maintenance, safety promotion, high risk times, organization collective values, individual competence and management behavior. These are all important general Safety Elements but they need to be formatted in such a way as to be measurable in order to use the implementation of Safety Elements as a possible predictor of a safe working environment [14]. Traditional measures of safety are measured after injuries have already occurred. Focusing on these measures e.g., accident rates and compensation. The problem lies here in injury actually occurred and the inability to avoid its occurrence. In recent years, there has been a movement away from safety measures purely based on retrospective data or lagging indicators, such as accident rates, toward so-called leading indicators such as site investigation and measurements of safety climate [43].

A study of the Nigerian construction industry concluded that safety programs applied by contractors operating in Nigeria were less formal and the accident insurance costs were fixed irrespective of the contractor's safety performance [35]. There are only two safety performance measures which are applied for the construction sector as a whole; a frequency measure and a severity measure. The frequency measure is based on the number of accidents. A severity measure, on the other hand, is based on the

number of lost days. Australia has made significant improvement in safety through the use of systems, structures, and modern technology, but they are inadequate to improve safety performance further. More of the same will not give the next big leap in safety performance [77]. This is because no matter how automated a production process or complex a management system is; people cannot be entirely separated from the process or the system. People still control production and sometimes must intervene when unplanned events occur. Therefore, it was not always effective in improving safety performance if a basic safety infrastructure was not in place. In contrast, a national policy program, Improving Occupational Safety, implemented in the Netherlands to increase the business community's knowledge and awareness of job site hazards, not only reduced job site incidents, but also enhanced enthusiasm and safety responsibility among both employers and employees. The objectives of this research is to identify factors that can influence the construction, safety performance in Nigeria, get the relative weight of each of these factors and develop a safety performance index to identify the level of safety of the different construction projects.

3. Research Methodology

The study was conducted through the following sequential steps. First, the study objectives were clearly identified. Then, comprehensive literature reviews were carried out to identify the most important safety factors. Hence, a questionnaire survey was conducted to identify the relative importance of the suggested safety factors. The questionnaire Surveys were performed by mail and interviews, and site visits to the different Egyptian construction sites. Some statistical analyses were carried out to develop the proposed safety performance index. Finally, based on the results of the analyses some conclusions and recommendations were provided.

There are many factors that affect safety performance in construction industry, the factors are

$$n^* = (z^2 s^2) / v^2 = [(1.645)^2 (0.5)^2] / (0.05)^2 = 270.6025 \approx 271$$

Taking into account all of the above, the size of the sample was calculated by using Eq. (1),

$$n = 271 / [1 + (271-1)/1955] = 238$$

So, the sample size of Contractors is 238 Contractors.

Data Collection

Questionnaire survey was conducted to assess the impact of the factors affecting safety performance and Probability for each factor in accordance with

Workers factor, environmental factor which include national commitment and working environment, organization factor such as incentive and project budget, policy and procedure, safety training, management practice and commitment, communication and feedbacks, inspection record and audits.

Questionnaire Survey

This research targeted Construction Contractors "acts of buildings, the work of foundations, works of metal constructions, and complementary actions of specialized". The targeted contractors were classified under the first and the second categories. Number of Contractors was 1955 according to the record of the Egyptian Federation for Construction and Building Contractors in 2014.

Simple Size

The appropriate sample size for survey is influenced by the purpose in conducting the survey. If the sample size is too small, important research findings will be lost. But if it's too large, valuable time and resources will be waste. This sample size that represents the targeted population was determined from following equation formula [66]:

$$n = n^* [1 + (n^* - 1)/N] \quad [1]$$

Where,

n is the sample size from finite population,

N is the total population (1955 contractors),

n^* is the sample size from infinite population,

which can be calculated from this formula.

$$n^* = (z^2 s^2) / v^2$$

Where,

V : Standard error of sample population equal 0.05, the margin of error equal 5%.

Z : Confidence Coefficient equal 1.645 for the confidence level 90%.

S^2 : Standard error variance of population elements which is defined as $S^2 = P(1 - P)$ and it is maximum at $P = 0.5$ so $S^2 = 0.5(1 - 0.5) = 0.5^2$. The sample size for the contractors' population can be calculated from the previous equations as follows:

experience in Nigeria. Pilot study of the questionnaire was achieved by a scouting sample, which consisted of 238 questionnaires.

A questionnaire survey was conducted and 86 factors were identified. The questionnaire was designed in English. The questionnaire was consisted of two parts:

- First part was related to general information about the companies and respondents. The respondents were requested to answer general information. This

part is optional to ensure accurate answers without any liability whatsoever.

- Second part was included the list of the factors affecting the safety performance in the construction industry. It was contained factors and sub factors represented in Figure 2. For each sub factor there is a question, for measuring.

1. The degree of impact factors on safety performance in construction project. The degree of impact is based on a five-point Likert scale. These five points are (very high), (high), (moderate), (low), and (very low).

2. The (Probability) per (number of the projects) for each factor in accordance with experience in Nigeria and it value ranging from (0 to 1). It measures the rate of implementation factor in the Nigerian sites.

The importance of the geographical location has been taken into consideration in this research. Hence the questionnaire was distributed in different cities in Nigeria. The cities include.

Osogbo, Akure, Ibadan, Ilesha, Abeokuta, Ife, Iwo, Ikeja The questionnaire were administered in all the cities mentioned based on the available projects.

4. Data Analysis and Development Safety

Performance Index (SPI)

In this study, an intelligent system was used to quantify the effect of factors on performance by using principal component analysis. There are two main issues that facilitate the determination of whether a particular data set is suitable for Factor Analysis (Principal Component Analysis). The first issue is the sample size, and the second issue concerns the strength of the inter-correlation among the independent variables.

Simple Size

The Statistical Package for the Social Sciences (or **SPSS**) was used for analysis collected data. The reliability of factor analysis depends on sample size because correlation coefficients are fluctuant from sample to sample, much more so in small samples than in large ones [24]. The absolute sample size and the absolute magnitude of factor loadings were the most important factor in determining reliable factor solutions [30]. So, they recommended guidelines for the minimum sample size needed to conduct factor analysis and suggested a minimum sample size of 100 to 200 observations. In our study we had **238** cases for each factor that actually are used in the principal component analysis.

The Inter-Correlation among Independent Variables

The second issue to be addressed concerns the strength of the inter-correlations among the items by following steps [72]:

- Correlation Matrix Scan

Correlation matrix (R-matrix) represents Pearson correlation coefficient between all pairs of variables. If correlation coefficients are less than 0.30 with all variables should be eliminated. And if correlation coefficients are greater than 0.90, the variables are strongly correlated and should be eliminated. Also, any variables that correlate with no others ($r = 0$) should be eliminated [24].

- Multicollinearity and Singularity Check

If the determinant of the correlation matrix less than 0.00001, it means the correlation matrix has multicollinearity, then the correlation matrix should be scanned to look for variables that correlate very highly and consider eliminating one of the variables (or more depending on the extent of the problem) before proceeding.

- **Anti-Image Correlation Matrix Scan**

All diagonal elements should be greater than 0.5 at a bare minimum. If any pair of variables has a value less than this, consider dropping one of them from the analysis. The off-diagonal elements should all be very small (close to zero) in a good model [24].

- **Kaiser-Meyer-Olken Measure of Sampling Adequacy (KMO)**

In [44] a recommendation that accepting values greater than 0.5 as barely acceptable (values below this index lead to collect more data or rethink which variables to include). Furthermore, values between 0.5 and 0.7 are mediocre, values between 0.7 and 0.8 are good, values between 0.8 and 0.9 are great and values above 0.9 are superb [41].

- **Bartlett's Test**

The Bartlett's test of sphericity can be used to test for the adequacy of the correlation matrix. If the test value is large and has a significance value (p-value) less than 0.05, it indicates the test is significance.

- **Reliability Statistics**

If the internal consistency of the sample groups' results Cronbach alpha has a value of 0.7 or more it is considered as an indication of reliability according to [26].

- **Formation Equations**

The five percent trimmed mean (5% TM) for each factor is defined as the average of observations remaining after the 5% of outlying observations have been removed. So, it can be considered more accurate than the traditional mean (M) to measure the construction safety performance. For example, Weight of Worker Factor [W_{WO}] = TM_{WO} / TTM
 $= TM_{WO} / [TM_{WO} + TM_{EN} + TM_{OR}]$

Where;

TM_{WO} : five percent trimmed mean for worker factor

TM_{EN} : five percent trimmed mean for environmental factors

M_{OR}: five percent trimmed mean for organizational factors (SPI) = [W_{WO}WO + W_{EN}EN + W_{OR}.OR)

Table 1. Comparison of Two Phases Analysis

	Analysis Degree of Impact	Analysis Degree the impact and the Probability/no. projects in Egypt
Variables Reduced	HI1, HI2, HI3, HI4, HI7, HB2, PS7, NE1, NE3, WE1, WE2, IR1, IR4, TR4, TR5, MC3, and MC4 Reduced 17 Variables	HI1, HI2, HI3, HI4, HI5, HI7, HB2, HB5, NE1, NE3, WE1, PP7, PL2, PL3, TR1, TR2, TR3, TR4, TR5, TR6, and EI7 Reduced 21 Variables
Remaining Variables	69 Remaining Variables	65 Remaining Variables
KMO	0.804	0.871
Bartlett's Test of Sphericity		
Approx. Chi-Square	19896.341	19875.942
degree of freedom (Df)	2346	2080
significance value (p-value)	0.000	0.000
Reliability Statistics	Cronbach's Alpha= .976	Cronbach's Alpha= .979

Equations

Worker Factor	<p>(WO) = 0.148 HI + 0.288 HB + 0.564 PS</p> <table border="1"> <tr><td>HI</td><td>HB</td><td>PS</td></tr> <tr><td>0.148</td><td>0.288</td><td>0.564</td></tr> </table>	HI	HB	PS	0.148	0.288	0.564	<p>(WO) = 0.065 HI + 0.216 HB + 0.719 PS</p> <table border="1"> <tr><td>HI</td><td>HB</td><td>PS</td></tr> <tr><td>0.065</td><td>0.216</td><td>0.719</td></tr> </table>	HI	HB	PS	0.065	0.216	0.719												
	HI	HB	PS																							
0.148	0.288	0.564																								
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0.065	0.216	0.719																								
Environmental Factor	<p>(EN) = 0.216 NE + 0.784 WE</p> <table border="1"> <tr><td>NE</td><td>WE</td></tr> <tr><td>0.216</td><td>0.784</td></tr> </table>	NE	WE	0.216	0.784	<p>(EN) = 0.205 NE + 0.795 WE</p> <table border="1"> <tr><td>NE</td><td>WE</td></tr> <tr><td>0.205</td><td>0.795</td></tr> </table>	NE	WE	0.205	0.795																
	NE	WE																								
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Management Practices on site	<p>(MP) = 0.091 PL + 0.082 IR + 0.148 TR + 0.179 MC + 0.280 CO + 0.220 EI</p> <table border="1"> <tr><td>PL</td><td>IR</td><td>TR</td><td>MC</td><td>CO</td><td>EI</td></tr> <tr><td>0.091</td><td>0.082</td><td>0.148</td><td>0.179</td><td>0.280</td><td>0.220</td></tr> </table>	PL	IR	TR	MC	CO	EI	0.091	0.082	0.148	0.179	0.280	0.220	<p>(MP) = 0.038 PL + 0.166 IR + 0.032 TR + 0.269 MC + 0.331 CO + 0.164 EI</p> <table border="1"> <tr><td>PL</td><td>IR</td><td>TR</td><td>MC</td><td>CO</td><td>EI</td></tr> <tr><td>0.038</td><td>0.166</td><td>0.032</td><td>0.269</td><td>0.331</td><td>0.164</td></tr> </table>	PL	IR	TR	MC	CO	EI	0.038	0.166	0.032	0.269	0.331	0.164
	PL	IR	TR	MC	CO	EI																				
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PL	IR	TR	MC	CO	EI																					
0.038	0.166	0.032	0.269	0.331	0.164																					
Organizational Factors	<p>(OR) = 0.098 PB + 0.206 PP + 0.696 MP</p> <table border="1"> <tr><td>PB</td><td>PP</td><td>MP</td></tr> <tr><td>0.098</td><td>0.206</td><td>0.696</td></tr> </table>	PB	PP	MP	0.098	0.206	0.696	<p>(OR) = 0.103 PB + 0.252 PP + 0.645 MP</p> <table border="1"> <tr><td>PB</td><td>PP</td><td>MP</td></tr> <tr><td>0.103</td><td>0.252</td><td>0.645</td></tr> </table>	PB	PP	MP	0.103	0.252	0.645												
	PB	PP	MP																							
0.098	0.206	0.696																								
PB	PP	MP																								
0.103	0.252	0.645																								
Safety Performance Index	<p>(SPI) = 0.206 WO + 0.075 EN + 0.719 OR</p> <table border="1"> <tr><td>WO</td><td>EN</td><td>OR</td></tr> <tr><td>0.206</td><td>0.075</td><td>0.719</td></tr> </table>	WO	EN	OR	0.206	0.075	0.719	<p>(SPI) = 0.237 WO + 0.121 EN + 0.642 OR</p> <table border="1"> <tr><td>WO</td><td>EN</td><td>OR</td></tr> <tr><td>0.237</td><td>0.121</td><td>0.642</td></tr> </table>	WO	EN	OR	0.237	0.121	0.642												
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In the above section two Phases of analysis will be carried out and compared:

The first was only analysis of data on the degree of impact on safety performance in construction project and the second was the analysis taking into account the impact and the Probability per number of the projects for each factor in accordance with experience in Nigeria.

Table 1 below shows, the majority of the sub factors in Historical Factors were eliminate except HI6: "Workers have background safety training". In the impact analysis HI5: "My experience helps me on responding to others' errors once a dangerous situation has developed and preventing an accident (or lessening its damages)" also remained. For Natural Environmental Factors, the sub factors were eliminated in both analyses NE1: "Weather conditions have a significant impact on the work safely" and NE3: "Wind intensity varies according to the site's geographic and topographic location, so it is effects on adjacent buildings", except: Weather related poor visibility was found to have a negative effect on safety performance"NE2".

• The situation is different for Safety Training and Plan. In the impact analysis both of them had a high weight, so it can be considered as a high-effect factor. On the other side, in 2nd phase safety training and Plan were eliminated in the first step of analysis due to its low weight. This can be considered as an evidence for the lack of appreciation of the Egyptian companies and contractors to these factors. This may be due to its negligible effect in their profits.

• A lot of factors were eliminated according to the results of the two phases' analysis. This may be attributed to their negligible effect on the expected safety performance. Among these factors were: HI1 "The social life is comfortable to the worker", HI2 "The smaller the age worker, the better the site to dispose of safely", HI3 "Due to foreign workers on construction sites, many sites are multilingual", HI4 "Qualification has a great importance in the speed safely dispose of", HI7 "The worker was suffering from health problems", HB2 "Successful safety programs can be achieved if the positive attitudes of employees toward safety are reinforced and expressing their safety concerns and issues", NE1 "Weather conditions have a significant impact on the work safely", NE3 "Wind intensity varies according to the site's geographic and topographic location, so it is effects on adjacent buildings", and WE1" Multilayers subcontracting practices have a negative impact on safety performance".

• The results of the most important Safety Performance factors were not changed according to the results of the two different analyses.

Method of Compensation in the Equation

Each element was expressed in values ranging from 0 to 1 according to its effect.

• Historical Factors (HI)

Workers' experience and background of safety training were evaluated in Table 2. Through that HI value can be obtained.

Table 2. Workers' experience and background of safety training

HI value	0	0.25	0.50	0.75	1
EXPERIENCE	0	5	10	15	20
Humber of Training courses	0	2	3	4	5

• Human Behavior Factors (HB)

Worker follows correct safety rules and procedures while carrying out my job were evaluated in Table 3. Through that HB value can be obtained.

Table 3. Worker follows correct safety rules and procedures

HB value	0	0.5	1
Ratio to follow the rules and procedure	Does not follow	Sometimes	Always

Psychological Factors (PS)

The correlation work team starting from worker and end of management and the strength of each element in the team were evaluated in Table 4. Through that PS value can be obtained.

Table 4. Correlation work team

PS value	0	0.5	1
Correlation work team	Weak	Moderate	Excellent

• **Natural Environmental (NE)**

Night work requirements to ensure safety were evaluated in Table 5. Through that NE value can be obtained.

Table 5. Night work requirements

NE value	0	0.5	1
Provide requirement tonight	NO	Sometimes	Always

• **Working Environment Factors (WE)**

Site-level coordination "include the location and equipment used" was evaluated in Table 6. Through that WE value can be obtained.

Table 6. Site-level coordination

WE value	0	0.5	1
Site Level Coordination	Weak	Moderate	Excellent

• **Incentives Factors and Project Budget (PB)**

The company's budget that covers everything related to safety was evaluated in Table 7. Through that PB value can be obtained.

Table 7. The company's safety budget

PB value	0	0.5	1
Safety Budget	Unrecognized	In some projects	Always

• **Policy and Procedures Factors (PP)**

Safety data sheets covering everything related to safety clearly and realistically and there are controls on their implementation so safety procedures were evaluated in Table 8. Through that PP value can be obtained.

Table 8. Safety procedures

PP value	0	0.5	1
Safety Procedures	Unrecognized	Available Partly	Always

• **Plan (PL)**

Health and safety plans (pre-tender, during construction, and emergency) is necessary for safety. Planning process was evaluated in Table 9. Through that PL value can be obtained.

Table 9. Planning process

PL value	0	0.5	1
Planning Process	Unrecognized	In some Projects	Always

• **Inspection, Record and Audits (IR)**

There is a periodic inspection for workplace and check achievement of the targets by everyone Supervisor and Management and it was evaluated in Table 10. Through that IR value can be obtained.

Table 10. Inspection and monitoring

IR value	0	0.3	0.7	1
Inspection/Monitoring	Not available	Annually	Weekly	Monthly

• **Safety Training (TR)**

Employees are trained to use safety clothing and equipment. Employees training is not only training, but supervisors and project managers receive safety training. Periodic training was evaluated in Table 11. Through that TR value can be obtained.

Table 11. Periodic Training

TR value	0	0.25	0.50	0.75	1
Periodic Training	NO	Only employee	Employee and Newly recruits	Employee, Newly recruits and supervisor	Employee, Newly recruits, supervisor and Managers

• Management Commitment (MC)

Site safety personnel have sufficient power and authority and all concerned parties from top to bottom hierarchical levels realize that preventing accidents is everyone's responsibility. Commitment was evaluated in Table 12. Through that MC value can be obtained.

Table 12. The commitment of all levels

MC value	0	0.5	1
Commitment	Weak	Moderate	Excellent

5. Conclusion and Recommends

The aim of this research is to developed safety performance index for Nigerian construction sites that can help to improve construction safety. A list of factors was identified from international literature. The surveyed contractors were classified under the first and the second categories according to the record. The collected data covered 238 different construction projects in Nigeria. A questionnaire survey was conducted to assess the relative impact of the previously identified safety performance. The questionnaire survey was conducted based on 86 factors. The analyses were carried out using SPSS software to evaluate the impact and Probability for each factor in accordance with the experience in Nigeria. The most important factors affecting the safety performance were found to be the organizational factors; especially those can cover the management practices. Therefore, it must have the first priority for the construction contractors. The working environment was found to be the most important environmental factors within the category of sub-factor in. Moreover, the psychological factors were found to have the first rank among those of the worker factors category. The order of influencing factors constant in two phases in Safety Performance Index. The results also showed that some of the high impact factors are safety training and plan. Consequently, it is recommended that special attention should be given to those important factors. On many sites, no training programs for workers, supervisors or project managers exist; therefore, no orientation for new staff or workers is conducted, safety rules and procedures are not pointed out, there is no periodic review of training needs, and no safety meetings are held. This indicates the lack of interest from the Egyptian companies and contractors as a result of their belief not to be effective in financial terms in profits. There is a need of strong awareness that could be generated through many methods like Safety poster

display, Signs and Signals posted up at suitable places to explain the safe work habits, well-trained on using safety clothing and equipment on site, safety meetings before the start of any work, movement of equipment are taken in design to work safely etc. Contractors should also encourage their project managers to develop safety incorporated project plans.

They should also recommend not rely on pre-construction health. Such plan should be continuously revised and updated according to the changed site conditions. They should have a Project Emergency Plan to ensure that all members of the project's management are able to respond to a major emergency quickly and systematically. A strict control should be conducted by the corresponding safety authorities. One of the priorities is not to sacrifice the safety requirements for production, budget constraints or lack of time. The owners should consider safety requirement in the construction contract. Employees are required to learn from their own mistake or experience. They should also have awareness of all the expected hazards associated with the construction work before starting the work (e.g. confined spaces, falls, high risk work, electrical safety, manual handling, etc.)

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