Analysis of Events and Exposures Leading to Construction Injuries in Developing Countries: The Case of Lebanon

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Abstract. There is unanimous agreement that the complex and dynamic nature of construction jobsites is coupled with inherent risks. Global occupational and health agencies revealed that the construction industry leads with the number of fatal injuries incurred every year. Lebanon, a developing country in the Middle East, is no exception. Studies on construction safety in the country showed that the industry has failed to implement safety regulations, while also witnessing a lack of safety incentives, training, and education. The situation worsens with the absence of a national experience multiplier that could reflect on contractors’ safety statuses and hold them accountable for their safety performance. This study addresses the problem by proposing a cost model that evaluates construction injuries. An analysis was performed on more than 3,000 accident claims collected from insurance companies to understand the events and exposures that construction labour face. Results showed that there are 17 different types of events and exposures which can be grouped into three clusters depending on their frequency and average cost. This paper presents and expands on the three clusters and identifies the events that fall under each of them. The findings will serve as the base of the cost model in a future study.

1. Introduction and Background
The construction industry is a hazardous industry that is responsible for thousands of injuries annually. Recent statistics show that construction incurred 1 in every 5 deaths in the United States of America (USA) and the European Union (EU) [1,2]. The safety situation was further disrupted with the coronavirus pandemic, which led to unprecedented challenges and concerns raised by construction workers [3]. Lebanon, a developing country in the Middle East, is no exception. The last study that analyzed occupational injuries found that, among all industries in Lebanon, the construction industry incurred the highest number of fatal and non-fatal injuries, with 1 in every 3 deaths attributed to construction [4]. The alarming rate of deaths triggered several construction safety studies that highlighted major safety issues including the absence of government enforcements [5], lack of training and safety certifications [6], overburdened employees and absence of employee engagement in safety decisions [7], absence of visual management practices [8], and lack of awareness and perception of hazardous activities [9]. In addition to the lack of government enforcements, the health and safety laws released by the Lebanese Ministry of Labor are outdated [5]. For example, a survey of contractors found that the most common reason for the lack of adoption of safety systems in Lebanon is that such safety practices are not required by law, in spite of the existence of Decree No. 11958 of 2004 concerning regulations of safety and labour protection in the construction industry [10].

Moreover, the difference in safety perspectives between contractors and insurance companies causes major challenges. A survey conducted of both parties showed significant differences between the safety
practices that contractors prioritize on site and the safety practices that insurance companies consider for controlling premiums [11]. Additionally, insurance companies do not investigate the previous history of any new contractor that they sign in because of inadequate record-keeping, the lack of a database that documents and tracks injuries, and the absence of a national experience multiplier to assess the safety performance of contractors such as the Experience Modification Rate (EMR) in USA [12].

Absent of government enforcements, safety education, and safety communication, and amid the neglect of safety and health laws, insurance companies could become the key player is setting and enforcing safety practices through their premiums. Money can act as a motivator for contractors to improve their safety performance. For instance, higher insurance premiums should be levied on contractors that incur a high number of injuries, forcing these contractors to enhance their safety regulations. However, putting such model into effect requires a better understanding and categorization of the types of construction injuries, especially in the light of the absence of a standardized and unified system among insurance companies that can investigate and evaluate construction injuries. Thus, this study contributes to the existing body of knowledge by filling a gap in the extant literature by proposing a new cost-based safety model that establishes a new basis for evaluating the safety performance of contractors in Lebanon. The rationale behind the proposed model is to analyse the events and exposures that lead to construction injuries. Understanding these causes and their consequences will benefit contractors in developing more robust safety systems and help insurance companies in properly measuring the risks involved with each type of work and assigning the appropriate premiums.

2. Methodology
Since Lebanon does not have a health and safety entity like the Occupational Safety and Health Administration (OSHA) that keeps track of occupational injuries, an archival research approach was adopted in this study to gather and analyze compensation and accident insurance claims from insurance companies [13]. As a result, a total of 3,883 construction-related compensation claims were collected from insurance companies, incurred between 2016 and 2019. Each data point provided information on the injury (event and nature) the injured worker (age and the affected body parts), and the total direct cost paid for the injury.

The development of the cost-based safety model consists of the following tasks: (1) classify the injuries into categories based on the Occupational Injury and Illness Classification (OIICS) Manual released by the United States Department of Labour [14]; (2) provide a descriptive analysis of the categories; (3) cluster the events leading to construction injuries based on their frequency of occurrence and cost; (4) perform bivariate analysis between the types of events and the remaining injury characteristics for every cluster; and (5) develop a cost-based model for insurance companies to evaluate the safety performance of contractors in Lebanon. This paper focuses on classifying the events and exposures of injuries into their OIICS categories (task 1), providing a descriptive analysis of the events and exposures (task 2), and clustering the events into groups based on their frequency and cost (task 3).

3. Data Analysis
3.1. Categorizing and describing the events and exposures leading to construction injuries
The OIIC manual is used by OSHA to classify the characteristics of occupational injuries, illnesses, and fatalities and divides the events into nine categories: (1) Violence and Other Injuries by Persons or Animals, (2) Transportation Incidents, (3) Fires and Explosions, (4) Falls, Slips, Trips, (5) Exposure to Harmful Substances or Environments, (6) Contact with Objects and Equipment, (7) Overexertion and Bodily Reaction, and (8) Non-classifiable. The distribution of the 17 types of events and exposures across the five categories of the OIICS manual are shown in Figure 1. None of the collected events were associated with categories two or three.

Category 6 (C6) had the highest total number of events. Within this category, most injuries were caused by being struck by falling objects or equipment (n=691), injured with handheld objects or equipment (n=625), and struck by discharged or dislodged flying objects (n=584). Other events that
occurred less frequently include struck against stationary objects or equipment (n=141), stepped on objects (n=114), and struck against moving objects or equipment (n=16).

Category 4 (C4) had the second highest number of events. Within this category, most injuries were caused by falling to lower levels from ladders, stairs or scaffolds (n=798) and falling on the same level due to tripping (n=668). Other less frequent events include slipping (n=28) or opening (n=21).

Category 5 (C5) had the third highest number of events. Within this category, most injuries were attributed to inhalation of harmful substances (n=12), followed by direct exposure to electricity (n=10), indirect exposure to electricity (n=7), and exposure to harmful substances (n=4).

Other events were distributed between category 1 (C1) (bites and stings from insects with n=2) and category 7 (C7) (overexertion in lifting or lowering with n=4).

Figure 1. Distribution of events within categories

In addition to obtaining the frequency of occurrence of each of the 17 events discussed above, cost data was also collected. Table 1 shows the total cost and the average cost for every event. Average cost of events varied between US $66.43 (Bites and stings) and US $9,109.93 (Falling to lower levels due to openings).

Table 1. Total cost and average cost of every event (in US Dollars)

| Category of Events | Event Description                               | Total (US Dollars) | Average (US Dollars) |
|--------------------|-------------------------------------------------|--------------------|----------------------|
| 1                  | Bites & Stings                                  | 132.85             | 66.43                |
| 4                  | Falls on Same Level due to Tripping             | 188,762.92         | 282.58               |
|                    | Fall on Same Level due to Slipping              | 12,840.99          | 458.61               |
|                    | Fall to Lower Level due to Openings a           | 191,308.43         | 9,109.93             |
|                    | Fall to Lower Level due to Other Reasons b      | 990,194.13         | 1,240.84             |
|                    | Fall to Lower Level (Unspecified)               | 102,692.43         | 1,406.75             |
| 5                  | Direct Exposure to Electricity                  | 31,012.50          | 3,101.25             |
|                    | Indirect Exposure to Electricity                | 22,601.03          | 3,228.72             |
|                    | Inhalation of Harmful Substances                | 1,525.43           | 127.12               |
|                    | Exposure to Harmful Substances                  | 19,526.82          | 4,881.71             |
| 6                  | Injured by Handheld Object or Equipment         | 245,178.39         | 392.39               |
|                    | Struck by Falling Object or Equipment           | 360,246.31         | 521.34               |
3.2. Clustering events and exposures based on frequency and average cost

After performing descriptive analysis on the types of events and exposures, k-means clustering was employed to group events based on their frequency of occurrence and average cost. Results of the analysis are shown in Figures 2 and 3. Events in categories C7 (overexertion) and C8 (unspecified) were excluded from the analysis for the lack of information on the event type and cost.

To determine the number of clusters, the elbow method was used (Figure 2). The plot of the variation of within sum of square as a function of clusters showed that the biggest drop happens at $k$ equals to three, indicating that the data can be clustered into three groups. The number of clusters was then verified by running the NbClust package in RStudio®, a package that determines the relevant number of clusters for a dataset based on 30 different indices. A majority of 10 of the 30 indices proposed 3 clusters [15]. Thus, the k-means cluster analysis was performed to group the events and exposures into three clusters. The results of the clustering are shown in Figure 3.

![Figure 2. Scree plot for the k-means cluster analysis of the events and exposures. As the number of clusters increases, the variance within-group sum of squares decreases. Based on the elbow method, the elbow at three cluster represents the optimal balance between minimizing the number of clusters and the variance within each cluster.](image)

3.2.1. Cluster 1: Low Frequency, High Cost

Cluster 1 is located at the bottom of Figure 3 and represents events that are the least frequent to occur on construction projects but incur a high cost when they do happen. Even though these events are uncommon, the impact of their occurrence can be extremely dangerous on construction workers because of the significant cost insurance companies pay to cover the claim. Events included in this cluster are direct electricity exposure (5A – where 5 is the category of the event and A is the sequence in Table 1 within the category), indirect electricity exposure (5B), exposure to harmful substances (5D), and falls to lower levels due to openings such as elevator shafts and openings in slabs (4C).

3.2.2. Cluster 2: Medium Frequency, Low Cost

Cluster 2 is located at the bottom-left corner of Figure 3 and represents events that have a medium frequency of occurrence and that incur a low cost when they happen on construction projects. While the events of this cluster occur more frequently than the events of Cluster 1, their risk on construction workers is not as dangerous because the cost of coverage paid by the insurance companies is low. Events included in this cluster are struck against stationary objects or equipment (6E), struck against moving...
objects or equipment (6D), step on objects (6F), slips (4B), inhalation of harmful substances (5C), and bites or stings (1A).

3.2.3. **Cluster 3: High Frequency, Low Cost**
Cluster 3 is located at the top-left corner of Figure 3 and represents events that have a high frequency of occurring and that tend to incur a low cost when they happen on construction projects. Events of this cluster are very common and frequently happen on construction sites. Despite the low average cost of each event included in this cluster, the high frequency of occurrence of these events could create a financial burden on insurance companies to cover resulting claims. Events included in this cluster are struck by falling objects (6B), trips (4A), handheld objects or equipment (6A), discharged objects or equipment (6C), and falls to lower levels from ladders, stairs, and scaffolds (4D).

The results of the cluster analysis show an interesting dynamic between the frequency of occurrence of events and their associated average cost. Understanding the relationship between frequency of occurrence and cost of insurance is a first step to providing a new perspective on how to categorize events in the construction industry and address the absence of a unified system to assign premiums accordingly (discussed in the background section). Correlating insurance premiums to events’ frequency of occurrence and costs will provide insurance companies with a strategy to better allocate premiums, forcing contractors to rethink safety on their job sites now that the premiums are driven by the results of their safety practices.

4. **Conclusion and Future Studies**
Recognizing the need for a new strategy to benchmark and evaluate construction safety practices in Lebanon, this paper presented the preliminary results of an ongoing effort to develop a new model for insurance companies to assess the safety performance of contractors. The scope of this paper focused on analysing 3,883 insurance claims to cluster events and exposures leading to construction injuries based on their frequency and average cost. First, a descriptive analysis using OSHA’s OIICS manual was performed to categorize the type of events and exposures. Results showed that the events fell into categories C1, C4, C5, C6, C7, and C8, with most events belonging to C4 (falls, slips, and trips) and C6.
(contact with objects and equipment). Next, k-means was employed to cluster events according to their frequency of occurrence and average cost. The analysis resulted in three clusters: a first cluster for low-frequency and high-cost events, a second cluster for medium-frequency and low-cost events, and a third cluster for high-frequency and low-cost events.

The next step of the study will expand on every cluster through performing a bivariate analysis on the events with respect to the age of the injured workers, nature of the injury, part of body affected, and source of injury. The detailed analysis of every cluster will help develop a cost-based model that can assist Lebanese insurance companies in controlling their premiums and enable contractors to re-examine and enhance their safety performance.

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