EVALUATION OF THE SAFETY ROLE ON THE CONSTRUCTION PHASES BUILDING PRODUCTION PROCESSES (BPP): A CASE STUDY IN NORTHERN CYPRUS

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Abstract

Improving safety in construction projects is a significant goal in many countries around the world. In other words, by considering safety issues throughout the whole construction project phases (Building Production Processes (BPP)), occupational accidents can be reduced or eliminated to achieve a safer workplace. This research intended to show the necessity of safety consideration and safety cost evaluation during the three BPP main phases of construction sites, especially in small-size projects in North Cyprus. For this reason, a case study is performed on a multi-story car park building on the campus of Eastern Mediterranean University (EMU). The construction steps are classified into three main phases: Preconstruction, construction, operation, and maintenance. Investigation was aimed to define a safety scheme to uplift the safety performance of the construction project, calculate the direct and indirect safety costs. The results had showed the importance of a safety plan and worksite analysis in preconstruction phases, safety monitoring of activities in the construction phase and traffic control plan in operation and maintenance phase.

Keywords: *construction safety, construction phases building production processes (BPP), safety cost, accident prevention, safety plan*

1. INTRODUCTION

From a statistical perspective, in most countries, the construction industry has been recognized as one of the most hazardous industries (Carter and Smith, 2006)(Wang, Liu and Chou, 2006)(López *et al.*, 2008)(Lingard and Rowlinson, 1997). With respect to safety management in developed countries, the rate of occupational accidents is decreasing every year; for example, from 1995 to 2015, the construction worker fatality rate was reduced by 45% in the UK (Health and Safety Executive, 2021), similarly, in the US, the fatality accidents rate decreased steadily by around 25% from 2006 to 2015 in the construction industry (Jones 2016). Besides, the number of accidents being gradually reduced or remained unchanged in developing countries. The workplace death rate slowly decreased by around 20% between 2004 and 2015 in the Singapore industry (*International Labour Organizations* 2017). A recent study in Hong Kong reveals that from 2011 to 2017, the number of occupational injuries were increased, while the number of fatal accidents remained relatively stable (Lingard and Rowlinson, 1997). Above all, the construction accidents not only cause human tragedy, but they also ruin the contractor's reputation, increase cost, and hinder the project's progress (Gangolells *et al.*, 2010). According to recent statistics, around three out of 100,000 workers lose their lives every day in the United States. Such concerning statistic emphasizes the urgent need for enhancing safety measures (United States Department of Labour, 2021). Moreover, a recent study shows that the economic statuses of the injured workers of industrial accidents were lowered compared to their pre-accident statuses (Bae *et al.*, 2019).

Construction work includes various activities, materials, techniques, and hazards. This diversity is known to be the main potential reason behind accidents occurring. In fact, there is a commonality of accidents in the industry and the indirect contributing factors (Baxendale and Jones, 2000). An accident is defined as "any unplanned event which results in ill health or injury of human beings, damage or property loss, materials, plants, and the environment" by Hughes and Ferrett, 2011. It is an undeniable fact that construction accidents result in substantial cost implications (Barro-Torres *et al.*, 2012). The construction sector of North Cyprus subsequently plays an essential role in terms of the economy in the industry. The number of construction projects was meagre before 2002, and the rate of construction activities increased incrementally until 2004. Then, the rate of building construction increased intensely,

which was called the construction sector explosion phenomenon (Mynet -2004). Some references have highlighted that within the past 50 years, real estate companies in Northern Cyprus have a mass investment in housing projects (Yorucu and Keles, 2007). Subsequently, the number of buildings increased by about 70% in 2016 when compared to 2004. The construction project's total floor area and value were 731,363 square meters and 236 million USD dollars, respectively (North Cyprus State Planning Organization 2022). Obviously, the continued increase in work sites, raises the chance of potential construction accidents. This study focused on the construction accidents in North Cyprus, their economic evaluation and the enhancing scheme that will be proposed. Table 1 presents the common accident types in North Cyprus (North Cyprus State Planning Organization 2022).

Table 1. Common accident types in North Cyprus

Cause of accident	**Rate of accidents**
Fall from height	37%
Struck by moving falling object	12.1%
Trapped by something or moving machinery	10.3 %
Hit by moving object	9.2 %
Traffic accident	6.3 %
Strike against moving	6.1 %
Slips, trips and falls on same level	5.4 %
Other accident	13.6 %

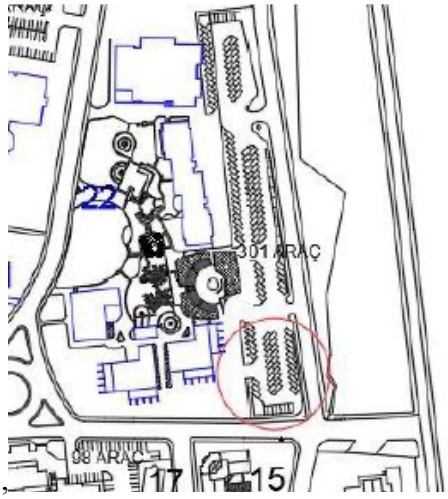
On the other hand, from an economic point of view, many researchers have addressed the significance of construction in the aggregate economy in the world for the past two decades (Boli, 2014) (Strassmann and others, 1970). To protect the workforce and reduce direct and indirect costs, adequate Occupational Safety and Health (OSH) management plays a significant role (Goetsch, 2020). Furthermore, preventive approaches such as investing in safety could bring productivity to the projects (Hasle and Limborg, 2006) and ultimately avoid budget waste (Shohet, Luzi and Tarshish, 2018). Many research studies have concluded that the actual cost that industrial accidents levies are considerably higher than the direct costs (Corcoran, 2002) (Dorman, 2000) (Shim and Siegel, 2009). Reference (Waehrer *et al.*, 2007) suggests that construction labourers reported the highest number of fatalities (299), which results in the highest average annual fatality, costing $1200 million in the US.

For example, in 2001, Bearson and Coleman performed a study that concerned nine selected European countries to estimate each country's aggregate economic costs of occupational injury and disease (Harms-Ringdahl, 2001). According to this reference, the most fees range from 2.5% to 6% of Gross Domestic Product (GDP).

In North Cyprus, companies are often Small and Medium-sized enterprises (SMEs) (North Cyprus State Planning Organization 2022). Evidence suggests that OSH issues tend to occur more in SMEs, and they are associated with a higher rate of occupational accidents when compared with large industries (Fabiano, Currò and Pastorino, 2004) (Sørensen, Hasle and Bach, 2007). Due to an increase in the number of students and staff at EMU, demand for additional car parking spaces also increased. Hence, a design group of civil engineering and architecture students, prepared a new multi-story car park project inside the campus as part of their Capstone project (AlFaouri et al). For this case study purpose, the project was used to investigate the type and expenditure of accidents and evaluate the perception of other costs attached to safety during construction projects.

The case study includes five stories car park with 216 cars capacity. The total cost for construction of this project is 1,952,564 USD and the total area is 2380 square meters. Also, limitations, such as work

hours, site boundaries, noise and air pollution, transfer of materials, access equipment, etc., should be considered throughout this project. These limitations are highly likely to increase the cost of building construction. Figures 1 and 2 represents the location and 3-D model for the car-park building, respectively.



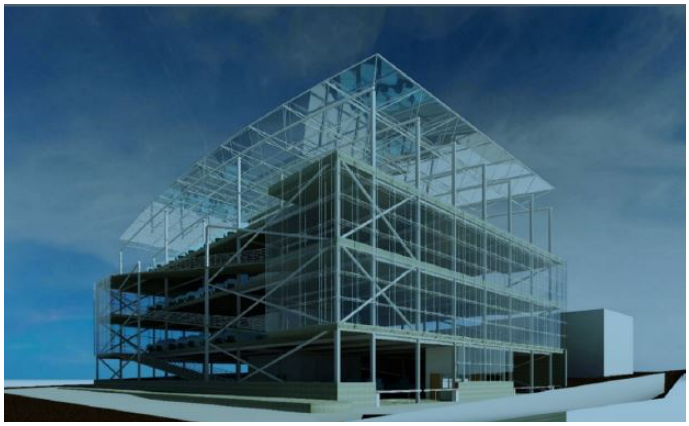


Fig. 1. The location of case-study **Fig. 2.** 3D-Model for the case study

This study will show the importance of safety in all BPP phases of construction projects and aims to calculate the expenditure of safety during construction projects. The first step shows the impact of safety arrangements and tools on the safety climate. The second step highlights the impact of the cost estimation of safety and possible occupational accident in each activity of the construction phase.

2. MAIN CONSTRUCTION PHASES OF BUILDING PRODUCTION PROCESSES

The safety of construction projects is affected by many steps regarding their feasibility, design, activities during the construction period, operation, maintenance, etc. Murray et al. (Murray, Nkado and Lai, 2001) categorized the construction steps into inception, initial (preliminary) design, feasibility assessment, detailed design, tender document preparation, tendering, contractor's choice, construction, operation, destruction (demolition), and recycling. Therefore, it may be extremely difficult to discover the best safety scheme covering all mentioned effective factors. According to Project Management Consultants (PMC), construction activity can be divided into three BPP phases, Preconstruction, Construction and Post-construction.

2.1. Preconstruction

This phase can be divided into two main steps; feasibility and planning at the beginning and then, basic, and detailed design/engineering, procurement, tendering document, and action until the construction phase (G.V.R. Srinivasa, 2016) Safety has a significant role in the pre-construction phase in recognizing hazardous locations and activities. Construction safety planning provides hazard prevention before the potential hazards arise at the worksite.

2.1.1. Risk Assessment

As an essential part of managing your business's health and safety, you must control the risks in your workplace. Therefore, it is required to think about what might cause harm to people and decide whether you are taking reasonable steps to avoid that harm. A risk assessment is to identify sensible measures to keep risks in your workplace under control (Health and Safety Executive 2022).

According to Health and Welfare at Work Act 2005, employers must assign expert and qualified personnel to provide and follow the health and safety duties in the project (Health and Safety Authority, 2005). Furthermore, the assessment of the risks in this case study includes the following:

- Recognizing the hazards during the construction and post-construction phases
- Considering who and how may be damaged
- Measuring the amount of risk for each action
- Prioritizing occupations that require Job Hazard Analysis (JHA)
- Preparing a record of the findings
- Reviewing the assessment

On the other hand, health and safety plans must be prepared under the Construction (Design & Management) Regulations (CDM Regulations) and give required information to the contractors operating the construction phase. The CDM regulations are responsible for dealing with most potential hazards on a building site. Besides these risks, there will be more general hazards, including manual handling, working at height, working under the exposure to electricity, noise, etc.) (Hughes and Ferrett, 2011).

The mentioned health and safety plans should be capable of dealing with significant risks and exclude trivial risks, which a competent contractor may be aware of. More specifically, the wording of health and safety plans should be kept simple and highlight the significant risks, increasing the feasibility of the information to be used and obeyed by the site management team (Baxendale and Jones, 2000).

2.1.2. Worksite Analysis

In this case study, a worksite analysis actions were conducted to make the project workplace safe:

- Perform JHA.
- Conduct comprehensive hazard surveys
- Analyze the hazard after specific changes in the workplace, including (new equipment, new processes).
- Conduct health inspections and regular site safety.
- Acquire staff reports of hazards or potential hazards.
- Investigate accidents and incidents with corrective actions and follow-up.
- Analyze the trend of injury and illness.
- Assess the Personal Protective Equipment (PPE).
- Specify identification and inspection of confined spaces (United States Department of Labor, 2017) The contractor company should employ JHA to identify the potential hazards and propose methods to reduce the exposure of their staff to the hazards (Hamid, Abd Majid and Singh, 2008).

2.1.3. Design

Designers can refer to a wide range of professionals, including architects, surveyors, specifiers, consulting engineers, principal contractors, and specialist sub-contractors. Under regulations, the term "design" can convey different meanings, such as drawings, specifications, and details. The main criteria for designers are dealing with health and safety issues by carrying out the design in a reasonable and "practicable" way; that is to say, balancing the risk versus the cost of preventing construction accidents (Baxendale and Jones, 2000).

In this stage, the client must supply pre-construction information to the designers of the project. If designers are faced with any risk, they should try to eliminate or reduce preventable accidents. If it is not possible, then the risk must be controlled.

2.1.4. Construction phase

The construction phase incorporates many activities and specialized services, where cost, time, quality, and safety are the most essential of all (Hamid, Abd Majid and Singh, 2008).

Typically, safety planning includes identifying all the possible hazards and choosing corresponding safety measures (Bansal, 2011). As previously named, a JHA technique investigates job tasks as a way for hazard identification before they happen. This process focuses on the relationship among different construction parts, such as workers, tools, duties, and the job environment (Chao and Henshaw, 2002).

While identifying the potential hazards in each step of the activity and introducing safety rules to avoid potential incidents related to these hazards, the company illustrates performing JHA that is applicable for the construction activities to react and highlight these potential hazards. The basic procedure of conducting a JHA consists of:

Identification of all job steps based on a given activity

Identifying the potential hazards based on the different steps of the jobs

Offering action procedures, for example, precautions and safety procedures to remove, decrease and control each hazard.

2.1.5. Personal Protective Equipment (PPE)

There are some essential rules related to the construction sites concern wearing protecting elements. The mentioned elements are collectively known under the umbrella term of Personal Protective Equipment (PPE) (Barro-Torres *et al.*, 2012). These PPE aim to isolate and shield users from potential physical, biological, and chemical hazards (Lippitt, Webb and Martin, 2000).

2.1.6. Safety inspections/ supervisor

The supervisors should personally take part in regular safety and health inspections. Also, the company will evaluate new facilities, processes, equipment, and materials for hazards or possible hazards. The finding will be documented, and plans will be devised to minimize or calculate the hazards. These inspections can range from daily to monthly and quarterly to alleviate identification of the unsafe actions, possible hazardous conditions and ultimately initiate corrections. The findings accidents/incidents based on the inspections will be reported to the in the following format (Name/Title/Safety Committee) for further review.

Identification of the potential hazards is supervisor's responsibility. These responsibilities also include controlling and removing such hazards, ensuring that the employee engages in safe work practices, and to ensure that employees are provided with safety training at (United States Department of Labor, 2017). It is important to mention that the purpose of such investigations is not to find the faults, yet it is to find the underlying causes so as to prevent these accidents from happening.

2.1.7. Safety training

Approximately 90% of workplace injuries are tracked down by unsafe behaviour and work practices (Teo, Ling and Chong, 2005). (Company Name) will offer training to ensure the Michigan Occupational Safety and Health Administration (MIOSHA)'s requirements are met and constantly investigate the employee training required to keep them safe and healthy while doing their jobs. The following steps must be taken about the safety training:

a) Orientation of new employees: new employees will be provided with appropriate training on the company's health management and safety system, expectations, safe work measures, and specific health and safety training related to each task.

b) After performing job site inspection using the following report format (Name/Title) will recognize and investigate all possible hazards for potential injuries and estimate the probability of each accident. Measures will be taken to minimize these hazards and ensure workers' safety.

c) The Safety Coordinator or other related site personnel will assess exposed workers' skills and knowledge level and provide any required training.

d) Appropriate training will be offered where safety and health training is needed including the following steps:

- Hazards will be recognized.
- Necessary precautions will be elaborated.
- Training duration and level of detail will be regulated by the requirements of MIOSHA and the hazard severity.

e) For all the training sessions, records will be collected that describe the topics covered and the name of the trainee workers.

f) Toolbox talks that cover the following topics will be conducted regularly (weekly/daily):

- The safe work practices that are required for that specific workday.
- Any concerns related to the safety that the workers might have.
- A short refresher training related to safety topics (such topics are chosen and provided by the safety coordinator)

2.1.8. Accident Reporting

Employees play a significant role in recognizing, controlling, and reporting hazards that might happen or already exist on the construction site. The employee reports of potential hazards can be a functional tool to encourage a closer look at a particular operation, piece of equipment, or performance. Moreover, the mentioned hazards might also yield suggestions to remove a hazard.

After every accident/incident and near miss, an investigation will be carried out. The main objective of such studies is to understand the "root cause" to avoid future occurrences. The investigation reports can potentially determine injury and illness trends over a specific period, and thus patterns with common causes can be recognized and avoided. It is noteworthy to mention that the aim of these investigations is not to place a blame.

Accidents and "near-miss" incidents will then be investigated using (Name/Title). Such reports will be analyzed by (Name/Safety Committee) after (Days/Hours) an accident/incident. The following measures should be taken with that regard:

- Regardless of how minor they may be, all the accidents must be reported immediately to the Foreman.
- It is necessary for the Foreman to report all the accidents to the Safety Coordinator without delay.
- Foremen must conduct an early written accident investigation on the day of the accident.
- All the witness workers must complete a written statement explaining the incident.
- A complete accident investigation will be carried out by the Safety Coordinator to understand the root causes and determine corrective actions.
- All the near misses should be reported, and corrective actions must be used to avoid the same situations that would have the potential for serious injury. Foremen must keep track of near misses and the required corrective actions that should be taken and report them to the safety coordinator. Thus, the same corrections can be made on the company's work sites.

2.1.9. Post-construction

After the construction is thoroughly completed, contractors conduct post-construction activities such as testing, functional performance tests, and commissioning. The mentioned activities lead to the continuation of the association of the contractor and the client (G.V.R.Srinivasa, 2016).

The safety or project manager is responsible for improving systems to prevent or mitigate hazards. These systems include personnel and work practice protective systems, instituting controls using engineering, administrative actions, hazard tracking correction systems, emergency preparation, preventive maintenance systems, and medical programs (United States Department of Labor, 2017)

In our case study, the employer appoints a person as a safety manager of the car-parking building to follow a written system like PPE. Also, any hazards identified should be recorded and an updated safety plan should be announced. Furthermore, for all the equipment and vehicles, a schedule should be established. Subsequently, the maintenance logs must be reported to document the work conducted and order or schedule reports. Such approach is highly likely to ensure traffic control, which is the supervision of involved construction parts movement such as people vehicles, or goods, to provide safety and efficiency.

3. COST EVALUATION

The benefits of the "pay-for-safety" principle are limited to the monetary term that it brings for the main construction companies and, more importantly, the message that it conveys to establish a safety management system on construction sites.

It is evident that the costs of preventive measures are more minor than accidents, and this fact has been proven through the experience of numerous industrial operations. The accident costs are categorized into direct and indirect types, where the direct costs refer to the medical care, compensation, (Hinze, 1997) The indirect cost that is 4 to 10 times the direct cost must be computed. Besides, the employee wage loss and the effect of such loss on the entire community should be calculated (Reese and Eidson, 2006).

Various costs, including direct or indirect, are interconnected with accidents, and their extent varies depending on the accident severity. The severity can range from slight accidents to fatalities (Pillay, 2014)

This part of the study measures the costs for safety the whole of the project and compares them to other expenditures. Table 2 shows the time, cost of implementation and safety, and the number of the human resource for each activity.

Table 2. Cost evaluation for implementing safety for our case-study

Phase of construction	**Description of work**	**Cost (USD)**	
Pre-construction	Risk assessment report	1000	3600
	Work analysis report	1200	
	Job safety analysis	800	
	Design (by considering safety)	600	
Construction	Health and safety supervisor	10000	25000
	Training	1000 per accident	
	Safety equipment	8000	
	Personal protective equipment	6000	
Post-construction	Health and safety manager	7600	26000
	Inspection	2400	
	Health and safety equipment	10000	
	Sensor	6000	

According to Table 2, implementation of safety measures for this multi-story parking, makes up 2.8% of the total budget designated for construction, which fits into standard safety implementation ratio according to other studies.

This paper introduces methods for a well-found evaluation of the costs involved in a hypothetical multi-story building. We implemented a management approach that is based on the Theory of Constraint (TOC), which was developed in the 1980s. It is a real challenge to carry out a reliable evaluation of the indirect costs, bearing that they often include uninsured costs. Direct costs such as wages for injured persons, medical care, and hospital (Hinze, 1997).

3.1. Direct Costs

We considered all parameters, which reflect all the possible costs levied by the accidents, to propose a model that can estimate the total industrial accident costs. The general model's structure presents that the total accident equals the sum of direct and indirect costs.

Damage Cost: When an accident happens, products, machinery, and equipment are damaged in addition to the entailed injuries. Such costs cover the damaged made to the raw machinery, damaged equipment, raw materials, cleaning and restoring the working area to operate again.

Medical Cost: Undeniably, the immediate medical operation is associated with costs. Such cost includes transferring to the hospital, hospitalization fee, treatment payment, medical equipment, etc.

Fine Cost: When the accident happens because of violating the safety procedures or trespassing the law, fines and claims may be levied on the organization by the authorities.

Insurance Cost: The companies pay an insurance premium, which is subject to the accident's severity, estimate of absence leave days, hospitalization period, facilities, commodities, potential lawsuit, and equipment financial loss. Every year, this premium changes according to the previous year; therefore, the higher accident rate will increase the insurance premium in the following year. This premium is a direct accident cause; the difference between two consecutive payments can be viewed as a direct cost.

In this section these breakdowns which make up the total direct costs were estimated using the data from a private Cyprian company. According to that data, the average damage cost for this case-study is predicted to be between $ 500_1000. As for the medical expenses the cost is determined by the type of accident and its severity. For this case study, the average medical cost is approximately between $ 300-500 for minor injuries. However, in case of major injury the medical cost can exceed this value depending on the accident severity. The minimum fine cost is equal to five times of minimum wage, which will be around $ 2000. On the other hand, for fatal accident depending on the age, gender, monthly salary, defective fraction, number of dependents can range between $ 20000-300000. By considering the insurance policy in this country, the amount of insurance can increase between $ 4000-6000.

3.2. Indirect Costs

Lost Capacity Cost: an accident can result in a pause or slowdown in the production. For example, consider an emergency fire case, in which evacuation of the damaged equipment and the injured person should take place immediately. Moreover, an accident can cause a new bottleneck, making the production process halt and imposing additional costs.

Schedule Cost: In the case of an accident, a production slowdown will adversely affect the timetable schedule and ultimately results in damages to the client. Clients can call off the contract or ask to lower the compensation.

Recruitment cost: Hiring is needed to replace the injured worker with additional ones. This process is associated with some costs, including the time and training of the new worker.

Work Time Cost: The manager carefully investigates the accidents, and the work time should be designated to instruct the simple workers. Also, extra work hours are required to replace the injured worker.

Work-in-Progress Cost: Bottlenecks are often created when an accident happens. Therefore, the inventory begins to grow, and the cost connected to that grows as well. Managers are required to come up with a solution for fitting the inventory to the new bottleneck, which is associated with additional costs. Such cost demands a specific manager and thus may be different from company to company depending on the managerial considerations.

Manager Cost: The cost related to the CEO's time is very costly and misusing this time can result in the company losing its sales.

$$Total\ cost = direct\ cost + indirect\ cost$$

$$Direct\ cost = damage\ cost + medical\ cost + fine\ cost + insurance\ cost$$

$$Indirect\ cost = capacity\ cost + schedule\ cost + recruit\ cost + work\ time\ cost + Work\text{-}in\text{-}Progress\ cost + manger\ cost$$

For this case study, the total indirect costs predicted are broken down into different categories. Based on the car-park contract, the fine for delay can cost around $ 500 per day due to the slowdown in production, which will negatively affect the timetable. The other indirect contributing fee is the recruitment fee, Lack of skilled and sufficient workforce is a major problem for North Cyprus where the case study under investigation is located. In other words, for majority of recruitment process, new workers should be hired from Turkey or other third world countries, which is likely to take minimum of two weeks. A group of people are responsible for investigating the accidents happened and training new workers, which is estimated to cost $1000 per accident. Other parameters were not calculated for this case study since it is considering the small-medium enterprise, which does not necessarily require a CEO manager.

4. EMPIRICAL ANALYSIS

For developing a model to estimate the total cost of a potential accident at this facility, all parameters, which represent possible costs levied by an accident were considered. To begin with, the general structure of the model consisting of direct and indirect cost is presented. Here, the cost evaluation of two different hypothetical scenarios, which includes potential accidents at this multi-story parking, were conducted.

4.1. Scenario 1

The first accident is assumed to be caused by falling from height, which according to the Table 1, it is the most probable construction accident that would cause injury of a worker needing to be evacuated by ambulance. Such accident is estimated to require six days of hospitalization. The total cost of direct and indirect cost for this potential construction accident is predicted to range from $7,000 to $8,000.

4.2. Scenario 2

The other hypothetical accident is a worker being struck by moving or falling object at the construction site. The worker should first be evacuated to intensive care and requires to be hospitalized for approximately 14 days. During this period, an outsourcing worker should be employed. It is likely to take around five days for him to be recruited and trained for the job, which would result in 40 working hours. Also, other workers can be asked to replace the injured worker, which makes the employer pay approximately 1.12 times more salary than the injured worker. To investigate this accident, two team managers should be asked to gather all the other workers for instruction and guidance. Even by considering the minimum fine for a fatal accident in North Cyprus, the cost of this scenario is estimated to be around $50,000 to $60,000.

5. CONCLUSIONS

This paper demonstrated the importance of evaluating accident and prevention costs. It first emphasizes the importance of implementing safety measures throughout all BPP phases to improve construction

safety and ultimately reduce the number of construction accidents. Then it was proven that considering this defined scheme is highly related to the costs, fines, and types of accidents.

The distinction between direct and indirect cost types is therefore critical and not trivial. It also creates an effective safety management system in the construction industry and records construction-related accidents.

After evaluating some empirical examples, it can be seen that the total of one fatal accident considered in this case study for a multi-story parking surpasses the cost of implementing safety measures. Hence the findings indicate that it is reasonable to implement safety measures throughout all BPP Phases. Nevertheless, for the other potential accident example discussed in this article, the cost of injury accidents is less than the safety measures implementation costs. Therefore, in North Cyprus, fines, and potential accident costs of not implementing safety measures do act as a deterrent for contractors who tend to ignore such action.

Finally, not all the costs that are imposed as a result of a construction accident can be measured; in other words, each accident adversely affects the mental health of the people involved and the reputation of the construction company.

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