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Hazard Identification and Risk Assessment in Construction Sector

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Abstract: *For any industry, to be successful it should meet not only the production requirements, but also maintain the highest safety standards for all concerned. The industry has to identify the hazards, assess the associated risks and bring the risks to as low as reasonably practicable level on a continuous basis. Construction sector being a potentially-hazardous sector has considerable safety risk to the workers associated with it. Unsafe conditions and practices in the site lead to a number of accidents and causes loss and injury to human lives, damages the property, interrupt developmental aspects etc. Because of the existing hazards of construction as an activity and the complexity of construction machinery and equipment and the associated systems, procedures and methods, it is not possible to be naturally safe. Regardless of how well the machinery or methods are designed, there will always be potential for serious accidents. It is not possible for an external agency to ensure the safety of an organization such as a construction company nor of the machinery or method it uses. The principal responsibility for the safety of any particular construction site and the manner in which it is operated rest with the management of that particular company undertaking the construction activity. Hazard identification and risk assessment involves identification of undesirable events that leads to an incident, the analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects. The objective of hazard and risk assessment is to identify and analyze hazards, the event sequences leading to hazards and the risk of hazardous events. Many techniques ranging from simple qualitative methods to advanced quantitative methods are available to help identify and analyze hazards.*

Keywords: Risk Assessment

I. INTRODUCTION

For any industry to be successful, it should meet not only the production requirements, but also maintain the highest safety standards for all concerned. The industry has to identify the hazards, assess the associated risks and bring the risks to as low as reasonably practicable level on a continuous basis. Construction sector being a potentially-hazardous sector, has considerable safety risk to the workers associated with it. Unsafe conditions and practices at the sites lead to a number of accidents and causes loss and injury to human lives, damages the property, interrupt developmental aspects etc.

Because of the existing hazards of construction as an activity and the complexity of construction machinery and equipment and the associated systems, procedures and methods, it is not possible to be naturally safe. Regardless of how well the machinery or methods are designed, there will always be potential for serious accidents. It is not possible for an external agency to ensure the safety of an organization such as a construction company nor of the machinery or method it uses. The principal responsibility for the safety of any particular construction site and the manner in which it is operated rest with the management of that particular company undertaking the construction activity.

Hazard identification and risk assessment involves identification of undesirable events that leads to an incident, the analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects.

The use of multiple hazard analysis techniques is recommended because each Hazard Identification & Risk Assessment in Construction Sector Department of Fire Tech & Safety Engineering, SKSITS, Indore Page 3 has its own purpose, strengths, and weaknesses. Some of the most commonly used techniques for Risk Assessment include: Failure Modes

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and Effects Analysis (FMEA), Hazard and Operability Studies (HAZOP), Fault-Tree Analysis (FTA), Event-Tree Analysis (ETA) etc.

A Hazard Identification and Risk Assessment (HIRA) is a systematic way to identify and analyze hazards to determine their scope, impact and the vulnerability of the built environment to such hazards and its purpose is to ensure that there is a formal process for hazard identification, risk assessment and control to effectively managed risks that may occur within the workplaces.

To briefly outline the risks associated in the construction industry and also to analyze them in order to come out with safety strategies to make the construction site safe in all aspects. Study of risk assessment methodologies. Application of Hazard Identification and Risk assessment for improvement of workplace safety in construction sector.

Hazard identification and risk analysis (HIRA) is a collective term that encompasses all activities involved in identifying hazards and evaluating risk at facilities, throughout their life cycle, to make certain that risks to employees, the public or the environment are consistently controlled within the organizations risk tolerance level. These studies typically address three main risk questions to a level of detail commensurate with analysis, objective, life cycle stage, available information, and resources.

Others may be willing to tolerate an explosion risk if proper codes and standards are followed. Still there could be some those may be unwilling to accept an explosion risk unless it can be shown that the expected frequency of explosion is less than 10-6/yr. HIRA encompasses the entire spectrum of risk analysis, from qualitative to quantitative. A process hazard analysis (PHA) is a HIRA that meets specific regulatory requirement in the U.S.

Construction is the process of constructing a building or infrastructure. Construction differs from manufacturing typically involves mass production of similar items without a designated purchaser, while construction typically takes place on location for a known client. Construction as an industry comprises 6 to 9 percentage of the Gross Domestic Product (GDP) of developed countries. Construction starts with planning, design and financing and continues until the work is built and ready for use.

II. LITERATURE REVIEW

The following is the brief review of the work carried out by different researchers in the field of hazard identification and risk assessment (HIRA).

- Qureshi (1987) has done a Hazard and Operability Study (HAZOP) in which potential hazards are identified by looking at the design in a dynamic manner
- To identify the nature and scale of the dangerous substances;
- To give an account of the arrangements for safe operation of the installation, for control of serious deviations that could lead to a major accident and for emergency procedures at the site;

Khan and Abbasi (1995) proposed optimal risk analysis (ORA) which involved the following:

1. Hazard identification and screening.
2. Hazard analysis using qualitative hazard assessment by optimal hazard and operability study (opt HAZOP).
3. Probabilistic hazard assessment by modified fault tree analysis (MFTA).
4. Consequence analysis which includes development of accident scenarios and damage potential estimates.
5. Risk estimates.

Carpignano et al. (1998) applied quantitative risk analysis (QRA) for drawing conclusions concerning serious accidental events with the occurrence frequency and the consequences. The QRA approach they selected was based on reservoir analysis and management systems (RAMS) such as Preliminary Hazard Analysis (PHA), Failure Mode Effect and Critical Analysis (FMECA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA) and Cause Consequence Analysis and were able

Lambert et al. (2001) used Hierarchical Holographic Modelling (HHM) for identification and management of risk source and prioritize the identified source of risk based on their likelihood and potential consequences and provided with options of risk management in terms of their costs and potential impacts on the acquisition schedule.

Bell and Glade (2003) have done a risk analysis focusing on risk to life. They calculated land slide risk and occurrence of potential damaging events as well as the distribution of the elements at risk and proposed the following approach for risk evaluation:

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RISK = HAZARD * CONSEQUENCE * ELEMENT OF RISK

Kecojevic and Nor (2009) studied reports on equipment related fatal incidents and showed that underground mining equipment including continuous miners, shuttle cars, roof bolters, LHD"s, longwall and hoisting contributed total of 69 fatalities. The study revealed the major hazards resulting in fatal incidents for continuous mining equipment, shuttle cars, roof bolters, LHD"s and hoisting system were due to failure of victim to respect equipment working area, failure of mechanical component, working under unsupported roof, failure of management to provide safe working conditions, and failure of mechanical components.

Wang et al. (2009) applied HAZOP analysis to determine if the operation has potential to give rise to hazardous situation and found the range of hazardous events. They identified the route by which each of the hazardous events could be realised. After HAZOP analysis they introduced MO-HAZOP program which calculates probability of an event which is the product of probabilities of every factor.

Chapter outline

The literature review findings on construction hazards and safety assessment methods are presented in this chapter. Firstly, the nature of occupational accidents in construction is described, followed by the identification of attributes for assessing hazards in various activities in building projects. Finally, the factors pertinent to safety-rating of building construction projects are explored.

Nature of occupational injuries in construction

Occupational injuries from construction activities in general are classified by Davies and Tomasin (1996) as:

Danger of physical injury and fatality; and Damage to health.

Construction accidents resulting in physical injuries and fatalities can be broadly categorised into the following eight basic groups.

- Falling from heights – involves workers falling from higher floors to lower floors/ground and falling from ground level to excavation level.
- Struck by falling/moving objects/vehicles – primarily involves workers being struck by equipment, private vehicles, falling materials, vertically hoisted materials and horizontally transported materials.
- Excavation related accidents – encompasses accidents due to cave-in, contact with underground utilities, subsiding of nearby structures, falling of materials/vehicles/ objects onto people working in the excavation as well as fumes, gases and inrushes of water at the bottom of excavations.

Assessing project hazards

A list of high hazardous activities in building construction projects for facilitating hazard assessments are as follows:

1. Demolition works;
2. Excavation works;
3. Scaffolding and ladder works;
4. False works (temporary structures);
5. Roof works;
6. Erection of structural frameworks;
7. Crane use;
8. Construction machinery and tools usage;
9. Works on contaminated sites;
10. Welding and cutting works; and
11. Works in confined spaces.

A particular project may have many of these activities and the degree of hazard inherent in each activity is attributed to its risk parameters.

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Demolition hazards

Demolition is one of the high-risk activities of the construction industry with a fatal and major injury incidence rate of about 17 times of that for the whole of the construction industry. Approximately 10% of all fatal accidents each year in the construction field occur in the demolition sector.

Demolition workers face a variety of hazards viz:

- Falling from heights;
- Being hit or trapped by falling objects;
- Excessive noise from hand-held tools, demolition balls, pneumatic drills, explosives and falling parts;
- Vibration from hand-held pneumatic tools;
- Respiratory hazards from dust which may contain toxic constituents such as asbestos and silica;
- Flying particles causing eye and skin injuries; and
- Fires and explosives, especially when demolishing tanks that contained oils or flammable chemicals.

Excavation hazards

Davies and Tomasin (1996) categorised excavations into three types: trenches; basements and wide excavations; and pits/shafts (for pad and pile foundations). They expose workers to similar hazards and accidents. Workers in the underground construction industry, especially water, sewer and utility line companies, have traditionally had a higher accident and injury rate than other workers in the heavy construction industry. According to the OSHA (2002), the fatality rate for excavation works is 112% higher than the rate for general construction. Accidents in excavation works occur in one of the following ways (HSE, 2005):

1. Collapse of sides/cave-in: Cave-in is perhaps the most feared and chief cause of accidents in excavation works. It buries workers and/or cause crushing injuries to survivors.
2. Contact with underground utilities: Works in excavations often encounter obstructions from intersecting utilities lines that may cause injuries and/or fatalities to workers by:

(1) Electrocution and/or explosion when electrical cables and/or gasoline pipes are damaged;
(2) Collapse of excavation due to flooding led by damage to water lines and/or sewer lines;
(3) Drowning in floods from damaged water/sewer lines**.**

Construction machinery and tools hazards

Of all the construction industry fatalities, 18% occur with construction machinery (Helander, 1991). The types of machinery involved in accidents include excavators and shovels, earthmoving equipment (i.e. crawler tractors and bulldozers, scrapers and graders), dumpers and dump trucks, forklift trucks, road rollers and lorries. Accidents in construction machinery usage occur in one of the following modes (Helander, 1991; Davies and Tomasin, 1996):

- Workers being run-over or struck by machinery moving forward or reversing;
- Collision between machinery or with fixed objects such as falseworks or scaffoldings;
- Overturning of machinery while in operation; and
- Workers falling from machinery.

These accidents are caused by the following major factors:

- Failure of machinery- inoperative back-up alarms, brake failures, etc.;
- Inadequate site planning resulting in poor visibility, inadequate man oeuvre space, inadequate signboards and poor site traffic control;
- Lack of supervision and training of workers and operators; and
- Construction noise that masks the sound of back-up alarms and the sound of plant.
- Davies and Tomas in (1996) observed that for 18% of the accidents, the primary external factor was hand-held tools. They are:

(1) Knife;
(2) Hammer, sledge hammer, etc.;
(3) Grinding/cutting machine;
(4) Jack hammer;

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(5) Drill;
(6) Manual saw;
(7) Crowbar, spit, etc.;
(8) Tools for screwing;

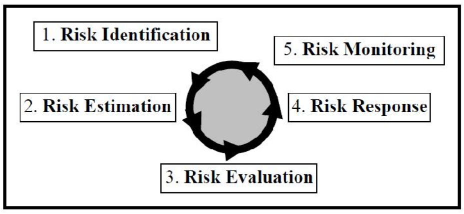
Clarifying Hazards & Risks

The UK Government, like many other countries, delegates the technical control of hazards to those who create them, concentrating their role instead towards policy making and assessment of safety related management systems (Swuste and Arnoldy 2003). Industry's answer is the use of Risk Management processes.

The British Standard BS4884-3:1996, identical to European standards IEC 300-3-9:1995, provides guidelines to risk analysis and defines the following (BSI 1996):

- Harm – physical injury or damage to health, property or the environment.
- Hazard – a source of potential harm or a situation with a potential for harm.
- Hazard identification – the process of recognizing that a hazard exists and defining its characteristics.
- Risk – combination of the frequency, or probability, of occurrence and the consequence of a specified hazardous event.

Examples of Industrial Disciplines, Hazard Groups & Risk Categories, adapted from BS4884-3:1996



Risk Estimation, or the calculation of risk, can be expressed as predicted mortality rates, frequency versus consequence plots and / or expected loss rates. A common method is to determine a risk level by combining the frequency of hazard event with and severity of associated consequences. Assignment of frequency and severity values, in addition to associated weightings, allows the level of risk to be estimated as the product of these two terms e.g.

Severity x Frequency = Risk Level.

Frequency and severity values can be estimated by either qualitative or quantitative methods. Qualitative methods are classified by descriptive arguments, such as a range 'low to high', or enumerated on a predefined scale (Cuny and Lejeune 2003; Smith and Harrison 2005) whilst quantitative examples include:

o Statistical analysis e.g. regression, least squares, path analysis.
o Artificial Intelligence Methods such as Expert Systems.
o Probability Theory.
o Bayesian Inference.

Safety Management

Safety Management exhibits the same processes as described in the RMC model but within this specific setting and includes the systematic application of management policies, procedures and practices to the tasks of analysing, evaluating and controlling safety risks (Papadakis and Amendola 1997). This also includes safety policy, initiatives, programs, training, campaigns, future research etc.

Occupational accidents are never intentional and can occur through risk being unidentified, incorrectly analyzed or the response being ineffective. This section examines hazards and risk within the safety setting, ultimately towards Keeping Bob Safe (see Chapter 1)

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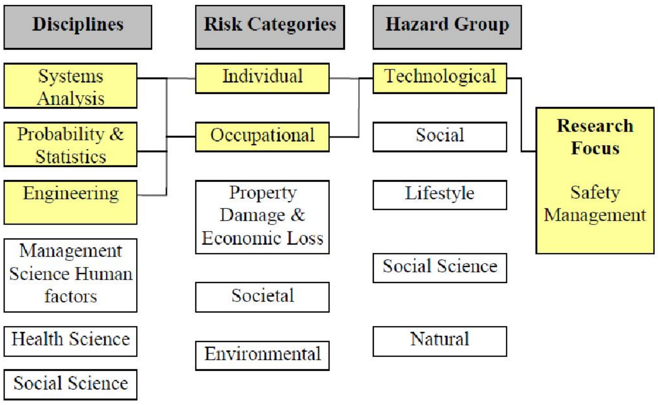

Safety Hazards & Risks

Accidents have been attributed to poor identification of hazards at a high level or inconsideration by those responsible for design, supply and purchase of material and equipment (Alistair et al. 1997). Some examples of hazards identified from previous construction-based research are given below (Alistair et al. 1997):

- Unsafe working conditions at heights.
- Stepping on, striking against or tripping over objects.
- Poor lighting conditions.
- Collapse of working platforms i.e. scaffoldings.
- Lifting operations.
- Electrocution.
- Fire hazards.

It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees."

ALARP is a common term in Industry relating to this statement and is an acronym for 'As Low As Reasonably Practical'.

There is no robust definition of what constitutes 'Reasonably Practical.'. The ALARP threshold level is set retrospectively by courts to reflect social demand which is constantly changing (Rail Safety and Standards Board 2005).

The UK Rail Industry estimates the costs of accidents to be in the region of £1.36M per fatality although the overall cost is closer to £10M when consideration is given to associated costs such as public enquiries, compensation payments, loss of time/earnings, additional management costs and court fines (Rail Safety and Standards Board 2005). The cost of proposed safety initiatives over time is therefore compared to savings in fatalities and where more than one option is available, likefor- like comparison between initiatives can be made. Other factors are often combined in these types of analysis to produce a more coherent estimation of 'valuefor money' comparisons.

Monitoring Tools can be used to enhance the existing safety management policy by flagging up areas of weak safety. This type of system also reduces human and mathematical errors as data is now directly entered by the user and data collection and calculation is now performed by the computer.

In addition to being highly bureaucratic, another downside of these systems is a tendency to become:

- Orphaned if maintenance is not ongoing to ensure validity.
- Scrapped due to inaction of management to correct identified problems.

Some examples of this type of research include:

- The use of incentives and performance assessment to enhance workplace safety (Cooper et al. 1994; McAfee and Winn 1989).
- measuring the effectiveness of safety campaigns and performance of safety objectives using checklists, inspections, attitude surveys, walk-through, and document / record analysis (Haupt 2002).

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Artificial Intelligence methods can be viewed as a 'black box' where the user's inputs and factors are processed to give the end solution. These systems can require sophisticated modelling techniques (neural networks etc) and rely on training sets based on:

• Past occurrences transposed from original documents into the programming language. These are reliant on a large knowledge base with ongoing maintenance, monitoring and re-evaluation of the system

• Recording, interpreting, coding and transposing the conversation and methodology of experts the as they solve a given problem

Workers Risk Assessments

The Transportation Industry relies heavily on qualitative risk assessments to ensure the safety of its work force. This is due to lack of time and resources needed to collect and process quantitative data. The majority of these risk assessments are based on technical factors, however individual organisational and / or cultural issues should also be considered such as financial constraints or political pressures.

Examples of these risk factors in a construction setting include:

• Technical and socio-technical systems (Annet and Stanton 2000; Harms- Ringdahl. 2001)

• The influence of 'Risk Factors' such as operator actions, site conditions and construction practices and 'Managerial Processes' towards accidents in construction (Suraji et al. 2001).

III. RISK ASSESSMENT

Risk assessment is the process used to determine likelihood that people may be exposed to an injury, illness or disease in the workplace arising from any situation identified during the hazard identification process prior to consideration or implementation of control measures.

Risk occurs when a person is exposed to a hazardous situation. Risk is the likelihood that exposure to a hazard will lead to an injury or a health issue. It is a measure of the probability and potential severity of harm or loss.

Risk assessment forms crucial early phase in the disaster management planning cycle and is essential in determining what disaster mitigation measures should be taken to reduce future losses. Any attempt to reduce the impact of disaster requires an analysis that indicates what threats exist, their expected severity, who or what they may affect, and why. Knowledge of what makes a person or a community more vulnerable than another added to the resources and capacities available determines the steps we can take to reduce their risk.

Risk assessment is carried out in series of related activities which builds up a picture of the hazards and vulnerabilities which explain disaster events.

DIFFERENT TERMINOLOGIES ASSOCIATED WITH RISK ASSESSMENT

Following are some of the important terminologies involved in hazard identification and risk analysis:

- **Harm**: Physical injury or damage to the health of peoples either directly or indirectly as a result of damage to property or to the environment.
- **Hazard:** Hazard is a situation that poses a level of threat to life, health, property or environment. Most hazards are dormant with only a theoretical risk of harm however once a hazard becomes active it can create emergency situation.
- **Hazardous situation:** A circumstance in which a person is exposed to a hazard
- **Tolerable risk:** Risk which is accepted in a given context based on the current values of society Protective measure: The combination of risk reduction strategies taken to achieve at least the tolerable risk. Protective measures include risk reduction by inherent safety, protective devices, and personal protective equipment, information for use and installation and training.
- **Severity:** Severity is used for the degree of something undesirable.

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Different Forms of Injury

• Serious Bodily Injury means any injury which involves the permanent loss of any part or section of the body or the permanent loss of sight or hearing or any permanent physical incapability or the facture of any bone or one or more joint or bone of any phalanges of hand or foot.

• Reportable Injury means any injury other than any serious bodily injury, which involves the enforced absence of injured person from work for a period of 72 hours or more.

TYPES OF HAZARD IDENTIFICATION AND RISK ANALYSIS

There are three types of hazard identification and risk assessments: Baseline Hazard Identification and Risk Analysis; Issue-based Hazard Identification and Risk Analysis; and Continuous Hazard Identification and Risk Analysis.

They are all inter-related and form an integral part of a management system. A brief description of each of the three types of Hazard Identification and Risk Analysis is given below:

Baseline Hazard Identification and Risk Analysis

The purpose of conducting a baseline HIRA is to establish a risk profile or setoff risk profiles. It is used to prioritize action programs for issue-based risk assessments.

Issue-based Hazard Identification and Risk Analysis

The purpose of conducting an issue-based HIRA is to conduct a detailed assessment study that will result in the development of action plans for the treatment of significant risk.

Continuous Hazard Identification and Risk Analysis

The purpose of conducting continuous Hazard Identification and Risk Analysis is to:

Identify Operational health and safety hazards with the purpose of immediately treating significant risks Gather information to feed back to issue-based Hazard Identification and Risk Analysis Gather information to feed back to baseline Hazard Identification and Risk Analysis.

IV. THE INTER-RELATIONSHIP BETWEEN TYPES OF HIRA

The relationship between the different types of HIRA is as illustrated in Figure 4.2. The figure illustrates

1. Risk profiles are used for planning the issue-based HIRA action programmed.
2. Provides clear guiding principles for compatibility so that the issue-based HIRA and continuous HIRA are more effective enabling continuous improvement.
3. Codes of practice, standard procedures and management instructions etc. and new information from issue-based HIRA can be used to improve on the continuous HIRA and update the baseline HIRA so that it remains comprehensive.
4. The issue-based HIRA and baseline HIRA draw from the data captured by the continuous HIRA process to be effective.
5. The risk management process serves management.

Steps in Risk Assessment

Step 1 Hazard Identification

The purpose of hazard identification is to identify and develop a list of hazards for each job in the organization that are reasonably likely to expose people to injury, illness or disease if not effectively controlled. Workers can then be informed of these hazards and controls put in place to protect workers prior to them being exposed to the actual hazard.

Step 2 Risk Assessment

Risk assessment is the process used to determine the likelihood that people exposed to injury, illness or disease in the workplace arising from any situation identified during the hazard identification process prior to consideration or implementation of control measures.

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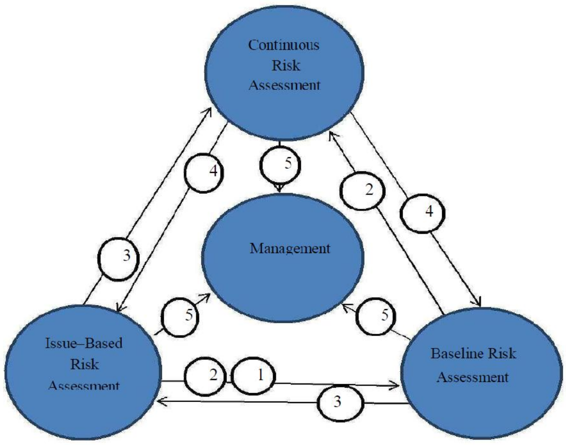

Risk occurs when a person is exposed to a hazard. Risk is the likelihood that exposure to a hazard will lead to injury or health issues. It is a measure of probability and potential severity of harm or loss.

Step 3 Risk Control

Risk control is the process used to identify, develop, implement and continually review all practicable measures for eliminating or reducing the likelihood of an injury, illness or diseases in the workplace.

Step 4: Implementation of risk controls

All hazards that have been assessed should be dealt in order of priority in one or more of the following hierarchy of controls

The most effective methods of control are:

1.Elimination of hazards

2.Substitute something safer

3.Use engineering/design controls

4.Use administrative controls such as safe work procedures

5.Protect the workers i.e. By ensuring competence through supervision and training, etc.

Each measure must have a designated person and date assigned for the implementation of controls. This ensures that all required safety measures will be completed.

Step 5: Monitor and Review

Hazard identification, risk assessment and control are an on-going process. Therefore regularly review the effectiveness of your hazard assessment and control measures. Make sure that you undertake a hazard and risk assessment when there is change to the workplace including when work systems, tools, machinery or equipment changes. Provide additional supervision when the new employees with reduced skill levels or knowledge are introduced to the workplace.

Safety assessment attributes

The following are the safety attributes under each safety aspect which has to be evaluated in any construction site depending upon the magnitude of the risks involved to life and surrounding property.

1. Project safety organization

Competency and duties of:

1. Workplace safety and health coordinator
2. Workplace safety and health auditor
3. Workplace safety and health committee

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2. Risk assessments and management

Risk management system with:

1. Risk assessment team and responsibilities
2. Risk assessment procedures
3. Reporting procedures to workers of identified risks
4. Control measures for risks identified

3. Safe work practices

Work procedures for:

1. Concrete works
2. Structural steel and pre-cast assembly
3. Erection and dismantling of scaffolds and false works
4. Works at heights
5. Demolition works
6. Excavation works
7. Piling operations
8. Welding and cutting works
9. Works in confined spaces
10. Works in toxic/contaminated environments
11. Use of construction plant such as excavators, trucks, etc.
12. Use of cranes
13. Electrical installation and use

Permit-to-work (PTW) system for:

1. Working at heights
2. Excavation works
3. Working in confined spaces
4. Welding and cutting works
5. Demolition works
6. Working in toxic/contaminated environments

Personal protective equipment (PPE) for:

1. Concrete works
2. Structural steel and pre-cast assembly
3. Erection and dismantling of scaffolds and false works
4. Works at heights
5. Demolition works
6. Excavation works
7. Piling operations
8. Welding and cutting works
9. Works in confined spaces
10. Works in toxic/contaminated environments
11. Use of construction plant such as excavators, trucks, etc.
12. Use of cranes
13. Electrical installation and use

4. Safety training and competency of people involved

Certification and safety training of:

1. Crane erector(s)

2. Crane operator(s)
3. Riggers(s)
4. Signal men
5. Scaffold erector(s) and/or suspended scaffold rigger(s)
6. Erectors of hoists and lifts
7. Operators of hoists and lifts
8. Operators of plant like excavators, bull dozer, etc.
9. Construction vehicle drivers

Safety training to:

1. Demolition supervisor(s)
2. Excavation supervisors(s)
3. Piling supervisor(s)
4. Lifting supervisor(s)
5. Scaffold and/or suspended scaffold supervisor(s)
6. False work supervisor(s)
7. Welding and cutting supervisor(s)
8. Confined space work supervisor(s)
9. Toxic/contaminated environment work supervisor(s)
10. Project management team members

In-house safety training to workers on:

1. Site rules & regulations and proper use of PPE
2. Emergency responses for various possible incidents
3. First aid procedures
4. Safe handling of tools and equipment
5. Safety inspection system

Inspection of:

1. Excavation by a competent person on a daily basis and after hazardous events (e.g. inclement weather)
2. Scaffoldings by a scaffold supervisor on a weekly basis and after inclement weather
3. False works by a PE or other competent person before, during and after casting and after inclement weather
4. Demolition by a competent person on a daily basis and after inclement weather
5. Material loading platform by a competent person on a regular basis and after inclement weather
6. Temporary structures such as site office, canteen, site hoardings and concrete batching plant on a regular basis
7. Specialized structures or operations like use of customized shoring system by a competent person
8. General site by a safety personnel or site manager

Housekeeping of:

1. Construction worksite
2. Workers' quarters
3. Toilets and washing facilities
4. Canteen or eating places
5. Site offices
6. Storages for materials, tools & wastes

7. Machinery and tools use and maintenance regime

Test certificates for:

1. Lifting gears (12 monthly)

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2. Lifting appliances (12 monthly)
3. Lifting machines (12 monthly)
4. Hoists and lifts (6 monthly)
5. Air receivers (24 monthly)
6. Explosive power tools (36 monthly)

Inspection of:
1. Cranes by crane operators on a daily basis
2. Electrical distribution board by a competent person on a daily basis
3. Electrical equipment and tools by operators or a competent person on a regular basis (weekly/more frequent)
4. Construction vehicles like trucks, forklift, bull dozer, etc. by drivers or a designated person on a daily basis
5. Temporary electrical installation by a licensed electrical worker
6. Specialized equipment by a competent person

Knowledge Management

The idea that knowledge is the most valuable source of competitive advantage has been widely considered for years, becoming an economic resource more important than oil, steel, or any of the products of the Industrial Age (Liaw 2005).

The actual definition of 'what knowledge is' can result in a socio-philosophical debate well outside the scope of this thesis. However, in simple terms knowledge is gained through trying to understand the context of information within our society and experiences, in conjunction with the way in which we individually view the world.

Information can be categorised into three strict definitions; structured (drawings or plans), semi-structured (written documents) and non-structured information dialogues and sketches (Gardoni et al. 2005). Many researchers have theorized definitions of 'knowledge' as:

• The advanced stage of information and hence requires interpretation, processing and constructs to form knowledge (Liaw 2005).

• Information in context, together with an understanding of how to find it and how to use it (Nonaka 1994).

V. EXPERIMENT

This chapter presents case studies on Construction safety , risk assessment and management in RANJIT BUILDCON LIMITED, which are used to illustrate the developed risk assessment and management methodology, including an evaluation of important safety risks using the many methods which have been incorporated into the model. The case study materials were collected from the particular in projects site of the RANJIT BUILDCON LIMITED. The results of the safety risk assessment are safety risk scores for overall project, hazard groups, hazardous events, and types of safety risk with a confidence percentage.

Hazards in Construction and their analysis Construction sites are dangerous places where injury or death or illness can cause to workers. These can happen due to electrocution, falling from height, injuries from tools, equipment and machines; being hit by moving construction vehicles, injuries from manual handling operations, illness due to hazardous substance such as dust, chemicals, .etc. Even a nail standing up from a discarded piece of wood can cause serious injury if trodden on in unsuitable shoes. In context to Indian scenario: The construction is the second largest economic activity in India after agriculture which is maintained at the first level.

It has accounted for around 40% of the development investment, during the past 50 years. Around 16% of India's working population depends on construction for its livelihood. The Indian construction industry employs over 35 million people and creates assets worth over Rs.200 billion. Construction accounts for nearly 65% of the total investment in infrastructure. Investment in construction accounts for nearly 11% of India's GDP. The market size of the construction industry for the 12th Five Year Plan period indicate that the aggregate output of the industry during the period 2012-13 to 2014-17 is likely to be 52.31 lakh crores.

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There are a number of Indian regulations dealing with the working conditions of construction workers. The main Indian regulations are: Building & Other Construction Workers (Regulation of Employment and Conditions of Services) Act, 1996. Building & Other Construction Workers (Regulation of Employment and Conditions of Services) Central Rules, 1998. Building & Other Construction Workers Welfare Cess Act, 1996.

SITE PREPARATIONS : Preparation of a construction site is an important aspect which should focus on a good site layout, easy access to the site and easy movement of vehicles in the site.

Site Layout: A badly planned and untidy construction site can lead to many accidents at construction sites, which may arise from:

(i) fall of materials,

(ii) collision between the workers,

(iii) plant or equipment.

To avoid the above causes of accidents, a good layout of the site is a must. While preparing the site layout, at-most care should be taken to avoid overcrowding the site. Also enough space should be provided for the movement of men, material and construction equipment within the site.

SITE OPERATIONS: The type of operations/ activities carried out in a construction site are many (See Fig.01) and they vary from site to site. However, all of them should be carried out only with due regard to safe operations. Some of the routine work/operations carried out in construction sites are listed below:

- Excavation Work
- Scaffolding Work
- Crane Operations
- Hoisting Operations
- Forklift Operations
- Ladder Safety
- Electrical Safety

Excavation Work: Excavation work is an important activity in the construction sites. However, many fatal accidents do occur in excavation work, if proper precautions are not taken. Many lives are lost being buried alive in the trenches. It should be remembered here that there is no safe ground that will not collapse and therefore, any trench sites can collapse without any warning.

They are safer and turn out good quality work. Of course, the steel scaffolds are too costly, but, it would be cheaper in the long run. In spite of the fact that the steel scaffolds are much safer, many of the smaller and medium size builders in India, neglect the safety aspects and prefer to use timber or bamboo scaffolds (See Fig.02) in order to cut the cost. In any case, while erecting the scaffolds, the workers should be forced to wear necessary safety belts with fall arrestors and helmets, so that the fall accidents can be avoided.

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Crane Operations: Various type of cranes are used in construction sites, which includes (i) Portable Cranes (See Fig.03) (ii) Tower Cranes (Sig Fig.04). A number of accidents are reported in the use of cranes, and many of them could be averted by adopting safe methods of operations. Some of the methods to be adopted for safe crane operations are given below:

- The weight of the load intended to be lifted by the crane must be carefully estimated.
- The crane must be fitted with an automatic safe load indicator.
- The crane must always work on a hard, level base.
- The load must be properly fixed and secured.
- The signal man must be trained to give clear signals.
- The ropes, hooks, chains, slings, etc. used in the lifting operations, must be inspected regularly for their worn out.
- When mobile cranes are used, care must be taken to prevent overturning of cranes.
- Wear appropriate personal protective equipment.

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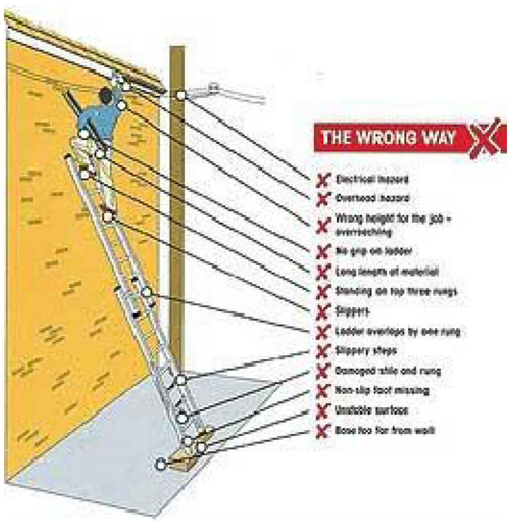
Hoisting Operations: Hoists are used to move heavy objects and equipment. The Fig. 05 shows various parts of hoists. As the hoists consists of various components, failure of any one component can lead to disastrous accidents. Therefore these components should be inspected daily.

The thumb rule is: if there is any doubt about the working conditions of a hoist, do not use it. The hoist inspections should cover the following aspects:

(i) The hooks on all blocks, including snatch blocks, must have properly working safety latches,
(ii) All hooks on hoisting equipment should be free of cracks and damage,
(iii) The maximum load capacity for the hoist must be noted on the equipment,
(iv) Electric cables and wiring should be intact and free of damages.

Ladder Safety: Ladders are one of the most popular item used in the construction sites for working at heights. However, if not used safely, it can kill a lot of people. The Fig.07 & Fig.08 will depict the wrong and right way of using the ladders. The following safe methods should be adopted while operating ladders:

- Always have a firm grip on the ladder and keep a good balance.
- Never allow more than one person on a ladder.
- Use tool belts or hand line to carry objects when you are climbing the ladder.
- Do not lean out from the ladder in any direction.
- If you have a fear of heights – don't climb a ladder.
- Do not allow others to work under a ladder in use.
- Do not use a defective ladder.



Wrong way of using a ladder

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Right way of using a ladder

Electrical Safety: Electricity can cause great damage to both people working in the construction sites and property. Contact with the electric current can trigger other accidents, like falls from ladders or scaffolding.

If the workers find a fault or malfunctioning piece of equipment, they should take it out of operation, and make the necessary arrangements to have the equipment repaired. Make sure that the workers at the construction site understand the importance of electrical safety and recognize, that abusing or misusing electrical equipment is an invitation to an accident.

VI. TYPES OF HEALTH AND SAFETY HAZARDS ON CONSTRUCTION SITE

- Height
- Slips and trips
- Equipment, machinery, tools and transport
- Electricity
- Fire
- Manual handling
- Noise
- Chemical substance
- Dust

BASIC CONCEPTS:

Risk:

Risk is something that we as individuals live with on a day-to-day basis. People are constantly making decisions based on risk. Simple decision in daily life such as driving, crossing the road and money investment all imply an acceptance risk. Risk is the combination of the likelihood and severity of a specified hazardous event occurring.

In mathematical term, risk can be calculated by the equation -

Risk = Likelihood x Severity

Where, Likelihood is an event likely to occur within the specific period or in specified circumstances and, Severity is outcome from an event such as severity of injury or health of people, or damage to property, or insult to environment, or any combination of those caused by the event.

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VII. PLANNING AND CONDUCTING OF HIRA

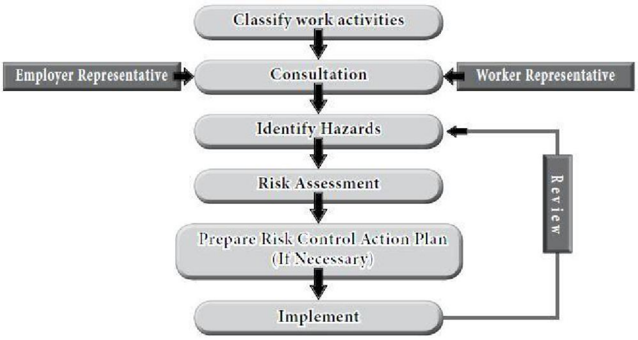
The purpose of HIRA are as follows:-

- To identify all the factors that may cause harm to employees and others (the hazards);
- To consider what the chances are of that harm actually be falling anyone in the circumstances of a particular case and the possible severity that could come from it (the risks); and
- To enable employers to plan, introduce and monitor preventive measures to ensure that the risks are adequately controlled at all times.

HIRA activities shall be plan and conducted.

Process of HIRA requires 4 simple steps:

- Classify work activities;
- Identify hazard;
- Conduct risk assessment (analyze and estimate risk from each hazard), by calculating or estimating -
- Likelihood of occurrence, and Severity of hazard;
- Decide if risk is tolerable and apply control measures (if necessary).
- Flow chart for HIRA process



Classify work activities:

Classify work activities in accordance with their similarity, such as :

- Geographical or physical areas within/outside premises;
- Stages in production/service process;
- Not too big e.g. building a car;
- Not too small e.g. fixing a nut; or
- Defined task e.g. loading, packing, mixing, fixing the door.

VIII. HAZARD IDENTIFICATION

The purpose of hazard identification is to highlight the critical operations of tasks, that is, those tasks posing significant risks to the health and safety of employees as well as highlighting those hazards pertaining to certain equipment due to energy sources, working conditions or activities performed. Hazards can be divided into three main groups, health hazards, safety hazards, and environmental hazards**.**

Health hazards:

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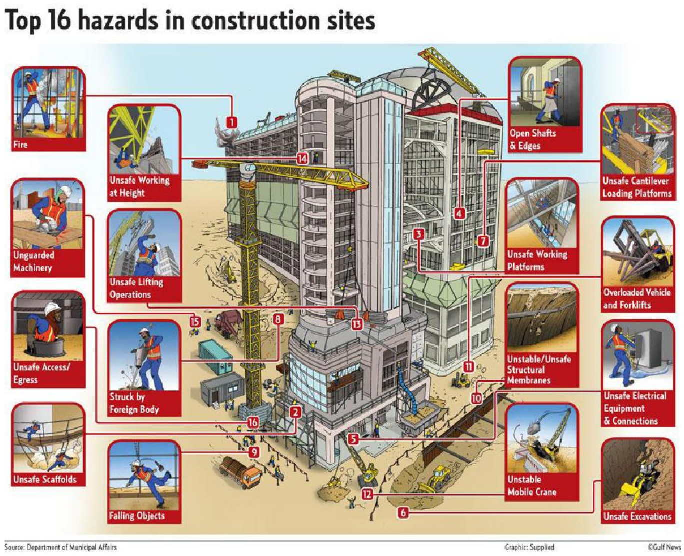
An occupational health hazard is any agent that can cause illness to an individual. A health hazard may produce serious and immediate (acute) affects, or may cause long-term (chronic) problems. All or part of the body may be affected. Someone with an occupational illness may not recognize the symptoms immediately. For example, noise-induced hearing loss is often difficult for the affected individual to detect until it is well advanced. Health hazards include chemicals (such as battery acid and solvents), biological hazards (such as bacteria, viruses, dusts and molds), physical agents (energy sources strong enough to harm the body, such as electric currents, heat, light, vibration, noise and radiation) and work design (ergonomic) hazards.

Safety hazards:



A safety hazard is any force strong enough to cause injury, or damage to property. An injury caused by a safety hazard is usually obvious. For example, a worker may be badly cut. Safety hazards cause harm when workplace controls are not adequate.

Some examples of safety hazards include, but are not limited to:

- Slipping/tripping hazards (such as wires run across floors);
- Fire hazards (from flammable materials);
- Moving parts of machinery, tools and equipment (such as pinch and nip points);
- Work at height (such as work done on scaffolds);
- Ejection of material (such as from molding);
- Pressure systems (such as steam boilers and pipes);
- Vehicles (such as forklifts and trucks);
- Lifting and other manual handling operations; and Working alone.

Environmental hazards:

Figure - Environmental Hazard

An environmental hazard is a release to the environment that may cause harm or deleterious effects. An environmental release may not be obvious. For example, a worker who drains a glycol system and releases the liquid to a storm sewer may not be aware, of the effect on the environment. Environmental hazards cause harm when controls and work procedures are not followed.

Analyze and estimate risk:

Risk is the determination of likelihood and severity of the credible accident/event sequences in order to determine magnitude and to priorities identified hazards. It can be done by qualitative, quantitative or semi quantitative method.

Likelihood of an occurrence:

This value is based on the likelihood of an event occurring. You may ask the question "How many times has this event happened in the past?" Assessing likelihood is based worker experience, analysis or measurement. Likelihood levels range from "most likely" to "inconceivable." For example, a small spill of bleach from a container when filling a spray bottle is most likely to occur during every shift. Alternatively, a leak of diesel fuel from a secure holding tank may be less probable.

Table A indicates likelihood using the following values:

LIKELIHOOD (L)	EXAMPLE	RATING
Most likely	The most likely result of the hazard / event being realized	5
Possible	Has a good chance of occurring and is not unusual	4
Conceivable	Might be occur at sometime in future	3
Remote	Has not been known to occur after many years	2
Inconceivable	Is practically impossible and has never occurred	1

Table A

Severity of hazard:

Severity can be divided into five categories. Severity are based upon an increasing level of severity to an individual's health, the environment, or to property. Table B indicates severity by using the following table:

SEVERITY (S)	EXAMPLE	RATING
Catastrophic	Numerous fatalities, irrecoverable property damage and productivity	5
Fatal	Approximately one single fatality major property damage if hazard is realized	4
Serious	Non-fatal injury, permanent disability	3
Minor	Disabling but not permanent injury	2
Negligible	Minor abrasions, bruises, cuts, first aid type injury	1

Table B

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IX. RISK ASSESSMENT

Risk can be presented in variety of ways to communicate the results of analysis to make decision on risk control. For risk analysis that uses likelihood and severity in qualitative method, presenting result in a risk matrix is a very effective way of communicating the distribution of the risk throughout a plant and area in a workplace.

Risk can be calculated using the following formula:

L x S = Relative Risk

L = Likelihood

S = Severity

	Severity (S)				
Likelihood (L)	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Table C

High
Medium
Low

To use this matrix, first find the severity column that best describes the outcome of risk. Then follow the likelihood row to find the description that best suits the likelihood that the severity will occur. The risk level is given in the box where the row and column meet.

X. CONTROL

Definition: Control is the elimination or inactivation of a hazard in a manner such that the hazard does not pose a risk to workers who have to enter into an area or work on equipment in the course of scheduled work.

Types of Control:

At the source of the hazard

- **Elimination** - Getting rid of a hazardous job, tool, process, machine or substance is perhaps the best way of protecting workers. For example, a salvage firm might decide to stop buying and cutting up scrapped bulk fuel tanks due to explosion hazards.
- **Substitution** - Sometimes doing the same work in a less hazardous way is possible. For example, a hazardous chemical can be replaced with a less hazardous one. Controls must protect workers from any new hazards that are created.

Engineering control:

- **Redesign** - Jobs and processes can be reworked to make them safer. For example, containers can be made easier to hold and lift.
- **Isolation** - If a hazard cannot be eliminated or replaced, it can sometimes be isolated, contained or otherwise kept away from workers. For example, an insulated and air-conditioned control room can protect operators from a toxic chemical.
- **Automation** - Dangerous processes can be automated or mechanized. For example, computer- controlled robots can handle spot welding operations in car plants. Care must be taken to protect workers from robotic hazards.
- **Barriers -** A hazard can be blocked before it reaches workers. For example, special curtains can prevent eye injuries from welding arc radiation. Proper equipment guarding will protect workers from con tacking moving parts.
- **Absorption -** Baffles can block or absorb noise. Lockout systems can isolate energy sources during repair and maintenance. Usually, the further a control keeps a hazard away from workers, the more effective it is.
- **Dilution -** Some hazards can be diluted or dissipated. For example, ventilation systems can dilute toxic gasses before they reach operators.

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XI. RISK ASSESSEMENT PROCEDURES Hazard and Operability Analysis (HAZOP)

A HAZOP is an organized examination of all possibilities to identify and processes that can malfunction or be improperly operated. HAZOP analyses are planned to identify potential process hazards resulting from system interactions or exceptional operating conditions.

Features of HAZOP study are:

- It gives an idea of priorities basis for thorough risk analysis,
- It provides main information on the potential hazards, their causes and consequences,
- It indicates some ways to mitigate the hazards,
- It can be executed at the design stage as well as the operational stage,
- It provides a foundation for subsequent steps in the total risk management program.

Advantages:

- Offers a creative approach for identifying hazards, predominantly those involving reactive chemicals.
- Thoroughly evaluates potential consequences of process failure to follow procedures.
- Recognizes engineering and administrative controls, and consequences of their failures.
- Provides a decent understanding of the system to team members.

Disadvantages

- Requires a distinct system of engineering documentation and procedures.

HAZOP is time consuming.

- Requires trained engineers to conduct the study.
- HAZOP emphases on one event causes of deviations or failures.
- List possible causes of deviation
- Select a process or operating step
- Repeat for all guide words
- Apply guide word to process variable or task to develop meaningful deviation
- Repeat for all process variables or tasks
- Repeat for all process sections or operating steps
- Select a process variable or task

Event Tree Analysis (ETA)

An ETA is an inductive analysis that graphically models, with the help of decision trees, the possible outcomes of an initiating event capable of producing a consequence.

Procedure of Event Tree Analysis

An analyst can develop the event tree by inductively reasoning chronologically forward from an initiating event through intermediate controls and conditions to the ultimate consequences.
An ETA can identify range of potential outcomes for specific initiating event and allows an analyst to account for timing, dependence, and domino effects that are cumbersome to model in fault trees.

Advantages

- Accounts for timing of events
- Models domino effects that are cumbersome to model in fault trees analysis
- Events can be quantified in terms of consequences (success and failure)
- Initiating event, line of assurance, branch point, and accident sequence can be graphically traced

Disadvantages

- Limited to one initiating event
- Requires special treatment to account for system dependencies
- Quality of the evaluation depends on good documentations
- Requires a skilled and experienced analyst

XII. CONCLUSION

The first step for emergency preparedness and maintaining a safe workplace is defining and analyzing hazards. Although all hazards should be addressed, resource limitations usually do not allow this to happen at one time. Hazard identification and risk assessment can be used to establish priorities so that the most dangerous situations are addressed first and those least likely to occur and least likely to cause major problems can be considered later.

Selection of proper method for assessing the hazards might result in a safety work site for any construction project. For a successful hazard identification and risk assessment program, it is very much ideal to consider all the minor aspects which may result in a major accident.

Based on the findings in a particular work place in a construction site, it is necessary to adopt any of the methods of risk assessment discussed in the earlier chapters in order to derive the respective risk scores for each activity involved in construction activity.

The risk scores thus obtained by following any of the methods are very much helpful in understanding the degree of risk involved in any action or activity in construction activity. The risk scores also helps the contractors or construction firms in taking prior safety measures to avoid accidents in the work place. Thus the risk scores are very much evident in decision making like adoption of specific type of operation for the said goal or purpose.

The first step for emergency preparedness and maintaining a safe workplace is defining and analyzing hazards. Although all hazards should be addressed, resource limitations usually do not allow this to happen at one time. Hazard identification and risk assessment can be used to establish priorities so that the most dangerous situations are addressed first and those least likely to occur and least likely to cause major problems can be considered later

Based on methods used to communicate risk at construction sites, it was revealed that toolbox meetings, site meetings, posters and informal verbal communication are used to communicate risk. It was also revealed that safety committees and gang supervisors play a major role in communicating health and safety risks. However the issue of power relations and conflicts was observed when there is a clear separation between health and safety communication and quality and productivity.

Regular inspections, penalties and compliance certificates issued by regulatory institutions influence risk management more. Furthermore, the organizational culture of safety is another factor influencing risk management. It is observed that construction firms with a safety culture considered health and safety when employing the site manager, the safety coordinator and safety officer. Knowledge of health and safety is a criterion for employment. Meanwhile firms with a safety culture provide resources for site workers, such as PPE and training. Additionally, individual characteristics such as experience of those working on construction sites, their educational background and knowledge of health and safety matters also influence health and safety risk management.

The study also provides factors hindering health and safety risk management in construction sites. The factors include the low level of public awareness of regulations, lack of resources such as personnel and funds, coverage of the regulations, complexity of design, the procurement system, and the low level of education, site configuration, and location. Thus the main 'mantra' is that every job on the construction site must be carried out with at-most activity.

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