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Development of a Safety Performance Index for Construction Projects in Egypt

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Abstract The objective of this research paper is twofold. First, identify the main factors that can be considered as safety performance indicators for the construction projects in Egypt. The identification of these factors can contribute to creating awareness and/or improving safety performance. Second, develop a safety performance index for the Egyptian construction projects. Through a comprehensive literature review the different safety performance indicators were compiled. 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 was included information regarding worker factors, environmental factors, and organizational factors. Finally, some 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 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 Egypt.

Keywords: *construction sites, safety factors, management practices, safety performance index*

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1. Introduction

According to the business Dictionary, 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 study, 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 labor 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].

Literature around the world has identified several leading occupational health and safety risk assessment methods and models, ([5,6,23,25,31,33,49,62,78]). However, all of these studies have been carried out in developed countries. None among the existing studies has been done to suit developing countries and Egypt in particular. A study on the construction safety in Egypt conducted by [50] discussed the main problems facing construction safety in Egypt and categorized them into economic, technical, and enforcement problems.

A study of the Egyptian construction industry concluded that safety programs applied by contractors operating in Egypt 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 Egyptian Labor Law 1981). 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 [54].

3. Problem Statement

Owners should recognize that the principles of management control commonly applied to costs, schedules, quality and productivity are equally applicable to safety and that, if used, will improve safety performance. So, we need a tool for safety evaluation and management by get a weight for each factor that that can influence the construction safety performance in Egypt.

4. Objectives

The objectives of this research are outlined as follows:

1. Identify factors that can influence the construction safety performance in Egypt.
2. Get the relative weight of each of these factors.
3. Develop a safety performance index to identify the level of safety of the different construction projects.

5. Research Methodology

According to Figure 1, the study was conducted through the following sequential steps. Frist, 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.

Figure 1. The methodology flow chart

6. Factors Affecting Safety Performance

There are many factors which can affect the safety performance as the safety at work is a complex phenomenon, and the subject of safety performance in the Construction industry is even more complicated to understand. Given below are many factors which could affect the safety performance in Egyptian construction sites. The conceptual framework in Figure 2 shows the factors and sub-factors [60].

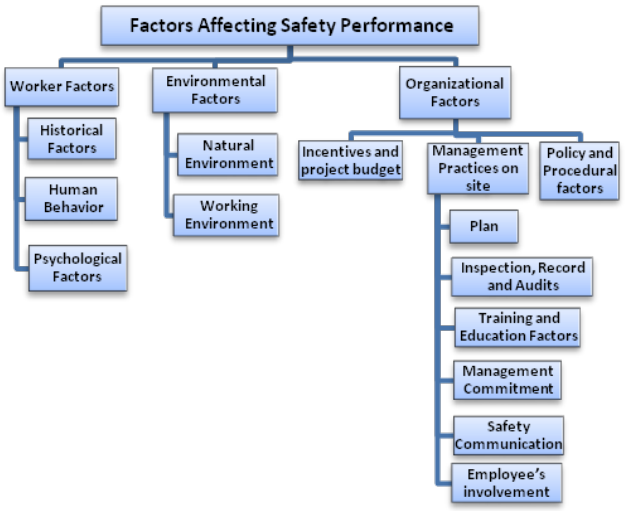


Figure 2. The conceptual framework shows Factors and Sub-Factors Affecting Safety Performance

6.1. Worker Factors (WO)

The human side of safety is seen as a key factor to improve safety performance in the construction industry. Consequently, much researches have been done in this area, such as attitudes, behavior, motivation, teamwork, leadership, and, from a bigger picture perspective, safety culture ([16,27,38,40,45,46,47,70]).

6.1.1. Historical Factors (HI)

In investigating age differences in safety attitudes and safety performance of Hong Kong construction workers, [69] concluded that occupational injuries and age have a curvilinear relationship. Work accident experience is positively linked with external attribution and unsafe behaviors but negatively linked with internal attributions [28].People with work accident experience tend to attribute the cause of accident to the external environment, and are likely to have unsafe behaviors. The Worker's background safety training providing safety skill and information should be completed by the techniques of persuasion. Persuasion has an important function. It is most common form is the poster used to refer to bad habits, and to identify the advantages of safe working, or give detailed information, advice, or instruction on special points [3].

6.1.2. Human Behavior Factors (HB)

Seventy to ninety percent of accidents are caused by unsafe behavior. A number of theories have connected accidents to the failure of persons (by their actions or oversight) in the accident chain to avert accidents ([2], [8], [34], and [71]). The safety behavior is represented as to employee risk-taking behavior and compliance to safety rules and procedures "beliefs, attitudes and perceptions of responsibility and control". The behavior base on safety refers to the behaviors which lead to reduction of risk behaviors and as a result reduce accidents and injuries. Factors such as supportive leadership and conscientiousness may affect safety behavior when estimated through compliance and participation.

6.1.3. Psychological Factors (PS)

The psychological climate has been shown to directly effect on the safety performance of individual workers. This climate includes the workers' relationship with or the behavior toward fellow crew members, the supervisor, and the employing firm. The safer workers worked in smaller crews and they also had a more cordial or friendly relationship among themselves. Safer workers also had supervisors who openly showed them respect and gratitude by integrating or considering their suggestions and by praising them for work well done. The safer workers were those who had positive feelings about their employer [20].

The worker psychological is an important factor to contribute safety performance workers will work more safely with a supervisor who is seen as someone who respects their workers and their contribution, and who is stimulated by a clear company policy on safety. Because they see that their supervisor regards safety equally important as production, so the supervisor position towards safety as a major source of influence on their behavior at the site. They can also expect activists to respond positively, when they work safely [64].

6.2. Environmental Factors (EN)

6.2.1. Natural Environment (NE)

Geographical location, weather condition "related to poor visibility" and night works have a significant impact on work at night. Organizational factors in different geographical location may vary in term of producing differential effects on safety performance SO organizational also keep updating and response to requirements imposed by the changing environment [67].

6.2.2. Working Environment (WE)

The construction site is a complex system with a lot of stakeholders working together to complete the construction project. This complex system also some information being passed from one team (design) to another (construction), which is required for risk assessment and communication. In the meantime, the physical space, the working procedure (site operation), tools and methods used and resources available are factors influencing risk assessment and communication. This study considers the physical space, instruments, tools and equipment as well as the working team and working procedures as factors in the work environment system [32].

6.3. Organizational Factors (OR)

Companies can take many approaches to developing and implementing safety programs. Some programs focus more on the application of safety rules through an accountability system. Other programs provide safety education/training to enhance employees' safety awareness, attitude and commitment through a cultural intervention ([32,54]). Other approaches integrate both aspects [48].

Organizational climate is widely defined as the perception of formal and informal organizational policies, practices, and procedures [58]. Organizational climate defined as "an experientially based description of what people see and report happening to them in an organizational situation. Climate involves employees' perceptions of what the organization is like in terms of practices, policies, procedures, routines, and rewards" [55].

6.3.1. Incentives Factors and Project Budget (PB)

Incentives factor is one of the determinants that motivate workers to behave in a desired manner to safety regulations on site. It can be viewed a psychological approach that rewards workers for their adhered routine on site ([12,75]). Combination of reward and punishment can be regarded as a strategy that inculcates safe behaviors among workers on site.

Incentives programs consist of these main elements such as monetary, non-monetary, and disciplinary action was suggested [74]. A system of rewards that use the money, coupled with non-monetary incentives. Employer costs included productivity losses, lost jobs, salary of the injured employee or of a replacement employee or additional overtime costs, expenses reimbursed to the injured employee, repair, rental or replacement costs,

changes to insurance premiums, and legal costs. All this affects the budget.

6.3.2. Policy Factors and Procedures Factors (PP)

Management should be working on the formulation of the operational procedures to provide tactical policy action guidelines [79]. So Policy Factors and Procedures Factors can be integrated in one group.

The health and safety policy statement should contain the aims which cannot be measured, and measurable goals of the organization or company. It aims probably unchanged through a political review, while the targets will be reviewed and amended or changed each year. It must be written statement in clear and simple language so that it is easy to understand [57]. The corporate management makes policies which give directives to the frontline workers, and supervise the work process to ensure safe and reliable operation within the safe and reliable environment in order to achieve high values of safety performance ([80], and [39]).

Procedures factors indicate that the provision and use of the right kind of equipment for a job, and the provision and use of protective clothing and equipment is a precondition to improve the safety performance [73].

6.3.3. Management Practices on site (MP)

There are many management practices which are appreciate to create safety culture. These management practices are rewards, training, management commitment, communication and feedback, hiring practices and employee participation. Base on the past literature the practitioners have found that these dimensions are key component to improve safety performance [76].

Improvements in organizational structure, organizational importance of safety, safety responsibility and accountability, communication, management behavior, employee involvement, and employee responses and behavior can help improve safety performance [21].

6.3.3.1. Plan (PL)

Sites which are properly planned are more likely to improve safety performance by reducing the causes of accidents on site. One of the key outputs of the planning process is plans and objectives to develop, maintain and improve the health and safety management system. The various plans across the different parts of an organization need to be aligned to meet the organization's overall aims and to provide a coherent approach to effective risk control [36]. The overall goals set at the highest level in the organization need to be put into effect by a series of linked plans and objectives. These should cascade down the various levels within the organization. Every project must have pre-tender health and safety plan, construction phase health and safety plan and Emergency Plan [4].

6.3.3.2. Inspection, Record and Audits (IR)

The use of safety inspections has been shown to have a positive effect on a company's loss control initiative. In fact companies who perform safety inspections have fewer accidents incidents than companies that do not perform inspections [59]. Audits look at systems and the way they function in practice, inspections look at physical conditions. So, while inspections of a site, or particular items of equipment, could (or possibly should) be done formally at least weekly, an audit of the inspection system throughout an organization would look at whether the required inspections were themselves being carried out, the way they were being recorded, who received copies of the report, whether action was taken promptly as a result, and so on [4], and [56].

6.3.3.3. Safety Training (TR)

Training and development (TD) defines as a process that enables people to acquire new knowledge, learn new skills, and perform behaviors in a new way [13]. Further distinguishes between training and development by stating that training refers to the acquisition of specific skills or knowledge, and development refers to the improvement of intellectual and emotional ability needed to perform better at a specific job. Therefore, investment in TD of employees improves profitability, organizational culture and is integral in the formation of a lean organization [42].

6.3.3.4. Management Commitment (MC)

Companies with affective safety committees are more likely to take steps that improve safety performance than those companies without. Top management should consider safety as equally important as other aspects in the organization, such as production and profit. There is also a need for top management to respond decisively when a safety issue is raised. Furthermore, it is crucial for top management to encourage all employees to follow safety procedures and implement initiatives to improve their safety performance. In order to demonstrate their commitment towards safety, top management needs to provide necessary resources, e.g., money, tools, and equipment, for employees to work safely and to monitor safety. Safety personnel must have sufficient power and authority to enforce safety regulations and procedures at all levels in the organization. Lastly, top management needs to evaluate employees' safety performance to keep people motivated in implementing safety measures [70].

6.3.3.5. Communication and Feed Back (CO)

Regular communication about safety issues between management, supervisors and workforce is an effective management practice to improve safety in workplace. [15], [76], [17], and [51] included communication and feedback as a factor in their surveys using questionnaire. Regular feedback on performance can be good to communicate to employees through sign boards, caution signs, and other indications. The data which is collected as a feedback will not only help the organization but it will also help the organization to have the behavioral data in maintaining safety. In order to encourage communication, it is very important not to blame worker for the accidents which occur. There are many managers who now work to solve production problems and they inspect for defects along with the worker ([9,61,76]).

The role of feedback is important for the worker‘s performance as it is critical because employee behavior depends on new occurrence. Base on efficient communication and feedback the management can track the hazards to prevent accidents and injuries [76]. This confirms that in order to have a better safety results, and site managers and supervisors should be involved in

regular talks with activists at the site. Supervisors and executives must support the implementation of safety through talks and actions. They need to demonstrate their safety commitment by promoting a safe place to work and creating supportive work relationships to tackle safety issues. It is also necessary for them to include safety an important indicator in assessing the performance of staff [70].

6.3.3.6. Employee's Involvement (EI)

Individuals can be involved in project teams, focus groups or through direct interviews to get their views. Involving them in focus discussion groups may be a way to maximize the utility of the numbers of participants. Worker involvement has been reported as a crucial factor in safety management by [63], [18], [65], and [17]. Therefore, workers' involvement in safety is considered as a management practice and is measured using items related to safety committee comprising of workers' representatives, involvement of workers in safety related decision making, involvement in identifying safety problems, and consultation with workers about safety matters.

Employee Involvement (EI) occurs when employees are solicited, and are involved in helping the organization to achieve its objectives [10]. Therefore, EI focuses on organizing employee's skills and knowledge to improve efficiency and customer service. Employee empowerment (EE) is happening when employees are given the authority and tools required to continuously improving the organizational performance [37]. EE has been implemented in job design and quality of work life programs [7]. Therefore (EE) means that all employees are responsible and have authority to participate in decision and problem solving in their operation levels [68].

7. 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.

7.1. 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]:

$$n = \frac{n'}{1+\frac{n'-1}{N}}, \quad (1)$$

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

$$n' = \frac{Z^2 S^2}{V^2},$$

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:

$$n' = \frac{Z^2 S^2}{V^2} = \frac{(1.645)^2 (0.5)^2}{(0.05)^2} = 270.6025 \approx 271.$$

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

$$n = \frac{271}{1+\frac{271-1}{1955}} = 238.$$

So, the sample size of Contractors is 238 Contractors.

7.2. Data Collection

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

The questionnaire was consisted of two parts:

- Frist 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 Egypt and it value ranging from (0 to 1). It measures the rate of implementation factor in the Egyptian sites.

The importance of the geographical location has been taken into consideration in this research. Hence the questionnaire was distributed in different areas in Egypt. The selected projects were distributed in different cities in

Egypt. Among these cities were Cairo, 10th of Ramadan, 6th of October, Zagazig, Mansoura, Damietta, Port Said, Assiut, Marina, Alexandria, Giza, and Mahalla al-Kubra.

Figure 3 shows participants' experience. It illustrates that, 51 participants (21.43% of the sample) were more than 20 years' experience, 49 of the participants were between 11 to 20 years' experience (20.59 % of the sample), 57 participants (23.95% of the sample) were between 6 to 10 years' experience, , and 81 participants (34.03% of the sample) were less than 5 years' experience.

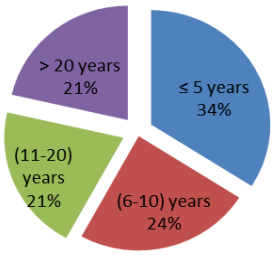


Figure 3. Percentages of Participants' Experience

8. 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.

8.1. 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.

8.2. 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,

$$\text{Weight of Worker Factor } (W_{WO}) = \frac{TM_{WO}}{TTM}$$

$$= \frac{TM_{WO}}{TM_{WO} + TM_{EN} + TM_{OR}}$$

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

$$(SPI) = W_{WO}WO + W_{EN}EN + W_{OR}OR.$$

In this section two Phases of analysis will be carried out and compared:

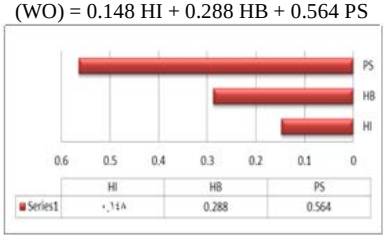
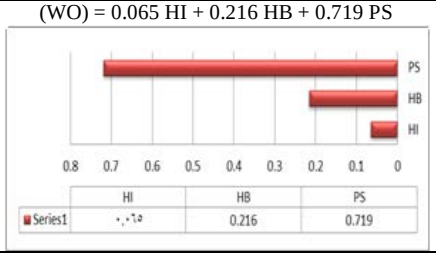
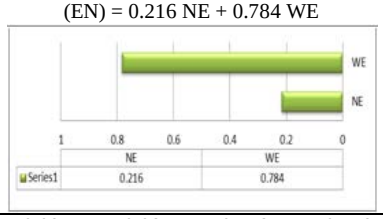
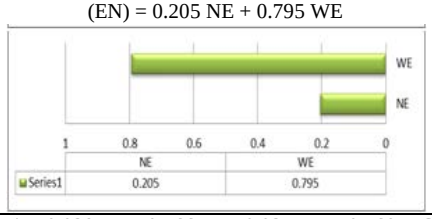
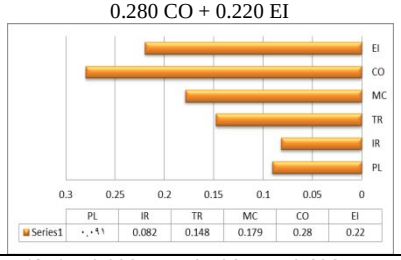
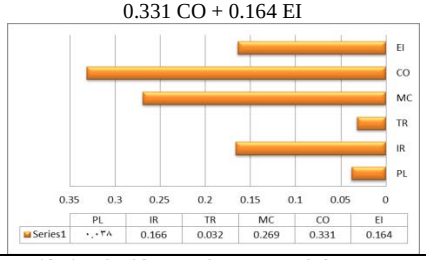
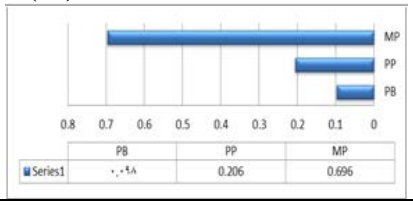
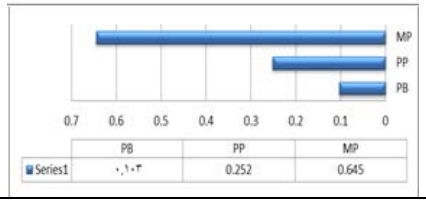
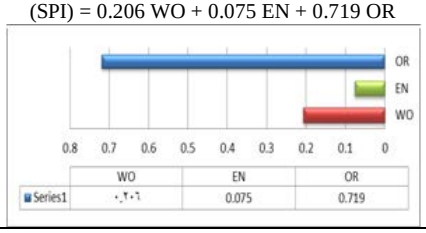
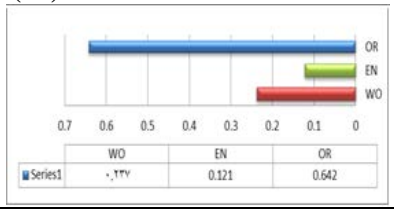
8.2.1. The first was only analysis of data on the degree of impact on safety performance in construction project.

8.2.2. 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 Egypt.

8.3. Discussion of the Results

According to the comparison in Table 1, it can be noted that:

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	(WO) = 0.148 HI + 0.288 HB + 0.564 PS 	(WO) = 0.065 HI + 0.216 HB + 0.719 PS 
Environmental Factor	(EN) = 0.216 NE + 0.784 WE 	(EN) = 0.205 NE + 0.795 WE 
Management Practices on site	(MP) = 0.091 PL + 0.082 IR + 0.148 TR + 0.179 MC + 0.280 CO + 0.220 EI 	(MP) = 0.038 PL + 0.166 IR + 0.032 TR + 0.269 MC + 0.331 CO + 0.164 EI 
Organizational Factors	(OR) = 0.098 PB + 0.206 PP + 0.696 MP 	(OR) = 0.103 PB + 0.252 PP + 0.645 MP 
Safety Performance Index	(SPI) = 0.206 WO + 0.075 EN + 0.719 OR 	(SPI) = 0.237 WO + 0.121 EN + 0.642 OR 

- In both phases, the majority of the sub factors in Historical Factors were eliminated 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 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" Multi-layers 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.

8.4. 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
Number 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 procedures	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 requirements 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 and Monitoring	Not available	Annually	Monthly	Weekly

- **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	0.5	0.75	1
Periodic Training	No	Only Employees	Employees and newly recruits	Employees, newly recruits and supervisors	Employees, newly recruits, supervisors, 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

- **Communication and Feed Back (CO)**

There is continuous communication to achieve a commitment at all levels, whether direct dialogue or paperwork. Level of communication between all team was evaluated in Table 13. Through that CO value can be obtained.

Table 13. Level of communication between all team

CO value	0	0.25	0.5	0.75	1
Level of communication between all team	No	Annually	Monthly	Weekly	Daily

- **Employee's involvement (EI)**

All responsible from top to bottom, including workers involved in safety meetings, job analysis, safety suggestions, identifying training needs, and investigating accidents. Employee's involvement was evaluated in Table 14. Through that EI value can be obtained.

Table 14. Employee's involvement

EI value	0	0.5	1
Employee's involvement	Weak	Moderate	Excellent

9. Conclusion and Recommends

The aim of this research is to developed safety performance index for the Egyptian 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 of the Egyptian Federation for Construction and Building Contractors in 2014. The collected data covered 238 different construction projects in Egypt.

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 questionnaire was designed in English and Arabic version. The analyses were carried out using **SPSS** software to evaluate the impact and Probability for each factor in accordance with the experience in Egypt.

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 were not to have the importance that deserve. Among these 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 especially the Egyptian Federation for Construction. All concerned parties from top to bottom hierarchical levels should realize that preventing accidents is everyone's responsibility. 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 work (e.g. confined spaces, falls, high risk work, electrical safety, manual handling, etc.). Accidents analysis can greatly help in this area.

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