AMERICAN UNIVERSITY OF BEIRUT

DEVELOPING AN INDEX TO ENHANCE CONSTRUCTION SAFETY IN THE GLOBAL SOUTH REGION

by
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AN ABSTRACT OF THE THESIS OF

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Due to the complexity and dynamic nature of construction sites, safety is increasingly becoming crucial. Findings from previous studies and the literature found construction to be one of the most hazardous industries in the world. Lebanon, a developing country in the Middle East, is no exception as it fails to implement safety regulations and witnesses lack of safety incentives, training and education, especially at the level of the foremen and workers. Moreover, no study has attempted to analyze in detail the injuries resulting from hazardous construction works in order to understand the underlying problem and further highlight the safety practices that are being neglected.

Therefore, there is a need to analyze recent construction injuries incurred by workers and construction personnel from the Lebanese construction industry with the aim of enhancing the safety performance of contractors and improve their safety strategies.

As such, the objective of this study is two-fold: (1) analyzing the injuries incurred by the construction industry in Lebanon and (2) proposing a tool that calculates the safety index for contractors by evaluating both the safety practices that the contractor implements and the injuries incurred by the same contractor. The proposed tool can be adopted by other contracting firms from various developing countries that share common characteristics with Lebanon and lack national safety laws. The index can potentially enhance the safety environment of their construction industry, especially at the level of the contracting firms' safety performances.

CONTENTS

ILLUSTRATIONS

TABLES

Table Page

ABBREVIATIONS

ILO	International Labor Organization
OEA	Order of Engineers and Architects
CAS	Central Administration of Statistics
OHS	Occupational Health and Safety
OSHA	Occupational Health and Safety Act
OIICS	Occupational Injury and Illness Classification System

CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction is one of the largest and most booming industries in the world with enormous financial outputs. Reports estimate that the annual outputs from the industry would increase by 85% in the next ten years reaching $15 trillion by 2030 with countries like China, United States and India tallying more than half of this increase as shown in Table 1-1 (PwC, 2018). According to statistics tracked by the Census Bureau in 2018, the construction industry in the United States has more than $1,200 billion in annual revenue, of which $919 billion is private (split between 55% residential and 45% nonresidential) and $281 billion is government (Census Bureau, 2018); the United States construction industry also hosted a preliminary total of around 7.5 million jobs within the same year (BLS, 2019). In the European Union, the total construction output in 2017 exceeded €1,300 billion and the construction industry provided more than 14.5 million jobs (FIEC, 2018).

Table 1: Estimated Construction Outputs and Workers (Source: PwC, 2016)

Country	**Predicted Construction Output**	**Predicted Construction Workers**
China	$ 4.1 trillion	$ 55 million
United States	$ 2.6 trillion	$ 6 million
India	$ 1.5 trillion	$ 51 million

In 2017, the Lebanese Order of Engineers and Architects issued 13,389 building permits in 2017 varying between new construction works, repair works, demolishing activities, quarrying etc. Out of these permits, more than 40% were issued for new construction buildings indicating that around 5,430 new sites were prevailed (OEA, 2019). Figure 1 below shows the variation of the issued permits since 2000, with a trend-line that shows a potential increase in the near future.

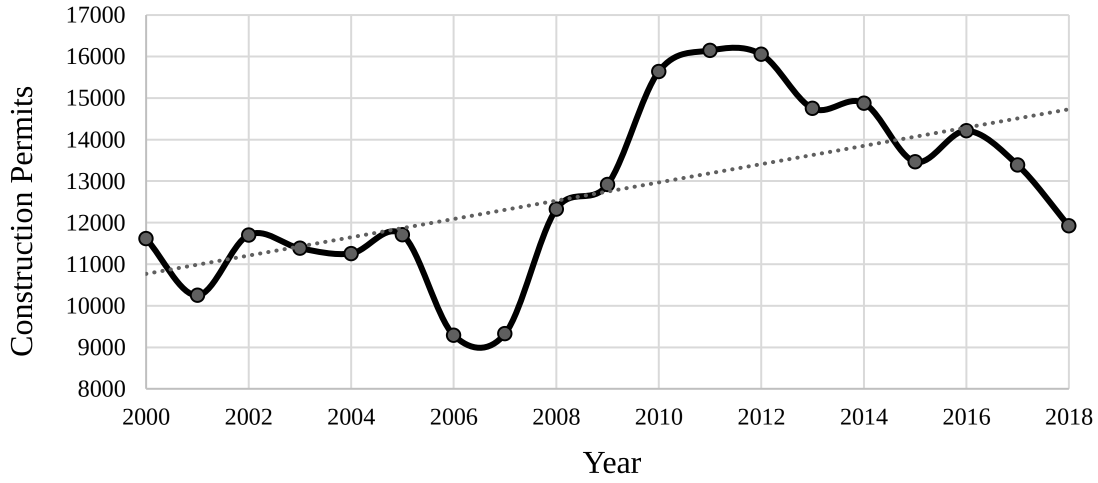


Figure 1: Variation of Issued Construction Workers (Source: OEA, 2019)

As such, the Lebanese construction sector in the last 10 years (2007 till 2017) averaged as the 6th highest percentage share of GDP after the real estate sector, wholesome and retail trade sector, public administration sector, financial services sector and education sector (CAS, 2017). In the last published study to assess the labor market of Lebanon, an estimate of 101,000 Lebanese active people (aged 15 and above) work in construction, accounting for 9% of the total Lebanese labor and 12% of the entire Lebanese male working population (CAS, 2009). However, according to the International Labor Organization (ILO), the number of construction workers in Lebanon and other developing countries may be underestimated since many of them are informally employed and thereby don't count in official data.

Despite the technological advancement in the construction industry, it remains one of the leading occupations in incurring occupational fatalities all around the world. In 2017, the construction industry was responsible for the death of one in every five worker deaths in the United States private industry, computing around 20.5% of the total occupational deaths (OSHA, 2018). The same rate was witnessed in the European Union in 2015 where construction contributed to the highest fatal injuries between all industries (at a rate of one in every five worker deaths) and the third highest for non-fatal injuries (Eurostat, 2018). The last attempt to analyze the occupational injuries in Lebanon concluded that construction incurred the highest number of injuries between all Lebanese industries, contributing to around 43.7% of all occupational injuries (Fayad et al., 2003).

The study performed by Fayad et al. (2003) analyzed occupational injuries almost two decades ago. Moreover, the studies that analyze safety practices of the Lebanese construction industry reflect on the problems facing safety practices and lack of safety incentives in the country (Awwad et al., 2014,2016; Abbas et al., 2018). Thus, there is a need to enhance safety performance of Lebanese contractors. The main objectives of this thesis are to analyze current injuries in the Lebanese construction sites and propose a model to calculate the safety index of contractors using leading and lagging indicators. This index will be used by contractors to assess their safety strategies and improve it. The index can also be used by insurance companies when issuing or renewing premiums.

1.2 Research Process

Planning for this study is done through setting a design for the research process, ensuring thereby a smooth transition from the beginning until completion of the work. The initial stage involved extensive and thorough research on all the subjects tackled in the study in order to highlight potential problems and gaps in the area. Then, a set of research questions is well formulated and supported by corresponding study motivation and objectives. The conducted background research and highlighted gaps serve as a guideline in developing the methodology and methods adopted to carry out the work. A conceptual model is elicited through the suggested methodology and transformed to a computational index that will be applied and analyzed through a case study. Finally, the study ends with putting forth of conclusions, limitations and recommendations.

1.3 Organization of the Thesis

Figure 2 summarizes the thesis structure. Background literature related to construction safety and injuries is extensively studied in Chapter 2. Chapter 3 pinpoints the gaps in literature based on the conducted research and provides a clear problem statement along with the declaration of significance and objectives of the research, while Chapter 4 summarizes the followed methodology in the study to achieve the desired objectives. Chapter 5 discusses the process of formulating the model for the index, then a case study application is developed in chapter 6 where the index is applied on the Lebanese construction industry. Chapter 7 details the analysis of recent injuries incurred by the construction industry. The last chapter, Chapter 8, offers conclusions, study limitations and the recommendations for future studies.

Chapter 1 — **Introduction**

- Introduction
- Research Process
- Organization of the Thesis

Chapter 2 — **Background Research**

- Safety analysis on construction sites
- Leading and lagging indicators
- Injuries on construction sites
- Construction safety in lebanon

Chapter 3 — **Research Motivation and Objectives**

- Problem statement and motivation
- Research objectives
- Research questions

Chapter 4 — **Methadology**

- Construction safety index
- Construction injury analysis

•Chapter 5 — **•Development of the Safety Index**

- Identification of safety practices
- Formation of the index's model heirarchy
- Weighting and measuring the model factors

•Chapter 6 — **•Application of the Safety Index**

- Application of the AHP survey on the lebanese construction professionals
- Analysis of AHP results with professionals in the insurance sector
- Application of the index on a lebanese construction project and its contractor

•Chapter 7 — **•Contruction Injury Analysis**

- Analysis of recentinjuries incurred by the Lebanese construction ijury

Chapter 8 — **Conclusions and Recommendations**

- Summary and concluding remarks
- Study limitations
- Recommendation for future research studies

Figure 2: Thesis Organization

CHAPTER 2

BACKGROUND RESEARCH

Accounting for safety in design and construction can date back to the year 1802 when E.I. du Pont famously said "We must seek to understand the hazards we live in" while establishing the gun powder factory in USA (Klein, 2009). Back then, an employer's decision to be responsible for the employees' health was solely an individual act. All works were performed under the "common laws" where employees were responsible for their health and worked under their own risks till the year 1916. At the time, the government forced employers to be responsible for the health and safety of their employees, and thus pay for medical care and lost wages (Rees, 2003). The new law created incentives for employers to avoid injuries and their costs, and thus the death rate in workplaces started decreasing drastically (Petersen, 1971). The Occupational Safety and Health Act (OSHAct) became effective in 1971; it is applied to millions of businesses that employ an estimate of sixty (60) million workers in the U.S.A, (Hammer & Price, 2000). Outside the USA, different organizations are setting guides, standards, regulations, and training for safety and health in the construction industry. For instance, in the United Kingdom, examples of organizations include the National Examination Board in Occupational Safety and Health (NEBOSH) that is an organization to set guidelines and standards, the Institution of Occupational Safety and Health (IOSH) that is an organization for health and safety professionals, and the International Institute of Risk and Safety Management (IIRSM) that is a professional body for health and safety practitioners. On the other hand, in Australia, there is the Safety Institute of Australia (SIA) that is a professional body for health and safety professionals and aims to develop, maintain and promote a body of knowledge that defines professional practice in Occupational health and safety (OHS). In the Asian Pacific region, there is the Asia Pacific Occupational Safety and Health Organization (APOSH) that is an organization dedicated to promote occupational safety and health practices.

Safety is defined as "the condition of being protected against any type of events (accidents) which could be considered non-desirable by controlling hazards to achieve an acceptable level of risk". Accident is defined as "some sudden and unexpected event taking place without expectation that causes injury, damages or death" (Mwombeki, 2005). Globally, the number of occupational injuries is still very high. According to the International Labor Organization (ILO), more than 375 million work related injuries and illnesses are reported annually causing around 2.78 million people to lose their lives and a vast economic burden estimated at 3.94% of the global Gross Domestic Product (GDP) annually. Most of these injuries and illnesses are caused by the poor occupational safety and health practices in different work places (ILO, 2018). When it comes to construction, its dynamic nature makes it a high-risk occupation leading to injuries, illnesses and fatalities, mostly due to poor safety practices. As a result, different studies aimed at investigating safety on construction sites, analyzing the factors affecting it, and promoting a positive safety culture. The following section presents the literature related to safety in the construction sector.

2.1 Safety Analysis on Construction Sites

A construction project uses specific resources (such as plans, labor, materials, finances and schedule) to attain specific goals. According to Love et al. (2002), these kinds of projects are dynamic in nature, creating a fluctuating relationship between the project's goals (in terms of functional performance, quality, time, cost and safety) and its resources. In such an environment, decision making becomes dynamic, and decision makers start shifting their focus over the course of the project prioritizing one goal over the other. Humphrey et al. (2004) hypothesized three relationships between production and safety over time, namely a negative monotonic relationship, a positive monotonic relationship and a curvilinear relationship. A negative monotonic relationship hypothesizes that emphasis on safety at the beginning of the project is high, whereby project participants allocate significant resources to safety; however, this emphasis steadily decreases as project reaches completion. In contrast, a positive monotonic relationship hypothesizes that project participants emphasize and allocate more resources to ensure safety as the project progresses. The curvilinear relationship reflects a "U" pattern of emphasis on safety over the life of the project and it hypothesizes that project participants give high importance to safety at the beginning of the project and near the finish to avoid incidents or injuries towards the end; however, at the middle stages of the project, focus is shifted to productivity and progress and safety attention decreases. The authors found evidence to support the curvilinear relationship using both simulation (which showed higher resource allocation to safety in the beginning and end of the project) and archival field study (which showed that injuries in the studied projects peaked in the middle of these projects).

The latter study was criticized by Zhang et al. (2016) since it only tackled the upper level decision makers of road construction projects. Road construction projects have similar project stages and thus the curvilinear relationship may not necessary apply to building construction projects, which are considered way more complex and dynamic. The study conducted by Zhang et al. (2016), which was done on five big construction projects in New Zealand, assessed the relationship between safety and the level of project completion in building construction projects through measuring the construction workers perception of safety responses by the client organization, principal contractor, supervisor and other co-workers. The results of the study showed no specific trend between coworkers' safety responses and the time progress of the project, indicating that co-workers may see each other as consistent in being safe. However, as opposed to Humphrey et al. (2004), a negative monotonic relationship was seen between the client organization and the principal contractor's safety perception with respect to the project progress, which indicates that the latter two focused less on the safety of construction workers and more on "getting the work done". At the level of the supervisors, a positive monotonic relationship was witnessed between the supervisors' safety responses and project progress and thus supports previous studies that highlight the importance of supervisory actions on site and the vital safety role they play even if the organizational safety climate was poor (Fang et al., 2015; Zhou et al., 2015). The results of this study are considered by the authors a first step to analyze the "safety climates" of dynamic construction projects at different points in time.

"Safety Climate'' describes a construct that depicts employees' assessments of the role that safety plays within their organization (Zohar, 1980). It is considered as a descriptive measure that reflects the workers' perception of safety and their attitudes towards it within the organizational atmosphere at a certain point in time (Gonzalez-Roma et al., 1999). In order to measure safety climate, surveys are often used and include a variety of climate dimensions, such as management commitment to safety, safety rules and procedure, safety training, worker involvement, and risk-taking behavior (Alruqi et al. 2018). Together, survey scores of each dimension comprise the overall safety climate score of an organization, and these composite scores often indicate performance.

Safety Climate are affected by different factors that may impact safety performance. These factors have been extensively studied in the literature. Sherif Mohamed (2002) reviewed existing literature and summarized five independent constructs that can potentially affect the safety climate: management, safety, risk, work pressure, and competence. Upon conducting a survey, a positive safe climate was influenced by proper management, safe and risk systems in which management show a committed and nonpunitive approach to safety, and promote a more open, free-flowing exchange about safety related issues. The study also indicated that work pressure has a negative effect on the safety climate through its impact on workers' willingness to take time-saving shortcuts under pressure. Fang et al. (2006) conducted a questionnaire on employees and subcontractors of a Hong Kong leading contractor to assess factors that affect safety climate. The factors were very similar to those of Mohamed (2002) with two additions: personal characters of the contractor's workers and the subcontractors' workers' perception. On the personal level of workers, the study concluded that employees who are older, married, or with more dependent family members and employees with increases social responsibilities have a more positive perception of the safety climate than those who are younger, single, or with fewer family members to support. Education and training were considered essential as well. Employees with an education level below primary school or with a poor safety level have a far less positive perception of the safety climate than those with a good safety level and higher education degrees. As for employees of subcontractors or joint ventures, they generally have a less positive safety climate than direct employees of the contractor, indicating that the extensive use of subcontracting on sites may lead to problems such as lack of safety control and lower levels of worker commitment. Thus, the study concludes that the safety climate of subcontractors should be considered in the assessment before a contract is signed with them. Using a case study approach, Zhou et al. (2011) carried out two rounds of investigation with an interval of three years using one safety-climate instrument. The study aimed to verify the existence of a standard first-order factor structure (safety-climate dimensions) and second-order construct (safety climate); dimensions being: safety regulations, safety supervision, safety training and workmate's support, management commitment, and safety attitude. Wu et al. (2015) suggested core and specific dimensions to standardize safety climate measurements. The core dimensions included the most mentioned ones in the literature: safety priority, safety supervision, training and communication, safety rules and procedures and safety involvement. Each core dimension was given related specific dimensions, or the existing safety factors that affect it. Relationships between core dimensions and between core dimensions and their specific ones were measured using Structural Equation Modeling (SEM). Newaz et al. (2018) developed a safety climate model that considers the five most common factors in the literature. The authors filtered 16 from 574 related literature studies and narrowed down the major factors of the safety climate model to five: Management Commitment, Safety System (including Communication and

Training), Supervisor's Role, Worker's Involvement and Group Safety Climate. The study concluded by giving the five factors 28%, 24%, 18%, 16% and 14% significance respectively.

All of the aforementioned models proposed to measure and assess safety climates in construction sites are based on different factors that influence safety performance, all of which were analyzed and studied in the literature. After carrying out an extensive literature review, Mohammadi et al. (2018) identified all factors that influence safety performance in construction projects, and these factors were clustered under 13 main groups as shown in Table 2-1. The study also presented a holistic hierarchical framework that shows the interactions among these factors at the level of the management systems that influence them. The systems that influence safety factors start at the level of the *Government*, then the *Company* (owners or clients, main contractors and sub-contractors), followed by the *Project* (project management, safety system, HSE team) till it reaches the *Individual Level* (or the level of the worker). In conclusion, the review paper shows the complexity of safety in construction in which more than 110 factors can affect safety in construction sites.

Table 2: Factors Affecting Safety Performance (Adopted from Mohammadi et al., 2018)

Main Factors	Sub-Factors	
Motivation	• Job motivators • Wage • Job satisfaction	• Reward and Penalty • Incentive programs • Peer pressure
Rules & Regulations	• Safety Rules • Rules Compliance	• Paperwork of Regulations
Competency	• Competence • Safety Experience	• Training and Education
Safety Investment and Costs	• Safety Budget • Cost of Accidents (Injury and Prevention Costs)	• Return on Investment (ROI) on Safety

Financial Aspects and Productivity	• Project Cost • Bidding Price/Contract Price • Project Size • Construction and Design Errors	• Quality • Productivity • Rework
Resource and Equipment	• Safety Personnel • Resource Constraints	• Equipment
Work Pressure	• Production Pressure • Work Overload • Fatigue and Burnout • Working Pace	• Working Time • Overtime Work • Schedule Delay
Work Condition	• Work Environment • Exposure to Hazard/Unsafe Work Situation	• Project Hazard Level • Workplace Health and Safety Conditions
Culture and Climate	• Safety Culture • Safety Climate • Supervisory Environment	• Supportive Environment • Leadership
Attitude and Behavior	• Supervisor's Behavior • Supervisor's Attitude • Supervisor's Effectiveness • Worker's Attitude • Perceived Behavior Control • Behavior Feedback • Participation for Safety Improvement	• Safety Effort • Worker's Behavior • Personal Responsibility for Safety • Risk-Taking Mindset/Behavior • Emotional State • Risk Perception • Perceived Safety State • Safety Compliance
Lessons Learned from Accidents	• Accident Rate (Frequency/Severity) • Number of Accidents • Injury (Death) Rate/ Type • First Aid Rate	• Safety Investigation/Inspection • Accident Investigation/Inspection • Incidents Control Pressure • Lessons Learned • Willingness to Investigate
Organization	• Company's Revenue • Company's Reputation • Company's Costs • Company Size	• Client's Control • Involvement of Subcontractors • Number of Subcontractors • Number of Employees/Crew Size

Safety Programs and Management Systems	• Limited Management Time • Management Commitment • Self-Example • Management Work Pressure • Pre-Hire Screening of Employees • Management Focus on Safety • Management Concern/Involvement • Communication and Information • Implementation/Thoroughness	• Safety Instructions • Safety Control Mechanisms • Safety Management Systems • Risk Assessment • Safety Policies and Procedures • Safety Committees / Meetings / Organization / Teams / Managers • Safety Management Practices and Skills

Moreover, safety climate can be used to predict future safety performance (Panuwatwanich et al., 2016). McCabe et al. (2016) conducted a longitudinal safety climate study and concluded that safety climates accounted for 20% variance in injury rate. Panuwatwanich et al. (2016) study examined the roles of safety motivation and safety climate in the improvement of safety behavior and safety outcomes; using SEM techniques. Main results indicated that safety motivation can positively influence safety behavior through safety climate, and safety behavior could predict safety outcomes. In conclusion, even though safety climates depend on the perception of workers, it reflects the strength of a safety system. However, it is based on general safety perceptions, i.e. management commitment to safety. Another method to reflect the strength of safety systems is through measuring what literature defines as “lagging indicators”, or empirical measures of specific safety activities (Alruqi & Hallowell, 2019).

2.2 Leading and Lagging Indicators

Traditionally, safety has been measured by OSHA’s TRIR (total recordable incident rate), DART (days away from work, days of restricted work activity, days of job transfer), lost time frequency and severity, compensation for losses for workers, and near hit reporting. These outcomes or “after the loss” measurements are referred to in the literature as “lagging indicators”. Grabowski et al. (2007) defined lagging indicators as measurements of safety performance after the accident has occurred or the worker has been injured. Toellner (2001) called them Trailing Indicators since they are the effect of accident outcomes. These indicators are popular in construction and other industries due to the history of their use, ease of use and analysis, easy to identify and record, and their usefulness to identify past trends and form a base of comparison between years (Tomlinson et al. 2011).

Despite their popularity, researchers believe that these indicators fail to precisely reflect safety performance. Hinze & Hallowell (2013) argues that improvements in injury rates were impressive when the OSHA Act was passed, but these improvements in the rate of injuries decreased significantly from year to year. Mengolini & Debabrberis (2007) and Manuella (2009) argue that future results can not be predicted on past safety performances. Peterson (1998) argues that lagging indicators do not reflect whether the system is functioning properly or not, they rather measure the “lack or luck of it”. Stricoff (2000) stressed the idea through demonstrating how injuries can change from one month to another without actual changes in the policy of the companies. Kjellen (2009) also criticized the lost time injury frequency rate for assigning the same weight to injuries with different severities. Moreover, lagging indicators don’t account for the complexity of the safety and hazard systems that lead to injuries. Current studies show that injuries are a result of many interrelated elements and deficiencies in the performance rather than one single cause (Reiman and Pietikainen, 2012; Grabowski et al., 2007). Because lagging indicators have a reactive nature and are only the “fix and fly” approach, they fail to predict future performance (Hale, 2009). Thus, studies and research started shifting to more pro-active indicators referred to as “leading indicators”.

Leading indicators are considered proactive measures to identify weaknesses in safety systems and provide corrective actions to avoid injuries (Hinze & Hallowell, 2013). Definitions of a leading indicator vary in literature based on different metrics. Some defined it based on time as metrics that measure events, activities or behaviors that may cause an accident, injury or change of risk levels (Grabowski et al., 2007; Kjellen, 2009). Others defined it based on proactivity as metrics measured at any point during the construction phase to provide corrective actions, monitor and enhance safety performance (Tomilson, 2011; Hallowell et al., 2013). Some also defined it based on measurability where these metrics should be set in a measurable frame with a proper benchmark for future evaluations (Toellner, 2011b).

Existing literature also classified leading indicators between passive and active. Passive leading indicators are defined as “safety strategies that should be implemented before the construction phase begins to set the project up for success,” while active leading indicators are defined as “safety related practices or observations that can be measured during the construction phase and can trigger positive responses.” (Hinze et al., 2012). Passive indicators are static, they can be either implemented or not before construction and will not likely change during the project phase; thus, they have a binary response of yes or no. Such indicators include 100% steel toed boots policy, design for safety review, sub-contract compliance with specific safety programs, etc.

Active leading indicators are dynamic and readily change during the project phase. They can be measured as frequency of occurrence or quality of implementation. Such indicators include frequency of onsite inspections, quality of safety meetings, involvement of upper management, etc. (Hinze et al., 2013b). Alruqi & Hallowell (2019) presented a procedure to distinguish between lagging and leading indicators based on three levels: first, its *status* during construction process (Change or does not change?), next the *frequency of Measurement* (once or regularly?) and then the *type of measurement* (qualitative or quantitative?). Indicators that don't change with time or change but are measured once are considered passive such as 100% steel toes boots policy or client requiring safety meetings. The data form and analysis will be binary, or 1/0. Indicators that change during the process and are measured regularly are considered active indicators. Indicators such as the frequency of safety meetings on job sides are measured quantitatively and will thus have a continuous data form and analysis. Indicators measured qualitatively such as rating the quality of safety meetings will have a continuous or categorical data form and analysis.

It was stated in the literature that the effective leading indicators should be easily measured (Biggs et al., 2010; Leveson, 2015), cost-effective and easy to implement (Biggs et al., 2010), unbiased (Leveson, 2015; Guo & Yiu, 2015), complete, consistent and reliable (Leveson 2015; Hale 2009), have valid correlation to safety performance (Sales & Hallowell, 2008), and continuously monitored and adjusted (Hinze & Hallowell, 2013; Leveson 2015; Guo and Yiu, 2015). Moreover, leading indicators should be site-specific and tailored to the organization (Reiman & Pietikainen, 2012), where similar indicators can be moved from a project to another only if specific circumstances are similar; such circumstances include hazard, safety and control systems (Leveson, 2015). Hinze & Hallowell (2013) suggested the following framework to implement and evaluate leading indicators:

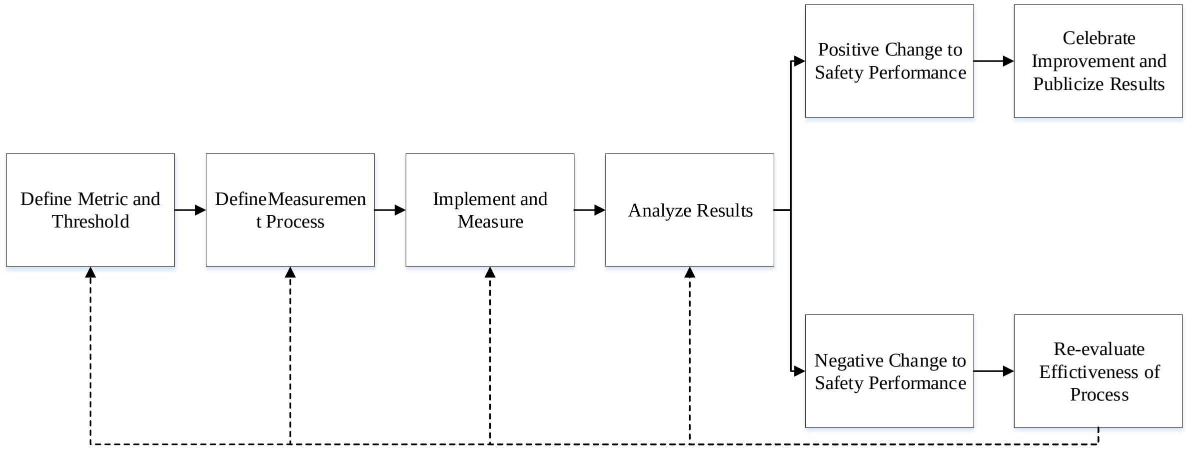


Figure 3: Implementation Flowchart of Active Leading Indicators (Adopted from Hinze & Hallowell, 2013)

The strong correlation between leading indicators and safety performance is essential for the leading indicator to properly monitor and control the safety system it is implemented in. To investigate whether or not a significant correlation exists between a leading indicator and safety performances in a specific organization, Tomlinson et al. (2011) suggested that a statistical analysis should be performed between that indicator and collected normalized safety performance data over a period of time. The period of time starts after implementing the safety indicator to monitor its effect on the system and safety performance. The correlations would allow organizations to reflect and witness the added value of the leading indicator, if proved, to their system (Rajendran, 2012; Tomlinson, 2011). In an attempt to standardize correlations between leading indicators and safety performance, Alruqi & Hallowell (2019) provided a first meta-analysis to determine the extent of frequent leading indicators in predicting injury rates.

The study identified nine common leading indicators: safety record, safety resource, staffing for safety, owner involvement, safety training, personal protective equipment, safety incentives program, safety inspections and observations and pre-task safety meeting. The study proved that all these indicators are valid in projects irrespective of their geographical location, industrial sectors, company types and safety cultures.

To identify leading indicators, research studies have used different methods such as questionnaires, surveys, interviews, safety audits, accident investigations, case studies, focal groups and Delphi method. Akroush (2017) summarized all existing leading indicators as shown in Table 3.

Table 3: Active and Passive Leading Indicators (Adopted from Akroush, 2017)

Category	Indicator	Passive Active
Contract and Design	Contracts sets minimum ratio of safety supervisors to worker	P
	Contract imposes work hour restrictions for workers	P
	Safety considered during the design phase	P
Owner	Owner review and approval of safety plan	P
	Aggressive owner promotion of jobsite safety	A
	Owner safety walkthroughs	A
	Owner's participation in worker orientation sessions	A
Contractor	Contractor selected based on safety	P
	Utilization of contractor safety performance record in decision making concerning contracts	P
	Contractors are trained on safety culture issues and work practices	P
	Participation of all contractors in safety meetings	A
Sub-Contractors	Number (or %) of subcontractors selected on the basis of satisfying specific safety criteria prior to being awarded the subcontract	A
	Participation of all subcontractors in safety meetings	A
	Subcontractor management	A
Vendors/ Suppliers	Vendor safety orientation	P
Staffing	Staffing for safety	P

	Number or percent of management personnel with 10- h (or 30-h) OSHA certification cards	P
	Number or percent of field employees with 10-h (or 30-h) OSHA certification cards.	P
Substance Abuse Program	Substance abuse program set in place and advertised to workers	P
	Percent of negative test results on random drug tests	A
Strategic Safety Management	Written and comprehensive safety and health plan	P
	Safety is visibly and systematically considered in the organization's official plans and strategy documents	P
	Safety policy conveyed to all relevant stakeholders	P
	On-site plan based on a thorough identification of possible accident scenarios	P
	The size of the safety budget	P
	Clear project safety authority, responsibility, and accountability;	P
Safety Training	Safety and health orientation and training	A
	Regular training on emergencies on-site	A
	Hours of safety training	A
	Supervisor training hours	A
	Number of safety training sessions completed vs. scheduled (%)	A
	Number of people trained	A
	Management/supervisor attendance at training meetings	A
	Number of safety trained supervisors	A
	Project-specific training and regular safety meetings	A
	Site-specific safety orientation for all managers	A
Management and Supervision	Management is actively committed to involved in safety activities	A
	Number of management walk around per month	A
	Number of times safety is a topic in the management meetings	A
	Superior provides positive feedback on safety-conscious behavior of the personnel	A
Safety Meetings	Toolbox safety meetings are conducted	A
	Number of toolbox meetings	A
	Percent of jobsite toolbox meetings attended by jobsite supervisors/ managers.	A
	Quality of participation in toolbox meetings	A

	Pre-task planning meetings conducted	A
	Number of pre-task planning meetings	A
	Attendance at safety meeting	A
	Explanations given of why actions suggested at toolbox talks/ pre-start meetings were undertaken or not	A
	Employees' satisfaction with the feedback on the outcome of safety meetings	A
	Percent of jobsite pre-task planning meetings attended by jobsite supervisors/managers.	A
Emergency Response Plan	Adequate on-site emergency preparedness plan	P
Hazard Identification and Corrective Actions	Hazard identification and risk assessments are used to develop policies, procedures and practices	P
	A systematic corrective action program is in place to deal with deviations	A
	Adequate barriers are set against the identified hazards	A
	Employees' perceptions of the presence of rules that make it easy for employees to identify procedures that are not safe	A
Accident Investigation and Follow up	Accident/incident investigations conducted with procedure for investigation identified	A
	Percentage of incident reports on which root cause analysis was undertaken	A
	System for follow-up of incident investigations and related recommendations exists	A
	Employees' satisfaction with regard to follow up and measures taken after accidents, injuries and near losses	A
Reporting	A clear procedure for reporting, with well-defined roles and responsibilities exists	P
	Willingness to report broken safety regulations	A
	Anonymous reporting	P
	Workers' perceptions of the effectiveness of the anonymous reporting system	A
	Workers' perceptions of the presence of a 'no–blame' culture in the organization	A
	Positive incentive to report potential hazards	A
Near Miss	There is a system for analyzing near miss events in the organization	P
	Number of close calls (near misses) reported per 200,000 h of worker exposure	A

	Employees' satisfaction with the feedback given near losses that occur	A
Safety Audits	Auditing program set in place	P
	Safety audit score calculated and monitored	A
	Management/Supervisor safety audits	A
	Number of Audits completed vs. scheduled (%)	A
	Percent of safety compliance on jobsite safety audits (inspections)	A
	A procedure to communicate the results of audits, inspections and similar activities to the employees	P

In summary, leading indicators precede or lead an incident, while lagging indicators follow or lag it. (Hale, 2009). While lagging indicators provide results from past statistics related to accidents, properly selected leading indicators monitor the present process to positively affect future outcomes (Hinze et al., 2012). The purpose behind both of these indicators remains to decreasing safety injuries in construction sites. Thus, the limited information provided by lagging indicators should be used collaboratively with a leading indicator program to provide a proper safety environment (Wehle & Hinze, 2009; Reiman and Pietikanien, 2012). Because of the importance of safety and injuries, many researchers aimed to investigate and analyze construction injuries on local, national and worldwide levels. Different studies from different regions are discussed in the following section.

2.3 Injuries on Construction Sites

Construction fatal and non-fatal injuries were investigated in different published studies. Perotti & Rosso (2018) analyzed the occupational fatal injuries in Italy between 1982 and 2015. Construction led the occupations with most deaths (36.62%). Mechanical trauma, such as such as falls, machinery-related events, blunt force, sharp force or explosions, led the cause of death (77.69%). Construction was also the leading occupation when it comes to fatal injuries (38.4%) and the second occupation with most non-fatal injuries (28.9%) in Spain (Villanuevaa & Garciac, 2010). The authors concluded that construction is one of the sectors that should focus on preventive policies and receive interventions for occupational injuries. Besides, results showed an increased risk with increasing hour of the work shift and an increased risk with temporarily workers, both of which apply to the construction industry. In Norway, the national average of 4.1 deaths per 100,000 construction workers was deemed underestimated by Winge & Albrechtsen (2018) since subcontractor injuries are not accounted for. Their analysis of the injuries in the Norwegian construction industry showed that the most frequent causes are falls from roofs or floors (17%), falls from scaffolding and contact with falling objects (15% each) and contact with moving parts of machines (11%). However, the most frequent causes that led to death were contact with falling objects (21%) and losing control of a moving machine (17%). The study also analyzed the physical barrier failures that led to these injuries and concluded that most of the injuries could be avoided by implementing a proper systematic barrier management, for one physical barrier "can be enough to keep a specific hazard under control".

Fatalities in Taiwan (Lin et al., 2008) where mostly due to construction where it contributed to 56.1% of all occupational fatalities, with falls being the main cause (16.5%). Construction also served as the industry with most male deaths (56.4%) and female deaths (53.1%) in the country. In Australia (Jones et al., 2012), construction served as the third occupancy with most fatalities for older workers aged 55and above (16.6%). Most frequent causes included being struck by an object or animal (18.1%)

and crushing (10.7%). The authors included that specific policies and safety interventions should be required in such occupations to accommodate ageing workers. Age groups of 45–49, 50–54, and 55–59 dominated the construction fatalities in Honk Kong (Chiang et al., 2017) reflecting acute problems of labor aging and skilled labor shortages. Aside age, the study analyzed the work duration of dead workers and the time and place of death. Most workers died in the hot humid days in summer after working for 2 h in the morning or 1 h after a lunch break, and more fatal accidents occurred in repair, maintenance, alteration, and addition (RMAA) works from the private sector. In southwestern Ethiopia, the overall prevalence of work-related injuries was 41.4% with major causes including injured by object (36.9%), lower back pain (35.6%), falling injury (23.5%), skin disorder (20.1%), and eye problem (18.2%). Reasons for these injuries included working without personal protective equipment (PPE), absence of vocational training, and working overtime (Lette et al., 2018). Another study done in the Ethiopian capital Addis Ababa showed that the prevalence of injury among building construction employees was reported to be 38.3 % in 2015 (Tadesse & Isreal, 2016). The most common events of injuries were cutting (66.3%) and falling (28.5%), targeting mostly the leg (46.6 %) and the finger/hand (43.5%). The major causes of these injuries were lack of safety awareness (46.7%) and poor working condition (33.1%).

Few studies analyzed injuries caused by construction works executed in the Arab region. Upon investigating injury cases in hospitals in Amman, Jordan, Al-Abdallat et al. (2014) found that the highest two distributions for occupational fatalities were for construction (44.3%). The most frequent causes of injuries were falling from heights (44.3%), struck by objects and electrocution (17% each). Head injury was the highest rated type of injury (21.6%) followed by thoracic and abdominal organs injuries (18.2%). The authors considered the main reason to be the ineffective safety precautions and implementations on construction sites and concluded that most of these injuries could be avoided by the proper use of safety-enhancing technologies.. In Kuwait construction was considered the most hazardous industry after its accidents accounted for 48%, 38% and 34% of all disabling injuries and 62%, 38% and 42% of all fatalities in 1994, 1995 and 1996 respectively (Lartam & Bouz, 1998). Upon analyzing the construction fatalities and injuries, the most frequent causes of these accidents were falling from heights followed by falling objects, while the most frequent injury types were fractures followed by wounds, and most of the injuries targeted the upper half of the body. The authors recommended that top management should commit to safety through developing an interest in safety and producing safety policies According to GOSI (2011), almost half of the occupational injuries (48%) in the Kingdom of Saudi Arabia (KSA) were from the construction industry. Major causes include struck by a falling/moving object (32%) and falling (29%). In the United Arab Emirates (UAE), the health and safety federal law is very general, with no emphasis on construction, and two thirds of the hospital injuries caused on construction sites are due to the lack or the inappropriate use of personal protective equipment (Kenrick, 2012). Upon analyzing safety in the Egyptian construction industry, Hassanein & Hanna (2008) 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. One third of construction injuries were found because of falling (ElSafty, et al., 2012).

Further analysis from the study found a noticeable difference between the work models used in construction firms in Egypt and those in Europe and the United States whereby Egyptian workers do not undergo safety training or meetings, and most companies do not include safety budgets. In Lebanon, a limited number of studies were done to analyze construction injuries.

2.4 Construction Safety in Lebanon

Few studies were made to analyze the safety in the Lebanese construction industry and its injuries. Fayad et al. (2003) analyzed occupational injuries in Lebanon for the year 1998. Construction was the industry with the most recorded injuries tallying around 43.7% of all injuries. Most frequent causes of the construction injuries were struck by objects (44.6%), falls (29.7%) and hitting objects (11.1%). Agents involved in construction accidents were mostly hard objects such as metals and wood (48.7%), flying objects and particles (13.7%) and equipment, tools and machinery (135%). The most frequent types of injuries were wounds and lacerations (29.5%), trauma (21.7%) and foreign body (16.5%). Hands were the most injured body parts (27.8%), followed by feet (19.5%) then eyes (16.7%). As for the severity of the injuries, more than half needed less than 3 days recovery (50.9%), other injuries needed between 3 and 30 days (45.5%) and the remaining were either more than a month of recovery, permanent disability or death. Construction was responsible for 33% of the analyzed fatalities. The direct cost of construction injuries were estimated to be more than 1.8 million dollars (equivalent to 2.88 million as inflated in 2018).

Recent studies investigated the safety practices and challenges in the Lebanese construction industry (Awwad et al., 2014: 2016). The study investigated contractors, owners, consultants and insurance companies. From the contractor's perspective, it was found that the size of the contracting firm and the implementation of Safety and Health Management Systems (SHMS) are correlated. Only large sized contractors and less than half of the medium sized ones implement safety programs, while the other half of medium-sized contractors and small-sized ones do not. Results of the study revealed that contracting companies adopt SHMS mainly to reduce injuries, and they base their system either on (1) their previous experience or standards such as OSHA, British Standard Institution (BSI), or International Organization for Standardization ISO 9001; (2) a full-time safety officer, or (3) a project manager for implementation of safety policies. These companies keep track of accident and safety injuries during the construction phase up until a maximum of five months after completion. On the other hand, it was found that most of the contractors that don't implement safety programs consider that it is not required by law, despite the presence of Decree No. 11958 of 2004 (Safety and Protection in Construction); other given reasons include time consumption and high cost of implementation. Those companies do not consider safety while sub-contracting, do not use safety signs, and only few of them keep track of injuries. On the other hand, results showed that safety training varies between contractors that adopt and don't adopt SHMS. Contractors that adopt SHMS have limited training to their workforce that includes a combination of hazards, work procedures, PPE, and safe handling of equipment. Contractors that do not adopt SHMS provide basic training such as safe equipment operation or safe work procedure. As for management commitment, top management of the studied firms were found to have a will to commit to safety procedures, but were not ready to allocate enough resources (More than half allocate more than 1% of the budget to safety). The study also revealed that new contractors in Lebanon are not shifting to adopt SHMS despite the rise of awareness worldwide, for no relationship was found between the age of the contractor and the SHMS implementation. As for consultants, the study findings showed that they are split between ones that follow what is required by the owner, ones that apply the minimum safety requirements as set by insurance companies and/or contractors, and those that develop their own SHMS and make sure contractors abide by it. Consultants also reported that they do not provide incentives for contractors to adopt safety and only few take penalizing measures in case of safety breaches. At the level of the owners, survey results indicated that most of them require safety implementation on their projects. However, only few appoint dedicated administrative to visit and inspect the worksite in person. Findings from insurance companies indicated that they don't recognize whether contractors emphasize safety standards or adopt safety manuals. Issuing or renewing premiums depend on the contractor's history of accidents: increase in premiums reaches as high as 200% while decrease was limited to a maximum of 20%. In summary, the study demonstrated that a problem in construction safety exists and all construction shareholders are responsible and liable.

The aforementioned study included safety findings from the perspective of contractors, consultants, owners and insurance companies, but did not include the standpoint of the construction workforce on safety. Abbas et al. (2018) presented the first study that included the Lebanese industry's workforce perception and investigated their awareness of on-site indoor hazards using a video-based interactive survey. Workforce included engineers, foremen and workers. Six hazards were identified and analyzed namely, welding, operating concrete mixer, grinding, stack of steel leftovers, fire, and stack of gravel. All workforces ranked fire as the most hazardous followed by grinding then welding. The study also explored the perception towards hardhat importance. Engineers, foremen and workers gave it an importance of 7.67, 8.13 and 6.13 respectively. More than half of the interviewed workforce would not wear the hardhat out of personal incentive, and the incentive use is limited to having survived an accident. The findings showed a lack of on-site personnel awareness and perception of hazardous activities, and Lebanese contractors are failing at properly implementing various characteristics of SHMS. The study called to have a unified national safety standard for all contracting companies to abide by and presented a hazard assessment user interface application inspired from the "Activity Risk Assessment Handbook" (Abbas et al., 2019).

Awada et al. (2016) analyzed the influence of three lean concepts: last planner system, Five S, and increased visualization. A survey as performed on 30 respondents from 14 different companies. Results show that while most of the respondents in the study acknowledged the importance of such concepts, more than 50% of them did not even have certified or educated safety field supervisors on their construction sites. Most of the respondents were not familiar with the lean tools, but their answers showed that some ideas within these concepts are applied in their companies. For example, while 30% of the claimed to have knowledge of the "Five S" process, more than 60% answered that their companies regularly maintain the site clean. Lack of knowledge and understanding of the lean philosophy, fear of implementing new techniques, lack of transparency between project participants, resistance to change and the lack of self-criticism represent major constraints in the way of implementing lean tools which enhance on site construction safety.

The same kind of resistance to change was witnessed in a study by Damaj et al. (2016) which assessed the application of ergonomics in the Lebanese construction industry, especially that ergonomics enhance safety by fitting tasks to the physical characteristics of the laborer. The study was applied to two medium-scaled residential projects, the most frequent projects in Lebanon. Workers expressed some pain they afce while performing certain activities, and they are usually not engaged in decisions regarding different tasks. In addition to the resistance to change, barriers of cost and time also stand in the way of applying ergonomics. Visual management practices were also analyzed in 12 different Lebanese construction sites that vary in size, location and type (Abdelkhalek, 2019). The study revealed that few sites use visual tools and follow safety regulations, mostly large-scaled projects. Construction injuries were less in sites that used VM practices. However, despite the concern most engineers or project managers have on ensuring a safe workplace, they don’t focus on VM techniques

CHAPTER 3

RESEARCH MOTIVATION AND OBJECTIVES

3.1 Problem Statement and Motivation

Findings from Awwad et al. (2016) highlight a major problem between insurance companies and contractors. The study shows that insurance companies renew premiums based only on the contractor's accident reports. Moreover, insurance company do not investigate new contractors when issuing them premiums. Thus, when a contractor neglects health and safety, they can easily avoid higher insurance rates by shifting between insurance companies. Another problem highlighted from Abbas et al. (2018) study is the lack of safety incentives, training and education, especially at the level of the foremen and workers. **Thus, there is a need to enhance the safety performance of contractors and improve the strategies that they implement.** Insurance companies can play a vital role in this improvement through encouraging them to emphasize on health and safety policies while issuing or renewing contractor premiums. **There is also a need to investigate the current most frequent and severe construction injuries to know where the industry stands after two de**cades.

To resolve these needs, the current study proposes a model to calculate the construction safety index of contractors using leading and lagging safety practices. This numerical index will reflect the safety status of the contractor. The proposed model will indirectly encourage contractors to improve their safety performance to score a higher index, which indirectly decreases accidents. Moreover, insurance companies can consider the index when issuing or renewing premiums; the higher the index goes, the lower premiums get. The study will also investigate recent construction injuries and compare it to the 1998 study and draw conclusions. Even though the index in this study is applied to Lebanon, the proposed tool can be adopted by different developing and undeveloped countries that lack national safety laws and share common characteristics with Lebanon. It will encourage their construction industry, especially at the level of the contractors, to enhance their safety performance.

3.2 Research Questions

In consideration of the stated objectives, this research will add to the existing literature by answering the following research questions:

1. How can a safety index be developed by evaluating safety practices followed by the contractors on their construction sites?
2. How can this index be implemented on Lebanese contractors to accurately reflect on their safety performance?
3. What is the estimated number of injuries incurred by the Lebanese construction industry, and what is their projected total direct cost?

3.3 Research Objectives

The overall objective of this study is to enhance construction safety, especially in countries with a similar safety situation to Lebanon. The interim research objectives are as follows:

Objective 1: Develop an index that reflects on a contractor's safety status in developing and undeveloped countries.

This objective consists of developing a model that inputs the evaluation of different safety indicators followed by a certain contractor and outputs an index that reflects on the contractor's safety status. These adopted safety indicators are based on safety practices studied in literature. The model includes hierarchy levels, assigns weights to the factors in these levels, and suggests means to measure each factor.

Objective 2: Apply the index to the Lebanese construction industry and analyze the results to further understand the current safety situation.

This objective involves applying the model to the Lebanese industry by using an Analytical Hierarchy Process (AHP) survey to calculate the weights of the model's factors. The AHP survey will be filled by construction managers and safety professionals. The factors of the index are further discussed with insurance companies to rank their relevance and study their potential effects on insurance premiums. The index will be validated with a case study.

Objective 3: Investigate recent injuries incurred by the Lebanese construction industry.

This objective involves analyzing different injury claims obtained from insurance companies. These claims will contain data about the construction – related injury, injured person (age, occupation) and the total direct cost.

3.4 Research Significance

The importance of this study is to promote safety incentives and a positive safety culture in construction. A positive safety culture would promote contracting companies to follow efficient safety procedures and educate their workforce about safety; it is not only about providing quality by finishing the job on time and within budget, it is also about doing all the required work "safely." Moreover, reducing injuries on site has a direct effect on the project progress and cost. By improving safety, lost times due to injuries and accidents will decrease, thus decreasing completion days of the project. As for the decrease in cost, less injuries would reduce insurance premiums and expenses of resource replacements. In fact, a cost-befit analysis of accident prevention showed that accident prevention can outweigh the costs of accidents by a ratio of 3:1 (Ikype, 2012). Through the proposed index, contractors will ought to improve their safety practices, and insurance companies will fairly control their premiums.

CHAPTER 4

METHODOLOGY

To answer the aforementioned research questions, a stepwise research methodology is designed to comprise the major tasks summarized in Figure 4.

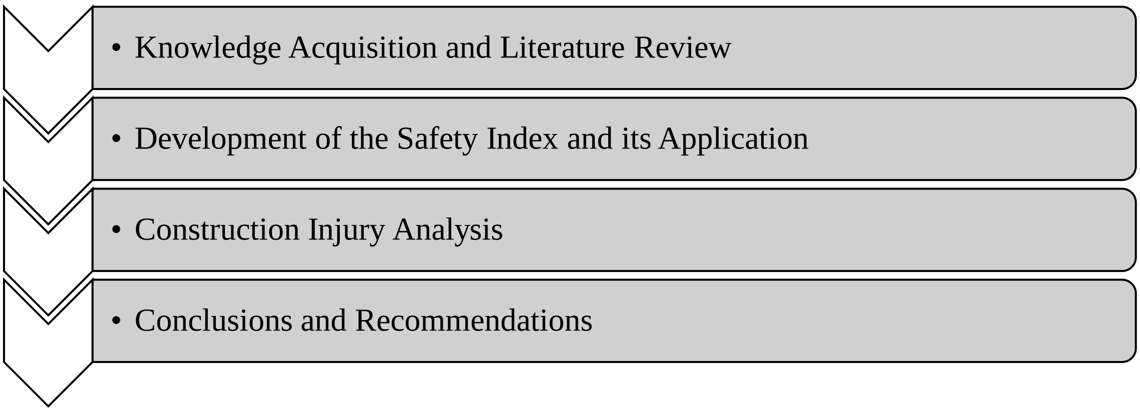


Figure 4: Major Tasks of the Research Methodology

4.1 Knowledge Acquisition and Literature Review

To achieve the stated objectives, safety in construction has been extensively researched to understand the aim and methods for the procedure. Based on the examined related research, it was found that most studies assess safety using leading or lagging indicators. Moreover, extensive research was done on papers and studies that analyze construction injuries from different Arab and western countries. As a result, research gaps have been identified, and the contribution of the thesis in enhancing the safety practices in construction has been set accordingly.

4.2 Development and Application of the Index

The "Contractor Safety Index" is both developed and applied in this research. The development section describes the inputs and outputs of the index, while the application section displays the results of applying the index on the Lebanese construction industry.

4.2.1 Development of the Index

The conceptual model of the index takes the form of a hierarchy. This hierarchy is the result of sorting and grouping notable safety practices that were discussed in literature and proved to play a significant role in decreasing construction accidents and injuries. Next, the obtained factors of the hierarchy are assigned specific weights, and an Analytical Hierarchy Process (AHP) survey is designed to calculate these weights. The output of the model will be an index; this index results from applying the factors of the model on a certain contractor to derive the assessment values (by evaluating the chosen contractor's safety measures and construction projects), and then multiplying the obtained assessment values by their factor's corresponding weights (derived from the AHP survey). The attained index reflects the safety status of the contractor.

4.2.2 Application of the Index

After developing the model and designing the AHP survey, the model will be applied to the Lebanese construction industry to prove its validity. First, the AHP survey is distributed to different Lebanese professionals in the construction industry (such as construction managers, safety inspectors, safety consultants, etc.) to determine the weights of the model's factors. These weights represent the perception of Lebanese construction professionals and are thereby only applicable to Lebanon. Next, the adopted safety practices are evaluated for a contractor by conducting a site visit to their projects and discussing how these practices are implemented with the construction managers. Results from the survey and the contractor evaluation will output the safety index for the contractor under study. Since the obtained index can be considered by insurance companies when issuing or renewing premiums to contractors, both the model and AHP survey are discussed with different professionals in insurance companies. Results from the discussions will (1) help in further understanding which safety practices may have a stronger impact on premiums and (2) serve as a base of comparison between the perception of both contractors and insurance companies when it comes to safety in construction.

4.3 Construction Injury Analysis

To analyze recent injuries in the Lebanese construction industry, insurance claims will be collected from different insurance companies. These claims will contain information related to the injury (nature, part of body affected, source, event), injured person (age, occupation) and direct cost. The injuries will be analyzed based on the latest version of the *Occupational Injury and Illness Classification Manual* (OIICS), released by the Unites States Department of Labor (OIICs, 2012). The manual provides a classification system to analyze the characteristics of occupational injuries, illnesses, and fatalities in four main code structures: (1) Nature of Injury or Illness, (2) Part of Body Affected, (3) Source of Injury or Illness/Secondary Source of Injury or Illness, and (4) Event or Exposure.

4.4 Conclusions and Recommendations

This section will summarize the study, infer conclusions from the application of the index and the analysis of the injuries, discuss the study's limitations and recommend further studies.

CHAPTER 5

DEVELOPMENT OF THE SAFETY INDEX

To assess the safety status of contractors in Lebanon, this research study proposes a “Contractor Safety Index” model. The model evaluated different safety strategies that are adopted by contractors, and the injuries incurred by the same contractor. The output of the model is an index that can help contractors in assessing their safety status and assist insurance companies in offering insurance premiums. The index can also be a base to compare the safety practices and statuses of contractors in developing and undeveloped countries that lack national health and safety monitoring systems. This chapter details the inputs and outputs of the model, as well as the AHP survey which will be used to determine the weights of the model’s factors. Developing the model is summarized in the four steps shown in Figure 5.

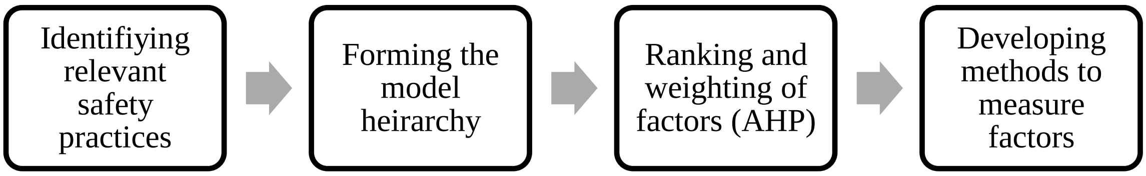


Figure 5: Steps of the Model Development

5.1 Identification of Relevant Safety Practices

Hinze et al. (2013a) study entitled “Construction-Safety Best Practices and Relationships to Safety Performance” identified 104 safety strategies, derived from literature and a survey conducted on safety experts, and analyzed these strategies’ effect on recordable injury rates in 57 projects across the United States. These safety practices, alongside relevant leading indicators described in Table 3 (Chapter 2), are adopted inside the model. Based on their common characteristics. The adopted practices are grouped and sorted based on their common characteristics; the grouping resulted in thirteen factors, all of which are named and described in Table 4.

Table 4: Assessment Factors of the Model

Factor	Description	Safety Practices Included
Staffing for Safety	Safety - related personnel and medical facilities that the contractor assigns on site.	• On-site medical facilities • Full-time safety manager on the project • Safety instructor for the project • First-aid log • Minimum ratio of number of safety supervisors to workers • Minimum ratio of number of safety professionals to workers
Adopted Safety Systems	Standard safety policies that the contractor enforces on labor while doing hazardous on-site activities.	• Lock-out tag-out policy • 100% fall protection • 100% hard-hat policy • 100% safety glasses policy • 100% gloves policy • 100% reflective vest policy • 100% steel toed boots policy • Electric Safety Policy • Restricted Area Work Permit • Lift safety policies • Hot work safety policy • Fire safety policies • Fatigue management program • Work-hour restrictions • Worker hydration program • Heat-and-cold-stress program • Stretch and flex program for workers
Commitment to Safety	Procedures and standards that the upper-level management of the contractor follow to assure that the safety policies are being implemented on construction sites and ensure the safety of the labor.	• Management review of craft-worker training • Management/Supervisor safety audits • Number of Audits completed vs. scheduled (%) • Percent of safety compliance on jobsite safety audits (inspections) • A procedure to communicate the results of audits, inspections and similar activities to the employees • Site-specific safety orientation for all employees

		• Root-cause analysis program • Injury reporting and analysis program • Established disciplinary program • Leadership-development program • Mandatory substance-abuse program • Unannounced random drug and alcohol program • Formal lessons learned • Knowledge management program
Risk & Hazard Management	Policies set and followed by the contractor to account for safety during the planning phase and before construction.	• Safety analysis during constructability reviews • Safety in scheduling and accounting for safety in design • Written site-safety plan • Emergency response plan for project • Job hazard analysis
On-Site Supervisors Role	Role of on-site safety supervisors.	• Foreman evaluation in safety performance • Project health and wellness review • Safety and health orientation and training • Regular training on emergencies on-site • Conducted toolbox safety meetings • Quality of participation in toolbox meetings • Pre-task planning meetings conducted
Safety Auditions & Inspections	On-site practices that fall under safety auditions and inspections at the level of the activities and allocated resources.	• Regular scheduled meetings for safety personnel • Workers involvement in inspections and audits • Auditing program set in place • Safety audit score calculated and monitored • Heavy-equipment inspection and approval program • Regular inspection and maintenance of all tools • Regularly scheduled equipment inspections • PPE inspection and maintenance policy
Near Misses Reporting	Reporting and investigating near misses.	• Track of near misses • Near-misses investigation
Recognition for Safety	Rewarding labors who show safety while working.	• Extrinsic Rewards • Intrinsic Rewards

Safety Training	Training programs provided by the contractor to the employees.	• Safety leadership training program supervisors, foremen and labor • Monthly H & S training program for supervisors, foremen and labor • Safety-monitoring program for worker
Engagement in Decision Making	Practices that engage the on-site labor while taking decisions related to safety.	• Safety goals development and communication • Participation in established percentage of daily toolbox safety meetings • Foremen involvement in accident investigation • Foremen involvement in hazard assessment • Foremen involvement in lessons learned and knowledge management • Foremen involvement in jobsite-safety inspections and audits • Foremen involvement in safety committees • Foremen involvement in policy creation and implementation • Safety perception surveys completed by foremen • Workers involvement in pre-task safety planning • Workers involvement in safety committees • Workers involvement in hazard assessment • Workers involvement in accident investigations • Workers involvement in perception surveys • Workers involvement in policy creation and implementation
Labor Experience	Assessment of the labors’ experience.	• Safety training history for all personnel • Employees’ skills
Level of Education	Assessment of the labors’ level of education.	• Employees’ level of education • Employees’ certifications

Sub-Contract Management	Safety procedures that the contractor follows while choosing and working with sub-contractors.	• Subcontractors prequalification's on safety • Subcontractors participation in GC's orientation and training • Subcontractor's safety standards compared with GC • GC's involvement in the investigation of sub-contractors' injuries

5.2 Formation of the Model Hierarchy

To determine the weight of the proposed strategies while calculating the index, the thirteen factors identified in the figures above are further compiled under five main factors: *Project Safety Policies*, *Safety Communication*, *Labor Safety Policies*, *Labor Characteristics* and *Sub-Contract Management*. These factors will be included under the "Leading Indicators" section of the index. The other section of the index will include "Lagging Indicators", or the current used strategies to evaluate a contractor while renewing insurance premiums: fatalities, lost time, and non-fatal injuries. The resulting hierarchy of the factors in the model is shown in Figure 6.

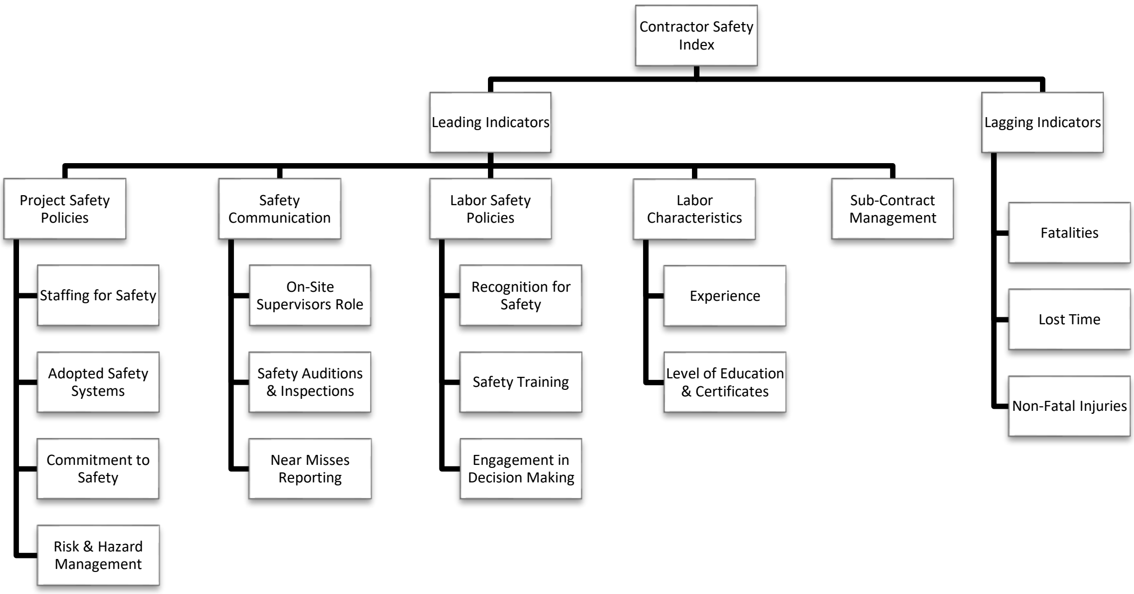


Figure 6: Hierarchy of the Model

5.3 Ranking and Weighting using Analytic Hierarchy Process (AHP)

To calculate the weights of the factors, Analytic Hierarchy Process will be used. Factors belonging to the same hierarchy level will be compared using an AHP survey. The survey will target experienced construction safety professionals to derive the weight of each factor. Their rank will be based on their personal perspective of what safety factor is more important to enhance construction safety. The model and AHP survey can also be discussed with professionals in insurance companies to determine which of these factors have a higher impact on issuing or renewing insurance premiums. The different rankings can also serve as a base of comparison between both parties.

5.3.1 AHP Definition

The Analytical Hierarchy Process is a method of measurement based on pair-wise comparisons between options. It is usually used to assign weights or scales for multiple factors contributing to the same problem, goal, or outcome, and it depends on judgments to derive priority weights or scales. AHP was first introduced by Sataaty (1980) as a management tool for decision making in multi-attribute environments. It approaches a "big" problem by breaking it into several "small" problems characterized by relatively simple solutions, while being conducted with a view to the overall solution of the big problem. To decide, AHP can weight a large number of factors, whether qualitative and quantitative, and produce a formal and numeric basis for solution. Although the current study did not deal with decision making, the use of AHP was deemed suitable given the platform it provides for weighting multiple varied factors. Shapira & Simcha (2009) performed a similar study when attempting to create a site safety index due to tower crane operations by weighing factors that affect safety on construction sites with tower cranes using AHP.

To implement an AHP, hierarchies are first constructed, then judgments or measurements on pairs of elements are made with respect to a criterion in order to derive preference scales or weights (Kumar & Maiti, 2012). The first step of the AHP is to set a goal or a predicted outcome. In this study, the goal is to derive an index that represent the safety status of a contractor based on the safety factors that this contractor implements. This goal is at the highest level of the hierarchy, followed by "sets of attributes," which are organized in several more hierarchy levels, and donated by dashed line frames in Figure 3. A typical second-level attribute set includes all of the secondary goals that together contribute to achieving the primary goal. These, in turn, are directly affected by all of the attributes in the set located one level lower. For example, the cumulative effect of “Labor Safety Policies” may be affected by *Recognition for Safety*, *Safety Training* and *Engagement in Decision Making*. In this index hierarchy, there are four levels and seven sets of attributes. Attributes with no other attributes under them in the hierarchy structure are termed “leaf attributes”, donated in Figure 3 by shaded boxes. All in all, this hierarchy structure expresses the interrelationships between the various attributes while retaining their linkage to the primary goal.

Another advantage of using AHP is the Consistency Ratio (C.R.). For example, if a respondent chose A to be better than B, then B to be better than C, then A should be better than C by a higher factor. If this was not the case, the C.R. ratio would increase to more than 10% indicating inconsistency in answers. If the consistency is inadequate, the prioritization is iteratively re-performed until the consistency is well validated, else the process is abandoned. Finally, assuming consistency, the key alternatives or elements are prioritized with respect to the goal. Two major assumptions embedded within the concept of AHP are as follows (Kumar & Maiti, 2012; Adamcsek, 2008):

- Decision-making can be modeled in a linear top-to bottom form as a hierarchy
- Dependencies among elements can only be between the levels of the hierarchy

The computations made by the AHP are always guided by decision makers’ experience. Thus, it can be considered as a tool that is able to translate the evaluations, which are both qualitative and quantitative, made by decision makers into a multicriteria Ranking without needed experience in filling AHP surveys.

To reach an accurate decision in the AHP: (1) the decision problem is stated, (2) the purpose or goal behind a certain decision is established, (3) the main criteria with respect to the decision goal is determined, (4) the adaptation options are determined, (5) a group of pair-wise comparison matrices, (6) all the pairwise comparison data and finally (7) the importance and weight for each alternative option is computed.

The decision problem in to calculate a safety index for a contractor, where the goal is to measure weights for the safety factors under study. Each level or group of factors that will be compared together is enclosed in a dotted rectangle in Figure 7.

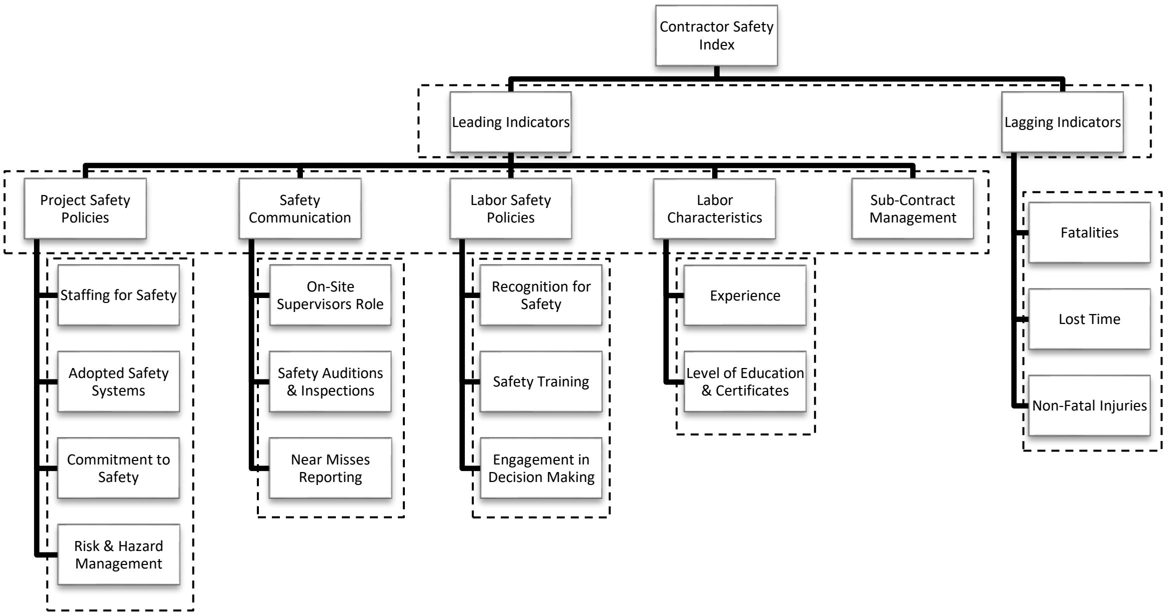


Figure 7: Comparison Levels of the Model Hierarchy

5.3.2 Implementation of the AHP Survey

The survey is divided into 5 sections. The first section includes a cover letter for the survey respondents, the second section presents the hierarchy of the index, the scale system which is adopted from Saaty (1980) and used to answer the survey questions, and an example on how to rank a priority between two criteria. The scale system adopted in the survey is explained in the Table 5.

Table 5: Saaty's Scale for AHP

Intensity of Weight	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objectives
3	Weak/moderate importance of one over another	Experience and judgment slightly favored one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent scale values	Used to represent compromise between the priorities listed above

Sections 3 and 4 present the pairwise comparison tables of the different choices and factors for insurance company respondents and construction industry respondents to fill out respectively. Section 4 also includes a table to evaluate the safety practices and calculate the assessment values, described in section 5.4 of this chapter. The last section of the survey lists the safety practices involved under each studied safety factor for the reference of the respondent.

5.3.3 Weighting the Model Factors

Each factor in the model is assigned a weight variable. These weight variables, which will be calculated from the AHP survey, form the index equation. The lowest level factors in the hierarchy are also assigned assessment values to numerically evaluate them and compute the safety index. Section 5.4 discusses the mechanism followed for assessment. Both the weight variables and the assessment values are summarized in Table 6.

Table 6: Weight Variables

	Weight Variables		Assessment Values
Contractor Safety Index	**CSI**		
Leading Indicators	**X**		
Project Safety Policies	X1		
Staffing for Safety		*X11*	*A11*
Adopted Safety Systems		*X12*	*A12*
Commitment to Safety		*X13*	*A13*
Risk & Hazard Management		*X14*	*A14*
Safety Communication	X2		
On-Site Supervisors Role		*X21*	*A21*
Safety Auditions & Inspections		*X22*	*A22*
Near Miss Reporting		*X23*	*A23*
Labor Safety Policies	X3		
Recognition for Safety		*X31*	*A31*
Safety Training		*X32*	*A32*
Engagement in Decision Making		*X33*	*A33*
Labor Characteristics	X4		
Experience		*X41*	*A41*
Level of Education & Certificates		*X42*	*A42*
Sub-Contract Management	X5		A50
Lagging Indicators	**Y**		
Fatalities	Y1		B1
Lost Time	Y2		B2
Non-Fatal Injuries	Y3		B3

Combining the weight variable with their corresponding assessment values, Equation 1 will be used to calculate the contractor safety index.

$$CSI = X[X1(X11.A11 + X12.A12 + X13.A13 + X14.A14) + X2(X21.A21 + X22.A22 + X23.A23) + X3(X31.A31 + X32.A32 + X33.A33) + X4(X41.A31 + X42.A42) + X5(A50)] + Y[Y1.B1 + Y2.B2 + Y3.B3] \quad (1)$$

5.4 Measuring the Model Factors

To compute the assessment value of each factor, safety practices corresponding to each factor are evaluated using a Likert's scale of 1 to 5; 1 being weakly implemented while 5 being strongly implemented. At the level of leading indicators, safety practices which are considered passive, such as "100% hard-hat policy", are given either a 1 (if they implemented) or a 5 (if they are not implemented). Safety practices which are considered active, such as "regular scheduled meetings for safety personnel", are evaluated from 1 to 5 depending on their frequency and quality. The final assessment value of every factor will then equate the average of the performed evaluations of all safety practices recognized under that factor. All practices under each factor are assumed to be of equal importance. For example, *Staffing for Safety* factor is assessed upon evaluating its six related safety practices: On-site medical facilities, full-time safety manager on the project, safety instructor for the project, first-aid log and minimum ratio of number of safety supervisors to workers. All these practices are passive and are therefore evaluated by either 1 or 5. Detailed evaluation of the assessment value is described in Table 6. The same method will be applied to all remaining factors.

Table 7: Sample Computation of the "Staffing for Safety" Assessment Value – A11

SAFETY PRACTICE	SITE EVALUATION
On-site medical facilities	1
Full-time safety manager on the project	5
Safety instructor for the project	5
First-aid log	1
Minimum ratio of number of safety supervisors to workers	5
Minimum ratio of number of safety professionals to workers	5
Staffing for safety	**3.67**

CHAPTER 6

APPLICATION OF THE SAFETY INDEX

The first three sections of this chapter present and summarize the results of the AHP survey and the perception of both contractors and insurance companies on safety. All the results and ranks obtained are an implementation of the proposed index of Chapter 5 on the Lebanese construction industry. The last section is a direct application of the index on an adopted construction project. The case adopted is the construction project of a bank headquarters in Beirut. For privacy, the construction project will be referred to as Project X.

6.1 Result of the AHP Survey – Contractor's Perception

The AHP survey was applied on 30 respondents with a total of 578 years of experience (average of 19.2 years of experience/respondent). 53.33% of the respondents had experience between 10 and 19 years, 33.33% between 20 and 29 years, and 13.33% between 30 and 40 years. The positions for the construction professionals were either construction managers, project managers, full time safety officers or safety auditors. The respondents worked in large-sized contractors, solely in Beirut region.

Construction industry professionals ranked "Leading Indicators" ahead of "Lagging Indicators" with 93.75% of the respondents choosing Leading over Lagging. The corresponding weights of Leading versus Lagging were calculated as 0.789 versus 0.211 respectively as shown in Table 9. Table 8 shows the resulted ranking of the factors falling under the leading indicator's section and their corresponding sub factors.

Table 8: Ranking of Leading Indicators - Contractors

Leading Indicators			
1	Project Safety Policies	*1*	*Commitment to Safety*
		2	*Staffing for Safety*
		3	*Adopted Safety Systems*
		4	*Risk and Hazard Management*
2	Safety Communication	*1*	*On Site Supervisors Role*
		2	*Safety Audits and Inspections*
		3	*Near Miss Reporting*
3	Labor Safety Policies	*1*	*Safety Training*
		2	*Engagement in Decision Making*
		3	*Recognition for Safety*
4	Labor Characteristics	*1*	*Years of Experience*
		2	*Level of Education & Certificates*
5	Sub-Contract Management		

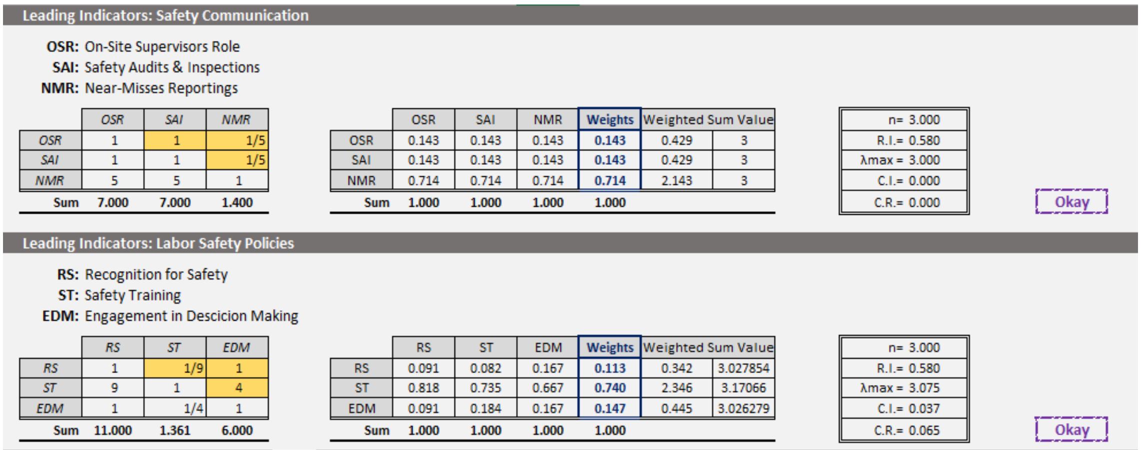
The results of the AHP survey of the weight variables are described in Table 9.

Table 9: Values of Weight Variables - Results of AHP Survey

	Weight Variable	AHP Result
Contractor Safety Index	**CSI**	--
Leading Indicators	**X**	**0.779**
Project Safety Policies	X1	0.377
Staffing for Safety	*X11*	*0.241*
Adopted Safety Systems	*X12*	*0.218*
Commitment to Safety	*X13*	*0.346*
Risk & Hazard Management	*X14*	*0.196*
Safety Communication	X2	0.255
On-Site Supervisors Role	*X21*	*0.429*
Safety Auditions & Inspections	*X22*	*0.393*
Near Miss Reporting	*X23*	*0.178*

Labor Safety Policies		X3		0.180
Recognition for Safety			*X31*	*0.245*
Safety Training			*X32*	*0.460*
Engagement in Decision Making			*X33*	*0.295*
Labor Characteristics		X4		0.113
Experience			*X41*	*0.562*
Level of Education & Certificates			*X42*	*0.438*
Sub-Contract Management		X5		0.074
Lagging Indicators	**Y**			**0.211**
Fatalities		Y1		0.526
Lost Time		Y2		0.256
Non-Fatal Injuries		Y3		0.219

Figure 8 is a screenshot from the spreadsheet that was deisgned to perform the pairwise comparison, check the cosistency ratio and return "okay" if the results were acceptable. It was done for every respeondent and each pairwise comparison. The screenshot shows the *safety communication* and *labor safety poilicies* compairsons.



Leading Indicators: Safety Communication

OSR: On-Site Supervisors Role
SAI: Safety Audits & Inspections
NMR: Near-Misses Reportings

	OSR	*SAI*	*NMR*
OSR	1	1	1/5
SAI	1	1	1/5
NMR	5	5	1
Sum	**7.000**	**7.000**	**1.400**

	OSR	SAI	NMR	Weights	Weighted Sum Value	
OSR	0.143	0.143	0.143	**0.143**	0.429	3
SAI	0.143	0.143	0.143	**0.143**	0.429	3
NMR	0.714	0.714	0.714	**0.714**	2.143	3
Sum	**1.000**	**1.000**	**1.000**	**1.000**		

n= 3.000
R.I.= 0.580
λmax = 3.000
C.I.= 0.000
C.R.= 0.000

Okay

Leading Indicators: Labor Safety Policies

RS: Recognition for Safety
ST: Safety Training
EDM: Engagement in Descicion Making

	RS	*ST*	*EDM*
RS	1	1/9	1
ST	9	1	4
EDM	1	1/4	1
Sum	**11.000**	**1.361**	**6.000**

	RS	ST	EDM	Weights	Weighted Sum Value	
RS	0.091	0.082	0.167	**0.113**	0.342	3.027854
ST	0.818	0.735	0.667	**0.740**	2.346	3.17066
EDM	0.091	0.184	0.167	**0.147**	0.445	3.026279
Sum	**1.000**	**1.000**	**1.000**	**1.000**		

n= 3.000
R.I.= 0.580
λmax = 3.075
C.I.= 0.037
C.R.= 0.065

Okay

Figure 8: Screenshot of the AHP Pairwise Comparison Spreadsheet

Table 10 shows the distribution of respondent's rankings of factors falling under *project safety policies*. Each of the factors were ranked first at least once, indicating different perceptions when it comes to these factors. Some respondents even considered all four factors as equally important. However, more than 67% of the respondents ranked *commitment to safety* first resulting in the highest weight. They considered that when the upper management or the construction managers are truly committed to safety, all other factors will follow. As for *adopted safety systems*, insurance companies ranked it lowest because they consider that the practices listed under it are required by the country's construction safety laws but not followed by contractors. *Adopted safety systems* and *risk and hazard management* were ranked third or fourth more frequently since some respondents considered that their related practices should be implemented in the company and serve as the safety base for any project.

Table 10: Distribution of Respondent's Rankings - Project Safety Policies

Rank	**1**	**2**	**3**	**4**	**Overall Rank**	**AHP Weight**
Commitment to Safety	66.67%	6.67%	26.67%	0%	1	0.346
Staffing for Safety	26.67%	46.67%	13.33%	13.33%	2	0.241
Adopted Safety Systems	33.33%	20%	20%	26.67%	3	0.218
Risk and Hazard Management	26.67%	20%	40%	13.33%	4	0.196

Table 11 shows the distribution of respondent's rankings of factors falling under *labor safety policies* and *safety communication*. At the level of *safety communication*, the two factors *on-site supervisors' role* and *safety auditions and inspections* almost got the same AHP weight indicating that most respondents ranked them as equally important. This is shown as well through the percentages of respondents who ranked the factors first (53.33% for on-site supervisors' role and 46.67% for safety auditions). As for *labor safety policies*, most of the respondents (60%) ranked *safety training* as most important while compared to the remaining factors.

Table 11: Distribution of Respondent's Rankings - Labor Safety Policies and Safety Communication

	Rank	**1**	**2**	**3**	**Overall Rank**	**AHP Weight**
Safety Commu-nication	On Site Supervisors Role	53.33%	33.33%	13.33%	1	0.429
	Safety Audits and Inspections	46.67%	46.67%	6.67%	2	0.393
	Near Miss Reporting	13.33%	26.67%	60%	3	0.178
Labor Safety Policies	Safety Training	60%	33.33%	6.67%	1	0.460
	Engagement in Decision Making	26.67%	46.67%	26.67%	2	0.295
	Recognition for Safety	20%	26.67%	53.33%	3	0.245

Table 12 shows the distribution of respondent's rankings of factors falling under *labor characteristics*. Respondents mostly ranked *experience* ahead of *level of education*, noting that it is hard to have educated construction labor on site. However, some respondents considered that experienced labor are lost costly than educated ones and therefore more economically beneficial for contractors. The only certified labor that contractors opt for are wielders.

Table 12: Distribution of Respondent's Rankings - Labor Characteristics

Rank	1	2	Overall Rank	AHP Weight
Experience	62.5%	37.5%	1	0.562
Level of Education	43.75%	56.25%	2	0.438

Table 13 shows the distribution of respondent's rankings of factors falling under *leading indicators*. Most of the respondents ranked *project safety policies* first (more than 86%) while most ranked *sub-contract management* last (60%). They considered that sub-contractors are bound to the contractor and would follow whatever practices implemented by the contractor. *Safety communication* and *labor safety policies* were mostly ranked second and third respectively, and barely ranked fourth or last. Respondents considered that factors ranked under *safety communication* policies are essential to maintain safety on construction sites, while those under *labor safety policies* depend on the type of construction project. Very few respondents ranked *labor characteristics* as most important, or equally important to *project safety policies*, considering that experienced or educated labor develop safety incentives that promote a better safety environment on construction sites.

Table 13: Distribution of Respondent's Rankings - Leading Indicators

Rank	1	2	3	4	5	Overall Rank	AHP Weight
Project Safety Policies	86.67%	0%	6.67%	6.67%	0%	1	0.377
Safety Communication	33.33%	46.67%	13.33%	6.67%	0%	2	0.255
Labor Safety Policies	13.33%	20%	53.33%	13.33%	0%	3	0.180

Labor Characteristics	6.67%	20%	6.67%	53.33%	13.33%	4	0.113
Sub-Contract Management	0%	20%	6.67%	13.33%	60%	5	0.074

At the level of lagging indicators, almost 73.33% of respondents considered that fatal injuries are the most important (with a weight of 0.526), followed by lost time and wages (with a weight of 0.256) then non-fatal injuries (with a weight of 0.219). However, lagging was considered way less important compared to leading, where 86.67% of respondents considered that leading indicators are strongly more important or very strongly more important than lagging. This ended up giving leading a weight of 0.779 while lagging a weight of 0.221.

After conducting the survey on construction professionals, the survey was passed to professionals in the insurance companies to rank the factors and analyze their perception of the construction industry. Results are displayed in section 5.2.

6.2 Insurance Companies' Perception of the Construction Industry

Insurance companies ranked the model factors based on their effect on premium rates issued to contractors. A total of 10 respondents with a combined 288 years of experience, ranked the factors and discussed the construction industry (average of 29 years of experience/respondent). Respondents were either senior managers of the claims departments, vice presidents of the claims departments or chief operating officers.

Based on discussions with respondents, issuing premium rates depend on the size of the project and the time it takes for completion. Other factors such as the contractor's payroll and the number of labors working on site are considered, however these inputs cannot be validated. Contractors can hide the correct number of labors assigned on site to decrease the premium rate. After completion of the first year, premium rates increase or decrease based on a loss ratio. This loss ratio can be summarized as the ratio of cost incurred by the contractor during the year to the net premium paid by the contractor. This total includes the direct and indirect costs for non-fatal injuries, lost wages due to injuries ($30/working day for skilled labor and $25/day for unskilled labor), fatal injuries and related compensation, etc. For example, a contractor paid a total premium of $100,000 for a project. The net premium is calculated by subtracting the indirect costs of the premium (such as paperwork, governmental fees, etc.) from the total premium. Assuming the indirect costs in this example were $15,000, the net premium will be estimated as $85,000. At the end of the first year, the contractor incurred claims at a total cost of $25,000. The loss ratio will therefore be around 29.5% (25,000/85,000 = 0.294). According to respondents, if this loss ratio remains below 75% (as opposed to 50% in other countries such as United Arab Emirates according to one of the respondents who worked in Dubai), contractors are not charged higher premiums. Moreover, the considered incurred costs are usually those of frequent claims. In other words, if a contractor had only one or two severe incidents through the entire year that incurred high costs, these accidents are not usually considered when calculating the loss ratio. However, if a contractor incurred frequent claims, then the entire total will be considered.

Different problems were discussed with respondents concerning contractor premiums. To begin with, **Decree No. 136 of 1983** stipulates the employers' responsibilities in cases of occupational injuries and corresponding compensation and workers' entitlements, it also stipulates the sanctions in case of violations. This decree hasn't been updated since it was set in 1983. The compensation of lost wages depends on this decree, so is the compensation for any death. Families of foreign labors who die on construction sites, especially those of Syrian or Egyptian nationalities, get paid vey low amounts (ranging between $5,000 to $8,000), cheaper than major or severe major injuries. It was followed by **Decree No. 11802 of 2004** (Regulation of OSH in the Enterprises which includes the OSH requirements and precautions required by the employers in their workplaces), **Decree No. 11958 of 2004** (Safety and Protection in Construction) and **Decree No. 14229 of 2005** (Occupational Diseases' Table). In 2005, the political situation in Lebanon was hindered and Decrees No. 11802, No. 11958 and No. 14229 were not completely implemented. Premium injury exclusions and construction safety regulations are set by insurance companies based on Decree No. 11958. This decree is very general and broad with safety practices and recommendations that lack details and specifications (Awwad et al., 2016), and thereby makes premium exclusions weak. For example, insurance companies recommend using safety boots on sites and exclude stepping on a nail from the covered injuries. However, when this injury happens, contractors can argue that the boot was loose, or the labor removed it for an urging matter such as praying. Unless, the injury claim is high, insurance companies do not investigate to avoid legal costs. The competition between insurance companies is also a big factor that affects premiums. One of the respondents noted the high frequency of injuries incurred from wielding and discharged particles that strike the eye of the worker because he or she is not wearing safety glasses. The high frequency was incurring high medical costs, and the insurance company became strict about not covering any injury related to that. Consequently, instead of enforcing on site practices to limit this injury, many contractors threatened to leave the insurance company and head to other companies that provide unconditional coverage. This led the company to revoke its decision. Other problems faced by insurance companies is the abuse of the insurance premiums. As mentioned before, the insurance company does not know the names of labors working on site neither investigate accidents. Accordingly, some labors use their medical insurance to medicate family members or friends that are injured, especially labor on construction projects that are based away from the big cities and are barely monitored by inspectors or engineers.

Aside the discussed problems with the construction industry, insurance company respondents were asked to rank the impact of the model's factors on insurance premiums. When it comes to the impact on insurance premiums, insurance companies ranked "Lagging Indicators" ahead of "Leading Indicators". All responders considered that the cost incurred from the fatalities, non-fatal injuries and the lost wages are what usually affect the rate of premiums. Factors under lagging indicators were not ranked because insurance companies depend on the loss ratio described before when it comes to assessing premiums. Table 14 shows the resulted ranking of the factors falling under the leading indicator's section and their corresponding sub factors.

Table 14: Ranking of Leading Indicators - Insurance Companies

Leading Indicators			
1	Project Safety Policies	*1*	*Staffing for Safety*
		2	*Commitment to Safety*
		3	*Risk and Hazard Management*
		4	*Adopted Safety Systems*
2	Labor Safety Policies	*1*	*Safety Training*
		2	*Engagement in Decision Making*
		3	*Recognition for Safety*
3	Labor Characteristics	*1*	*Level of Education & Certificates*
		2	*Years of Experience*

4	Safety Communication	*1*	*On Site Supervisors Role*
		2	*Near Miss Reporting*
		3	*Safety Audits and Inspections*
5	Sub-Contract Management		

Table 15 shows the distribution of respondent's rankings of factors falling under *project safety policies*. All respondents ranked *staffing for safety* as the first or second due to safety practices related to the presence of medical facilities on site and OSHA's required minimum number of safety personnel. As for *adopted safety systems*, insurance companies ranked it lowest because they consider that the practices listed under it are required by the country's construction safety laws but not followed by contractors.

Table 15: Distribution of Respondent's Rankings - Project Safety Policies

Rank	**1**	**2**	**3**	**4**	**Overall Rank**
Staffing for Safety	20%	80%	0%	0%	1
Commitment to Safety	40%	20%	40%	0%	2
Risk and Hazard Management	0%	0%	40%	60%	3
Adopted Safety Systems	0%	0%	40%	60%	4

Table 16 shows the distribution of respondent's rankings of factors falling under *labor safety policies* and *safety communication*. Each factor in *safety communication* was ranked first at least once, indicating the importance of all three factors. *On site supervisors' role* was ranked first since supervisors will be available on site all through working hours to monitor safety unlike the practices under *safety audits and inspections*, while *near miss reporting* was ranked second with insurance companies welcoming such reports noting that it can be a good indicator for safety performance. As for the *labor safety policies* factors, *safety training* was ranked first since most labor according to respondents lack professional training, it was followed by *engagement in* *decision making* where respondents noted the importance of involving labor in improving their safety environment. *Recognition for safety* was mostly ranked third because respondents believe that such practices are not followed or adopted in Lebanon, and therefore will not have an impact. However, respondent did encourage it.

Table 16: Distribution of Respondent's Rankings - Labor Safety Policies and Safety Communication

	Rank	**1**	**2**	**3**	**Overall Rank**
Safety Commu-nication	On Site Supervisors Role	60%	40%	0%	1
	Near Miss Reporting	20%	60%	20%	2
	Safety Audits and Inspections	20%	0%	80%	3
Labor Safety Policies	Safety Training	60%	0%	40%	1
	Engagement in Decision Making	40%	20%	40%	2
	Recognition for Safety	0%	80%	20%	3

Table 17 shows the distribution of respondent’s rankings of factors falling under *labor characteristics*. Despite being quite hard to implement in Lebanon, respondents noted the importance of having educated labor instead of experienced ones on site. According to respondents, experienced labors that lack education develop high self confidence that drive them to do their work without taking safety precautions, especially when it comes to working on heights. Not taking precautions such as safety belts on scaffolds lead usually to fatal injuries.

Table 17: Distribution of Respondent's Rankings - Labor Characteristics

Rank	**1**	**2**	**Overall Rank**
Level of Education	80%	20%	1
Experience	20%	80%	2

Table 18 shows the distribution of respondent's rankings of factors falling under *leading indicators*. All respondents ranked project safety policies first while most ranked *sub-contract management* last. They considered that sub-contractors are bound to the contractor and would follow whatever practices implemented by the contractor.

Table 18: Distribution of Respondent's Rankings - Leading Indicators

Rank	**1**	**2**	**3**	**4**	**5**	**Overall Rank**
Project Safety Policies	100%	0%	0%	0%	0%	1
Labor Safety Policies	0%	40%	40%	20%	0%	2
Labor Characteristics	0%	40%	20%	20%	20%	3
Safety Communication	0%	20%	40%	40%	0%	4
Sub-Contract Management	0%	0%	0%	20%	80%	5

Section 5.3 compares and analyzes the differences between the perceptions of both contractors and insurance companies before applying the model to a construction site and calculating its safety index in section 5.4.

6.3 Comparison between Contractors and Insurance Companies

Table 19 display the differences of the results and ranking of model factors between contractors and insurance companies.

At the level of the *project safety policies*, insurance companies ranked *staffing for safety* first while *adopted safety systems* last, considering that safety resources should be available on site while the latter includes practices considered exclusions from construction premiums. Contractors however ranked *commitment to safety* first since it has practices that serve as a base for the remaining factors, while *risk and hazard management* last.

At the level of *safety communication*, both contractors and insurance companies ranked the *on-site supervisors' role* as most important. This indicates how much both parties acknowledge the importance of having a safety professional available full tie on construction sites. As for the other two factors, insurance companies would care more about the *near misses reporting* since it will project injuries and accident occurrences, while contractors would focus more on *safety auditions and inspections* to avoid on-site accidents.

Both parties ranked the factors under *labor safety policies* in the same way, enforcing the importance of *safety training* above engaging employees and recognizing their safe acts. However, contractors should be more aware that engaging their employees and recognizing them through awards are very good incentives to create a positive safety environment. In contrast, at the level of labor characteristics, insurance companies rathe labor to be educated than experienced since they would have a better safety perception, while contractors would rather experienced ones for financial benefits.

At the level of *leading indicators,* both parties ranked *project safety policies* first, indicating that both parties acknowledge the importance of adopting safety practices, staffing safety personnel and committing to safety. Difference was noted at the level of *safety communication* where it was ranked fourth by insurance companies and second by contractors. This difference is explainable since the safety communication is internal within the contracting company and enhances its safety environment to pursue the best safety results. However, when it comes to premiums, insurance companies would be more interested in the policies the contractor is implementing and the outcomes of these practices (aka increasing or decreasing injuries and accidents) rather than the internal communication inside the contracting company.

Finally, insurance companies consider lagging indicators more important than leading indicators when it comes to finding an index. This is explainable because premiums will eventually depend on the outcomes of the contractor's work and the cost being incurred from injuries and practices. However, respondents did acknowledge the importance of the leading indicators and considered that an index which is based on them and calculated efficiently would help predict the accidents that may be incurred b the contractor before signing the premium, instead of only depending on the type and length of the project. As far as contractors, it would definitely be more beneficial for them to pick leading over lagging because (1) it would provide a proper base for comparison between contractors and (2) would not involve their records of accidents and injuries.

Table 19: Difference between Contractors and Insurance Companies

	Insurance Companies		Contractors	
Project Safety	1	Staffing for Safety	1	Commitment to Safety
	2	Commitment to Safety	2	Staffing for Safety
	3	Risk and Hazard Management	3	Adopted Safety Systems
	4	Adopted Safety Systems	4	Risk and Hazard Management
Safety Communication	1	On Site Supervisors Role	1	On Site Supervisors Role
	2	Near Misses Reporting	2	Safety Audits and Inspection
	3	Safety Audits and Inspection	3	Near Misses Reporting

Labor Safety Policies	1	Safety Training	1	Safety Training
	2	Engagement in Decision Making	2	Engagement in Decision Making
	3	Recognition for Safety	3	Recognition for Safety
Labor Characteristics	1	Level of Education	1	Experience
	2	Experience	2	Level of Education
Leading Indicators	1	Project Safety Policies	1	Project Safety Policies
	2	Labor Safety Policies	2	Safety Communication
	3	Labor Characteristics	3	Labor Safety Policies
	4	Safety Communication	4	Labor Characteristics
	5	Sub-Contract Management	5	Sub-Contract Management

6.4 Application of the Contractor Safety Index

As mentioned in the beginning of the Chapter 6, the index will be implemented on a construction project for a bank in Beirut, and will be referred to as Project X. The outcomes of the evaluation will be the safety index given to the contractor under study. Since the values of the weight variable were only computed from the construction industry, the valued calculated and displayed in Table 9 (section 6.1 of this chapter) were replaced in the contractor safety index equation (Equation 1 in Chapter 5, section 5.3).

Upon substituting the weight variables with the corresponding AHP results, the equation that represents the Contractor Safety Index in Lebanon will be as follows:

$CSI = 0.779 * [0.377(0.241 * A11 + 0.218 * A12 + 0.346 * A13 + 0.196 * A14) +$
$0.255(0.429 * A21 + 0.393 * A22 + 0.178 * A23) + 0.180(0.245 * A31 + 0.460 *$

$A32 + 0.295 * A33) + 0.133(0.562 * A31 + 0.438 * A42) + 0.074(A50)] +$

$0.221[0.526 * B1 + 0.256 * B2 + 0.219 * B3]$ (2)

To calculate the assessment values, a site visit was conducted to the project to evaluate the safety practices with the help of the full-time safety inspector and auditor. The evaluated practices are listed in Table 4 (Chapter 5, section 5.1) as described in Chapter 5, section 5.4. Results and how practices were assessed are summarized in the Table 20.

Based on the table, A11 = 4.33 (staffing for safety), A12 = 3.588 (adopted safey systems), A13 = 3.308 (commitment to safety), A14 = 4 (risk and hazard management), A21 = 4.429 (on-site supervisors role), A22 = 4 (safety auditions and inspections), A23 = 4.5 (near misses reporting), A31 = 2 (recognition for safety), A32 = 3.667 (safety training), A33 = 3.125 (engagement in decision making), A41 = 4 (experience) , A42 = 3 (level of education and certifications), A50 = 4.750 (sub-contract management), B1 = 5 (fatalities), B2 = 4 (lost time), B3 = 4 (non-fatal injuries).

Substituting the assessment values in equation 2, the Contractor Safety Index will result in **CSI = 3.712**.

With the strong safety practices, the contractor adopt on site, good safety communication, and low number of injuries, the resulted CSI truly represents the safety status. Going through the data of the minor injuries, they were mostly stepped on nails or struck by a flying particle. The causes of stepping on nails were mostly in the early construction phases of the project before praying time when labor used to remove their safety boots and walk around to wash and pray. The contractor dealt with the issue by keeping the entrance of the site always clean and designating a prayer room. As for the struck by flying particle, it was mostly when a labor was working next to a labor who was using a saw or wielding. The contractor obliged labors to have a warning sign at the entrance of the floor when such tasks are being performed.

Recommendations for the contractor would be to engage the workers more when taking safety related decisions, investigating safety accidents, or planning safety tasks. Another recommendation would be to follow more safety practices that fall under the factor *commitment to safety* and recognize the safe acts of labor by either extrinsic or intrinsic rewards. Such practices would further improve the safety atmosphere of the construction site.

Table 20: Evaluation of the Safety Practices

Factor	**Safety Practices**	**Eval.**	**Comment**	**Asses. Value**
Staffing for Safety	On-site medical facilities	1	Not Available	4.333
	Full-time safety manager on the project	5	Available	
	Safety instructor for the project	5	Available	
	First-aid log	5	Available	
	Minimum ratio of number of safety supervisors to workers	5	Available (1:50 as set by OSHA)	
	Minimum ratio of number of safety professionals to workers	5	Available	
Adopted Safety Systems	Lock-out tag-out policy	1	Not Applied	3.588
	100% fall protection	5	Applied	
	100% hard-hat policy	5	Applied	
	100% safety glasses policy	5	Applied	
	100% gloves policy	5	Applied	
	100% reflective vest policy	5	Applied	
	100% steel toed boots policy	5	Applied	
	Electric Safety Policy	5	Applied	
	Restricted Area Work Permit	5	Applied	
	Lift safety policies	5	Applied	
	Hot work safety policy	5	Applied	
	Fire safety policies	5	Applied	
	Fatigue management program	1	Not Applied	
	Work-hour restrictions	1	Not Applied	
	Worker hydration program	1	Not Applied	

	Heat-and-cold-stress program	1	Not Applied	
	Stretch and flex program for workers	1	Not Applied	
Commitment to Safety	Management review of craft-worker training	4	Applied	3.308
	Management/Supervisor safety audits	4	Applied	
	Number of Audits completed vs. scheduled (%)	5	100%	
	Percent of safety compliance on jobsite safety audits (inspections)	5	100%	
	A procedure to communicate the results of audits, inspections and similar activities to the employees	4	Available (existing forms + scheduled meetings)	
	Site-specific safety orientation for all employees	3	Not for all employees	
	Root-cause analysis program	1	Not Applied	
	Injury reporting and analysis program	5	Applied (existing form for reporting and another one for analysis)	
	Established disciplinary program	4	Applied	
	Leadership-development program	1	Not Applied	
	Mandatory substance-abuse program	1	Not Applied	
	Unannounced random drug and alcohol program	1	Not Applied	
	Formal lessons learned	5	Applied (on weekly basis)	
Risk & Hazard Management	Safety analysis during constructability reviews	3	Applied (with designer + before tasks start)	4.000
	Safety in scheduling and accounting for safety in design	4	Applied (risk assessment for each activity)	
	Written site-safety plan	5	Applied (printed on each floor)	
	Emergency response plan for project	5	Applied (evacuation plan)	
	Job hazard analysis	3	Applied	

On-Site Supervisors Role	Foreman evaluation in safety performance	5	Applied (weekly)	4.429
	Project health and wellness review	4	Applied	
	Safety and health orientation and training	4	Applied (weekly meetings)	
	Regular training on emergencies on-site	4	Applied (monthly)	
	Conducted toolbox safety meetings	5	Applied (weekly)	
	Quality of participation in toolbox meetings	5	Very High (mandatory)	
	Pre-task planning meetings conducted	4	Applied (before hazardous tasks start)	
Safety Auditions & Inspections	Regular scheduled meetings for safety personnel	4	Applied (weekly)	4.000
	Auditing program set in place	4	Available	
	Safety audit score calculated and monitored	4	Applied (monitored weekly)	
	Heavy-equipment inspection and approval program	4	Applied	
	Regular inspection and maintenance of all tools	4	Applied (daily)	
	Regularly scheduled equipment inspections	4	Applied (daily)	
	PPE inspection and maintenance policy	4	Applied and Available	
Near Misses Reporting	Track of near misses	4	Applied (special form available)	4.500
	Near-misses investigation	5	Applied (special form available)	
Recognition for Safety	Extrinsic Rewards	1	Not Applicable	2.000
	Intrinsic Rewards	3	Applicable Sometimes	
Safety Training	Safety leadership training program supervisors, foremen and labor	4	Applied and Available	3.667
	Monthly H & S training program for supervisors, foremen and labor	3	Applied and Available	

	Safety-monitoring program for worker	4	Applied and Available	
Engagement in Decision Making	Safety goals development and communication	5	Applicable	3.125
	Participation in established percentage of daily toolbox safety meetings	3	Applied Weekly	
	Foremen involvement in accident investigation	1	Not Applicable	
	Foremen involvement in hazard assessment	5	Applicable	
	Foremen involvement in lessons learned and knowledge management	5	Applicable	
	Foremen involvement in jobsite-safety inspections and audits	5	Applicable	
	Foremen involvement in safety committees	5	Applicable	
	Foremen involvement in policy creation and implementation	5	Applicable	
	Safety perception surveys completed by foremen	1	Not Applicable	
	Workers involvement in pre-task safety planning	5	Applicable	
	Workers involvement in safety committees	5	Applicable	
	Workers involvement in hazard assessment	1	Not Applicable	
	Workers involvement in accident investigations	1	Not Applicable	
	Workers involvement in perception surveys	1	Not Applicable	
	Workers Involvement in inspections and audits	1	Not Applicable	
	Workers involvement in policy creation and implementation	1	Not Applicable	
Labor Experience	Safety training history for all personnel	4	Estimated 75% of Labor	4.000
	Employees' skills	4	Estimated 75% of labor have more than 5 years experience	

Level of Education	Employees' level of education	3	Estimated 50% of on-site labor have education	3.000
	Employees' certifications	3	Estimated 50% of on-site labor are certified	
Sub-Contract Management	Subcontractors prequalification's on safety	4	Applied (subcontractors have to show their safety plans and work method statements)	4.750
	Subcontractors participation in GC's orientation and training	5	Applied	
	Subcontractor's safety standards compared with GC	5	Applied	
	GC's involvement in the investigation of sub-contractors' injuries	5	Applied (special forms)	
Lagging Indicators	Fatalities	5	No Fatalities	4.333
	Lost Time	4	Only one injury with lost time	
	Non-Fatal Injuries	4	Very low frequency of minor injuries/Only one major injury	

A spreadsheet was created to perform and make sure of the above calculations. Figure 9 shows a screenshot f page 1 displaying the hierarchy of the model in which the AHP resulting weights are inputted next to each factor. Figures 10 and 11 are from page 2, displaying the evaluation on a scale of 1 to 5, in which the assessment values are averaged and calculated automatically. Then, both weights and assessment values are automatically calculated in page 3 to obtain the index, shown in Figure 12.

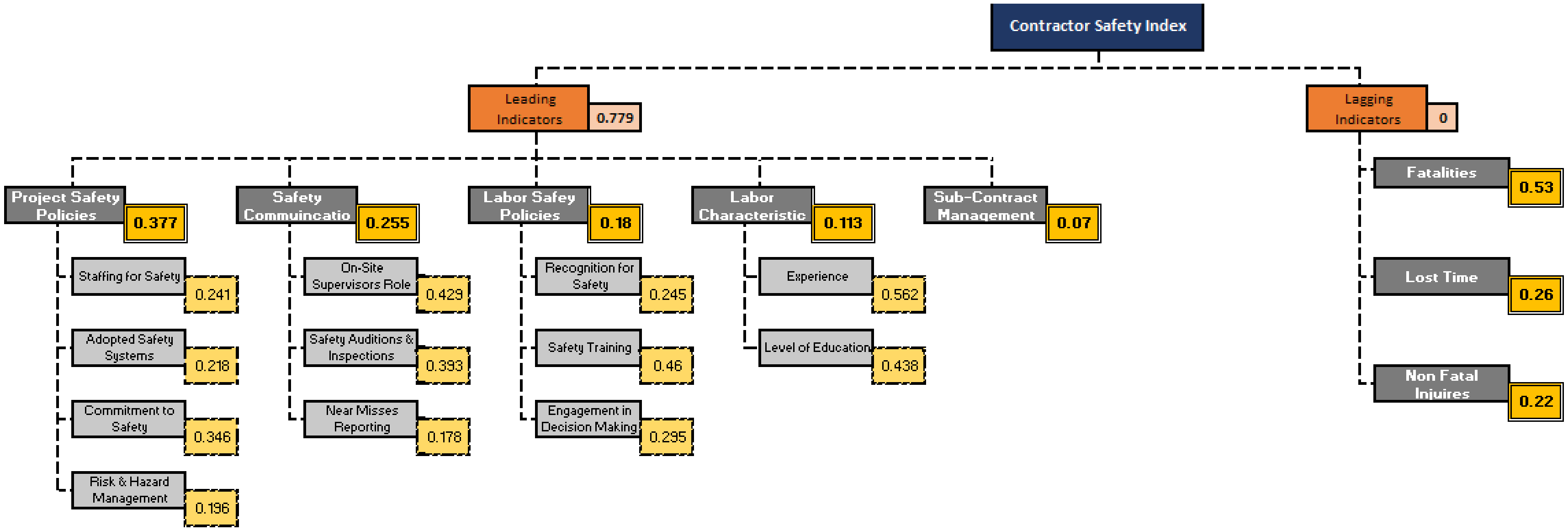


Figure 9: Screenshot of the Hierarchy with the Weights

Safety Practices	Evaluation	Comment	Assesment Value
Staffing For Safety			
On-site medical facilities	1	Not Available	4.333
Full-time safety manager on the project	5	Available	
Safety instructor for the project	5	Available	
First-aid log	5	Available	
Minimum ratio of number of safety supervisors to workers	5	Available (1:50 as set by OSHA)	
Minimum ratio of number of safety professionals to workers	5	Available	
Adopted Safety Systems			
Lock-out tag-out policy	1	Not Applied	3.588
100% fall protection	5	Applied	
100% hard-hat policy	5	Applied	
100% safety glasses policy	5	Applied	
100% gloves policy	5	Applied	
100% reflective vest policy	5	Applied	
100% steel toed boots policy	5	Applied	
Electric Safety Policy	5	Applied	
Restricted Area Work Permit	5	Applied	
Lift safety policies	5	Applied	
Hot work safety policy	5	Applied	
Fire safety policies	5	Applied	
Fatigue management program	1	Not Applied	
Work-hour restrictions	1	Not Applied	
Worker hydration program	1	Not Applied	
Heat-and-cold-stress program	1	Not Applied	

Figure 10: Screenshot showing the Evaluation of some Safety Practices and the Resulting Assessment Value

Safety Auditions & Inspections			
Regular scheduled meetings for safety personnel	5	Applied (weekly)	4.714
Auditing program set in place	5	Available	
Safety audit score calculated and monitored	3	Applied (monitored weekly)	
Heavy-equipment inspection and approval program	5	Applied	
Regular inspection and maintenance of all tools	5	Applied (daily)	
Regularly scheduled equipment inspections	5	Applied (daily)	
PPE inspection and maintenance policy	5	Applied and Available	
Near Misses Reportings			
Track of near misses	5	Applied (special form available)	5.000
Near-misses investigation	5	Applied (special form available)	
Recognition for Safety			
Extrinsic Rewards	1	Not Applicable	2.000
Intrinsic Rewards	3	Applicable Sometimes	
Safety Training			
Safety leadership training program supervisors, foremen and labor	5	Applied and Available	5.000
Monthly H & S training program for supervisors, foremen and labor	5	Applied and Available	
Safety-monitoring program for worker	5	Applied and Available	
Engagement in Decision Making			
Safety goals development and communication	5	Applicable	
Participation in established percentage of daily toolbox safety	3	Applied Weekly	
Foremen involvement in accident investigation	1	Not Applicable	
Foremen involvement in hazard assessment	5	Applicable	
Foremen involvement in lessons learned and knowledge	5	Applicable	
Foremen involvement in jobsite-safety inspections and audits	5	Applicable	

Figure 11: Screenshot showing the Evaluation of some Safety Practices and the Resulting Assessment Value

Contractor Safety Index	3.724			
Leading Indicators	0.779			3.491
Project Safety Policies	0.377		3.755	
Staffing for Safety	0.241	4.333		
Adopted Safety Systems	0.218	3.588		
Commitment to Safety	0.346	3.308		
Risk & Hazard Management	0.196	4.000		
Safety Communication	0.255		4.273	
On-Site Supervisors Role	0.429	4.429		
Safety Auditions & Inspections	0.393	4.000		
Near Miss Reporting	0.178	4.500		
Labor Safety Policies	0.18		3.099	
Recognition for Safety	0.245	2.000		
Safety Training	0.46	3.667		
Engagement in Decision Making	0.295	3.125		
Labor Characteristics	0.113		3.562	
Experience	0.562	4.000		
Level of Education & Certificates	0.438	3.000		
Sub-Contract Management	0.074	4.750	0.352	
Lagging Indicators	0.221			4.542
Fatalities	0.526	5		
Lost Time	0.259	4		
Non-Fatal Injuries	0.219	4		

- *Values in* **Column C** *represent the* **Weight Variables**
- *Values in* **Column D** *represent the* **Assement Values**
- *Values in* **Column E** *represent the* **Resulting Assesment for the Sub-Fact**
- *Values in* **Column F** *represent the* **Resulting Assesment for the Main Fac**

Figure 12: Screenshot of the Index Calculation

CHAPTER 7

ANALYSIS OF CONSTRUCTION INJURIES

To answer the last research question, the study analyzes recent injuries incurred by the construction industry. According to decree **No. 11958 of 2004**, Safety and Protection in Construction**,** any workplace injuries should be reported to the Lebanese **Ministry of Labor** within 24 hours of occurrence. However, very rare enterprises are abiding (Makki, 2016), making this source useless to gather data. Fayad et al. (2003) study that analyzed occupational injuries incurred in 1998 described five different sources of data:

1. *Death certificates*, but they are often incomplete and limited to only fatal injuries
2. *Industry records* or the records kept at establishments, but these records are usually limited to large industries especially that it is not required by law
3. *Surveillance systems*, but they only cover selected reportable and communicable diseases. Reporting of occupational diseases and accidents is nonexistent.
4. *National Social Security Fund (NSSF)* which is important in funding the hospitalization of the working community/ However, it does not cover all occupational accidents or injuries.
5. *Accident insurance claims,* which may be the best existing system to collect data on work - related injuries. Upon occurrence of accidents or injuries in insured workplaces, visas and claims are issued at the level of insurance companies or their corresponding mediators. Despite taking specific forms, these systems are not standardized in Lebanon, but they include different information related to the injured person, the injury incurred and the setting of the accident.

This study followed a similar methodology to that of Fayad et al by picking the fifth source, or the accident insurance claims as a source to gather the required data. The data called required companies to submit general information related to the issued claims, such as the type of injury, description of the event, cost, age of the injury, his or her occupation and nationality. mediators or third-party groups between the insurance companies and health providers were contacted first. Such companies work with different insurance claims and have access to all their incurred injuries. However, these companies either refused to participate in the study or did not respond. Companies that declined explained that they signed confidential agreements that does not allow them to hand in data and a better option would be to contact insurance companies directly. As a result, different insurance companies were contacted. Some companies declined the request for data considering that it goes against their policies, while others did not save or keep tracks of the requested data (since they are already kept at the mediator). Finally, three large insurance companies agreed to participate and 3883 construction-related claims were gathered, all incurred in 2016 between January 1 and December 31.

The analysis of the gathered data was performed based on the latest version of the *Occupational Injury and Illness Classification Manual* (OIICS), released by the Unites States Department of Labor (OIICs, 2012). The manual, which is followed by OSHA, provides a classification system to analyze the characteristics of occupational injuries, illnesses, and fatalities in four main code structures: (1) Nature of Injury or Illness, (2) Part of Body Affected, (3) Source of Injury or Illness/Secondary Source of Injury or Illness, and (4) Event or Exposure.

7.1 Data Analysis

7.1.1 Age Distribution

Table 21 shows the age distribution of the injured workers. Nearly 6% of the claims has missing information regarding the age. Around 66% of all injured workers were between the age of 20 and 39. Around 8.1% were less than 20 and around 20% were 50 or older.

Table 21: Age Distribution of the Injured Workers

Age Group	Frequency	Freq. (%)	Cost ($)	Average Cost ($)
15-19	315	8.112	150,893.470	479.026
20-29	1448	37.291	1,023,527.970	706.856
30-39	1113	28.663	571,605.560	513.571
40-49	509	13.108	346,102.010	679.964
50-59	230	5.923	137,224.710	596.629
60-69	40	1.030	53,434.310	1,335.858
70-79	1	0.026	0.000	0.000
80-89	2	0.052	206.780	103.39
Unspecified	225	5.794	169,402.230	752.898
Total	**3883**	**100.000%**	**2,452,397.040**	**631.572**

In terms of cost, the total cost for the 20-29 age distribution was highest, especially that most injured persons where within this age group. The average cost of the injury (around $706.85) was also higher than the average cost of the entire sample ($631.57). It is also noted that as the frequency of injuries increases, the total incurred cost for the age group increased. However, the average cost of injury for the 50-59 age group is higher than that of the 15-19 age group despite having less frequency. The same can be said while comparing age groups 30-39 to 40-49, despite age group 30-39 incurring almost double the frequency of 40-49, the average cost of the 40-49 was higher. This indicates that injuries at this age are either more severe or the effect of the same type of injury is more severe as the labor grows older.

7.1.2 Nature of Injury or Illness Distribution

The OIICs manual distributes the nature of injuries on nine different divisions: (1) Traumatic Injuries and Disorders , (2) Systemic Diseases and Disorders , (3) Infectious and Parasitic Diseases , (4) Neoplasms, Tumors, and Cancers , (5) Symptoms, Signs, and Ill-defined Conditions , (6) Other Diseases, Conditions, and Disorders, (7) Exposures to Disease – No Illness Incurred, (8) Multiple Diseases, Conditions, and Disorders, and (9) Non-classifiable. As seen in Table 22, the distribution of the nature of injuries were mainly in the first division of the manual.

From the studied claims, 14 fatal injuries were recorded (contributing to 0.36% of the total injuries). The non-fatal injuries were mostly Trauma (around 44.25%), followed by open wound (around 21.4%), surface wound (around 19%) and fracture (around 10.5%).

Table 22: Nature of Injury Distribution

Nature of Event	Frequency	Freq. (%)	Cost ($)
Polytrauma	113	2.910	146,982.14
Trauma	1718	44.244	526,536.32
Fracture	404	10.404	107,7154.1
Dislocation	7	0.180	4,040.69
Sprain, Strain, Tear	30	0.773	52,894.91
Open Wound	829	21.349	333,524.27
Surface Wound & Bruises	737	18.980	71,882.59
Burns	7	0.180	21,794.76
Others*	24	0.618	42,734.92
Death	14	0.361	174,852.34
Total	**3883**	**100**	**2,452,397.04**

*Others include loss of conscious, hypotension, syncope, dyspnea, etc.

In terms of cost, trauma incurred the highest total considering it has the highest frequency. Despite having a high frequency to, surface wound and bruises incurred a low total while compared to other types of injuries, indicating the low severity of such injuries. In contrast, the low frequency of fatalities incurred a high total cost, indicating the major severity of fatal injuries, averaging almost $12,5000 for every death.

7.1.3 Part of Body Affected Distribution

The OIICs manual distributes the part of body affected on ten different divisions: (1) Head, (2) Neck including Throat, (3) Trunk, (4) Upper Extremities, (5) Lower Extremities, (6) Body Systems, (8) Multiple Body Parts, (9) Other Body Parts and (10) Non-classifiable.

As shown in Table 23, most of the analyzed injuries targeted the upper limbs (35.127%) especially the hands, then the lower limbs (23.590%) especially feet and legs, followed by the head (22.946%) especially the face.

Some injurie affected multiple parts of the body (3.374%) especially upper and lower limbs together or the trunk region with the lower limbs, while others injured the entire body parts from head (0.67%).

When it comes to cost, the highest cost was incurred by hand injuries, considering it has the highest frequency. However, despite the face being the second most frequently injured part of the body, injuries of the arms, cranial region, back, legs and ankles incurred higher costs though their total frequency remains less than that off face. This indicates that major severity of the injuries that target those body types. Full body injuries averaged around $12,000 similar to the average of fatal injuries, indicating that most of the injuries that affected the full body were fatal.

Table 23: Part of Body Affected Distribution

Part of Body	Freq.	Freq. (%)	Cost ($)	Average Cost ($)
Cranial Region	192	4.945	135,656.78	706.54
Ear	4	0.103	3,545.61	886.4
Face	690	17.770	115,168.99	166.91
Multiple Head Parts	5	0.129	3,293.98	658.769
Sub-Total	*891*	*22.946*		
Neck	5	0.129	6,855.02	1371.00
Chest including Ribs	15	0.386	13,544.84	902.98
Back including Spine, Spinal Cord	333	8.576	285,684.24	857.91
Abdomen	24	0.618	18,097.03	754.04
Pelvic Region	23	0.592	28,544.95	1,241.08
Multiple Trunk Parts	28	0.721	38,629.19	1,379.61
Sub-Total	*423*	*10.894*		
Shoulder(s) including Clavicle(s) & Scapula(s)	104	2.678	46,720.21	449.23
Arm(s)	158	4.069	126,598.08	801.19
Wrist(s)	58	1.494	31,563.74	544.20
Hand(s)	1,011	26.037	457,013.6	452.04
Multiple Upper Limbs' Parts	33	0.850	28,950.68	877.29
Sub-Total	*1,364*	*35.127*		
Leg(s)	284	7.314	247,449.01	871.29
Ankle(s)	162	4.172	131,644.21	812.61
Foot (Feet)	403	10.379	119,293.74	296.01
Multiple Lower Limbs' Parts	67	1.725	51,426.61	767.56
Sub-Total	*916*	*23.590*		
Multiple Body	131	3.374	186,801.15	1,425.96
Full Body	26	0.670	312,681.89	12,026.22
Unspecified	127	3.271	63,242.49	497.97
Total	**3,883**	**100**	2,452,397.04	631.57

7.1.4 Event or Exposure Distribution and Source of Injury

The OIICs manual distributes the event of exposure on nine divisions: (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.

Table 24: Event or Exposure Distribution

Event or Exposure	**Freq.**	**Freq. (%)**	**Cost ($)**	**Average Cost ($)**
Bites & Stings	2	0.052	132.85	66.43
Falls on Same Level due to Tripping	668	17.203	188,762.92	282.58
Fall on Same Level due to Slipping	28	0.721	12,840.99	458.61
Fall to Lower Level due to Openings*	21	0.541	191,308.43	9,109.93
Fall to Lower Level due to Other Reasons**	798	20.551	990,194.13	1,240.84
Fall to Lower Level (Unspecified)	73	1.880	102,692.43	1,406.75
Sub-Total	*1,588*	*40.896*		
Direct Exposure to Electricity	10	0.258	31,012.50	3,101.25
Indirect Exposure to Electricity	7	0.180	22,601.03	3,228.72
Inhalation of Harmful Substances	12	0.309	1,525.43	127.12
Exposure to Harmful Substances	4	0.103	19,526.82	4,881.71
Sub-Total	*33*	*0.850*		
Struck by Falling Object or Equipment	691	17.796	360,246.31	521.34
Struck by Discharged or dislodged Flying Object	584	15.040	69,382.24	118.81
Injured by Handheld Object or Equipment	625	16.096	245,178.39	392.29
Struck Against Moving Object or Equipment	16	0.412	10,207.82	637.99
Struck Against Stationary Object or Equipment	141	3.631	35,760.28	253.62
Stepped on Object	114	2.936	16,934.73	148.55
Sub-Total	*2,171*	*55.910*		
Overexertion in Lifting or Lowering	4	0.103	0.00	0.00
Unspecified	85	2.189	154,089.74	1,812.82
Total	**3883**	**100**	**2,452,397.04**	631.57

*Openings include elevator shafts, openings in slabs, etc.

**Other reasons include falling to lower levels from ladder, stairs, scaffolding, etc.

As for the source of injury, it is distributed on ten different divisions: (1) Chemicals and Chemical Products, (2) Containers, Furniture, and Fixtures, (3) Machinery, (4) Parts and Materials, (5) Persons, Plants, Animals, and Minerals, (6) Structures and Surfaces, (7) Tools, Instruments, and Equipment, (8) Vehicles, (9) Other Sources, and (10) Non-classifiable.

According to Table 24, more than 95% of the events or exposures of the injuries landed in Division 4 (Falls, Slips, Trips) and Division 6 (Contact with Objects and Equipment) with 40.89% and 50.91% respectively. Most of the Division 4 injuries were due to tripping and falling on the same level, and falling to lower level from scaffolds, ladders, etc. As for division 6 injuries, most events were struck by objects or injured by handhelds objects or equipment. These injuries are mostly due to the lack of basic safety policies such as wearing safety boots, hard hats, safety eyeglasses and belts on heights.

When it comes to cost, the highest incurred costs were from the event with the highest frequency, falling to lower levels due to reasons such as scaffolds, ladders, stairs, etc. The highest incurred average costs were from falling from openings or elevator shafts, despite having a low frequency compared to other events. The reason is cause elevator shafts would go deep down in heights leading to major injuries. Exposure to harmful substance, direct and indirect exposure to electricity also have a high average cost despite the low frequency. In contrast, despite the high frequency of injuries due to being struck by discharged or flying objects or particles, the average cost is one of the lowest due to the minor severity of such injuries.

When it comes to source of injuries, almost half the injuries sorted under *falling to lower levels due to openings* were because of unsafe elevator shafts. Around 40% of the injuries sorted under *falling to lower level due to other reasons* were because of falls from scaffoldings, 21% were because of ladders, and 21% were fallings from slabs or roofs. Nearly all *indirect exposure to electricity* injuries were because of pumps striking electric wires and indirectly electrifying the workers causing severe injuries, even death. As for *struck by falling objects*, 28.08% of falling objects were metals and iron boards, 21.42% were stone and masonry, and 16.64% were wood materials and wooden boards. More than 85% of *struck by flying objects or particles* were dust due to wielding or using the chainsaw or wood or concrete, while more than 78% of the *stepped-on object injuries* were stepping on nails. As for *injured by handheld object*, the objects were mostly saws (around 28%) or hammers (around 15%).

7.2 Cost Analysis and Projection

Table 25: Severity Distribution of Injuries

Severity	Frequency	Freq. (%)	Cost ($)	Cost (%)	Average Cost ($)
Minor	3639	93.716	835,136.1	34.05%	229.496
Middle	208	5.357	881,915.6	35.96%	4,239.979
Major	36	0.927	735,345.34	29.98%	20,426.259
Total	**3883**	**100**	**2,452,397.04**	**100.00%**	**631.573**

Because data lacked recovery days and time, insurance companies assume that injuries that cost less than $2000 can be considered minor, between $2000 and $10,000 can estimated to be middle, and more than $10,000 considered major. Table 25 shows the distribution of the severity of the injuries. Most injuries were minor, with an average cost of $229.5. Middle injuries averaged $4,239, while major injuries averaged around $20,426, higher than the double of the minimum cost to be considered major (which is $10,000). According to table 26, *falling to a lower level* incurred the most frequent minor (18.55%), middle (49.04%) and major costs (58.33%). This is normal considering it is the most frequent cause of injuries between all studied cases. *Struck by falling* *objects or equipment* incurred the second most frequent minor (18.16%), middle (12.50%) and major injuries (11.11%). *Tripping and falling on the same level* incurred the third most frequent minor (17.86%) and middle injuries (8.65%), while *falling in openings* was for major injuries (11.11%).

Table 26: Analysis of Event with respect to Cost

Event	**Minor**		**Middle**		**Major**	
Bites & Stings	2	0.05%	0	--	0	--
Falls on Same Level (tripping)	650	17.86%	18	8.65%	0	--
Fall on Same Level (Slipping)	27	0.74%	1	0.48%	0	--
Fall Below (unspecified)	54	1.48%	19	9.13%	0	--
Fall Below (openings)	13	0.36%	4	1.92%	4	11.11%
Fall Below (other)	675	18.55%	102	49.04%	21	58.33%
Direct Electricity Exposure	9	0.25%	0	--	1	2.78%
Indirect Electricity Exposure	5	0.14%	0	--	2	5.56%
Inhalation of Harmful Substances	12	0.33%	0	--	0	--
Exposure to Harmful Substances	3	0.08%	0	--	1	2.78%
Struck by Falling Object or Equipment	661	18.16%	26	12.50%	4	11.11%
Struck by Discharged or Flying Object	581	15.97%	3	1.44%	0	--
Injured by Handheld Object or Equipment	605	16.63%	20	9.62%	0	--
Struck Against Moving Object or Equipment	15	0.41%	1	0.48%	0	--
Struck Against Stationary Object or Equipment	138	3.79%	3	1.44%	0	--
Stepped on Object	114	3.13%	0	--	0	--
Overexertion in Lifting or Lowering	4	0.11%	0	--	0	--
Unspecified	71	1.95%	11	5.29%	3	8.33%
Total	3639	100.00%	208	100.00%	36	100.00%

As for nature of injuries, as seen in Table 27, most minor injuries were trauma (46.58%), open wound (22.29%) then surface wound (20.23%). Most middle injuries were fracture (68.27%), trauma (10.10%), then open wound (7.69%). As for major injuries, most injuries were fracture (41.67%), death (27.78%) then polytrauma

(11.11%). This indicates that fractures are the most severe injuries incurring very high costs, while surface wounds are usually very minor. As for workers that died in the construction industry, it was mostly due to the very severe and major injuries that resulted from the accident.

Table 27: Analysis of Nature of Injury with respect to Cost

Nature of Injury	**Minor**		**Middle**		**Major**	
Polytrauma	100	2.75%	9	4.33%	4	11.11%
Trauma	1695	46.58%	21	10.10%	2	5.56%
Fracture	247	6.79%	142	68.27%	15	41.67%
Dislocation	7	0.19%	0	--	0	--
Sprain, Strain, Tear	17	0.47%	13	6.25%	0	--
Open Wound	811	22.29%	16	7.69%	2	5.56%
Surface Wound & Bruises	736	20.23%	1	0.48%	0	--
Burns	6	0.16%	0	--	1	2.78%
Others	20	0.55%	2	0.96%	2	5.56%
Death	0	--	4	1.92%	10	27.78%
Total	**3639**	**100.00%**	**208**	**100.00%**	**36**	**100.00%**

As for the age groups, as seen in Table 28, minor, middle and major injuries were mostly frequent with the 20-29 years old (37.40%, 34.13%, and 44.44% respectively). This indicates that a problem exists with this age group and doing tasks safely, especially that almost half the major injuries targeted it.

Table 28: Analysis of Cost with respect to Age Groups

Age Group	**Minor**		**Middle**		**Major**	
15-19	299	8.22%	15	7.21%	1	2.78%
20-29	1361	37.40%	71	34.13%	16	44.44%
30-39	1046	28.74%	62	29.81%	5	13.89%
40-49	472	12.97%	31	14.90%	6	16.67%
50-59	216	5.94%	12	5.77%	2	5.56%
60-69	32	0.88%	5	2.40%	3	8.33%
70-79	1	0.03%	0	--	0	--
80-89	2	0.05%	0	--	0	--
unspecified	210	5.77%	12	5.77%	3	8.33%
Total	**3639**	**100.00%**	**208**	**100.00%**	**36**	**100.00%**

Age group between 30-39 were the second age group with most minor and middle injuries, while age group 40-49 had the second most frequent major injuries. This can be explained that despite being experienced, older labors are subjected to more severe injuries than younger ones even if the event of the injury was the same.

The total direct cost of the studied injuries is around $2,452,397.04 for 3,883 claims. These claims were gathered from insurance companies that heavily ensure construction projects and represent around 30% of the total premiums released in 2016. Consequently, these injuries may represent at least 30% of the construction injuries released that year. If the remaining companies that were not analyzed have the same cost of injuries incurred, the total direct cost of the injuries incurred would be $8,174,656.8 ($2,452,397.04/0.3) for around 12,944 claims. However, not all companies ensure construction projects, and the data gathered and analyzed in this research are from insurance companies that profoundly ensure construction projects. Thus, the total cost that year would range between 2.45 million and 8.17 million dollars for a total number of claims between 3,883 and 12,944. For the purpose of this research, the total number of claims and the total cost would estimate the average. The total number of injuries incurred from the construction injury in 2016 is estimated to be 8,413 injuries with a total direct cost around $5,313,526.92.

7.3 Comparison with 1998

Fayad et al. (2003) analyzed occupational injuries in Lebanon for the year 1998. The results of the study are compared to the results in this study in Table 29.

Table 29: Difference between 1998 and 2016

	1998	2016
Frequent Causes	struck by objects (44.6%), falls (29.7%) then hitting objects (11.1%)	falling to lower levels (20.551%), struck by falling objects (17.796%) then tripping and falling on the same level (17.203%).
Frequent Types	Wounds and Lacerations (29.5%), trauma (21.7%) then foreign body (16.5%)	Trauma (44.244%), Open Wound (21.349%) and Surface Wound & Bruises (18.980%), then fracture (10.404%)
Frequent Body Parts	Hands (27.8%), feet (19.5%) then eyes (16.7%)	Hands (26.037%), face (17.770%), then feet (10.379%)
Severity	less than 3 days recovery (50.9%), between 3 and 30 days (45.5%) and the remaining were either more than a month of recovery, permanent disability or death	between 1- and 30-days recovery (93.716%), and the remaining either more than a month of recovery, permanent disability or death
Estimated Direct Cost	1.8 million dollars (equivalent to 2.88 million as inflated in 2019).	$5,313,526.92 (equivalent to $5,669,633.54 in 2019)

As seen in Table 29, the frequent causes of injuries changed where the top 2 most frequent causes in 1998 switched in 2016, and tripping replaced struck against objects. Frequent types and frequent organs remained the same, however more fractures were witnessed in 2016, especially that falling to lower levels became more frequent. As for the similarities in body parts between both years, this indicates that problems still exist with safety gloves, protective glasses and safety boots. The severity of injuries did not change much, with mostly being minor to middle injuries taking a month or less to recover. As for the estimated direct cost, it almost doubled between 1998 and 2016. The total number of construction permits issued by the OEA for the year 1998 was 12,775 permits for a total construction area of of 8,166,920 m^2. In 2016, OEA issued 14,212 for a total construction area of 9,929,031 m^2, indicating an 11.24% increase in permits and a 21.57% increase in construction area. The witnessed increase in construction projects plays a role in increasing the number of injuries and their corresponding direct cost. However, despite the increase in construction safety research, the major increase witnessed in the cost of injuries and the similar frequent causes of injuries between both years indicate that a lack of safety practices can still be noticed and remains evident in the Lebanese construction industry.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

Within the dynamic nature of construction sites, safety and the well-being of the on-site personnel is crucial. That's why, planning projects should not be based on finishing on time and within budget only, tasks should be planned to be performed safely as well. Findings from previous studies and literature found construction to be one of the most hazardous industries in the world. Lebanon is no exception, as it remains a developing country that develops a big problem when it comes to construction safety. Studies showed lack of safety incentives, training and education, especially at the level of the foremen and workers. Moreover, insurance company do not investigate new contractors when issuing them premiums. Thus, when a contractor neglects health and safety, they can easily avoid higher insurance rates by shifting between insurance companies. Thus, there is a need to enhance the safety performance of contractors and improve the strategies that they implement**,** and insurance companies can play a vital role in this improvement through encouraging them to emphasize on health and safety policies while issuing or renewing contractor premiums. Moreover, since 1998, no significant studies have attempted to analyze injuries incurred by the construction industry to understand the problem and deduce what safety practices are being neglected.

To resolve these needs, the current study proposes a model to calculate the construction safety index of contractors using leading safety practices and lagging indicators. This numerical index will reflect the safety status of the contractor. The proposed model will indirectly encourage contractors to improve their safety performance to score a higher index, which indirectly decreases accidents. Moreover, insurance companies can consider the index when issuing or renewing premiums; the higher the index goes, the lower premiums get. The study also investigated recent construction injuries and compared it to the 1998. Even though the index in this study is applied to Lebanon, the proposed tool can be adopted by different developing and undeveloped countries that lack national safety laws and share common characteristics with Lebanon. It will encourage their construction industry, especially at the level of the contractors, to enhance their safety performance.

Between analyzing the results of the AHP survey under study and the construction injuries, it can be concluded that Lebanon suffers from a severe construction safety problem. Results from the AHP survey show that contractors acknowledge the importance of safety training, safety inspections and presence of onsite safety personnel. However, they need to acknowledge more the importance of engaging their labor in taking safety decisions and recognizing them when they perform the job safely. Such practices would further promote a positive safety environment. Despite that, with falls leading the cause of construction injuries, basic and essential safety practices are being neglected by contractors, most notable safety belts when on scaffolds and ensuring safe elevator shafts and openings. Wearing safety glasses when wielding or using the saw and wearing safety boots are also heavily neglected. The analysis of these injuries verifies the perception of insurance companies, that most contractor do no abide by safety procedures. Instead of mitigating the problem, insurance companies increase it more with the strong competition between them and the lack of transparency. The root cause of the problem goes mostly back to the Lebanese outdated work laws that still stand from 1983, and the lack of responsibility from the government in monitoring and controlling construction activities. Even the 2004 decree that discusses safety in construction, it is general, broad, and lacks the proper specifications to maintain a safe construction work environment. The Order of Engineers and Architects (OEA) and the Ministry of Work can play a more vital role as well by obliging contractors and designers to submit detailed safety plans to issue construction permits.

Upon applying the suggested index, it was successful in expressing the safety status of a contractor. The contractor who served as the case study ended with a solid contractor safety index of 3.724. With the low frequency of injuries incurred by the contractor, it is safe to say that the application of the index was successful and properly represented the safety status.

The study comes with certain limitations. At the level of the AHP survey, it was only filled by construction professionals who work in large sized contractors located mostly in Beirut. Beirut construction sites are generally considered safer than sites located away from it. At the level of the index, the comparative assessment stopped at the safety practices being evaluated. These practices were assumed to be of equal importance, but some practices are more important than the other. At the level of the construction injuries, the sample taken was from three major insurance companies. Other companies either refused to participate or did not reply to the call for data, thus the analyzed results reflect the gathered sample.

Because of the limitations, further study can include filling the survey with more engineers in the North, South, Bekaa and Mount-Lebanon to check their perception of construction safety and compare it to that of Beirut engineers. Other further research might include comparing the safety practices chosen and assigning weights to them instead of averaging their evaluations. Also, the evaluations of each safety practice can be standardized, and the standards induced into the spreadsheet. Further research can use visual technologies that evaluate certain practices using drones (was already done by Abbas et al. for hard hats, similar studies can be performed and added into the index). As far as construction injuries, Decree No. 1158 of 2004 should be implemented more seriously so that researches can get access to data and annually analyze the injuries incurred form the construction industry and understand ongoing problems. Further study can also include analyzing the coloration between lagging and leading indicators, and how does this coloration affect the index in the Lebanese construction industry

Finally, the importance of this study is to promote safety incentives and a positive safety culture in construction. A positive safety culture would promote contracting companies to follow efficient safety procedures and educate their workforce about safety. Through the proposed index, contractors will ought to improve their safety practices, and insurance companies will fairly control their premiums.

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