Sudan University of Science and Technology

College of Graduate Studies

Electrical and Mechanical Safety in Construction Industry

السلامة الكهربائية والميكانيكية في صناعة التشييد

A Thesis submitted in partial fulfillment of the requirements for the degree of Master in Civil Engineering- Construction Management

By:

Alnazeer Altegani Mustafa Mohamed

Supervisor:

DR. Osama Mohammed Ahmed

October 2020

الآيـة

قال تعالي

بسم الله الرحمن الرحيم

(قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ)

[سورة البقرة – الاية 32]

DEDICATION

I would like to dedicate this work to:

- My beloved father, mother, brothers, wife, daughters and friends for their unlimited encouragement.

- All teachers and everyone who taught and help me in my career.

- All the special people in my life

- Thanks from bottom of my heart for being my inspiration

ACKNOWLEDGMENT

First of all, I would like to thank Allah for blessing me and enabling me to complete this thesis.

Indeed, many people contributed time, knowledge, skill, and support to my research, and I am pleased to acknowledge their contributions.

This thesis is submitted in partial fulfillment of the requirements for the Master of Construction Management at Sudan University of Science and Technology.

I wish to express my sincere thanks to my supervisor. Dr. Osama Mohammed Ahmed, who was abundantly helpful and offered invaluable assistance, support and guidance that enabled me to conduct my research.

My sincere gratitude also goes to management staff and colleagues at Sudan Air ways for their appreciation help during study period and thesis preparation.

I also wish to express my gratitude to all who helped me with support, suggestions that has contributed to making my thesis a good job.

I also wish to express my gratitude to all my friends, colleagues and family together group members especially my companion Rashid for their unlimited support.

Last but not least, I owe my loving thanks to my wife, daughters and the wider family members especially my father, mother, brothers, without their encouragement and understanding it would have been impossible for me to finish this work

ABSTRACT

Safety in the construction project has always been a major issue. Wherever reliable records are available, construction is found to be one of the most dangerous on safety and health criteria, particularly in developing countries construction sites are characterized by rapid pace and complicated organization of work processes, one of the important safety issue on a construction site is Electrical and Mechanical (E&M) works.

The (E&M) works was identified as one of the most hazardous in the construction industry worldwide, this research provides a closer look at some common E&M hazards in the workplace and how to be safe around them.

The safety of E&M works has not been given the attention it deserves. Only limited safety research and accident statistics specifically on E&M works could be found. This research project aims to improving safety awareness in construction sites and Minimize the number of electrical & mechanical accidents and Maximize level of safety performance on sites and make safety stander main issue on workers' culture.

- There are three specific objectives with this research, including (1) Identify risks and E&M hazard thus reducing rate of accident; (2) Encouragement firms to follow health and safety standards; (3) Help worker to use safety culture at construction sites

A field survey was conducted through a questionnaire at construction companies in Khartoum State. The collected data were analyzed to presents statistical measures

It was concluded that There are lack of safety awareness among E&M labor and technician and Commitment to safety roles reduced the probability of potential hazard during E&M works execution

Finally, in order to improve the E&M safety in construction industry, a set of recommendations were made.

المستخلص

تعتعبر السلامة دائما من القضايا الاساسية في مشاريع التشييد. حيثما توفرت سجلات موثوقة ، وجد أن التشييد هو أحد أخطر الصناعات من ناحية معايير السلامة والصحة المهنيية ،خصوصا في البلدان النامية.

تتميز مواقع التشييد بالإيقاع السريع والتنظيم المعقد لعمليات العمل ، ومن أهم قضايا السلامة في مواقع التشييد تنفيذ الأعمال الكهربائية والميكانيكية بسلام.

تعرف الأعمال الكهربائية والميكانيكية واحدة من أكثر الأعمال خطورة في صناعة التشييد في جميع أنحاء العالم ،يلقي هذا البحث نظرة عن قرب على بعض مخاطر الشائعة في الاعمال الكهربائية والميكانيكية وكيفية التحلي بسلامة وامان حولها.

لم تحظ سلامة الأعمال الكهربائية والميكانيكية بالاهتمام الذي تستحقه ،تم ايجاد ابحاث محددة خصوصا حول الأعمال الكهربائية والميكانيكية واحصائيات الحوادث الناتجة عنها.

يهدف هذا المشروع البحثي إلى تحسين الوعي بالسلامة في مواقع التشييد وتقليل عدد الحوادث الاعمال الكهربائية والميكانيكية إلى الحد الأدنى وزيادة مستوى أداء السلامة في المواقع وجعل معيار السلامة من القضايا الاساسية في ثقافة العمال.

هنالك ثلاثة اهداف محددة لهذا البحث تتمثل في (1) تحديد المخاطر و المخاطر الكهربائية والميكانيكية تقلل معدل الحوادث(2) مساعدة العمال لاستخدام ثقافة السلامة في مواقع التشييد (3) تشجيع الموسسات او الشركات علي اتباع معتيير السلامة و الصحة المهنية.

تم إجراء مسح ميداني من خلال استبيان لشركات العاملة في مجال التشييد بولاية الخرطوم. تم تحليل البيانات التي تم جمعها لتقديم مقاييس إحصائية.

تم استنتاج أن هناك نقصًا في الوعي بالسلامة بين عمال وفنييالاعمال الكهربائية و الميكانيكية، كما أن الالتزام بأدوار السلامة يقلل من احتمالية المخاطر المحتملة أثناء تنفيذ أعمال الكهربائية و الميكانيكية.

في الختام ، من أجل تحسين سلامة أعمال الكهربائية و الميكانيكية في صناعة التشييد، تم تقديم مجموعة من التوصيات

TABLE OF CONTENT

CHAPTER - 3 STUDY METHODOLOGY AND PROCEDURES

CHAPTER - 4 VIEW AND ANALYZE STUDY DATA

CHAPTER - 5 FINDING AND RECOMMENDATIONS

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

E&M	Electrical and Mechanical
LOTO	Lock out Tag out
OSHA	Occupational Safety and Health Administration
GFCIs	Ground Fault Circuit Interrupters
PPE	Personal protective equipment
MMHE	Mechanical Material Handling Equipment
SPSS	Statistical Product and Service Solutions
T-Test	Statistical Hypothesis Test
P -Test	Monochromatic Variation Test
PhD	Doctor of Philosophy
Fr	Frequency
Per%	Percentage
Sig	Significant
R2	Correlation Coefficient

CHAPTER 1
INTRODUCTION

1.1 Interdiction

Construction industries are generally identified as one of the most hazardous industries due to the nature of works.

Safety is relevant to all branches of industry, it is particularly important for the Construction industry. It has always been a major issue as it is considered as among the most exposed sectors when it comes to occupational accidents. Although tremendous.

Improvements have been made in safety performance in some countries, the construction industry continues to lag behind most other industries

Electrical and mechanical (E&M) works are significant to most construction projects regardless of new construction works or repair, maintenance, alteration and addition works.

Electrical and mechanical works consist of various specialist trades such as fire services installation, electrical wiring, and plumbing

and drainage, air-conditioning installation, and lift and escalator installation. With the presence of ageing buildings which lack of proper maintenance, the deterioration of fire services, water pipes and electrical wiring in old buildings commonly occurs.

Electrical and Mechanical (E&M) works are indispensable to any construction projects. In the light of number of workers and companies involved, E&M works play an important role in the Construction industry.

There are many causes of accidents of Electrical and mechanical works in the Construction in sites in the world special in developing countries.

This accidents lead to minor injuries & serious injuries and sometimes to

death, all above has direct impact on the constructions projects, on multiple aspects as project time lain, quality and final project cost.
All those provide recommendations to improve safety of Electrical and Mechanical practitioners.

1.2 Problem Statement

The construction project is characterized has poor safety performance in the world, the construction industry in Sudan has a very poor site safety record in comparison to other countries.
E&M doesn’t come without hazards. If we’re not careful, and mishandle E&M, it could lead to accidence, fire injure, electric shock or even death
In order to ensure that we enjoy a steady E&M, along with all the Convenience and comfort it brings, without incident.
There are many accidences come out due to lobbers mistake or lake of awareness in E&M safety.

1.3 Significance of the Study

The importance of the research comes from the need to improve an understanding the problem of E&M safety in construction sites and make a contribution to knowledge of hazard witch come from it, Reduced E&M risks in the workplace.
Accidences and injuries in construction sites have impact to the project cost and tend to be costly in human and financial terms.
E&M safety is concerned to reducing rates of accidents and controlling or eliminating hazards at the construction sites.

1.4 Research Aim

The aims of this research are to improving safety awareness in construction sites in Sudan.
Minimize the number of electrical & mechanical accidents and Maximize

level of safety performance on sites and make safety stander main issue on workers culture.

1.5 Research Objectives

To achieve the research aim, the following objectives were set:

- Identify risks and E&M hazard thus reducing rate of accident
- Help worker to use safety culture at construction sites.
- Encouragement firms to follow health and safety standards

1.6 Research Hypotheses

- There is a significant lack of safety awareness among E&M labor and technician
- Accelerate E&M project deadline increasing the accidents
- Commitment to safety roles reduced the probability of potential hazard during work execution
- Following E&M safety procedure reduce project cost

1.7 Research Methodology

The research methodology will include steps, which can be in the Following points:

1 Perform review of literatures relating to the topic of this study. The objective of the review is to identify the factors that affect the safety performance in large construction companies and the methods of safety performance measurement.

2 Collect data via a questionnaire survey to evaluate the factors that affect the safety performance identified in the literature review.

3 Perform analysis of data using appropriate statistical techniques.

4 Ranking the results according to their importance.

5 Establish a tool to assess the safety of construction companies.

6 Report and discuss results and major findings to introduce conclusions and recommendations.

1.8 Thesis Organization

This research organizing into five chapters, references and appendixes. It includes the following:

Chapter 1

Presents an introduction to the research. It includes the problem statement, the objective, the scope and limitations, and the methodology of the study.

Chapter 2

Presents the literature review and the previous efforts and studies which have been made in the field of safety and the factors affecting the safety performance and of the signs, signals and symbols in the site, and about safety measurement.

Chapter 3

Discusses the research methodology which includes the information about the research design, research population, research location, questionnaire design, questionnaire validity, questionnaire reliability, research structure and statistical data analysis.

Chapter 4

Presents and discusses data analysis, statistical methods used, tables and information deduced from statistical analysis and statistical results. The procedures for assessing and improving the safety performance and practice are discussed.

Chapter 5

Summarizes the results and major finding, to present the conclusions and recommendations of this research.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The main aim in carrying out the literature reviews is to gather information on the research topic. As it will be mentioned in the references at the end of the thesis, the mains sources are from journal papers, seminar, internet web sites, paperwork and reference books.

E&M works is an essential work category in new construction works and repair, maintenance, alteration and addition works. E&M works involve a wide range of building services trades such as air-conditioning, fire services, plumbing and drainage, electrical wiring and lift installation and maintenance works. It plays an important role in the construction industry and involves a considerable number of workers

E&M installation was identified as one of the most hazardous trades in the construction industry worldwide. A safe E&M work is essential to the success of any construction projects. A comprehensive research on E&M safety is vital to improve the safety performance of E&M works.

By applying the proposed safety measures in practice, safer E&M work environment can be created.

2.2 Characteristics of E&M Works

Both E&M works and general builders' works may cause fatal accidents. As various trades, regardless of E&M works or builders' works, have their own characteristics, the major causes of accidents would be different. For E&M works, the key hazards are identified in activities that involve working at height, electricity, confined space, lifting, machinery (for lift and escalator), welding, and using handheld tools, etc. Some hazards in E&M works are quite particular as per the E&M work processes like lifting of chiller or generators, electrical hazard at switch gear works, and confined space hazards at water tank, etc. Compared with general builders' works, E&M works often require working at height. Over 80% of air-conditioning and fire services installation works involve working at height. This greatly increases the likelihood of fall of person from height.

With a tight working schedule and long working hours, workers may neglect the safety procedures and overlook the hazardous of working environments. Most of the E&M installation works is always being put at the last construction stage. Multi building service trades are concurrently working at the same location more or less at the same time under a compressed working schedule that will substantially increase the safety risk of the E&M workers. [1]

2.3 Major Categories of E&M Works Related Accidents

Major categories of E&M accidents were summarized in Table 2.1 the major types of accidents related to E&M works are fall of person from height and electrocution. Air-conditioning works comprise of work at height outside the external wall and use of ladder inside the building. Use of ladder is very frequent in new air-conditioning works and maintenance works. Trapped in or between objects and injured by moving machinery, striking against fixed or stationary object and struck by falling object would be commonly occurred in lift installation and maintenance works. The major types of accidents related to fire services installation works are fall of person from height, injured whilst lifting or carrying, contact with moving machinery and hazardous energy. As most of the plumbing works are mainly located at height, working platform cannot be used due to the limited size of working area. Only ladder can be used to carry workers for works at height, fall accidents may easily happen. When replacing of drainage pipes and other plumbing work, workers may cut by the sharp edge of a pipe or injure by hand tool. A worker may be injured by fragments when welding and cutting pipes without suitable protective measures. Struck-by accidents may happen when the pipes are not fixed or anchored properly when lifting or unload. Demolition of pipe and drainage works would be dangerous for workers. Sludge in pipe may contain hazardous gases which may cause suffocation. The major type of accidents related to electric wiring works include fall of person from height, contact with electricity or electric discharge and injured whilst lifting or carrying. Electrocution is a major type of E&M related accident. For electrical wiring works, the E&M workers are vulnerable to electric shock hazard whilst working on the conductive parts of the electrical cable which has not been properly isolated from the power source. [1]

Major categories of accidents	**Air-conditioning**	**Lift/ escalator**	**Fire service**	**Plumbing & drainage**	**Electrical Wiring**
Fall of person from height (e.g. ladder, working platform)	X	X	X	X	X
Electrocution	X	X			X
Cut during the working process				X	
Slip and fall on same level		X			
Trapped or injured by moving machines		X	X		
Injured whilst lifting or carrying			X		X
Struck by falling object		X		X	
Laceration by sharp edges or tools				X	
Suffocation in confined space				X	
Striking against fixed or stationary object		X			
Contact with hazardous rgy			X		

Table No. 2.1 Major Categories of Accidents

2.4 Electrical Safety

2.4.1 Principles of Electricity

Electricity is the flow of electrons through a conductor. A commonly used conductor is copper wire.

For electricity to flow the conductor must be arranged with a power source to make a circuit. a very simple circuit is shown in the following figure where a battery and a light bulb have been connected together using copper wire to form a loop. Electricity flows in one direction around the circuit, from one terminal of the battery to the other. as it passes through the bulb the filament in the bulb resists the flow of electricity, heats up and emits light. if the wire is disconnected from the battery or bulb the circuit is broken, flow stops and the bulb goes out.

The basic parameters of an electrical system, such as the circuit

shown, are:

7 Voltage – a measure of the potential difference or electrical driving force/pressure that is forcing electricity through the conductor (unit: volt; symbol: V).

8 Current – a measure of the rate of flow of electricity through a conductor (unit: ampere or amp; symbol: i).

9 Resistance – a measure of how much a component in the circuit resists the passage of electricity (unit: ohm; symbol: r).

These three parameters are linked by a simple relationship called ohm's law:

Voltage = current *resistance

Volts (V) = amps *ohms = $i * r$ [2]

2.4.2 Need to know about electricity.

All electrical systems have the potential to cause harm. Electricity can be either "static" or "dynamic." Dynamic electricity is the uniform motion of electrons through a conductor (this is known as electric current). Conductors are materials that allow the movement of electricity through it. Most metals are conductors. The human body is also a conductor.

Electric current cannot exist without an unbroken path to and from the conductor. Electricity will form a "path" or "loop". When you plug in a device (e.g., a power tool), the electricity takes the easiest path from the plug-in, to the tool, and back to the power source. This is also known as creating or completing an electrical circuit. [3]

2.4.3 Factors influence the severity of injury associated with receiving an electric shock:

1. Voltage – as Ohm's law shows, there is a simple relationship between voltage and current: the higher the voltage, the greater the current.
2. Duration – the length of time that a person is exposed to the flow of electricity is critical. For example, a current flow of 60 ma for 30 milliseconds (30 thousandths of a second) is unlikely to cause a severe injury, whereas the same current flow over a period of two seconds can induce VF and prove fatal.
3. Frequency – of the ac current.
4. Current path – the route that the electricity takes as it flows through the body is also critical. if it runs through the chest it is likely to affect the heart.
5. Resistance – as Ohm's law shows there is a simple inverse relationship between current and resistance – the higher the resistance, the lower the current. Most of the body's resistance to the passage of electricity is

because of the skin. a person with dry skin has a resistance of about 100,000 ohms, but if their skin is wet or damaged this reduces dramatically to 1000 ohms. Any clothing that the person is wearing will also affect their resistance to the passage of electricity.

6. Contact surface area – the more skin that is in contact with the live surface, the lower the resistance and the more severe the injury.
7. Environment – any environmental factors that reduce resistance will cause an increase in current flow and therefore increase the severity of the shock, e.g. wet surfaces, humid air, metal surfaces, etc.
8. Nature of the clothing and footwear – may provide some protection.
9. Presence of potential secondary hazards – can result in additional injuries, e.g. if working off a ladder the person may fall. [2]

2.4.4 Workplace Electrical Equipment

A wide variety of workplace equipment is operated by electricity, including:

1. Equipment that is 'hard-wired' directly into fuse or distribution boards and distribution systems such as bus-bars. Hard-wired equipment still needs to be inspected and tested (see later) to ensure connections and system components remain secure and operational, particularly cables that may be exposed to pedestrian and vehicle traffic, but it is less likely to undergo the rigours of being unplugged and moved around the workplace.
2. Portable appliances. Portable electrical equipment can be defined as equipment with a flex and plug on it that can be moved from one location to another for use. (Whether it actually is moved is irrelevant; a photocopier may never be moved but it has a flex and plug and is, therefore, portable.) a high proportion of electric shock accidents

involve portable electrical equipment.

As an example of vulnerable portable electrical equipment, consider a small concrete breaker used on a construction site. it is:

- Subject to frequent heavy use in an outdoor environment.
- Often handled and transported
- Used by a variety of users who may not own the item and therefore have little interest in taking care of it.

The same hazards apply to these types of equipment, but the risks can be different, especially with portable appliances.

2.4.5 Strength and Capability of Equipment

Electrical equipment must be carefully selected to ensure that it is suitable for:

- The electrical system that it will become a part of.
- The task that it will perform.
- The environment in which it will be used.

No electrical equipment should be put into use where its electrical strength and capability may be exceeded and give rise to danger. It should be able to withstand normal, overload and fault currents. It should also be used within the manufacturer's rating and in accordance with any instructions supplied. This may require reference to electrical specifications and tests undertaken by the manufacturer and accredited testing organizations, based on international and national standards. [2]

2.4.6 Kinds of injuries result from electrical currents

Humans are more conductive than the earth (the ground we stand on) which means if there is no other easy path, electricity will try to flow through our bodies.

There are four main types of injuries: electrocution (fatal), electric shock, burns, and falls. These injuries can happen in various ways:

1. Direct contact with exposed energized conductors or circuit parts.
2. Thermal burns including burns from heat generated by an electric arc, and flame burns from materials that catch on fire from heating or ignition by electrical currents or an electric arc flash. Thermal burns from the heat radiated from an electric arc flash. Ultraviolet (UV) and infrared (IR) light emitted from the arc flash can also cause damage to the eyes.
3. Muscle contractions, or a startle reaction, can cause a person to fall from a ladder, scaffold or aerial bucket. The fall can cause serious injuries. [3]

2.4.7 General safety tips for working with or near electricity

1. Inspect portable cord-and-plug connected equipment, extension cords, power bars, and electrical fittings for damage or wear before each use. Repair or replace damaged equipment immediately.
2. Always tape extension cords to walls or floors when necessary. Nails and staples can damage extension cords causing fire and shock hazards.
3. Use extension cords or equipment that is rated for the level of amperage or wattage that you are using.
4. Always use the correct size fuse. Replacing a fuse with one of a larger size can cause excessive currents in the wiring and possibly start a fire.
5. Be aware that unusually warm or hot outlets may be a sign that unsafe wiring conditions exists. Unplug any cords or extension cords

to these outlets and do not use until a qualified electrician has checked the wiring.

6. Always use ladders made with non-conductive side rails (e.g., fiberglass) when working with or near electricity or power lines.
7. Place halogen lights away from combustible materials such as cloths or curtains. Halogen lamps can become very hot and may be a fire hazard.
8. Risk of electric shock is greater in areas that are wet or damp. Install Ground Fault Circuit Interrupters (GFCIs) as they will interrupt the electrical circuit before a current sufficient to cause death or serious injury occurs.
9. Use a portable in-line GFCI if you are not certain that the receptacle you are plugging your extension cord into is GFCI protected.
10. Make sure that exposed receptacle boxes are made of non-conductive materials.
11. Know where the panel and circuit breakers are located in case of an emergency.
12. Label all circuit breakers and fuse boxes clearly. Each switch should be positively identified as to which outlet or appliance it is for.
13. Do not use outlets or cords that have exposed wiring.
14. Do not use portable cord-and-plug connected power tools with the guards removed.
15. Do not block access to panels and circuit breakers or fuse boxes.
16. Do not touch a person or electrical apparatus in the event of an electrical accident. Always disconnect the power source first.[3]

2.4.8 Most common electrical hazards in the workplace and tips to mitigate it.

1. Overhead Power Lines

Overhead powered and energized electrical lines have high voltages which can cause major burns and electrocution to workers. Remember to maintain a minimum distance of 10 feet from overhead power lines and nearby equipment. Conduct site surveys to ensure that nothing is stored under overhead power lines. Also, safety barriers and signs must be installed to warn nearby non-electrical workers of the hazards present in the area.

2. Damaged Tools and Equipment

Exposure to damaged electrical tools and equipment can be very dangerous. Do not fix anything unless you are qualified to do so. Thoroughly check for cracks, cuts or abrasions on cables, wires and cords. In case of any defects, have them repaired or replaced. Lock out Tag out (LOTO) procedures should be performed at all times before commencing electrical maintenance and repairs. LOTO procedures are there to protect all workers on a worksite.

3. Inadequate Wiring and Overloaded Circuits

Using wires with inappropriate size for the current can cause overheating and fires to occur. Use the correct wire suitable for the operation and the electrical load to work on. Use the correct extension cord designed to heavy duty use. Also, do not overload an outlet and use proper circuit breakers. Perform regular fire risk assessments to identify areas at risk of bad wiring and burns secure these items with proper guarding mechanisms and always check for any exposed part to be repaired immediately

4. **Improper Grounding**

The most common Occupational Safety and Health Administration (OSHA) electrical violation is improper grounding of equipment. Proper grounding can eliminate unwanted voltage and reduce the risk of electrocution. Never remove the metallic ground pin as it is responsible for returning unwanted voltage to the ground.

5. **Damaged Insulation**

Defective or inadequate insulation is a hazard. Be aware of damaged insulation and report it immediately. Turn off all power sources before replacing damaged insulation and never attempt to cover them with electrical tape.

6. **Wet Conditions**

Never operate electrical equipment in wet locations. Water greatly increases the risk of electrocution especially if the equipment has damaged insulation. Have a qualified electrician inspect electrical equipment that has gotten wet before energizing it. [4]

2.4.9 Identify the electrical hazards

Identifying hazards involves finding all of the tasks, situations and sequences of events that could potentially cause harm.

Hazards from electrical equipment or installations may arise from:

1. The design, construction, installation, maintenance and testing of electrical equipment or electrical installations
2. Design change or modification
3. Inadequate or inactive electrical protection
4. Where and how electrical equipment is used. For example, equipment may be at greater risk of damage if used outdoors or in a

factory or workshop environment

5. Electrical equipment being used in an area in which the atmosphere presents a risk to health and safety from fire or explosion, for example confined spaces
6. Type of electrical equipment. For example, ‘plug in’ electrical equipment that may be moved around from site to site, including extension leads, are particularly liable to damage
7. the age of electrical equipment and electrical installations
8. Work carried out on or near electrical equipment or electrical installations, including electric overhead lines or underground electric services, for example work carried out in a confined space connected to plant or services. Identifying hazards involves finding all of the tasks, situations and sequences of events that could potentially cause harm.

Potential electrical hazards may be identified in a number of different ways including:

1. Talking to workers and observing where and how electrical equipment is used
2. regularly inspecting and testing electrical equipment and electrical installations as appropriate
3. reading product labels and manufacturers’ instruction manuals
4. talking to manufacturers, suppliers, industry associations, and electrical safety specialists
5. Reviewing incident reports.[5]

2.4.10 Control the risks

Once hazards have been identified, appropriate control measures must be put in place.

The ways of controlling risks are ranked from the highest level of protection and reliability to the lowest. This ranking is known as the hierarchy of risk control (Fig.2.1). You must work through this hierarchy to choose the control that most effectively eliminates or minimizes the risk in the circumstances, so far as is reasonably practicable. This may involve a single control measure or a combination of two or more different controls.

1. **Elimination**

   The most effective control measure is to remove the hazard or hazardous work practice. By designing-in or designing-out certain features, hazards may be eliminated.

2. **Substitution & Isolation**

   Replacing a hazardous process or material with one that is less hazardous will reduce the hazard, and hence the risk. For example, it may be reasonably practicable to use extra-low voltage electrical equipment such as a battery-operated tool rather than a tool that is plugged into mains electricity.

   Isolation to prevent workers from coming into contact with the source of an electrical hazard will reduce the relevant risks.

3. **Engineering controls**

   Use engineering control measures to minimize the risk, for example installing residual current devices (commonly referred to as safety switches) to reduce the risk of receiving a fatal electric shock.

4. **Administrative controls**

   Administrative controls involve the use of safe work practices to control the risk, for example establishing exclusion zones, use of permits and warning signs.

5. **Personal protective equipment (PPE)**

   PPE includes protective eyewear, insulated gloves, hard hats, aprons and breathing protection. Most forms of PPE are not relevant to minimizing electrical risks in workplaces, except in relation to energized electrical work.

   Administrative controls and PPE do nothing to change the hazard itself. They rely on people behaving as expected and require a high level of supervision. Exclusive reliance on administrative controls and PPE must only occur where other measures are not reasonably practicable or as an interim control while the preferred control measure is being implemented.

   You should check that your chosen control measure does not introduce new hazards. [5]

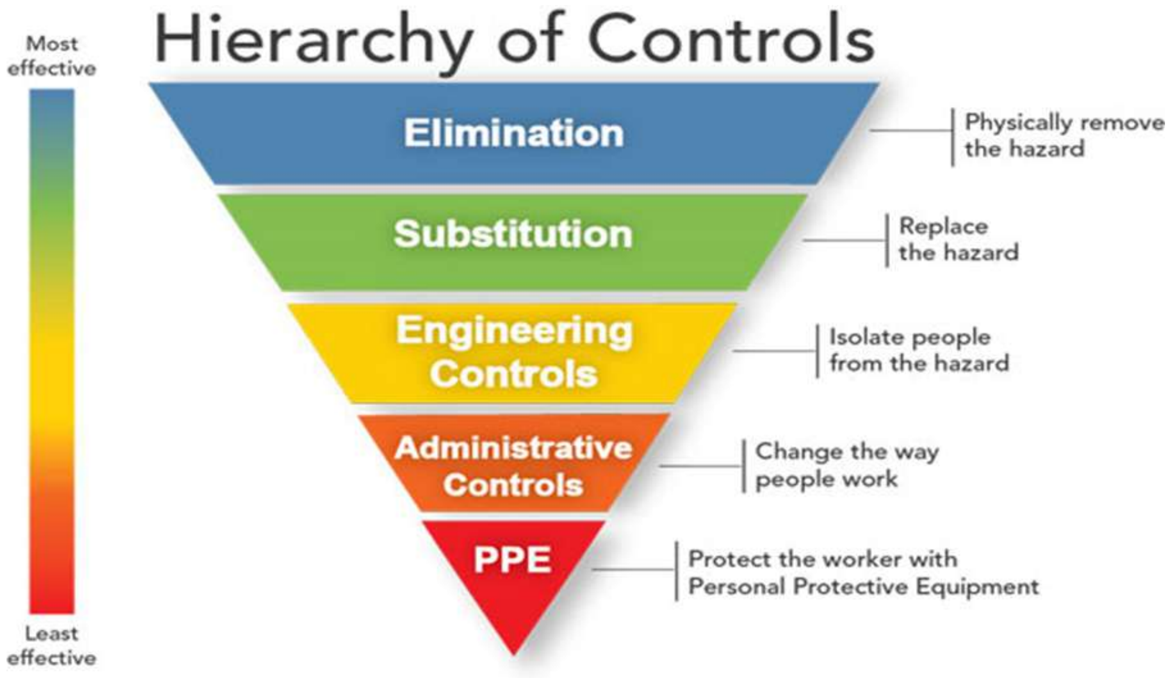


Fig.2.1 Hierarchy of Control

2.4.11 Emergency Procedures Following an Electrical Incident

if, in spite of all the available control measures being in place, an electrical incident occurs in the workplace, all workers should be aware of the following method for dealing with an electric shock casualty:

- Do not touch them.
- Call for help.
- Switch them off (turn off the power supply).
- Call for an ambulance.
- If they cannot be switched off then carefully push or pull them away

from the live part using non-conducting material such as timber or dry clothing.

- Check breathing: if breathing, place in the recovery position if not breathing, apply cardiopulmonary resuscitation.
- Treat any obvious burns.
- Treat for physiological shock.
- Make sure they get professional medical treatment (heart problems and internal burns may not be apparent to the casualty or the first aider).

Careful assessment of the situation when approaching the casualty is important for two reasons:

- The casualty may still be receiving an electric shock, in which case touching them will involve their potential helper in the shock as well.
- High-voltage conductors can arc electric current through the air over large distances (over 10 meters).[2]

2.5 Mechanical Safety

Work equipment covers a wide range of hand-held tools, powered tools and machinery. Work equipment should be suitable for the task it is being used for and the environment it is used in.

2.5.1 Key principles of machinery and equipment safety

1. Mechanical hazards

Machinery and equipment have moving parts. The action of moving parts may have sufficient force in motion to cause injury to people.

When assessing machinery and equipment for possible mechanical hazards, consider:

- machinery and equipment with moving parts that can be reached by people
- machinery and equipment that can eject objects (parts, components, products or waste items) that may strike a person with sufficient force to cause harm
- machinery and equipment with moving parts that can reach people, such as booms or mechanical appendages (arms)
- mobile machinery and equipment, such as forklifts, pallet jacks, earthmoving equipment, operated in areas where people may gain access. [6]

Common mechanical hazards and associated risks for machinery and equipment are shown in table 2.2

Hazard	Risk
Rotating shafts, pullies, sprockets and gears	Entanglement
Hard surfaces moving together	Crushing
Scissor or shear action	Severing
Sharp edge – moving or stationary	Cutting or puncturing
Cable or hose connections	Slips, trips and falls (e.g. oil leaks)

Table 2.2 Common mechanical hazards and associated risks for machinery and equipment

2. Non-mechanical hazards

Non-mechanical hazards associated with machinery and equipment can include harmful emissions, contained fluids or gas under pressure, chemicals and chemical by-products, electricity and noise, all of which can cause serious injury if not adequately controlled. In some cases, people exposed to these hazards may not show signs of injury or illness for years. Where people are at risk of injury due to harmful emissions from machinery and equipment, the emissions should be controlled at their source.

When assessing machinery and equipment for possible non-mechanical hazards, consider how machinery and equipment can affect the area (environment) around them. Common non-mechanical hazards are shown in table 2.3 below.[6]

Non-mechanical hazards	
Dust	Mist (vapors or fumes)
Explosive or flammable atmospheres	Noise
Heat (radiated or conducted)	Ignition sources (flame or spark)
High intensity light (laser, ultraviolet)	Molten materials
Heavy metals (lead, cadmium, mercury)	Chemicals
Steam	Pressurized fluids and gases
Ionizing radiation (x-rays, microwaves)	Electrical

Table 2.3 Common non-mechanical hazards

2.5.2 General Principles for Selection of Work Equipment

There are some general safety principles that can be applied to all items of work equipment, irrespective of type.

Types of Work Equipment

In this element we will use the phrase "work equipment" in a very wide sense to include:

- Simple hand tools, e.g. a hammer, screwdriver or chisel.
- Hand-held power tools, e.g. a portable electric drill or circular saw.
- Single machines, e.g. a bench mounted abrasive wheel, photocopier, lathe or compactor.
- Mobile work equipment, e.g. a tractor or mobile crane.
- Machine assemblies, where several machines are linked together to form a more complex plant, such as a bottling plant.

Suitability

In terms of the provision of equipment, all items of work equipment should be suitable for the:

- Task it is going to be used to perform, e.g. a chisel is not appropriate for prizing lids off tins.
- Environment in which it is to be used, e.g. a standard halogen spotlight is not suitable for use in a flammable atmosphere.

Equipment must be carefully selected to ensure that it is suitable for the task and environment on the basis of manufacturers' information.

In many regions of the world there are regulations that require manufacturers to ensure that the equipment that they produce meets basic safety standards. For example, in the European Union and UK, a set of safety standards exists that manufacturers are legally obliged to meet; manufacturers are required to:

- Fix a "CE" (Conformité Européenne) mark to the equipment.
- Provide a written "Declaration of Conformity" to the purchaser.[2]

2.5.3 Machinery Hazards

The hazards of machinery can be divided into:

- Mechanical hazards – mainly from contact with or being caught by dangerous moving parts.
- Non-mechanical hazards – mainly from the power source or things emitted by the machine. [2]

Mechanical Hazards

The mechanical hazards of machinery can be further subdivided into the following classes:

- **Crushing** – the body is trapped between two moving parts or one moving part and a fixed object (e.g. a hydraulic lift collapses crushing a person underneath it).
- **Shearing** – a part of the body (usually the fingers) is trapped

between two parts of the machine, one moving past the other with some speed. the effect is like a guillotine, shearing off the trapped body part.

- **Cutting** or severing – contact is made with a moving sharp-edged part such as a blade (e.g. the blade of a band saw).
- **Entanglement** – loose items such as clothing or hair get caught on a rotating machine part and the person is drawn onto the machine.
- **Impact** – the body is struck by a powered part of a machine (this is similar to crushing, but there is no fixed structure to trap the person; the speed and weight of the object does the damage).
- **Drawing in or trapping -** a part of the body is caught between two moving parts and drawn into the machine, e.g. at "in-running nips" where two counter-rotating rollers meet.
- **Stabbing or puncture** – sharp parts of the machine, or parts or material ejected from the machine, penetrate the body (e.g. swarf, sewing machine needle, abrasive wheel Fragments, nails from a nail gun). [2]

Other (Non-Mechanical) Hazards

The other hazards of machinery are non-mechanical hazards – those hazards that do not arise directly from contact with dangerous moving parts. They are mainly associated with the power source of the machine or are things that it emits. In other words, they are all the hazards that remain once the mechanical hazards have been listed. [2]

2.5.4 Mechanical Safety at construction industries

Mechanical Safety in construction industries deals with various areas such as excavation, scaffolding, work at height and manual and mechanical material handling equipment (MMHE). Construction safety covers all safety aspects in a construction industry. MMHE safety is a science under research infield of construction machineries, during operation or while assembly and disassembly.[7]

2.5.5 Prevention of access to dangerous Parts of Machinery

Generally, if a piece of work equipment could cause injury when being used in a foreseeable way, it can be considered a dangerous part. Access to dangerous parts of machinery should be prevented and safeguards applied according to a hierarchy of control measures.

The levels of protection (hierarchy of controls) are:

- Fixed enclosed guards.
- Other guards and protection devices, such as interlocked guards and pressure mats.
- Protection appliances, such as jigs, holders and push-sticks.
- The provision of information, instruction, training and supervision.

These safeguards use one of three distinct principles. They:

- Place a physical barrier between a person and the dangerous part.
- Use devices that only allow access while the equipment is in a safe condition.
- Detect a person's presence and stop the machine. [2]

2.5.6 Restricting Use

Use of work equipment should, where necessary, be restricted to competent operators only. This relates to all equipment where risk of serious injury to the operator or to others ("specific risks") exists, e.g. a metal-working lathe.

Repair, modification or maintenance of equipment should be restricted to designated competent people. [2]

2.5.7 Hand-Held Tools and Portable Power Tools

Simple hand tools can cause injury through user error, misuse or mechanical failure.

- Safe use of hand tools requires user training, compliance with safety rules, and routine inspection and maintenance of the tools.
- Portable power tools present greater risks because of the severity of injury that might be caused and the additional hazards presented by each tool.
- Safe use of power tools requires the same basic approach as that for hand tools, but with greater emphasis on user competence, supervision and maintenance, with additional precautions being introduced to combat each of the hazards associated with a tool and its power source. [2]

2.5.8 Hazards of Hand-Held Tools and Requirements for Safe Use

Simple hand tools, such as a hammer, chisel or screwdriver, present relatively simple hazards:

- The tool may shatter during use, throwing off sharp metal
- Fragments (e.g. a hammer head or chisel blade).
- The handle may come loose during use (e.g. an axe head comes off its handle).
- The tool may be blunt leading to use of excessive force which causes loss of control (e.g. blunt knife).
- Simple human error, where the user misjudges a movement (e.g. hits their own thumb with hammer).
- The tool may be misused, i.e. used in an inappropriate way or for an inappropriate task (e.g. a screwdriver used as a crowbar).

Some relatively simple precautions can therefore be applied to ensure safe use of hand tools:

- Tools must be **suitable** for the **task** that they are going to perform and for the **environment** in which they are to be used, e.g. non-sparking tools (which do not produce sparks when struck) are suitable for use in a potentially flammable atmosphere.
- Users should be given appropriate **information**, **instruction** and **training**. many workers serve some form of apprenticeship or spend several years in training where they acquire an understanding of safety in the use of the tools for their trade, but not all workers come to the workplace with
- This knowledge (which may seem like common knowledge to others).
- Tools should be **visually inspected** routinely before use to ensure they are in an acceptable condition. This should be done by the user. Spot checks by line management will ensure that users comply. Substandard tools should be maintained or discarded.
- tools should be **maintained** in a safe condition and be fit for use, e.g. blades should kept sharp and handles firmly attached; chisels should have 'mushroom' heads ground off to prevent metal splinters breaking off when struck.
- **Supervision** is important to ensure that safe working practices are adhered to and misuse does not become commonplace. [2]

2.5.9 Mechanical Material Handling Equipment

Construction machineries and MMHE form basis for majority of construction tasks and hence, safety management with these materials forms an important necessity. The construction equipment cover a variety of machineries such as hydraulic excavators, wheel loaders, backhoe loaders, bull dozers, dump trucks, tippers, graders, pavers, asphalt mix plants, vibratory compactors, cranes, forklifts, dozers, off-highway dumpers, drills, scrapers, motor graders, rope shovels etc. When it comes to handling these equipment, each tools requires a safety procedure and a method of operation. These procedures, on an overall is known as the safety management system at the construction industries.[7]

2.5.10 Tower cranes and lifting operations

Tower cranes with fixed jib are commonly used in building sites. Accidents involving tower cranes as well as mobile cranes are not uncommon. Following the introduction to amendment legislation and code of practice in recent years, coupled with considerable effort in education, training, publicity and certification of workers, the number of fatal accidents has decreased sharply.

The causes of tower crane and mobile crane accidents are quite varied. Most tower crane accidents happened during the erection, climbing (up and down) and dismantling. The term "climbing" with respect to tower cranes is the process whereby an entire crane is raised on or within/outside a structure that is under construction. It generally refers to changing the height (up or down) of fixed tower cranes. Climbing of tower crane is more accident-prone.

Mobile crane accidents are mainly due to overturning, failing of jib as a result of unauthorized assembly or modification of the lattice not according to the manufacturer's specifications or misuse by crane personnel or operator, e.g. using the crane's counterweight instead of a vibrator to pull sheet piles, thus causing the mobile crane to tip forward.

Another common cause is overloading due to unauthorized defeat or alteration of the automatic load sensing device. In March 1999, a newly commissioned heavy-duty truck-mounted hydraulic crane at a marine base suddenly overturned while in operation, leading to the death of a marine police officer

Accidents can happen to mobile cranes engaged in large scale foundation work as a result of collision of jibs resulting in the cranes overturning.

Statutory requirements on tower and mobile cranes are clearly laid down in “The Code of Practice for Safe Use of Mobile Cranes.” and “The Code of Practice for the Safe Use of Tower Cranes” published by the Labor Department. The purpose is to assist duty holders to comply with the provisions of the Construction Sites (Safety) Reguations and the Factories and Industrial Undertakings (Lifting Appliances and Lifting Gear) Regulations. These guides provide guidance on the safe application and operation of mobile cranes and tower cranes to ensure the safety of employees working at or in close proximity to a moving crane.

Apart from the general requirement of a safe system of work which should cater for the safe lifting operation and the safety of non-operators, the Code also provides guidelines regarding the safe distance between the crane in operation and other non-operators in different situations.

The Code addresses in detail the following issues –

- Management of the lifting operation
- Planning of the lifting operation
- Responsibilities/requirements of personnel
- Selection of tower cranes
- Markings and documentation
- Operation features of tower cranes
- Siting of tower cranes
- Erection and dismantling
- Procedures and precautions
- Safe working loads and operating conditions

- Maintenance
- Inspection, examination and testing
- Securing of loads before lifting
- Recommended hand signals
- Frequency of test, thorough examination and inspection of tower cranes under LALGR

Apart from statutory requirement and the Code, the industry has in recent years successfully developed a number of good safety practices to enhance the safe use of tower cranes and lifting operations:

Adjustment and maintenance

For adjustment or maintenance to be performed safely, some improvements have been devised (apart from the standard design by the manufacturer) on access walkways, handholds, footholds, safety lines, or other safeguards as necessary to eliminate the hazard of falling from a crane.

Safety devices and signaling aids.

The development and implementation of additional active systems which prevent cranes from exceeding their safe performance envelope have contributed to significant decreases in the number and severity of crane accidents by minimizing the opportunity for human errors. These safety devices include CCTV, anti-collision device (to prevent overlapping loads and collision of jibs of cranes), wind speed detection device, visual warning devices, audible signals and automatic stops, which operate in relation to rated loads, limit devices, and constant pressure control devices.[8]

2.5.11 Machinery guarding and protection against mechanical hazards

Risk of loss of stability

- Machinery and its components and fittings should be stable enough to avoid overturning, falling or uncontrolled movements during use, transportation, assembly and dismantling.
- If the shape of the machinery itself or its intended installation does not offer sufficient stability, appropriate means of anchorage
- Should be incorporated and indicated in the instructions.

Risk of break-up during operation

- The various parts of machinery and their linkages should be able to withstand the stresses to which they are subject when used.
- The durability of the materials used should be adequate for the nature of the working environment foreseen by the manufacturer, in particular as regards the phenomena of fatigue, ageing, corrosion and abrasion, and the maintenance schedule of the owner.
- The instructions should indicate the type and frequency of inspections and maintenance required for safety reasons. They should, where appropriate, indicate the parts subject to wear and the criteria for replacement.
- Where a risk of rupture or disintegration remains despite the measures taken, the parts concerned should be mounted, positioned and guarded in such a way that any fragments will be contained, preventing hazardous situations.
- Rigid or flexible pipes carrying fluids, particularly those under high pressure, should be able to withstand foreseeable internal and external stresses and should be firmly attached and protected to ensure that no risk is posed by a rupture.

- Where the material to be processed is fed to the tool automatically, the following conditions should be met so as to prevent risks to persons:

  (a) When the work piece comes into contact with the tool, the latter should have attained its normal working condition; and

  (b) When the tool starts and stops (intentionally or accidentally), the feed movement and the tool movement should be coordinated.

Risks due to falling or ejected objects

- Measures should be taken to prevent risks arising from falling or ejected objects.

Risks due to surfaces, edges or angles

- In so far as their purpose allows, parts that are accessible during use and maintenance of the machinery should have no sharp edges, sharp angles or rough surfaces likely to cause injury.

Risks related to moving parts

- Prevention of hazards due to moving parts of machinery should take into account:

  (a) the movement of machinery parts consisting basically of rotary, sliding or reciprocating motion, or a combination of these, such as the movements of spindles, chucks, fan blades, counter-rotating gear wheels or rollers, and stroking blades; and

  (b) the movement of machinery parts which may have the potential to cause injury, for example by entanglement, friction or abrasion, cutting, shearing, stabbing or puncture, impact, crushing, or drawing a person into a position where injury can occur.

- Moving parts of machinery should be designed and con- structed in such a way as to prevent risks of contact which could lead to accidents and should, where risks persist, be fitted with guards or protective devices.

- All necessary steps should be taken to prevent accidental blockage of moving parts involved in the work. If a blockage remains possible despite the precautions taken, the necessary specific protect- ive devices and tools should be provided to enable the equipment to be unblocked safely. The instructions and, where possible, a sign on the machinery should identify these specific protective devices and how they are to be used.

Risks of uncontrolled movements

- When a part of the machinery has been stopped, any drifting away from the stopping position for whatever reason other than action on the control devices should be prevented or should not present a hazard. [9]

2.5.12 Risk Control of Mechanical Hazards

Separation is a simple and effective machinery and equipment risk control and may be achieved by distance, barrier or time.

- Distance separation means a person cannot reach the hazard due to distance.
- Barrier separation means an effective barrier or guard denies access and controls ejection of parts, products or waste.
- Time separation means at the time of access, the machinery and/or equipment is disabled.

Examples of separation include:

- Physical barriers and guards, such as fences, screens or fixed panels of various materials
- Various forms of guarding and interlocking.

- Making the hazard inaccessible by reach (where the distance between a person and the hazard forms an effective barrier).

Note: When considering the suitability of distance guarding, consider the safe access requirements of maintenance people who gain access by ladder, scaffold or elevated work platform.[9]

2.5.13 Guarding

A guard can perform several functions including:

- denying bodily access
- containing ejected parts, tools, off-cuts or swath
- preventing emissions escaping
- Forming part of a safe working platform.

Guarding is commonly used with machinery and equipment to prevent access to:

- rotating end drums of belt conveyors
- moving augers of auger conveyors
- rotating shafts
- moving parts that do not require regular adjustment
- machine transmissions, such as pulley and belt drives, chain drives, exposed drive gears
- any dangerous moving parts, machinery and equipment.[6]

2.5.14 General requirements for guards

Guards and protective devices should protect against danger, including risks from moving parts. They should:

- be of robust construction;
- be securely held in place;
- not give rise to any additional hazard;
- not be easy to bypass or render non-operational, or be easily defeated;

- be located at an adequate distance from the danger zone;
- cause minimum obstruction of the view of the production process; and
- enable essential work to be carried out on the installation and replacement of tools and for maintenance purposes by restricting access exclusively to the area where the work has to be done, if possible without the guard having to be removed or the protective device having to be disabled.

In addition, guards should protect against the ejection or falling of materials or objects and against emissions generated by the machinery. [9]

2.6 Previous Research

2.6.1 Effectiveness of Mechanical Material Handling Equipment Safety in Construction Sites for Operation Safety and Environmental Health

Hariharan Pethaperumal and Nagappan Sivakumar - Department of Chemistry, AMET University, Kanthur Chennai-603112, India.

Safety management systems require highly qualified management and professionals who have sound Knowledge in safety procedures. Improper safety measures lead to accidents which are, uncontrollable occurrences that result in minor or major injury and damage. The construction sites are considered to be a common place of more hazards because of the higher incidence of fatal accidents. To curtail these occurrences, various elements need to be incorporated in the modern construction machinery such as equipment, resource allocation, and overall management. This paper studies and analyses safety management in the construction sites through means of safety survey, interviews with different level of employees and accident data analysis with specific reference to the mechanical material handling equipment and recommendations are suggested for enhancing the overall safety in the construction sites. The results are then statistically tested for significance through a ‘t’ test analysis.[7]

2.6.2 Accidents of Electrical and Mechanical Works for Public Sector Projects in Hong Kong

Francis K. W. Wong [1], Albert P.C. Chan [1], Andy K. D. Wong [1], Carol K. H. Hon [2] and Tracy N. Y. Choi [1,*]

10 Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China; francis.wong@polyu.edu.hk (F.K.W.W.); albert.chan@polyu.edu.hk (A.P.C.C.); andy.wong@polyu.edu.hk (A.K.D.W.)

11 School of Civil Engineering and Built Environment, Queensland University of Technology, 2 George St., Brisbane, QLD 4001, Australia; carol.hon@qut.edu.au

* Correspondence: bsnychoi@polyu.edu.hk; Tel.: +852-2766-4309

Received: 17 January 2018; Accepted: 6 March 2018; Published: 10 March 2018

A study on electrical and mechanical (E&M) works-related accidents for public sector projects provided the opportunity to gain a better understanding of the causes of accidents by analyzing the circumstances of all E&M works accidents. The research aims to examine accidents of E&M works which happened in public sector projects. A total of 421 E&M works-related accidents in the “Public Works Programme Construction Site Safety and Environmental Statistics” (PCSES) system were extracted for analysis. Two-step cluster analysis was conducted to classify the E&M accidents into different groups. The results identified three E&M accidents groups: (1) electricians with over 15 years of experience were prone to ‘fall of person from height’; (2) electricians with zero to five years of experience were prone to ‘slip, trip or fall on same level’; (3) air-conditioning workers with zero to five years of experience were prone to multiple types of accidents. Practical measures were recommended for each specific cluster group to avoid recurrence of similar accidents. The accident analysis would be vital for industry practitioners to enhance the safety performance of public sector projects.

This study contributes to filling the knowledge gap of how and why E&M accidents occur and promulgating preventive measures for E&M accidents which have been under researched. [10]

2.6.3 Investigating the Electrical and Mechanical Safety in Construction

12 Francis K.W. WONG, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China (email: francis.wong@polyu.edu.hk)
13 Albert P.C. CHAN, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China (email: albert.chan@polyu.edu.hk)
14 Andy K.D. WONG, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China (email: andy.wong@polyu.edu.hk)
15 Carol K.H. HON, Queensland University of Technology (QUT), Brisbane, Australia. (email: carol.hon@qut.edu.au)
16 Tracy N.Y. CHOI, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China (email: bsnychoi@polyu.edu.hk)

Electrical and Mechanical (E&M) installations are indispensable to any construction projects. In the light of number of workers and companies involved, E&M works play an important role in the construction industry. The objectives of this study are to reveal causes of accidents of E&M works and provide recommendations to improve safety and health of E&M practitioners. A systematic approach with multidisciplinary inputs will lead to the formulation of a series of holistic and practical measures. An investigation in “WiseNews”, a comprehensive newspaper search engine, shows that there were at least 60 E&M works related fatal cases between 1998 and 2014 in Hong Kong. Fatalities due to fall of person from height and contact with electricity account for over 70 % of all occupational fatalities in electrical and mechanical installations. The study also found that the proportion of occupational fatalities due to fall of person from height is occurred more frequently in air-conditioning installation trade. Focus group meetings with frontline workers and experts will identify the root causes of the E&M accidents. Structured interviews will solicit views of different stakeholders to formulate safety preventive measures. NVivo, which is a software package that supports qualitative and mixed methods research will be used to analyse the qualitative data obtained from the interviews. A questionnaire survey will validate and prioritize the causes of accidents and strategies for improving E&M safety. The proposed study will be useful in improving the safety performance of E&M practitioners in Hong Kong.[11]

2.6.4 Mechanical Safety and Survivability of Buildings and Building Structures under Different Loading Types and Impacts

Vladimir Travusha, Sergey Emelianovb, Vitaly Kolchunovb, Alexey Bulgakovb*

"GOROPROEKT, st. Academician Tupolev 15, build. 15, off 5, Moscow, 105005, Russia b Southwest State University, St. 50 let Oktyabrya 94, Kursk, 305040, Russia

Modem construction sites are characterized by rapid pace and complicated organization of work processes. One of the important problems of a construction site is the human safety. The paper contains a categorization of human hazards during construction activities and an analysis of main causes of accidents in buildings and at construction sites. Together with general definitions of safety the paper reviews some new research trends in the field of mechanical safety and structural survivability of buildings and structures under different loads and impacts, including regular and accidental types of loading. It is shown that up-dating of safety regulations should mean not only the clarification of new terminology adopted in building codes and regulations on structural safety, but also supplementation of the regulations with sufficiently justified and experimentally verified provisions that should regulate the safety of buildings and structures under design and beyond-design basis loads and actions.[12]

Chapter Three
Study methodology and procedures

3.1 Introduction:

In this chapter, the researcher will show the methods and procedures that he followed in determining the study and sample community and explain the practical steps and procedures that he followed in building and describing the study tools, then explaining the study plan, its design and its variables, and finally indicating the types of statistical tests that were used in the study.

3.2 Description of the questionnaire:

The researcher attached with the questionnaire a letter to the respondents in which he enlightened the subject of the study, its purpose, the purpose of the questionnaire, and the contents of the questionnaire. The questionnaire contains two main sections:

The first section: It includes the personal data of the study sample individuals, as it contains data (What is the job title for you in the company? How many years has the company been in the construction field? How many years have you been in the construction field? – Age - Academic degree – Employment - Professional class)

The second section: In this section, the researcher presents the practical procedures of the field study, data analysis and test axes based on the questions below that represent the essence of the research:

- There is a significant lack of safety awareness among E&M labor and technician
- Accelerate E&M project deadline increasing the accidents
- Commitment to safety roles reduced the probability of potential hazard during work execution
- Following E&M safety procedure reduce project cost

This section contains a number (22) phrases that are analyzed according to the five Likert scale that consists of five levels (Strongly Agree - Agree – Neutral - Disagree - Strongly Disagree). These phrases were distributed on four axes as follows:

The first axis includes (7) phrases.

The second axis includes (5) phrases.

The third axis includes (5) phrases.

The fourth axis includes (5) phrases.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5	4	3	2	1

Table (3.1) Five Liker Scale

3.3 Curriculum:

In spite of the multiplicity of approaches used in studies and scientific research, the researcher adopted the descriptive survey approach, which is based on collecting data related to the subject of the study with a view to describing, analyzing and interpreting it, in addition to revealing the relationships that link them and some independent variables to reach appropriate generalizations, and this is appropriate for such Kind of studies.

3.4 Study Population:

The study community consists of a number of owners, contractors, consultants and engineers from different companies limited to Khartoum State.

- Sudan Pile for roads and bridges.
- Talant International Limited.
- Serial for roads and bridges.
- White horse.

N	Statement	Response
1	Total questionnaires distributed to respondents	60
2	Total questionnaire returned	60
3	Questionnaires not retrieved	0
4	Total questionnaires used	60
5	Response rate	%100

Source: Researcher preparation from field study data 2020.

Table (3.2) Response Rate

The researcher was keen on the diversity of the viewing units and that this diversity in the characteristics of the respondents related to their opinions.

3.5 Stability and Validity of Study Tool:

A- Statistical reliability and honesty:

The stability of the test is intended to give the scale the same results if it is used more than once under similar conditions, and the stability also means that if a test is applied to a group of individuals and the scores of each of them are monitored then the same test is applied again to the same group and the same scores are obtained The test is completely consistent.

Stability is also defined as the degree of accuracy and consistency of the measurements obtained, which the test measures. Among the most commonly used methods for estimating stability of measurement are:

1- Halftone division method using the Spearman-Brown equation.

2- The Alpha-Cronbach equation.

3- How to re-apply the test.

4- Equivalent method.

5- Gutman's equation.

As for honesty, it is a measure that is used to know the degree of honesty of the respondents through their answers on a specific scale, and it calculates honesty in many ways that are easier, as it represents the square islands of the coefficient of stability.

The value of both honesty and consistency ranges between zero and the correct one, and measuring the honesty is knowing the validity of the tool to measure what was set for it.

The researcher used the alpha coefficient method to test the stability of the answers to the questionnaire paragraphs, as this parameter measures the internal stability of the questionnaire paragraphs and its ability to give consistent results to the respondents' responses to the questionnaire paragraphs. The value of the alpha coefficient ranges between (0 - 100%) and is statistically acceptable if it exceeds 60 % Then the tool is stable and we can generalize the results.

The researcher selected a random sample from the total sample size in order to test the stability and reliability scale. (15) were selected from the total sample and the test was performed before and after, and the following table shows the reliability test of the study hypotheses:

Honesty and reliability coefficient of samples (before):

	Number	Percent
Experimental sample	15	100%
Total	15	100%

Table (3.3) Cronbach's alpha coefficient for stability of all questionnaire expressions

Number of questions	**Cronbach's alpha**
22	0.901

Source: Preparing the researcher using the questionnaire 2020.

(3.4) Cronbach's alpha coefficient (Before)

The researcher notes through the above table that the accuracy of the questionnaire (901.), i.e. at a rate of 90%, that is, the questionnaire has a high stability factor and this is what achieves the purposes of the research and makes the statistical analysis acceptable.

As for the reliability and reliability coefficient of the same samples (dimension):

Number of questions	**Cronbach's alpha**
22	0.901

Source: Preparing the researcher using the questionnaire 2020.

(3.5) Cronbach's alpha coefficient (After)

The researcher notes through the above table that the accuracy of the questionnaire (0.901), that is, at a rate of 90%, that is, the questionnaire has a high stability factor when re-testing the same respondents, and this is what achieves the purposes of the research and makes the statistical analysis acceptable.

3.6 Statistical Methods Used:

The SPSS program was used to statistically package SPSS, which is known in Arabic as the Statistical Package for Social Sciences. The statistical methods used in data analysis are:

A - Cronbach's alpha for the validity and reliability test of questionnaire questions used in data collection.

B - Repetitions and percentages to describe the study members and determine the proportions of their answers to the questionnaire phrases.

A - The mean is used to describe the data, i.e. to describe the direction of the respondents towards the phrase, is it negative or positive for the phrase? If the actual mean is greater than the hypothetical mean (3), this means that the direction of the respondents' answers is positive for the phrase, meaning the approval of the phrase.

D - the standard deviation to indicate the efficiency of the arithmetic mean in the representation of the data center.

E - T-Test for one sample This test is used to examine a hypothesis related to the arithmetic mean, and to identify the general feature of the phenomenon under study.

F- The T test for the two independent samples is an examination of a hypothesis related to the equality of a variable variable for two independent samples, and it has two forms, the first in the case of the assumption that the variance of the two samples is equal, and the other in the case of the assumption that the variance of the two samples is not equal. To use this variable, each of the sample items must have a value on two variables. The first is called the aggregation variable, and it is the variable that divides the total sample into two non-overlapping sub-samples, such as the gender variable that divides the sample into a male and female sample. The second one is called the test variable) or the dependent variable ..

G- Monochromatic Variation Test (P). It is a way to test the significance of the difference between the averages of several samples with one comparison. It is also known as a method that leads to dividing the total differences for a group of experimental observations for several parts to identify the source of the difference between them.

H- Pyrosen correlation coefficient to know the relationship between the variables

K - degrees of freedom, which are the options that were answered by the respondents minus one and are used in reading the tabular values of the specified test.

L- A square test, such as any measure of the extent to which the observed frequencies are approaching or moving away from the expected frequencies, i.e. the difference between the obtained frequencies and the expected frequencies.

.We get a square test like any according to the following equation:

$$x^2 = \sum_{i=1}^{n} \frac{(O_i - E)^2}{Ei}$$

O_i // obtained duplicate viewing

Ei // Expected frequencies from the study

$\sum_{i=1}^{n}$ //: represents the Chi square and is called x squared.

n //The number of respondents

i // 1. 2. 3. 4. 5

The probabilistic value is that which determines whether there are statistically significant differences between the expected frequencies and the observed frequencies, by comparing the probability value with a significant level (5%) and if it is less than (5%), this indicates that there are differences between the observed frequencies and the expected repetitions.

$$\text{Hypothetical mean} = \frac{\text{sum of weights}}{\text{Number}} = \frac{5 + 4 + 3 + 2 + 1}{5} = 3$$

The purpose of calculating the hypothetical mean is to compare it with the actual mathematical mean of the phrase, so if the actual mathematical mean of the phrase is less than the hypothetical mean, this indicates the lack of consent of the respondents to the phrase, but if the actual calculation mean exceeds the hypothetical mean, this indicates the consent of the respondents to the phrase.

Chapter Four

View and Analyze Study Data

4.1 Analysis Personal Data:

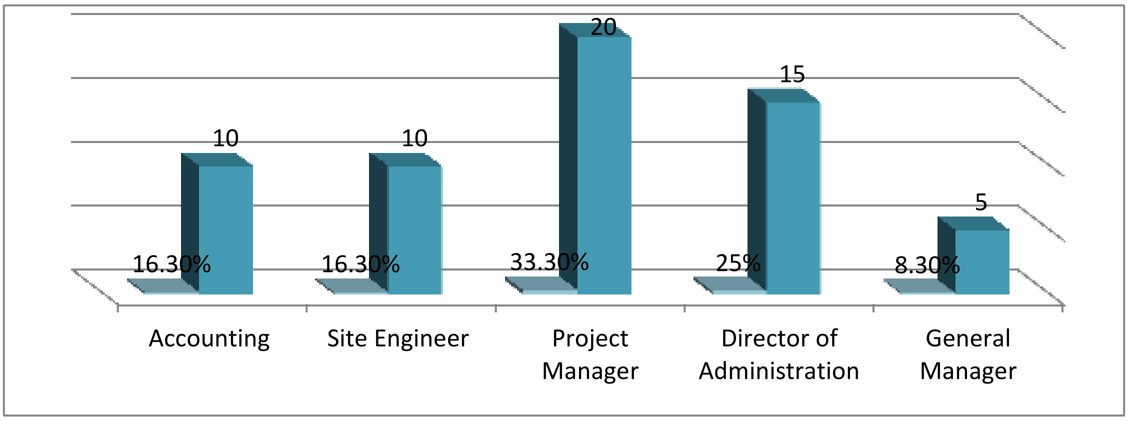
Section One: Distribution of sample properties:

First: The respondents were distributed according to the what is your job title in the company

Variable	Frequency	Percentage
General Manager	5	8.3%
Director of Administration	15	25%
Project Manager	20	33.3%
Site Engineer	10	16.3%
Accounting	10	16.3%
Total	**60**	**100%**

Source: Preparing the researcher based on the questionnaire 2020.

Table No (4.1) what is your job title in the company



Source: Preparing the researcher based on the above table.

Figure No: (4.1) what is your job title in the company

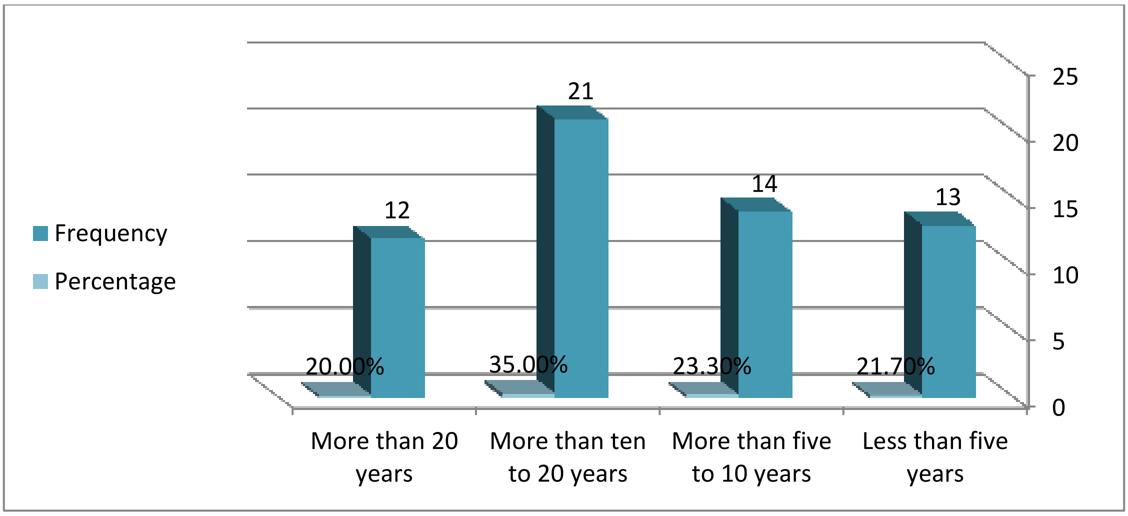
From the table and graph above, the researcher notes that 8.3% was General Manager, 25% director of administration, 33.3% was project manager, 16.3% was site engineer and 16.3% was accounting.

Second: The respondents were distributed according to the how many years the company has been in the construction field

Variable	Frequency	Percentage
Less than five years	13	21.7%
More than five to 10 years	14	23.3%
More than ten to 20 years	21	35.0%
More than 20 years	12	20.0%
Total	**60**	**100%**

Source: Preparing the researcher based on the questionnaire 2020.

Table No (4.2) How many years has the company been in the construction field



Source: Preparing the researcher based on the above table.

Figure No: (4.2) how many years the company has been in the construction field

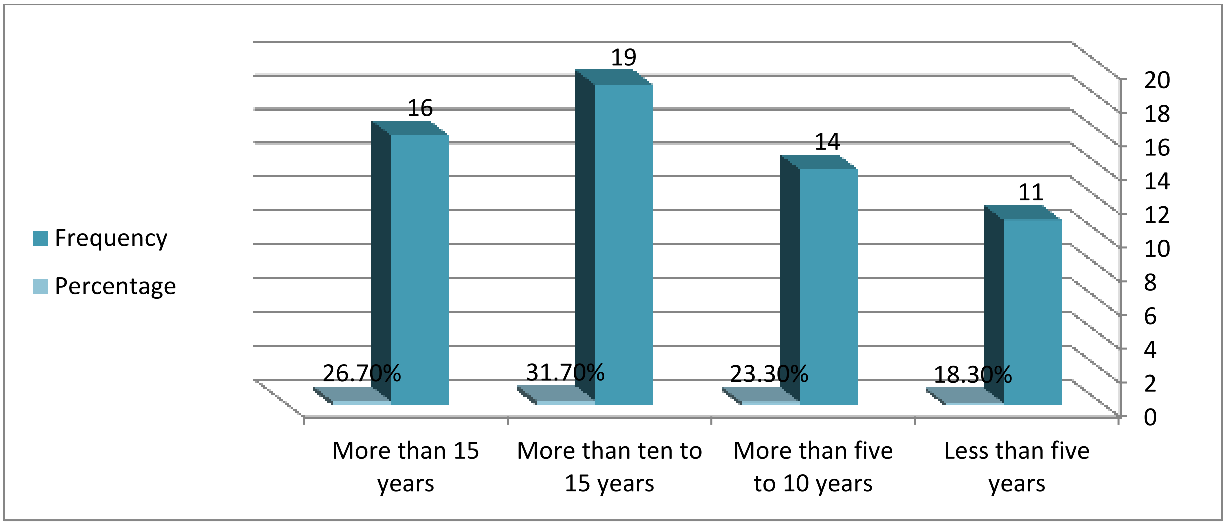
From the table and graph above, the researcher notes that 21.7% answered less than five years, 23.3% more than five to ten years, 35% more than ten to 20 years and 20% more than 20years.

Third: The respondents were distributed according to the how many years you have been in the construction field

Variable	Frequency	Percentage
Less than five years	11	18.3%
More than five to 10 years	14	23.3%
More than ten to 15 years	19	31.7%
More than 15 years	16	26.7%
Total	**60**	**100%**

Source: Preparing the researcher based on the questionnaire 2020.

Table No (4.3) How many years have you been in the construction field



Source: Preparing the researcher based on the above table.

Figure No: (4.3) How many years have you been in the construction field

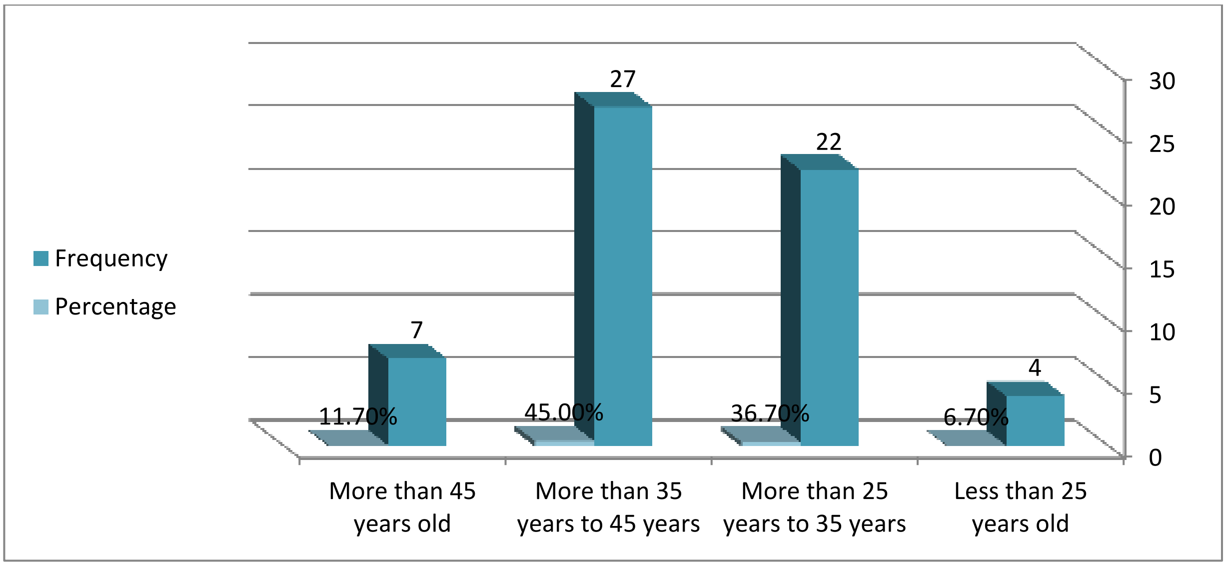
From the table and graph above, the researcher notes that 18.3% answered less than five years, 23.3% more than five to 10 years, 31.7% more than ten to 15 years and 26.7% more than 15 years.

Fourth: The respondents were distributed according to Age

Variable	Frequency	Percentage
Less than 25 years old	4	6.7%
More than 25 years to 35 years	22	36.7%
More than 35 years to 45 years	27	45.0%
More than 45 years old	7	11.7%
Total	**60**	**100%**

Source: Preparing the researcher based on the questionnaire 2020.

Table No (4.4) Age



Source: Preparing the researcher based on the above table.

Figure No: (4.4) Age

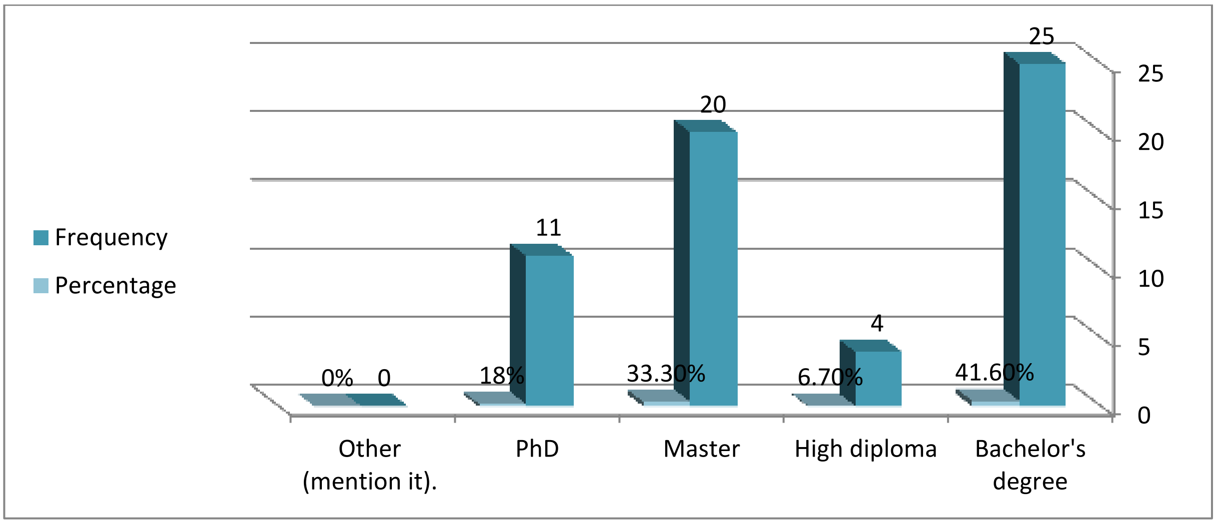
From the table and graph above, the researcher notes that 6.7% was less than 25 years old, 36.7% more than 25 to 35 years, 45% more than 35 to 45 years and 11.7% more than 45 years old.

Fifth: The respondents were distributed according to the Academic degree

Variable	Frequency	Percentage
Bachelor's degree	25	41.6%
High diploma	4	6.7%
Master	20	33.3%
PhD	11	18.4%
Other (mention it).	0	0%
Total	**60**	**100%**

Source: Preparing the researcher based on the questionnaire 2020.

Table No (4.5) Academic degree



Source: Preparing the researcher based on the above table.

Figure No: (4.5) Academic degree

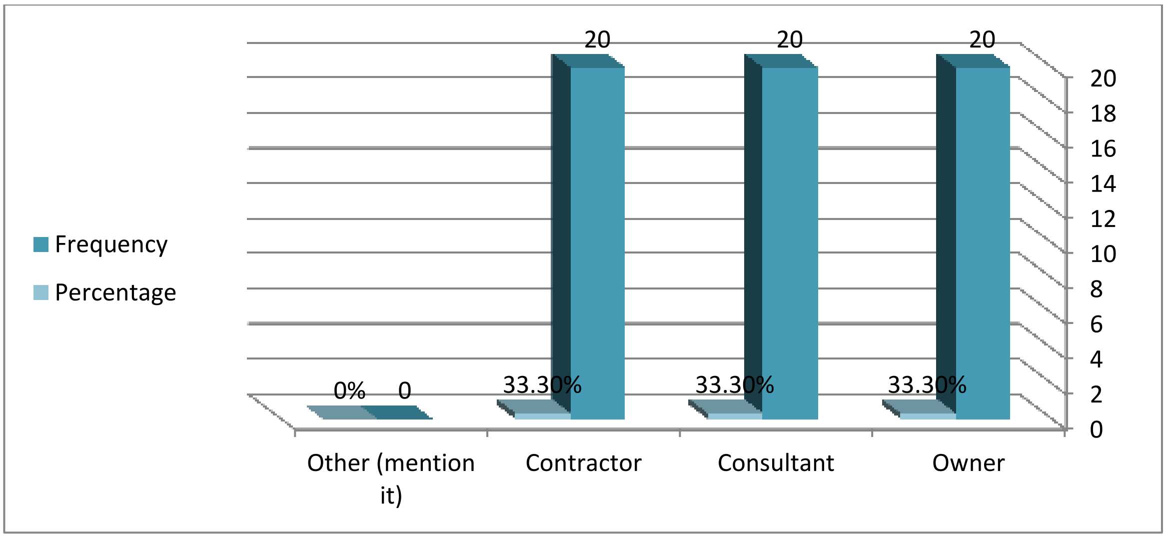
From the table and graph above, the researcher notes that 41.6% academic degree was Bachelor's degree, 6.7% high diploma, 33.3% master and 18.4% was Ph.D.

Sixth: The respondents were distributed according to The field of work

Variable	Frequency	Percentage
Owner	20	33.3%
Consultant	20	33.3%
Contractor	20	33.3%
Other (mention it)	0	0%
Total	**60**	**100%**

Source: Preparing the researcher based on the questionnaire 2020.

Table No (4.6) the field of work



Source: Preparing the researcher based on the above table.

Figure No: (4.6) the field of work

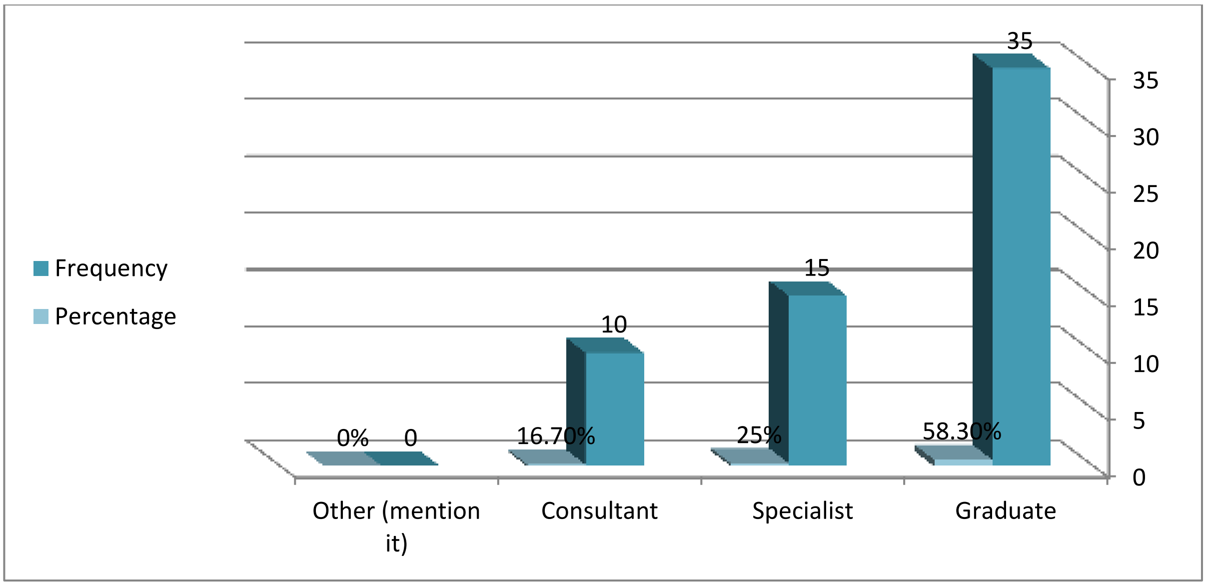
From the table and graph above, the researcher notes that 33.3% they field of work was owner, 33.3% consultant and 33.3% contractor.

Seventh: The respondents were distributed according to the Professional class

Variable	Frequency	Percentage
Graduate	35	58.3%
Specialist	15	25%
Consultant	10	16.7%
Other (mention it)	0	0%
Total	**60**	**100%**

Source: Preparing the researcher based on the questionnaire 2020.

Table No (4.7) the Professional class



Source: Preparing the researcher based on the above table.

Figure No: (4.7) the professional class

From the table and graph above, the researcher notes that 58.3% they professional class was graduate, 25% specialist and 16.7% consultant.

Section Two: Hypothesis

The first hypothesis: There is a significant lack of safety awareness among E&M labor and technician.

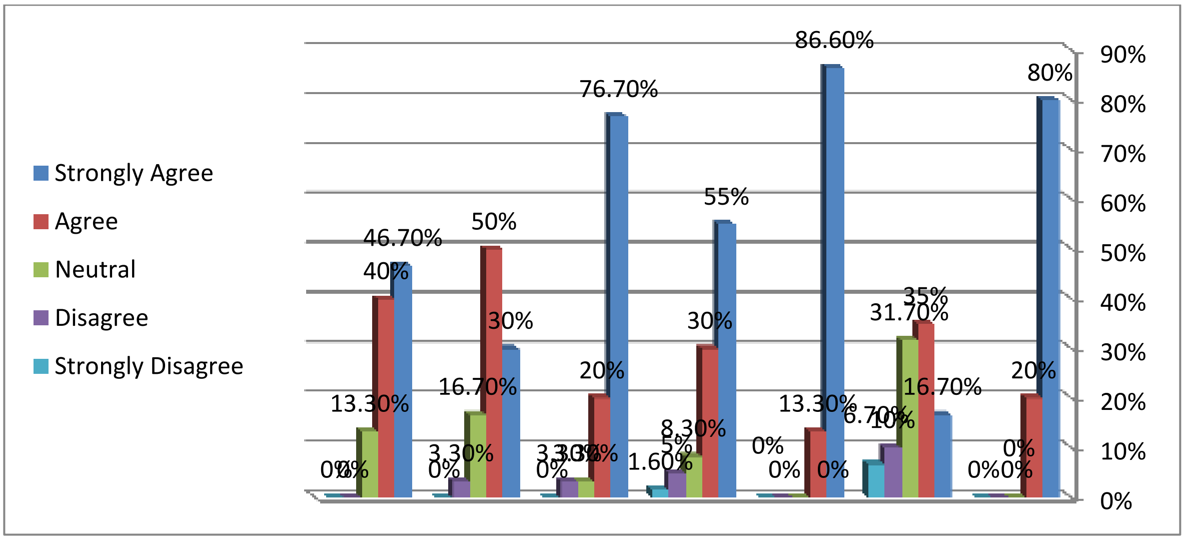
The primary goal of this section is to choose the research assumption that says (**There is a significant lack of safety awareness among E&M labor and technician**) to achieve this goal, queries were gathered from the respondents about their perceptions and the answers were limited to (Agree - Strongly Agree – Neutral – Disagree - Strongly Disagree)

Phrase	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Fr	Total Per%
	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**		
1. I think there is a lack of safety awareness training among E&M technician and labor	48	**80%**	12	**20%**	0	**0%**	0	**0%**	0	**0%**	60	**100%**
2. E&M technician and labor attend safety training courses at least one	10	**16.7%**	21	**35%**	19	**31.7%**	6	**10%**	4	**6.7%**	60	**100%**
3. There is a safety officer in all company sites	52	**86.6%**	8	**13.3%**	0	**0%**	0	**0%**	0	**0%**	60	**100%**
4. The company provides safety tools for E&M workers	33	**55%**	18	**30%**	5	**8.3%**	3	**5%**	1	**1.6%**	60	**100%**
5. Electrical and Mechanic	46	**76.7%**	12	**20%**	2	**3.3%**	2	**3.3%**	0	**0%**	60	**100%**

al Workers have an idea of the importance and how to use safety tools												
6. Workers on Site are informed of existing and potential hazards by the safety engineer on a regular basis	18	**30%**	30	**50%**	10	**16.7%**	2	**3.3%**	0	**0%**	60	**100%**
7. E&M technician and labor have knowledge or idea of safety signs on the site	28	**46.7%**	24	**40%**	8	**13.3%**	0	**0%**	0	**0%**	60	**100%**

Source: Preparing the researcher by adopted on the questionnaire 2020.

Table (4.8) iterations and percentages of study sample' answers, of the first axis.



Source: Researcher preparing by using data from the above table 2020.

Figure No. (4.8) study viewing units as per the first hypothesis

Table (4.8) shows the following:

- Phrase (1): I think there is a lack of safety awareness training among E&M technician and labor, the response rate was strongly agreed (100%) and neutral (0%), and strongly disagree (0%).
- Phrase (2): E&M technician and labor attend safety training courses at least one, the response rate was strongly agreed (51.7%) and neutral (31.7%), and strongly disagree (16.6%).
- Phrase (3): There is a safety officer in all company sites, the response rate was strongly agreed (100%) and neutral (0%), and strongly disagree (0%).
- Phrase (4): The company provides safety tools for E&M workers, the response rate was strongly agreed (85%) and neutral (8.3%), and strongly disagree (6.6%).
- Phrase (5): Electrical and Mechanical Workers have an idea of the importance and how to use safety tools, the response rate was strongly agreed (96.7%) and neutral (3.3%), and strongly disagree (0%).
- Phrase (6): Workers on Site are informed of existing and potential hazards by the safety engineer on a regular basis the response rate was strongly agreed (80%) and neutral (16.7%), and strongly disagree (0%).
- Phrase (7): E&M technician and labor have knowledge or idea of safety signs on the site, the response rate was strongly agreed (86.7%) and neutral (13.3%), and strongly disagree (0%).

Hypothesis validation test:

To prove the hypotheses, a measurement was made by the hypothetical or weighted arithmetic mean, to know the extent of the high or low responses of the study members on each of the phrases of the basic study variables, knowing that it is useful in arranging the phrases according to the highest weighted arithmetic mean. And a square quay test to measure the extent to which the observed frequencies are approaching or away from the expected frequencies, i.e. it is the difference between the obtained frequencies and the expected frequencies.

Where the answers of the viewing units were coded at the expense of the Lekart five-point scale, so that it can be easily entered into the computer for statistical analysis according to the following weights:

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5	**4**	**3**	**2**	**1**

Table (4.9) five Likert scale

Calculated weighted mean:

The arithmetic mean is calculated according to the weights given to the respondents' answers, as follows:

Strongly Agree 5

Agree 4

Neutral 3

Disagree 2

Strongly Disagree 1

$$\text{Hypothetical mean} = \frac{\text{sum of weights}}{\text{Number}} = \frac{1 + 2 + 3 + 4 + 5}{5} = 3$$

- If the mean is (3) or more, then the statement supports the hypothesis

- If the mean is less than (3) then the statement does not support the hypothesis

Standard deviation: To know the extent of deviation of study responses of each of the phrases of the study variables, and for each of the main axes of their mean.

The first hypothesis Test:

{There is a significant lack of safety awareness among E&M labor and technician}

Phrase	Std. Deviation	Mean	Chi-Square	Asymp. Sig.
I think there is a lack of safety awareness training among E&M technician and labor	.403380	3.8000	25.216a	0.00
E&M technician and labor attend safety training courses at least one	0.07146	2.0667	37.216a	0.00
There is a safety officer in all company sites	0.12295	3.4000	15.216a	0.00
The company provides safety tools for E&M workers	0.09583	3.4500	82.000C	0.00
Electrical and Mechanical Workers have an idea of the importance and how to use safety tools	1.31956	3.2333	21.600c	0.00
Workers on Site are informed of existing and potential hazards by the safety engineer on a regular basis	0.21567	3.1256	30.000c	0.00
E&M technician and labor have knowledge or idea of safety signs on the site	1.12456	3.1247	19.333a	0.00

Prepared by the researcher according to the questionnaire 2020

Table (4.10) Explain the Descriptive Statistics (mean & Std. & Chi-Square & Asymp. Sig.) For the first hypothesis phrases

From the above table, the researcher notes that the mean of all expressions is greater than the mean arithmetic mean (3).This indicates that the respondents' responses to these statements indicate a positive trend, their approval. The standard deviation of these terms ranges from (0 - 1) and this indicates the homogeneity of respondents' answers to the terms.

And that the value of the significance level is less than the value of the level of significance (0.05) for all the terms of the first hypothesis, which proves the validity of the hypothesis that "

There is a significant lack of safety awareness among E&M labor and technician)

To verify the validity of the hypothesis was used (T) test for the independent sample

Statistics for the first hypothesis

Variable	Frequency	Mean	standard deviation	Standard error
first hypothesis	60	3.19000	.74422	.06463

Table (4.11.1) test (T) for the independent sample

Test value = 0						Variable
95% confidence interval		Means difference	sig	Degree of freedom	T test value	
Upper bound	Lower bound					
3.4130	**2.9670**	**3.19000**	**.000**	**59**	**28.628**	first hypothesis

Prepared by the researcher according to the questionnaire 2020

Table (4.11.2)T test for independent sample of first hypothesis

Table (4.11) shows that the T-test was used where we find the value of T = (28,628). The significance level (0.000) It is less than the hypothetical significance level of 0.05 and this validates the hypothesis that "

There is a significant lack of safety awareness among E&M labor and technician"

Factor	Phrase	Percentage%
1	I think there is a lack of safety awareness training among E&M technician and labor	**100%**
3	There is a safety officer in all company sites	**100%**
5	Electrical and Mechanical Workers have an idea of the importance and how to use safety tools	**96.7%**
7	E&M technician and labor have knowledge or idea of safety signs on the site	**86.7%**
4	The company provides safety tools for E&M workers	**85%**
6	Workers on Site are informed of existing and potential hazards by the safety engineer on a regular basis	**80%**
2	E&M technician and labor attend safety training courses at least one	**51.7%**

Table (4.12) Arranging the statements of the first hypothesis (Rank) in descending order (Important index)

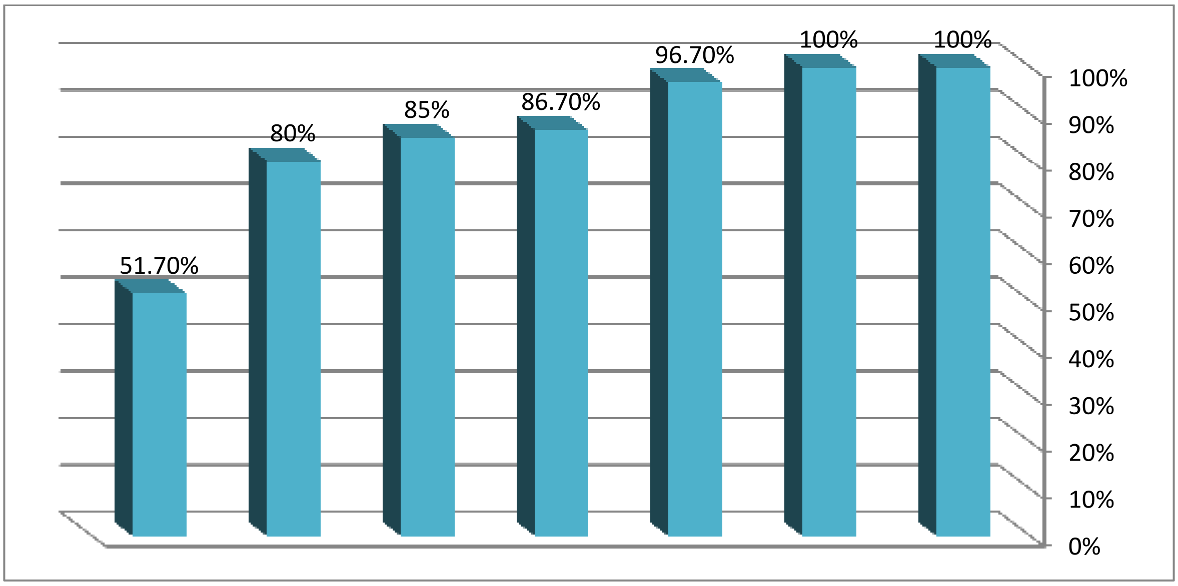


Figure No. (4.9) Arranging the statements of the first hypothesis (Rank) in descending order

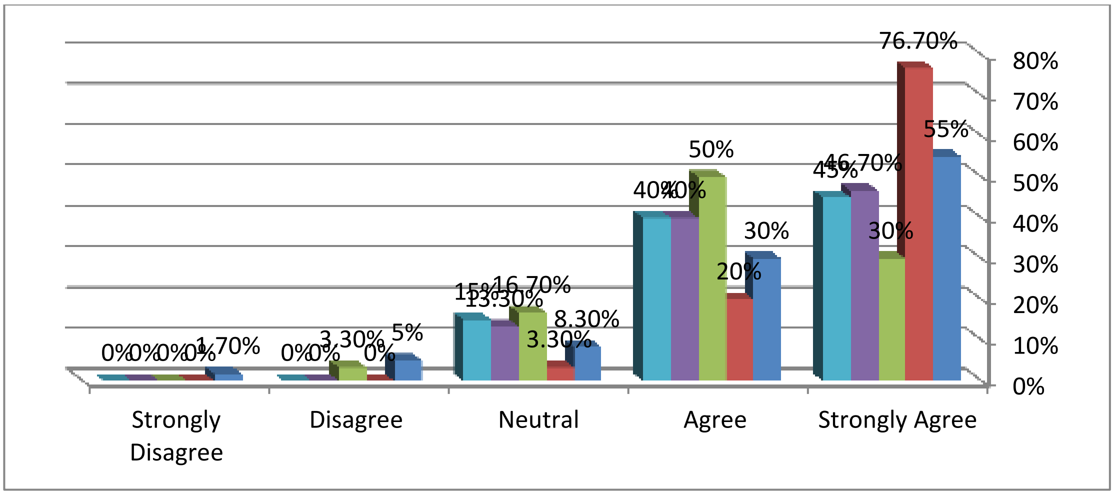
The second hypothesis: Accelerate E&M project deadline increasing the accidents.

The primary goal of this section is to choose the research assumption that says (**Accelerate E&M project deadline increasing the accidents**) to achieve this goal, queries were gathered from the respondents about their perceptions and the answers were limited to (Agree - Strongly Agree – Neutral – Disagree - Strongly Disagree)

Phrase	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Fr	Total Per%
	Fr	Per %	Fr	Per %	Fr	Per %	Fr	Per %	Fr	Per%		
1. I think accelerating E&M project deadline lead to accidents and human errors	**33**	**55%**	**18**	**30%**	**5**	**8.3%**	**3**	**5%**	**1**	**1.7%**	60	**100%**
2. I think accelerating E&M project deadline poses a great risk	**46**	**% 76.7**	**12**	**20%**	**2**	**3.3%**	**0**	**0%**	**0**	**0%**	60	**100%**
3. Accelerating deadline of E&M projects lead to procedures violations to overcome time factor	**18**	**30%**	**30**	**50%**	**10**	**% 16.7**	**2**	**% 3.3**	**0**	**0%**	60	**100%**
4. The Safety engineer directives on site are not complied with if it causes the project delay	**28**	**% 46.7**	**24**	**40%**	**8**	**% 13.3**	**0**	**0%**	**0**	**0%**	60	**100%**
5. Squeezing schedule frequently influence quality and safety	**27**	**45%**	**24**	**40%**	**9**	**15%**	**0**	**0%**	**0**	**0%**	60	**100%**

Source: Preparing the researcher by adopted on the questionnaire 2020.

Table (4.13) iterations and percentages of study sample' answers, of the second axis



Source: Researcher preparing by using data from the above table 2020.

Figure No. (4.10) study viewing units as per the second hypothesis

Table (4.13) shows the following:

- Phrase (1): I think accelerating E&M project deadline lead to accidents and human errors, the response rate was strongly agreed (85%) and neutral (8.3%), and strongly disagree (6.7%).
- Phrase (2): I think accelerating E&M project deadline poses a great risk, the response rate was strongly agreed (96.7%) and neutral (3.3%), and strongly disagree (0%).
- Phrase (3): Accelerating deadline of E&M projects lead to procedures violations to overcome time factor, the response rate was strongly agreed (80%) and neutral (16.7%), and strongly disagree (3.3%).
- Phrase (4): The Safety engineer directives on site are not complied with if it causes the project delay, the response rate was strongly agreed (86.7%) and neutral (13.3%), and strongly disagree (0%).
- Phrase (5): Squeezing schedule frequently influence quality and safety, the response rate was strongly agreed (85%) and neutral (15%), and strongly disagree (0%).

Hypothesis validation test:

The second hypothesis Test: { Accelerate E&M project deadline increasing the accidents }

Phrase	Std. Deviation	Mean	Chi-Square	Asymp. Sig.
I think accelerating E&M project deadline lead to accidents and human errors	.94764	3.3167	60.667	.000
I think accelerating E&M project deadline poses a great risk	.51640	3.7333	53.200	.000
Accelerating deadline of E&M projects lead to procedures violations to overcome time factor	.77824	3.0667	28.533	.000
The Safety engineer directives on site are not complied with if it causes the project delay	.70511	3.3333	11.200	.004
Squeezing schedule frequently influence quality and safety	.72017	3.3000	9.300	.010

Prepared by the researcher according to the questionnaire 2020

Table (4.14) Explain the Descriptive Statistics (mean & Std. & Chi-Square & Asymp. Sig.) For the second hypothesis phrases

From the above table, the researcher notes that the mean of all expressions is greater than the mean arithmetic mean (3).This indicates that the respondents' responses to these statements indicate a positive trend, their approval. The standard deviation of these terms ranges from (0 - 1) and this indicates the homogeneity of respondents' answers to the terms.

And that the value of the significance level is less than the value of the level of significance (0.05) for all the terms of the first hypothesis, which proves the validity of the hypothesis that **"Accelerate E&M project deadline increasing the accidents)**

To verify the validity of the hypothesis was used:

(T) test for the independent sample

Variable	Frequency	Mean	standard deviation	Standard error
second hypothesis	**60**	**4.35556**	**.92341**	**.012841**

Table (4.15.1) Statistics for the second hypothesis

Test value = 0						Variable
95% confidence interval		Means difference	sig	Degree of freedom	T test value	
Upper bound	Lower bound					
4.5175	**4.1936**	**4.35556**	**.000**	**59**	**53.811**	second hypothesis

Prepared by the researcher according to the questionnaire 2020

Table (4.15.2) T test for independent sample of second hypothesis

Table (4.15) shows that the T-test was used where we find the value of T = (**53.811**). The significance level (0.000) It is less than the hypothetical significance level of 0.05 and this validates the hypothesis that" **Accelerate E&M project deadline increasing the accidents** "

No	Phrase	Percentage%
2	I think accelerating E&M project deadline poses a great risk	**96.7%**
4	The Safety engineer directives on site are not complied with if it causes the project delay	**86.7%**
1	I think accelerating E&M project deadline lead to accidents and human errors	**85%**
5	Squeezing schedule frequently influence quality and safety	**85%**
3	Accelerating deadline of E&M projects lead to procedures violations to overcome time factor	**80%**

Table (4.16) Arranging the statements of the second hypothesis (Rank) in descending order (Important index)

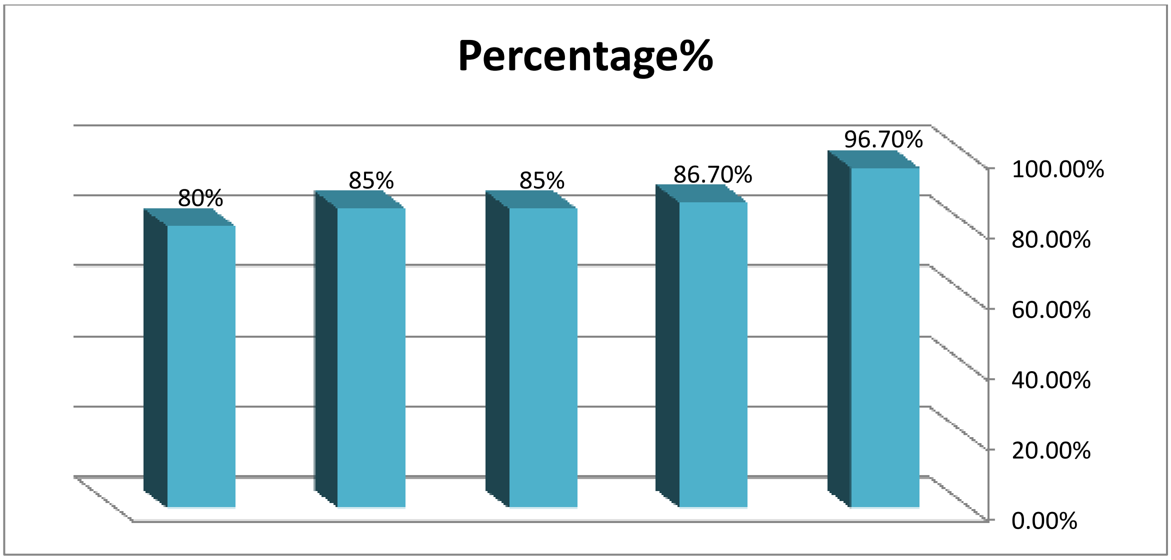


Figure No. (4.11) Arranging the statements of the second hypothesis (Rank) in descending order

The third hypothesis: - Commitment to safety roles reduced the probability of potential hazard during work execution.

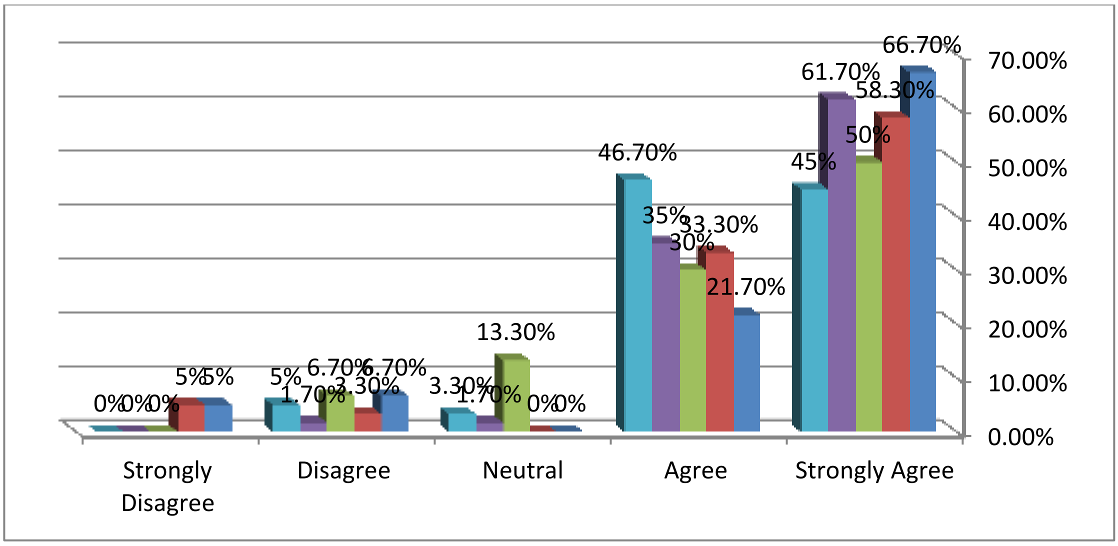
The primary goal of this section is to choose the research assumption that says (**Commitment to safety roles reduced the probability of potential hazard during work execution**) to achieve this goal, queries were gathered from the respondents about their perceptions and the answers were limited to (Agree - Strongly Agree – Neutral – Disagree - Strongly Disagree)

Phrase	**Strongly Agree**		**Agree**		**Neutral**		**Disagree**		**Strongly Disagree**		**Total Fr**	**Total Per%**
	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**		
1. Taking safety roles responsibility reduces potential hazard in work execution	**40**	**66.7%**	**13**	**21.7%**	**0**	**0%**	**4**	**6.7%**	**3**	**5%**	60	**100%**

2.	Clear safety roles accountability reduces potential hazard in work execution	**35**	**58.3%**	**20**	**33.3%**	**0**	**0%**	**2**	**3.3%**	**3**	**5%**	60	**100%**
3.	Providing safety tools and optimum use reduces the possibility of significant risks	**30**	**50%**	**18**	**30%**	**8**	**13.3%**	**4**	**%6.7**	**0**	**0%**	60	**100%**
4.	Raising the efficiency of human resources Reduces potential hazard in work execution on site	**37**	**61.7%**	**21**	**35%**	**1**	**1.7%**	**1**	**1.7%**	**0**	**0%**	60	**100%**
5.	Maintain appropriate work place environment reduces accidents and potential hazard in work execution	**27**	**45%**	**28**	**46.7%**	**2**	**3.3%**	**3**	**5%**	**0**	**0%**	60	**100%**

Source: Preparing the researcher by adopted on the questionnaire 2020.

Table (4.17) iterations and percentages of study sample' answers, of the third axis



Source: Researcher preparing by using data from the above table 2020.

Figure No. (4.12) study viewing units as per the third hypothesis

Table (4-17) shows the following:

- Phrase (1): Taking safety roles responsibility reduces potential hazard in work execution, the response rate was strongly agreed (88.4%) and neutral (0%), and strongly disagree (11.7%).
- Phrase (2): Clear safety roles accountability reduces potential hazard in work execution, the response rate was strongly agreed (91.6%) and neutral (0%), and strongly disagree (8.3%).
- Phrase (3): Providing safety tools and optimum use reduces the possibility of significant risks, the response rate was strongly agreed (80%) and neutral (13.3%), and strongly disagree (6.7%).
- Phrase (4): Raising the efficiency of human resources Reduces potential hazard in work execution on site, the response rate was strongly agreed (96.7%) and neutral (1.7%), and strongly disagree (1.7%).
- Phrase (5): Maintain appropriate work place environment reduces accidents and potential hazard in work execution, the response rate was strongly agreed (91.7%) and neutral (3.3%), and strongly disagree (5%).

Hypothesis validation test:

The third hypothesis Test: {Commitment to safety roles reduced the probability of potential hazard during work execution}

Phrase	Std. Deviation	Mean	Chi-Square	Asymp. Sig.
Taking safety roles responsibility reduces potential hazard in work execution	.14476	3.3833	45.178	.000
Clear safety roles accountability reduces potential hazard in work execution	.13227	3.3667	76.144	.000
Providing safety tools and optimum use reduces the possibility of significant risks	.11971	3.2333	27.132	.000
Raising the efficiency of human resources Reduces potential hazard in work execution on site	.08014	3.5667	71.119	.000
Maintain appropriate work place environment reduces accidents and potential hazard in work execution	.09941	3.3167	41.099	.000

Prepared by the researcher according to the questionnaire 2020

Table (4.18) Explain the Descriptive Statistics (mean & Std. & Chi- Square & Asymp. Sig.) For the third hypothesis phrases

From the above table, the researcher notes that the mean of all expressions is greater than the mean arithmetic mean (3).This indicates that the respondents' responses to these statements indicate a positive trend, their approval. The standard deviation of these terms ranges from (0 - 1) and this indicates the homogeneity of respondents' answers to the terms.

And that the value of the significance level is less than the value of the level of significance (0.05) for all the terms of the first hypothesis, which proves the validity of the hypothesis that " **Commitment to safety roles reduced the probability of potential hazard during work execution)**

To verify the validity of the hypothesis was used: (T) test for the independent sample

Variable	Frequency	Mean	standard deviation	Standard error
Third Hypothesis	**60**	**4.07424**	**.84562**	**.47141**

Table (4.19.2) Statistics for the third hypothesis

Test value = 0						Variable
95% confidence interval		Means difference	sig	Degree of freedom	T test value	
Upper bound	Lower bound					
4.2975	**3.8510**	**4.07424**	**.000**	**59**	**36.514**	Third hypothesis

Prepared by the researcher according to the questionnaire 2020

Table (4.19.2) T test for independent sample of third hypothesis

Table (4-19) shows that the T-test was used where we find the value of T = (**36.514**). The significance level (0.000) It is less than the hypothetical significance level of 0.05 and this validates the hypothesis that" **Commitment to safety roles reduced the probability of potential hazard during work execution** "

No	Phrase	Percentage%
4	Raising the efficiency of human resources Reduces potential hazard in work execution on site	**96.7%**
5	Maintain appropriate work place environment reduces accidents and potential hazard in work execution	**91.7%**
2	Clear safety roles accountability reduces potential hazard in work execution	**91.6%**
1	Taking safety roles responsibility reduces potential hazard in work execution	**88.4%**
3	Providing safety tools and optimum use reduces the possibility of significant risks	**80%**

Table (4.20) Arranging the statements of the third hypothesis (Rank) in descending order (Important index)

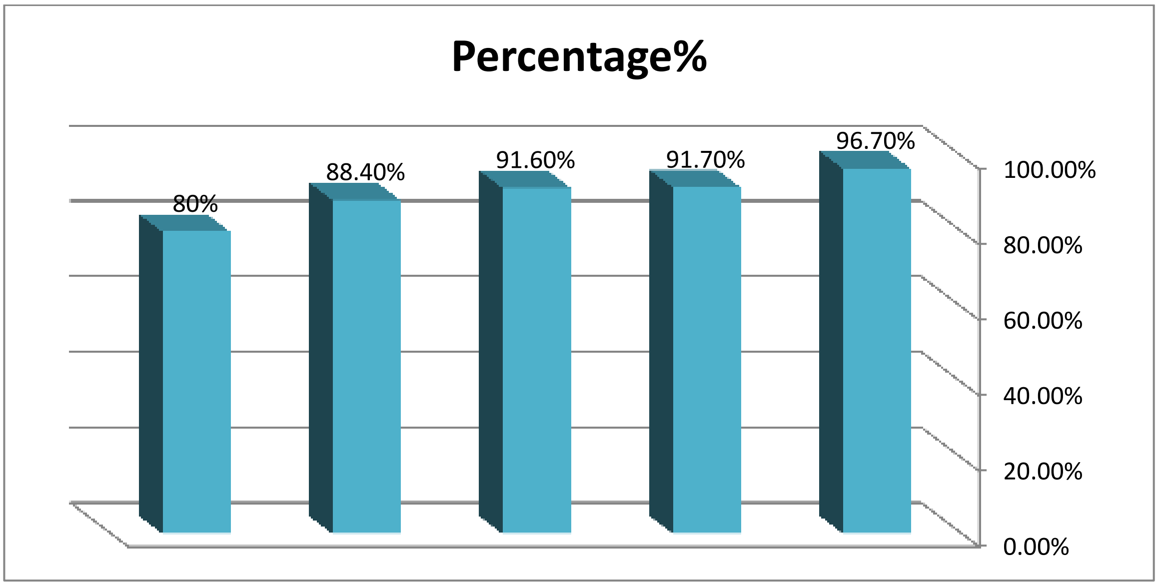


Figure No. (4.13) Arranging the statements of the second hypothesis (Rank) in descending order

The fourth hypothesis: Following E&M Safety Procedure Reduce Project Cost.

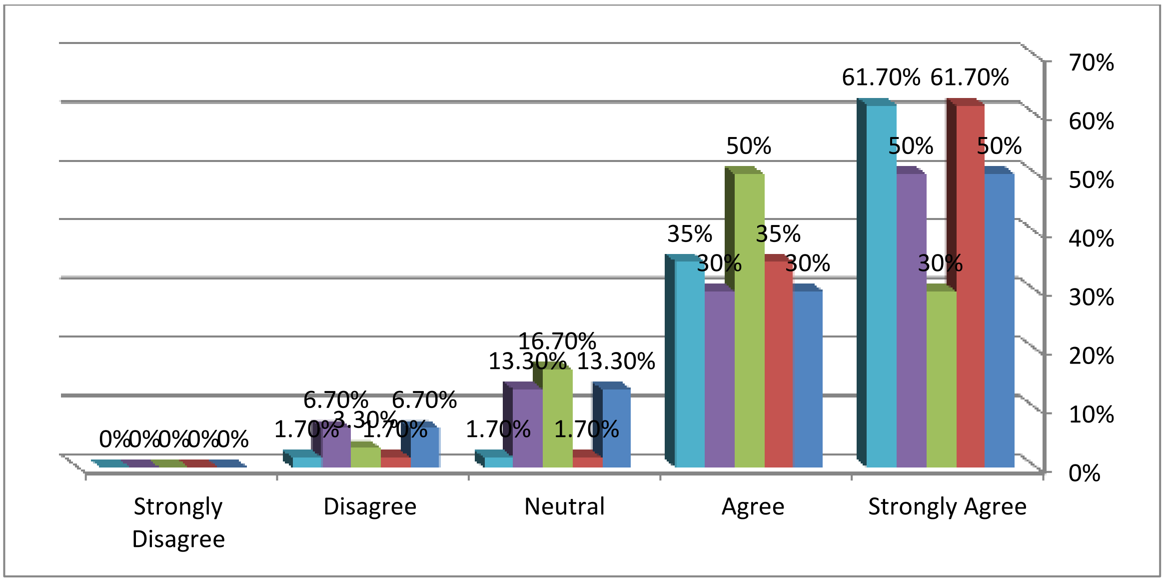
The primary goal of this section is to choose the research assumption that says (**Following E&M Safety Procedure Reduce Project Cost**) to achieve this goal, queries were gathered from the respondents about their perceptions and the answers were limited to (Agree - Strongly Agree – Neutral – Disagree - Strongly Disagree)

Phrase	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Fr	Total Per%
	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**	Fr	**Per%**		
1. Following E&M safety procedure reduce direct project cost	30	**%50**	18	**%30**	8	**%13.3**	4	**%6.7**	0	**0%**	60	**100%**
2. Following E&M safety procedure reduce indirect project cost	37	**%61.7**	21	**%35**	1	**%1.7**	1	**%1.7**	0	**0%**	60	**100%**
3. Improper safety procedures are wasting project resources	**18**	**30%**	**30**	**50%**	**10**	**16.7%**	**2**	**3.3%**	**0**	**0%**	60	**100%**
4. Improper safety procedures	**30**	**50%**	**18**	**30%**	**8**	**13.3%**	**4**	**%6.7**	**0**	**0%**	60	**100%**

increases the cost of reworking the wrong work												
5. Training on safety procedures reduces the high cost of accident	**37**	**61.7%**	**21**	**35%**	**1**	**1.7%**	**1**	**1.7%**	**0**	**0%**	60	**100%**

Source: Preparing the researcher by adopted on the questionnaire 2020.

Table (4-21) iterations and percentages of study sample' answers, of the fourth axis



Source: Researcher preparing by using data from the above table 2020.

Figure No. (4.14) study viewing units as per the fourth hypothesis

Table (4.21) shows the following:

- Phrase (1): Following E&M safety procedure reduce direct project cost, the response rate was strongly agreed (80%) and neutral (13.3%), and strongly disagree (6.7%).

- Phrase (2): Clear safety roles accountability reduces potential hazard in work execution, the response rate was strongly agreed (96.7%) and neutral (1.7%), and strongly disagree (1.7%).
- Phrase (3): Improper safety procedures are wasting project resources, the response rate was strongly agreed (96.7%) and neutral (3.3%), and strongly disagree (0%).
- Phrase (4): Improper safety procedures increases the cost of reworking the wrong work, the response rate was strongly agreed (80%) and neutral (13.3%), and strongly disagree (6.7%).
- Phrase (5): Training on safety procedures reduces the high cost of accident, the response rate was strongly agreed (96.7%) and neutral (1.7%), and strongly disagree (1.7%).

Hypothesis validation test:

The third hypothesis Test: { Following E&M Safety Procedure Reduce Project Cost }

Phrase	Std. Deviation	Mean	Chi-Square	Asymp. Sig.
Following E&M safety procedure reduce direct project cost	.40338	4.8000	21.600	.000
Following E&M safety procedure reduce indirect project cost	.07146	3.0667	30.000	.000
Improper safety procedures are wasting project resources	.12295	3.4000	19.333	.000
Improper safety procedures increases the cost of reworking the wrong work	.09583	3.4500	19.500	.000
Training on safety procedures reduces the high cost of accident	.31956	3.2333	25.667	.000

Prepared by the researcher according to the questionnaire 2020

Table (4.22) Explain the Descriptive Statistics (mean & Std. & Chi-Square & Asymp. Sig.) For the fourth hypothesis phrases

From the above table, the researcher notes that the mean of all expressions is greater than the mean arithmetic mean (3).This indicates that the respondents' responses to these statements indicate a positive trend, their approval. The standard deviation of these terms ranges from (0 - 1) and this indicates the homogeneity of respondents' answers to the terms.

And that the value of the significance level is less than the value of the level of significance (0.05) for all the terms of the first hypothesis, which proves the validity of the hypothesis that **“Following E&M Safety Procedure Reduce Project Cost)**

To verify the validity of the hypothesis was used test (T) for the independent sample

Variable	Frequency	Mean	standard deviation	Standard error
Fourth hypothesis	60	3.0782	.85533	.09563

Table (4.23.1) Statistics for the fourth hypothesis

Test value = 0						Variable
95% confidence interval		Means difference	sig	Degree of freedom	T test value	
Upper bound	Lower bound					
2.2686	1.8879	307821.	.000	59	21.732	Fourth hypothesis

Prepared by the researcher according to the questionnaire 2020

Table (4.23.2) T test for independent sample of fourth hypothesis

Table (4-19) shows that the T-test was used where we find the value of T = (**21.732**). The significance level (0.000) It is less than the hypothetical significance level of 0.05 and this validates the hypothesis that" **Following E&M Safety Procedure Reduce Project Cost** "

No	Phrase	Percentage%
2	Following E&M safety procedure reduce indirect project cost	**96.7%**
3	Improper safety procedures are wasting project resources	**96.7%**
5	Training on safety procedures reduces the high cost of accident	**96.7%**
1	Following E&M safety procedure reduce direct project cost	**80%**
4	Improper safety procedures increases the cost of reworking the wrong work	**80%**

Table (4.24) Arranging the statements of the fourth hypothesis (Rank) in descending order (Important index)

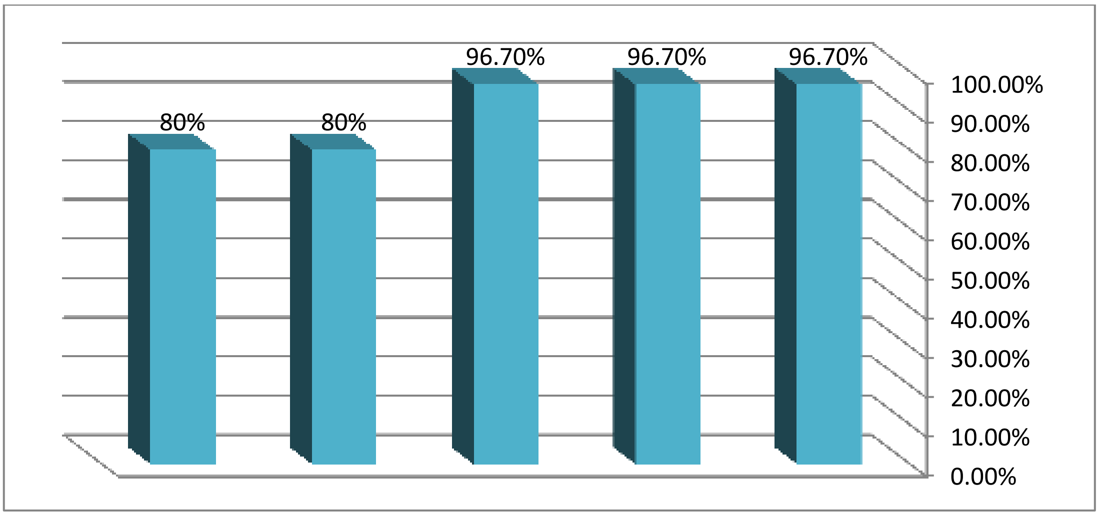


Figure No. (4.15) Arranging the statements of the second hypothesis (Rank) in descending order

Variable	correlation coefficient R2	degree of response
Owner vs consultant	0.968	**very strong**
Owner vs contractor	0.864	**very strong**
consultant vs contractor	0.870	**very strong**

Table (4.25) Spearman Correlation Coefficient to see the relationship between the owner, consultant and contractor:

The correlation test (R2 coefficient) was performed by (SPSS). As shown in the above table, R2 indicates that there is a very good and ideal linear correlation and an ideal linear regression between the owner, consultant, and contractor.

Chapter Five

Finding and recommendations

5.1 Findings:

Through the assumptions that have been tested, it is shown that:

1. There is a significant lack of safety awareness among E&M labor and technician**.**
2. The study confirmed that Accelerate E&M project deadline increasing the accidents.
3. The study confirmed that Commitment to safety roles reduced the probability of potential hazard during work execution.
4. The study confirmed that Following E&M safety procedure reduce project cost.
5. Improper safety procedures are wasting project resources.
6. Training on safety procedures reduces the high cost of accident.
7. There is a lack of safety awareness training among E&M technician and labor.
8. Electrical and Mechanical Workers have an idea of the importance and how to use safety tools.
9. The company should provide safety tools for E&M workers.
10. Workers on Site are informed of existing and potential hazards by the safety engineer on a regular basis.

5.2 General Recommendations:

The study came out with a set of recommendations related to the concept of safety, and the level of safety awareness in projects contain E&M activities, the most important of which are:

1. To plan and execute electrical work safely, there should be adequate information available about the electrical system and the work to be done.
2. Electrical contractors should not work 'live' if it can be avoided nor should they make systems live before they have finished their work and everything has been installed correctly.
3. Society has a sensitivity to the concept of security due to insufficient knowledge of the truth of the concept of security, and they do not have that awareness to differentiate between the concepts of security and safety.

5.3 Future Recommendation

When portable electrical equipment is used on a construction site there are many controls which can be used to reduce the risk of injury from electric shock. Ideally the use of mains voltage should be avoided and replaced by battery-powered tools. If this is not possible, the voltage could be reduced to 110V – if this is generated by a Centre tapped transformer a person can't receive a shock of more than 55V. The use of RC Ds would also reduce the risk of injury by rapidly detecting fault currents and disconnecting from the supply. Where cables are used, these should be armored to provide protection from the harsh environment, and located so as to avoid damage. Equipment should only be used in conditions that it was designed for - suitably robust, industrial equipment should be used rather than domestic equipment, and only suitable equipment should be used in wet conditions.

Users of equipment should be trained to carry out simple visual inspections to detect simple faults before the equipment is used, and instructed when it should be taken out of use. Finally, maintenance should be carried out by competent persons to ensure that equipment, power supplies and cables are maintained in good working order.

REFERENCES

1. Prof. Francis K. W. WONG , Prof. Albert P. C. CHAN , Dr Andy K. D. WONG , Ms. Tracy N. Y. CHOI & Dr Carol K. H. HON Q , ElectricalAnd MechanicalSafety InConstruction (2018) , Construction Industry Council, Hong Kong SAR
2. Dr J Phelpstead, BSc, PhD, CMIOSH , NEBOSH Certificate Unit GC2 (International) Control of International Workplace Hazards, RRC International , RRC Module No: GC2.1 (2013) edition
3. Electrical Safety - Basic Information , Canadian Centre for Occupational Health and Safety (CCOHS) http://www.ccohs.ca/oshanswers/safety_haz/electrical.html
4. 7 Common Electrical Safety Hazards in the Workplace , Safety Culture 2018 , https://safetyculture .com/topics/electrical-hazards
5. General and Minister for Justice and commences , Electrical safety code of practice , Managing electrical risks in the workplace , ESOPDF179 Electrical safety code of practice 2013
6. Office of Industrial Relations -Workplace Health and Safety Queensland, Guide to machinery and equipment safety, PN10596 Version 3 Last updated January (2019) ,www.worksafe.qld.gov.au.
7. Hariharan Pethaperumal and Nagappan Sivakumar,Effectiveness of Mechanical Material Handling Equipment Safety in Construction Sites for Operation Safety and Environmental Health , International Journal of Applied Environmental Sciences(2017) , SN 0973-6077 Volume 12, Number 3, pp. 541-552 ,www.ripublication.com.
8. The Real Estate Developers Association of Hong Kong and The Hong Kong Construction Association, Construction Site Safety Handbook, June 2005

9. International Labour Office Geneva, Safety and health in the use of machinery, International Labour Organization (2013),www.ilo.org/publn
10. Francis K. W. Wong, Albert P. C. Chan, Andy K. D. Wong, Carol K. H. Hon ID and Tracy N. Y. Cho,Accidents of Electrical and Mechanical Works for Public Sector Projects in Hong Kong, International Journal of Environmental Research and Public Health (2018)
11. Francis K.W. WONG,Albert P.C. CHAN,Andy K.D. WONG,Carol K.H. HON and Tracy N.Y. CHOI,Investigating the Electrical and Mechanical Safety in Construction (2015)

APPENDIX