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Elements of Safety Management System in the Construction Industry and Measuring Safety Performance – A Brief

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Abstract. Construction industry is considered to be one of the most hazardous industries in the world. The reason could be attributed to its hazardous nature as it is an accident-prone industry. Thus, a need for better understanding of safety management system is essential for improving safety performance in this sector. This paper discusses briefly the elements of safety management by presenting different systems (such as Oregon OSHA Occupational Health and Safety Administration, and OTAR Overseas Territories Aviation Circle) and elaborating their elements. It also discusses two types of measuring safety performance the first is the lagging indicators and the second is the leading indicator. In addition, a field study was conducted to explore contractors' perception on safety management. A questionnaire was distributed to construction firms. 200 responses were collected and analyzed. All of the results showed positive answers which indicate that safety in performance in Egypt is slightly above average as all means were close to average.

1. Introduction

Construction industry is considered one of the most dangerous industries in the world. By looking at accidents records, it turns out that the construction industry scores the highest among other industries. For example, it was reported that 9209 accidents occurred in 2012 in the construction industry by the Turkey Statistical Institute, and 568 of them were permanent disability, and 256 resulted in fatality[1]. Moreover, a recent study in Nigeria revealed that the incident rate (IR) in the construction industry in Nigeria is 2 (which means that for every 100 workers, 2 of them encounter an accident)[2]. The reason could be attributed to its unique characteristics which reflect how hazardous it is. The characteristic of the construction industry has been analysed in different studies[3,4]. Briefly, construction industry creates one-of-a-kind product which creates a difficult in safety fixtures as the have to be replaced continuously, and being a temporary multi organization industry makes it difficult to communicate

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between different parties.Thus, it is important to implement a safety management system in this industry to improve its safety indicators.

There is no specific definition that can best describe safety management system as this term may have different interpretation among different countries and even among different organizations. Table (1) shows different definitions of safety management system by different organizations and studies. Another reason for having different definitions could be that most studies done on safety management, in the past as noted, have been done in the field of psychology and sociology, as noted in the previous section about human behavior[5].

Table 1: Definitions of safety management systems by different organizations.

Organization or Study	Definition
SMIC (Safety Management International Collaboration Group) [5,6]	"A safety management system is a series of defined, organization-wide processes that provide for effective risk-based decision-making related to your daily business."
ILO (International Labour Organization) [7,8]	"A set of interrelated or interacting elements to establish OSH policy and objectives, and to achieve those objectives."
ICAO (International Civil Aviation Organization) [9,10]	"A systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures."

Most of the studies have showed over the years that safety management systems have a positive relationship with safety performance.Bottani et al. [11] have investigated the influence of safety management system between adopting and non-adopting companies. The results showed companies adopting safety management systems exhibit higher performance in training employees and assessing risks. The benefits of safety management system according to [5] are briefly:

- Reducing the number of accidents and minimize the risk accidents in the workplace by controlling the workplace hazards.
- Improving the employee morale and enhancing their productivity by minimizing production interruptions.
- Reducing the cost of employees' absence and the cost of their insurance as well.
- Reducing the cost of legal litigation in court, and reducing investigation time for accident.

2. Elements of Safety Management System

Elements of safety management systems varies from one organization to another [12]. Some organizations have drawn the elements of safety management by making a comparison between high and low accident rate in companies. Whereas, others have drawn the elements of safety management based on actual case studies of highly safe and reliable organizations with good safety performance [5]. The following section will cover different safety management systems according to different organizations in different countries from various studies. In each safety management system, elements proposed will be discussed and elaborated.

A study aimed to detect successful elements of safety management by comparing high and low accident firms revealed five major successful elements of safety management [13]:

- The first and the most important element is the strong top management commitment towards safety. This commitment can appear in various ways. For instance, it was found that in low-accident companies top management was highly involved in safety activities on a regular basis, whereas, this involvement was on the other hand absent in high-accident companies. It has been reported that top management take safety issues seriously in meetings in all low-accident companies.
- The second element of safety management according to [13] is safety training of workers. Safety training in low-accident companies has been addressed as an essential part of new workers training, as well as, as a following up for old personnel.

- The third element is establishing well communication link between management and workers. This may include periodic safety inspection by professionals.
- The forth safety element is good housekeeping which may include high usage of the latest safety devises.
- The fifth element is maintaining low turnover rates. It is found that low turnover rates reinforce work relations and enhance the personal development practices. Finally, the last element of safety management is incentives. This could be implemented in a variety of ways such as praising individuals through recognitions for safety performance.

A more developed safety management system was developed and created by Oregon OSHA (Occupational Health and Safety Administration) consists of seven elements of safety management [14]:

- The first element is management commitment to protecting employees. In fact, this element is the most important element in any safety management system as it determines how much the top management are committed on the safety of their workers.
- The second element of Oregon OSHA is accountability. One of the most important methods which can improve the accountability is stating in the employees' job description their safety responsibility.
- The third element is employee involvement in safety such as: allowing employees to participate and be part of the committee, and posting safety policies and guidelines in workplace where all of them can see, and promoting recognitions awards for best safety awards. It was found that safety incentives and rewards are one of the most effective techniques for improving safety performance [15].
- The fourth element is hazard identification and control. There are a variety of ways to identify hazard (such as maintaining a periodic inspection, providing an efficacious reporting system for the employees). As whole, well-developed hazards identification techniques can be classified into two categories: First is the Reactive Approach which is identifying hazards that may lead to an accident event before it occurs. Second is the Proactive Approach which is identifying the hazards before an accident occur depending on historic data and previous experiences [16,17].
- The fifth element of Oregon OSHA is accident analysis. Accident analysis is very important to prevent future accidents and improve the safety performance.
- The sixth element is educating and training. It is very important to train the employees about the risks and the hazards and teach them how to protect themselves.
- The last element is evaluating and reviewing the safety program [14].

Another organization the Overseas Territories Aviation Circle OTAR has developed another safety management system consisting of six elements[18]:

- The first element is objective which includes the organization's mission and vision towards safety. It acts as a motivation for the whole organization.
- The second element is defining roles and responsibilities, which is similar to accountability (from the previous system).
- The third element is hazard identification which is similar to the previous system.
- The forth element is risk assessment.
- The fifth element is monitoring and evaluation such as safety audits and reviews.
- The last one is safety documentation like safety manuals, and accident records.

3. Safety Performance Measurements

Measuring safety performance allows the organizations to take important decisions and appropriate actions towards their adopted safety management system. Measurements are very important as it determines the effectiveness of the safety management system on the overall safety performance, which can be either accident prevention strategies and/or safety practices and activities [19]. However, is safety performance measurable? For example, the standard unit for measure lengths is "meter" and a measure tape can be used for that. The standard unit for measuring mass is "kilogram" and a balance can be used for that. So, how to measure the safety performance?

In fact, there are two types of measuring safety performance actually based completely on two different concepts. The first is “lagging indicators”, and the second is “leading indicators”.

Lagging indicator is safety performance measurement based on failures in the past. So, it is a retroactive measurement which only record incidents in the past [19]. Lagging indicator measure the incident after it occurs, that is why it was described as measuring the absence of safety rather than the presence of safety [5,19]. According to [20] the lagging indicators are widely use as easy to collect and understood, comparable with each other, and useful in the identification of a trend.)

The most common lagging indicators were discussed briefly by [5,19]. Table (2) shows the most common lagging indicator used for measuring safety performance and Table (3) shows a brief description for each of them. Most of them are lagging indicators developed by OSHA organization which has a standard. It bases its calculation on 200,000 labour hours in a year, and this should be equivalent to 100 employees working 40 hours per week, and 50 weeks per year.

Table 2: The most common lagging indicators.

Lagging Indicator Name	Equation
OSHA Recordable Incident Rate (TRIR)	$TRIR = \frac{Total\ recorded\ incidents\ a\ year * 200{,}000}{Total\ labor\ hours\ worked\ a\ year}$
OSHA Lost Time Case (LTC)	$LTC = \frac{No. of\ lost\ time\ cases * 200{,}000}{Total\ labor\ hours\ worked\ a\ year}$
OSHA Lost Work Day Rate (LWD)	$LTC = \frac{No. of\ lost\ days\ a\ year * 200{,}000}{Total\ labor\ hours\ worked\ a\ year}$
OSHA Days Away, Restricted or Job Transfer (DART)	$DART = \frac{No. of\ DART\ incidnts\ a\ year * 200{,}000}{Total\ labor\ hours\ worked\ a\ year}$
Incident Rate (IR)	$IR = \frac{Total\ Incidents * 100}{Total\ workers}$
Severity Rate (SR)	$SR = \frac{Total\ lost\ days}{Total\ incidents}$
Risk Rate (RR)	$RR = \frac{Total\ lost\ days * 100}{Total\ workers}$

Table 3: Description of the lagging indicators.

Lagging Indicator Name	Description
OSHA Recordable Incident Rate (TRIR)	The number of OSHA recordable incidents per year for every 100 workers working the standard OSHA working hours a year. For example, if the TRIR for an organization is 8, this means that for every 100 workers working (the standard OSHA working hours) in that organization, 8 of them had recordable accident/injury in a complete year.
OSHA Lost Time Case (LTC)	The number of incidents in a year which results in sick leaves for every 100 workers working the standard OSHA working hours. For example, if the LTC is 8, this means that 8 workers for every 100 workers (working the standard OSHA hours) were unable to go to work for some time because of an incident.
OSHA Lost Work Day Rate (LWD)	The number of lost work days in a year for every 100 workers (working the standard OSHA working hours). For example, if LWD is 8, this means that 8 complete days were lost in a year for every 100 workers (working the standard OSHA hours).
OSHA Days Away,	It is the number of incidents in a year for every 100 workers which

Restricted or Job Transfer (DART)	results in workers being restricted,
Incident Rate (IR)	Total number of incidents per 100 workers (not necessarily working the standard OSHA hours) in a certain time (not necessarily a year).
Severity Rate (SR)	The total number of lost days for every incident within a period of time.
Risk Rate (RR)	The total number of lost days for every 100 workers (not necessarily working the standard OSHA hours) in a certain time (not necessarily a year).

Although lagging indicators are widely used in almost all organization in all sectors, yet they have many problems and defects. The first problem is luck. Some workers might have worker for a long period of time without encountering incidents. That doesn't mean that they were safety, they might have been exposed to extreme hazards but without and accident. Such traditional measurements will not detect this kind of events. The second problem is susceptibility to manipulations and lack of precision. Many organizations tend to not reveal information concerning injuries occurred in their workplace. Moreover, some attempt to play with injury records and description to reduce the compensation costs. The third problem is as stated before that these measurements are used to project the absence of safety not the presence of safety as they measure past incident which have already occurred. So, they cannot be used efficiently to determine hazards or eliminate them, or even to improve the safety [21].

There is a more improved type of safety performance measurement than lagging indicators, which is leading indicators. Leading indicator are safety measurement which provide a future forecast of the safety performance based on the activities and practices implemented not incidents. So, it is proactive measure to what might happen in the future [22]. Leading indicators were developed from the root causes of accidents, that is why they are very practical in improving safety performance.

There are many examples of leading indicators. In fact, each industry has its own leading indicators developed as mentioned before from the nature of the accidents in that industry. All safety practices and activities are considered as leading indicators. For instance, all workers in an organization should have an OSHA safety certificate. Another example is providing a certain number of training hours in a certain period of time [5]. Table 4 shows different examples of leading indicators.

Table 4: Examples of different leading indicators

Leading Indicator	Description
Worker Observation Process [23]	• Common techniques used to evaluate ongoing tasks in construction. • Unsafe conditions and acts that contribute to injury, property damage, or equipment failure can be identified, recorded and used to monitor and predict safety performance.
Near Miss Reporting [23]	• Defined as an incident where no property damage and no personal injury was sustained, but where, given a slight shift in time or position, damage and injury easily could have occurred. • Near misses are measurements of processes, activities and conditions that assess safety performance and can predict future results. • Near miss reporting is used as a safety management tool in many other industries within the U.S. private sector.
Project Management Team Safety Process Involvement[23]	• Demonstration of leadership and commitment via active management walking around. • Senior management and supervisors are encouraged to participate in site safety walks. • Management plays a key role in promoting a positive safety culture. • Allocating resources, time, and inspections.

Job Site Audits **[24]**	• Systematic measurement and evaluation of the way in which an organization manages its health and safety program against aseries of specific and attainable standards. • Conducted to identify problem areas including unsafe conditions and unsafe behaviors. • The results can predict trends to show that safety is improving or that jobsite safety is decreasing.
Stop Work Authority [23]	• Workers are expected to stop any work they consider to be unsafe until they feel it is safe to proceed. • Stop work authority is to be clearly communicated to workers in initial orientation and at regular intervals throughout each project.
Housekeeping Program [23]	• Helps achieve a further reduction in the occurrence of job site accidents. • The level of housekeeping at a given site is an indicator of safety at that site.
Safety Orientation and Training **[24]**	• Helps workers become aware of project hazards. • The nature of the orientation will help to determine the probable success of delivering a safe project. • The orientation training should be provided to all individuals who will be working on site, including the field employees, subcontractors' employees, and all salaried personnel on site.

4. Methods.

4.1. Data Collection.

Data collection in this research was done in two stages. First stage is gathering relevant data through literature review. The second stage was a field study which was done in the form of a questionnaire.

The questionnaire aimed to investigate contractors' perception of their evaluation of their companies in terms of safety performance. It consists of nine Likert-scaled questions about evaluating safety management adopted from **[24]**. It consists of nine questions and is expected to be answered in 2:30 minutes. The questionnaire consisted of two sections (general information and evaluation of companies). All questions were designed on 4-point closed-end Likert-type scale measuring the level of agreement of each variable, except for an open-end question. The reason why even number of (4-point) alternatives was used instead of the most common 5 alternatives explained by [25] is: first to avoid selecting the middle alternative if the respondent felt bored, second some respondents tend to choose the middle alternative despite of having a solid answer. This would be because some respondents would not exert the cognitive effort to form an opinion about the question and this is called "satisficing". The only disadvantage for this type of scale is that those respondents, who actually do not have any idea about the question or the topic, will be forced to select one of the two-directional answer categories [26]. Because this questionnaire was distributed to experts, this problem did not exist.

4.2. Techniques of analysis

All the quantitative questions in this questionnaire were analysed using two methods. The first method is done by measuring the central tendency. Central tendency presents a certain value for a variable or probability distribution. Its most used measures are the arithmetic mean, median and mode. The second method used in this questionnaire is dispersion. Dispersion specifies the nature of data whether it is homogeneous or heterogeneous. It also assesses how much differences and variations are presented in the data and are apart from the presented value in the sample. The dispersion measures, which were used, are standard deviation and variance [27]. Excel was used to get both central tendency (mean, median and mode) and dispersion (standard deviation and variance) and relative importance index RII.

4.3. Sampling and questionnaire distribution

The statistics of contractors for complete building works were obtained from the Egyptian Federation for Construction & Buildings Contractors (EFCBC). Table 5 shows the number of contractors (for complete buildings works) in Egypt and some of its governates. It shows all the seven grades of contractors as well. According to [28] the large firms are the first 3 grades, the medium firms are the fourth and fifth grades, and the sixth and seventh grades are the small firms. This study targeted the large and medium firms as the large firms must be registered in the International Project Management Association IPMA. The medium firms were also selected as one of the terms required for their registration that they should have an experience for at least 2 years, which is suitable for this study to cover a wide spectrum of opinions.

Table 5: Number of contractors for complete buildings works in different governates in Egypt

Class	1st	2nd	3rd	4th	5th	6th	7th	Total
Egypt	138	144	182	453	653	565	4884	**7019**
Cairo	79	57	62	154	161	100	787	**1400**
Giza	23	21	20	44	68	66	389	**631**
Alexandria	6	6	10	24	32	35	296	**409**
Sohag	4	4	3	11	22	20	368	**432**
Minya	2	1	3	13	15	17	178	**229**
Dumyat	2	3	0	4	15	6	120	**150**
Asyut	2	4	7	10	16	19	175	**233**
Fayoum	1	5	8	21	22	31	172	**260**
Suez	0	2	5	13	27	11	119	**177**
Port Said	3	4	6	10	16	13	44	**96**
Others	16	37	58	149	259	247	2236	**3002**

Source: [29]

The total number of the large and medium categories was 1570 which is the population size. The sample size was calculated using the simplified formula by Yamane [30]:

$$n = \frac{N}{1 + N(e^2)}$$

Where:
n is sample size
N is the population size
e is the level of precision (5% in this case)

$$n = \frac{1570}{1 + 1570(0.05^2)} \approx 319$$

This takes into consideration that the confidence = 95%... If the confidence is a value different from 95%, this equation becomes invalid.

Another equation could be chosen for that instead of the simplified equation which is the most common fundamental equation for large population (which should be adjusted if the population is small) by Cochran [30]:

$$n_o = \frac{z^2 pq}{e^2}$$

Where:
no is sample size for large population
p is an estimated proportion of an attribute that is present in the population
e is the level of precision (5% in this case)
q is equal to 1-p
z is a point on the abscissa of the standard normal curve that specifies the confidence level

It is recommended to take the product p*q (which is called the variance) as the maximum value. Therefore, p = 0.5 and q = 0.5. For a confidence percentage of 95% z value should be 1.96

$$n_o = \frac{z^2pq}{e^2} = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} = 384.16$$

If no (sample size) is greater than 10% of the population, then the population is not considered a large one. Therefore, no should be subjected to adjustments for true sample value. The true sample value can be calculated using the following equation:

$$n_R = \frac{n_0}{1 + \frac{(n_0-1)}{N}} = \frac{384.16}{1 + \frac{384.16-1}{1570}} \approx 309$$

309 companies were contacted. The questionnaire was distributed in large construction sites in Cairo, as well as, it was sent on Linkedin to reach firms in Cairo and other governates which are inaccessible. 200 of the 309 respondents, answered the questionnaire.

5. Results and Discussion

Table 6: Results of the questionnaire

Questions	Mean	Median	Mode	SD	Variance
Q1: When a risk is detected, management in my company (the company you work in) ignores it without an action	1.995	2	1	0.97	0.95
Q2: Management in my company ensures that safety problems discovered are corrected immediately	2.99	3	3	0.93	0.86
Q3: Management in my company places safety before production	2.64	3	3	0.99	0.98
Q4: Management in my company ensures that everyone receives the necessary information on safety	2.875	3	4	1.01	1.02
Q5: Workers have confidence in the management's ability to deal with safety in my company	2.735	3	3	0.94	0.89
Q6: Management in my company encourages employees to participate in decisions which affect their safety	2.72	3	3	0.93	0.86
Q7: Management in my company never considers employees' suggestions regarding safety	2.245	2	2	0.96	0.92
Q8: Fear of negative consequences from management discourages employees from reporting near-miss accidents	2.275	2	2	0.95	0.90
Q9: Management always blames employees for accidents	2.45	2	2	0.98	0.95

It is noticed from Table 6 and the radar diagram that more than half of results showed positive responses (level of agreement). All the nine questions showed positive responses, however almost close to the average. The Mean showed that respondents pointed out that management in their companies did not ignore risks without an action, ensures that safety problems discovered are corrected immediately, places safety before production, ensures that everyone receives the necessary information on safety, encourages employees to participate in decisions which affect their safety, and considers employees' suggestions regarding safety. In addition, they believe that workers have confidence in management, and they do not fear to report near-miss accidents. They also believe that their management don't blame workers for accidents.

In the professional opinion of the author, that these results may not be as they seem, and there may be problems related to management whom respondent did not point out. Respondent might have been afraid to answer this section as it directly asks them to assess the company, they work in. So, results were good. The author believes that results are over-assessed because some of the respondents refused to answer this questionnaire.

6. Conclusion

The continuous increase in the accident rates in the construction industry makes it a necessity to start implementing safety management systems. Thus, this paper has presented a brief review in some of the most important safety management systems such as: Oregon OSHA, and OTAR in a better way of improving the safety performance. In addition, this paper has elaborated tools used for measuring safety performance for more accurate performance assessment.

The paper has also explored contractors' perception on their safety management. Most of the respondents showed positive answers to the questions.

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