Role of Inherently Safer Concept in Hazard Identification and Risk Assessments in Viaduct Work: Design based approach

By

Bikarama Prasad Yadav

COLLEGE OF ENGINEERING STUDIES

Under the Guidance of

Dr. Nihal Anwar Siddiqui

Internal Guide
Sr. Associate Professor & Head
Health Safety & Environment
University of Petroleum & Energy Studies,
Dehradun

Dr. Ashutosh Gautam

External Guide
General Manager
(Environment & QC)
India Glycols Limited, Kashipur
Uttarakhand

Submitted

IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

To

UPES
THE NATION BUILDERS UNIVERSITY

UNIVERSITY OF PETROLEUM & ENERGY STUDIES,
DEHRADUN,

September 2016

Dedication

This thesis is dedicated to my parents, wife, son, friends & colleagues who have always stood by me and supported me in continuing education and dealt with all my absence from many personal occasions with a smile.

Declaration

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

Bikarama Prasad Yadav

20th September 2016

<u>Thesis Completion Certificate</u>

This is to certify that the thesis entitled ***"Role of Inherently Safer Concept in Hazard Identification and Risk Assessments in Viaduct work: Design based approach"*** submitted by Bikarama Prasad Yadav to ***University of Petroleum and Energy Studies*** for the award of the degree of ***Doctor of Philosophy*** is a confide record of the research work carried out by him under our supervision and guidance. The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

Dr. Nihal Anwar Siddiqui

Internal Guide
Sr. Associate Professor & Head
Health Safety & Environment
University of Petroleum & Energy Studies
Dehradun, Uttarakhand, India

Dr. Ashutosh Gautam

External Guide
General Manager
(Environment & QC)
India Glycols Limited, Kashipur
Uttarakhand, India

Acknowledgements

I express my sincere thanks to my thesis supervisors Dr**. N A Siddiqui** and **Dr. Ashutosh Gautam** for the continuous support of my Ph.D study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis.

I am grateful to Dr. Srihari, Dr. Kamal Bansal, Dr. Rajnish Garg and other senior faculty members in UPES for their critical reviews on my research work at various stages.

I express my gratitude to Mr. Devendra Gill (Additional General Manager-Safety, DMRC), Mr. M T A Kidwai (HSE Expert), Mr. Pawan Bisnoi (AGM- Safety, JKIL) & Rajendra Kandpal (Chief SHE Manager, ITD Cementation India Ltd.) for their morale support and encouragements.

I express my thanks to Dr S M Tauseef, Mr. Abhishek Nandan, Mr. Ajay Kumar, Mr. P Mondal and my other colleagues who helped me lots during this period.

I appreciate Dr. Anjali, Ms. Rakhi Ruhal, Mr. S S Farmer & Vivek Bisht for their support in UPES administrative matters.

I am especially thankful to my wife Mrs. Pushpa Yadav and all my close family members for their co-operation, understanding and support during the course of my research.

Bikarama Prasad Yadav

20th September 2016

Abbreviation

AHP	Analytic Hierarchy Process
ALOP	Advance Loss Of Profit
BIM	Building Information Model
BNs	Bayesian Network System
CCA	Cause Consequence Analysis
DFS	Design For Safety
ELCB	Earth Leakage Circuit Breaker
ETA	Event Tree Analysis
FACE	Fatality Assessment and Control Evaluation
FI	Factor Index
FMEA	Failure Mode Effect Analysis
FMECA	Failure mode, effects and criticality analysis
FTA	Fault Tree Analysis
GAMA	Groundwater Ambient Monitoring and Assessment
HAZOP	Hazard And Operability
HIRA	Hazard Identification Risk Assessment
HSE	Health Safety and Environment
HSG	Health Safety Guidelines
ILO	International Labor Organization
ITA	International Tunneling Association
JPD	Joint Probability Distribution
JSA	Job Safety Analysis
KPI	Key Performance Indicator
MCCB	Miniature Circuit Breaker
MRL	Maximum Residue Levels
MRL	Modified Risk Level
MS	Method Statement
MSDS	Material Safety Data Sheet
NATO	North Atlantic Treaty Organization
NIOSH	National Institute of Occupational Safety and Health
OHS	Occupational Health and Safety
OHSAS	Occupational Health And Safety Management System
ORMML	Overall Risk Management maturity Level
OSHA	Occupational Safety and Health Administration
P&IP	Piping and Instrumentation Diagram
PBBS	Principles of Behavior Based Safety
PFD	Process Flow Diagram
PHA	Preliminary hazard analysis
PR	Probability Rating

PRA	Process Risk Assessment
PRM	Process Risk management
PSV	Process Safety Valve
PtD	Prevention Through Design
RBNNF	Radial Basis Function Neural Network
RCCB	Residual Current Circuit Breaker
RL	Risk Likelihood
RL	Risk Level
RMF	Risk Management Framework
RMF	Risk Multiplication Factor
RRL	Residual Risk Level
RS	Risk Severity
RTSRA	Real-time safety risk assessment
SAFOP	Safer Operation Study
SHEMSM	Safety Occupational Health and Environment Management System Manual
SHEOM	Safety Health and Environmental Operational Manual
SMACC	Stochastic Multi-Agent Simulation For Construction Project
SOP	Standard
SR	Severity Rating
STFN	Standardized Trapezoidal Fuzzy Number
WCI	Workers Compensation Insurance

Abstract

Most Indian metro cities are facing the problem of traffic congestion, arising from indiscriminate use of personal vehicles, due to lack of an effective transport system to meet the demands of increasing population. An effective public transport system can not only ease the traffic flow but also improve the air quality of a region by taking personal vehicles off the road in large numbers.

Providing an effective rail or road transport system requires construction of viaducts for safe and congestion free movement of traffic. Viaducts also facilitate connecting existing network over otherwise difficult terrain and optimized use of available land. Construction of rail and road network requires working in hazardous environment. Rail and road construction work at ground level is hazardous but this hazard increases manifold for work above ground level.

As per estimates given by Occupational Safety Administration (OSHA), UK more than 10 % of the workers involved in viaduct construction meet accidents ranging from minor injuries to fatality. Therefore, the importance of reviewing the existing safety measures and suggestions to improve the existing safety record cannot be undermined.

Minimization of injuries starts with identification of hazards and quantification of risk. Hazard identification and risk assessment (HIRA) techniques are available to identify hazard at construction site and assessing their risk level,. Although HIRA is implemented in construction industry all across the country, and is a part of the management system, some crucial aspects, which would enhance the effectiveness of HIRA, are still missing. Due to this certain inherent hazards are not identified resulting in accidents during execution of work. These aspects

affect the project directly or indirectly. This also results in below par safety performances at site and also breeds poor safety culture.

This thesis reviews the existing safety practices and standards followed by viaduct construction industries. The causes of high accident rate are identified and suggestions are given to improve the safety of workers involved in viaduct construction, thereby, drastically bringing down the number of injuries.

Various aspects overlooked, intentionally or unintentionally, during hazard identification and risk assessment using HIRA are identified and included in order to strengthen the existing techniques. A framework, based on the twelve different considerations identified after rigorously sifting through various method statements has been developed. Each consideration, in the developed framework, has six sub categories or concern areas. Quantification of each area is done based various study and analysis of data and set of questionnaire and survey conducted at work site.

These considerations have been quantified and risk multiplication factor (RMF) is generated. Finally, a modified risk level **(MRL)** is obtained by multiplying initial risk level with RMF.

Control action plan can be revised based on the new MRL. Using this framework for risk assessment various areas/ concern, which would have otherwise been overlooked if classical HIRA technique was used, can be identified. The framework has also colour codes or risk rating – red for critical (all work is to stop unless corrective steps are taken), yellow requires immediate attention, and green for acceptable risk levels. The developed framework for risk assessment is effective from site selection stage to execution stage of a construction project. Using this framework the occurrence of accidents can be eliminated, or at least the number of accidents that happen during construction activities can be considerable reduced.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

CHAPTER 1

Introduction:

1 Title of thesis

Role of Inherently Safer Concept in Hazard Identification and Risk Assessments in Viaduct work: Design based approach

1.1 Statement of proposal

1.1.1 Problem Statement

Construction industry is backbone of Indian economy. Viaduct construction works plays an important role and it supports the Indian economy as well as infrastructure takes its shape to the global level. Same time safety standard and its implementation have been an issue for construction industry in India. Numerous accidents are reported in construction since beginning of the project which has significant impacts on individual and nation. Infrastructural development and time frame associated with it along with cost factor makes the execution process most challenging. Competent Supervision and its placement with respect to competency lack in construction industry which impacts and encounters majority of accidents.

In construction Industry, visually progress is main or prime concern and safety concerns are not coming upfront although legislative requirements understands the importance of safety concerns. Accidents are driven since design stage of construction and focused done on assessment of risk is not updated or not quantified properly to mitigate the hazard and risk associated in it.

Therefore, approach to understanding the safer approach and concept of quantification of risk, reassessment of activity since design stage to implementation stage could be recognized in mitigating inherent hazard and risk involved in viaduct work.

1.1.2 Background

Construction is third most accident prone industry and ill organized industry due to involvement of illiterate and untrained workers. There are various types of dependency involved in roles and responsibility assigned by management which supervision always carried by the engineers/ supervisor in available time and resources.

Viaduct work consists of most vulnerable work activity where availability of inherent risk remains consistent. Although in recent years accidents frequency rate in construction industry has decreases involving the technological approach. In recent few years it has been found that the majority of accidents coming from construction work activity is “work at height” which consist up to 56% of total accidents coming out from construction work and it is majorly involved in viaduct construction work where it has been noticed approx. 60%. Rather from work at height, material handling, excavation, hot work etc. are main concern where incident rate are majorly recognized.

Based on initial design, planning of executing the work comes first where safety issued and its regulatory requirements discussed. Management concern towards hazard and risk involved in the planning stage remain theoretical and they remain eager to accept the challenges. Although while during its execution, time frame restriction, resources limitations and cost effectiveness bring the instability to the real approach towards implementation of safety at work place which lack the concentration of assessing the inherent risk which indirectly involved in the process.

Therefore, to minimizing the accident frequency it will be favorable to assess all vital part of a project by applying the concept of implementation of inherent safer way to identification of hazard and risk assessment involve since design stage to execution of work till its completion.

1.1.3 Role of viaduct in sustainable development

As reasonable improvement turns into a more imperative target in common base arranging and approach making, Quality of Life is an inexorably vital measure to comprehend, describe and apply viably in the inquiry and advancement of suitable framework answers for practical improvement.

The illustrations exhibit how foundation can be deliberately created or re-created to enhance local personal satisfaction and financial intensity while saving or upgrading the common habitat.

The most well-known and generally utilized meaning of manageable advancement originates from the United Nations' Brundtland Commission's report: "addressing the necessities (and desires) of the present era without trading off the capacity of future eras to address their own issues and yearnings" (WCED 1987).

As a rule, it is additionally comprehended that reasonable improvement has three angles: natural, monetary, and social. While meanings of and ways to deal with supportable advancement and assessment change, the applied premise of practical improvement is in a general sense the same: to give a worthy or enhancing personal satisfaction for groups while safeguarding that normal resources that empower such arrangement to proceed. Viaducts are scaffolds made out of a few little traverses for intersection a valley or a crevasse.

Alongside improvement and enhancing network, viaducts ought to be practical. This could be accomplished through powerful arranging and planning. Millau Viaduct is an impeccable case of a maintainable development artful culmination.

1.1.4 Motivation/ Need of research

In India construction has accounted for around 40 per cent of the development investment over the past 50 years. Around 16 per cent of the nation's working population depends on construction for its livelihood. The Indian construction industry employs over 30 million people and creates assets worth over Rupees 4000 billion (approx.).

Major accidents of construction particularly bridges or viaduct structures which has been happened recently in India who motivates to look some alternative or research which could able to minimize the impact or accidents ratios. Investigation and analyzing the past accidents, it reveals the root causes of accidents which has been happened in viaduct work (Metro rail work or other bridges work) and various aspects has come to work in. Commonly human error and technical assessment of work by team leader or concern engineer has played important role in leading to the accidents. Site Engineer/ team leaders' job is to identification of hazard and risk assessment carrying during and at the time of construction activities plays an important role. The risk quantification barrier which indicates to change its methodology or planning is the vital part or concern which an engineer or team leader or designer may take in priority before executing the work.

During my research, it will be focused to use all inherent safer approach to identify hazard and its risk quantification including re assessment in all levels of activities by which we will be able to justify the risk rating by which there will be a way to change the methodology or design and probably frequency of accidents can be reduced.

1.1.5 Scope

In recent scenario various technique and methods are available worldwide for hazard identification and risk assessment although every technique has its own limitation and scope. Taking it further, we have been thought to reconstruct the technique and conceptualize in a way we can take it forward to assessing risk in construction more significantly. In this way, we have been taken consideration of safety in design, analysis of inherent risk available since inception, coordination between designer and engineers.

1.2 Objective

- Study of method statements, design proposals and all safety management system

- Study of various techniques used for identification of hazard and risk assessment for construction projects (mainly in design and execution of bridges/ metro rail viaduct works)

- To introduce the framework for risk assessment in construction of viaduct work and to provide a palette of techniques facilitating the various steps of risk assessments including utilization of inherent safer concept from design stage to completion stage of a project.

- To assess the effectiveness in eliminating and minimizing accidents rates by validating the model.

CHAPTER 2

Literature review:

2 Overview of viaduct construction:

Infrastructure work has taken its large shape globally and subsequently it is a need of society today for increasing infrastructure work as urban population growing day by day. Construction of viaduct majorly contributes to the urban population which has increased in last few years. One side it is a need of society while other side it has number of challenges in health safety and environment areas. The major HSE challenges or issues in construction today are near misses or accidents in construction which happens at the time of execution of work. Many methods are in place minimizing accidents scenario in constriction work still it has identified as third largest accident rate by today. Construction work has many peculiarities during construction and has number of inherent issues e.g. social issues, environmental issues, health issues and most importantly the safety issues. There are many works has done in past minimizing hazard and risk of construction and scenario has improved but still miles to go in this areas improving further. Hazard identification and risk assessment is a technique by which incidences has reduced or minimized during execution. There are many works has been done previously and suggested for improvements which has been included as below in table.

2.1 Previous studies based of construction risk assessment and mitigation:

Multiple studies has been done to understand the risk involved in construction work especially in viaduct work and has been tabulated (Table 1) during the state-of-art and peer review.

Table 1: Previous studies done on construction industry safety and risk assessment

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
1.	Construction safety	Study aims to reduce construction industry hazards through design in planning stage.	• Identifying risks during construction process. • Assessment of construction safety risk	During study following observations were noted- • The risk levels during construction work due to concrete structure were observed to be high but level of safety risk for precast designing structure was less. • During the designing of precast structure below are the risk which gets minimize : 1. Injuries due to reinforcement. 2. Injuries due to falling object or collapse. 3. Cut and blow injuries from objects and tools during foundation and structure work	(Gangolells et al, 2010)
2	Construction safety	Early warning system	• Implementation of RBFNN (Radial Basis Function Neural Network) models.	• During study following observations were noted- • Construction Safety management requires diverse, systematic	(Ding & Zhou,2012)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
			• Calculation of Probability Assignment (BPA)	information for decision making. • By web based system it makes easy to collect information related to project, data measurement and visual inspection data.	
3	Climate heat stress risk management in construction	Climatic heat stress can lead to accidents and develop methodology for effective decision making process	• Find out indicators of heat strain • Find out environmental heat stress indices and environmental threshold • Assessing metabolic heat and work place • Assessing clothing effects • Assess individual factors	Following points were observed during study- • Lack of research into real industrial situations has been observed. • So there is an inability to formulate effective guidelines for managing problem.	(Rowlinson et al, 2014)
4	Hazard Recognition	Aim is to explore the awareness of superintendents towards hazards and how well they associate them with	• Population consisting of students, superintendents, safety directors was chosen. • Scope of hazard was determined by accident types reported in UK, US and Israel. • In test, each subject was asked to examine set of photographs	Following observation were noted during study- • Superintendents who had work experience and had formal safety training were able to assess risk level more than students. • They also assessed probability of each hazard to occur more than	(Perlman et al, 2014)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
		risks	from construction site with respect to hazards. • In this step virtual test was carried out by simulation model of the same construction site.	students. • It has clearly concluded that ability to identify hazard has positive correlation with work experience.	
5	Construction safety	Study aims to know how potential hazards are incorporated in construction schedule, their identification and elimination in planning phase.	• Existing safety benchmarks, guidelines, and best practices were used. • Building Information Model (BIM) once developed and there is set up associations between models the calendar can be practiced upon and rules for distinguishing risk can be connected	Following are the noted observations- • The device created identifies unprotected section, edges and introduced safe framework. • This model empowers client for streamlined model representation and work. • Limitation of this framework is that it depends on data given by BIM.	(Zhang et al, 2015)
6	Safety management analysis in construction industry	Study of worker behavior, perception, and safety climate.	• Systematic review of existing literature on construction safety for useful findings and identifying gaps. • Appropriate publications were identified and were used to select according to publication type and criteria.	Following are the observations noted- • During review 33 research topics were identified, which were divided into 3 different categories. • First group focused on aspect on safety management, second	(Zhou et al, 2015)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
			• Papers selected were compiled and coded according to aspects like Paper title, publication, Country etc. • Based on such aspects data analysis was carried out.	group focused on site workers (e.g. attitude, behaviour etc.), third group focused on accident/incident data and involved accident cost etc. • Systematic review had done and gaps were identified for further practices	
7	Construction safety	Study aims to do risk assessment at construction site by a method called Job Safety Analysis	• Specific job or activities were chosen and they were broken down into sub activities. All incidents during work were identified.	Following are noted observations- • Methodology has dynamic approach in assessing risk in process. • Challenges and risk were considered by probability of failure and verifying and assessing potential casualties.	(Rozenfeld et al, 2010)
8	OSH Manage-ment in enterprises	Analytic Hierarchy Process (AHP) method.	• Developing 109 PPIs (proactive performance indicators)for individual OHS-MS • Selection of KPIs(Key performance indicators) for AHP	• Implementation of different criteria for the determination of OH &S has been done. • Assessments were done for KPIs in approved OH&S method statements.	Podgorski et al,, (2014)
9	Fire safety in	The Overall	• Thorough studying of the	• Proper management and	Gehandle et

S.No	Project involved	Study objective and aspect covered	Gist of Work	Key findings	Reference
	road tunnel	objective is to protect life ,property, health, environment and the key social functions from the fire	Swedish European regulations for the fire safety and for the life safety of the community has been identified. • Verifying the Performance based requirements through risk analysis of operational and knowledge related uncertainties.	organization techniques have been included. • Limiting the generation and spread of smoke and assessment for proper load bearing capacity has been analyzed. • Providing means for self-evacuation and safety precautions for rescue service.	al,,(2014)
10	Land slide risk assessment	The main objective is to develop new methodologies for landslide hazard management.	• Reviewing the method and techniques of landslide risk assessment. • Applicability of various land slide risk assessment methods.	• Controlling of landslide movement. • Monitoring and warning systems. • Assessment of decision making.	Dai et al,, (2001)
11	Identify the top risk probabilities affection the construction projects.	The main objective is to identification of risk probabilities.	Prioritizing risk based on the significance.	• Identifying and analyzing top major risks in the construction sites. • Currency and economic fluctuation. • Change in taxations/new tax rates.	Laila et al ., (2013)
12	Hazard identification in CO2	The main objective is to risk assessment in	• Bow-tie analysis • Retrieval of risk notions prioritization	• Mechanical stress plays a critical role in accident related to vessels by external factors.	Paltreineri et al ,, (2013)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
	capture installations.	emerging concept of CO2 capture installation.		• Presence of corrosive materials in the vessels had great impact on the site.	
13	Construction industry risk assessment	The main objective of this project is the usage of expert options like risk mapping for risk assessment in construction industry.	• Overview of decision-making process: risk attitudes and behavior. • The risk attributes: how the reliability of risk assessment can be enhanced? • Overview of previous attribute-based risk identification approaches	Adverse Country Related Conditions were analyzed like- • Design Problems Project Complexity • Uncertainty of Geological Problems • Requirements Contract Specific Problems • Engineer's Incompetency Client's Incompetency • Adverse Site Conditions	Yildiza , et al (2014)
14	Construction industry risk assessment	An Assessment of Risk Identification in Large Construction Projects in Iran	• The questionnaires were designed to identify their method of risk identification and their effects	• The results were obtained through questionnaire and survey conducted. • Multiple specifications for the identification of project risk have been particularized.	Mehdi Tadayon et al.(2012)
15	Construction industry risk assessment	Hazard identification	• Improving safety of the site by applying the safety significance	• Proposed method can be used to raise the level for the identification of hazard to apply suitable control measures.	Carter1and Smith (2008)
16	Construction	Assessment of	• Study presented a result based	• The system created present an	Tugnoli et

S.No	Project involved	Study objective and aspect covered	Gist of Work	Key findings	Reference
	industry risk assessment	Quantitative Inherent Safety by Key Performance Indicators (KPIs)	technique for the inborn safety evaluation of procedure frameworks.	immediate connection among risk components and outcome of potential situations, superseding a few issues prove in the utilization of past strategies	al.(2010)
17	Construction industry risk assessment	Quantification and communication of construction safety risk	• Work shows a technique for measuring development risk and risk mitigation capacity utilizing scales that characterize hazard as a part of terms of safety.	• The likelihood and severity scales proposed in this work contemplate hazard management technique which could able to enhance existing strategies for risk evaluation.	Hallowell and John (2009)
18	Construction industry risk assessment	The Effects of Risk Assessment (HIRAC) on Organizational Performance	Work concentrates on the impacts of risk evaluation (HIRAC) on hierarchical execution in chose development organizations in Nigeria.	• Work predicts the risk evaluation and its assessment by application of "Domino Theory". • Risk mitigation and its effective controls are visible when assessment of management system after applying HIRAC.	Agwu(2007)
19	Construction industry risk assessment	Risk analysis of building construction Project	• This work means to know the probability of an event failure and determining risk pertaining to that.	• Observed risk should be prioritize and ascertained during the task performed. The action should be initiated immediately once identified. • Preferably change required once risk calculated above its	Firmansyah et al. (2004)

S.No	Project involved	Study objective and aspect covered	Gist of Work	Key findings	Reference
				permissible level.	
20	Construction industry risk assessment	Research needs for Building Information Modeling for Construction Safety	• The paper characterizes BIM by its difficulties during design and relevant mapping required DFS (Design for safety) ideas to represent the various inputs coming in.	• Need of prevention through design that can help in identifying inherent hazard and risk and can be handled to improve safety and quality of work. • PtD minimizes the risk pertainin to any process or activity and risk level can be minimized from the beginning.	Ku and Mills (2003)
21	Construction industry risk assessment	Safety Hazard and Risk identification and management in infrastructure management	• This work has focused on understanding issues of any project and highlight past, present and future issues concern to safety.	• Significant changes have brought in to enhance the safety during transportation of laborers by encouraging risk recognition and supervision for related control measures.	Jennifer (2012)
22	Construction industry risk assessment	Tolerable risk for dams: and its safety	• Dam safety and its implications. • Bringing down risk level by applying suitable technique.	• This work deals about successful execution and implementation of risk assessment from a wide viewpoint however with application to dam safety and security.	David (2014)
23	Construction industry risk assessment	Construction Risk Modelling and Assessment.	• Utilization of 'risk expense' as a typical scale inside a conviction based basic	• Reason that the utilization of 'risk expense' as a typical scale inside a conviction based basic	Taroun et al, (2012)

S.No	Project involved	Study objective and aspect covered	Gist of Work	Key findings	Reference
			leadership.	leadership system would be a creative arrangement, conquering current deficiencies and enhancing risk assessment and their control measures. • No risk assessment technique was found bears a typical scale to all the while and evaluates risk for the different task.	
24	Construction industry risk assessment	Risk Assessment of Common Construction Hazards	• The information for this study was gathered utilizing a web review. The poll was sent to 300 safety experts including safety directors, security officers, and safety specialists who were haphazardly chosen from 20 nations. Of those, 76 finished reactions were returned.	• The outcomes suggest that there is no huge difference in severity and recurrence of accident between developing nations. It was moreover found that absences of proper safety system, negligence of attention towards safety aspects are most common causes behind accidents.	Zolfagharian et al.(2011)
25	Construction industry risk assessment	Identifying the latest risk probabilities in construction	• Risks were assessed based on importance of impacts and their causes, whether inward or outside.	• Strategies for risk response were appropriate for each type of identified risk.	Khodeir et al.(2006)
26	Construction industry risk	Risk Management of Construction by	• In this paper, a recommended	• The paper demonstrates the need	Oleg Kaplinski

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
	assessment	Utility Theory	strategy for risk investigation has been exhibited, in view of the utilization of utility hypothesis.	of checking the individual components of the leader, expertness and their effectiveness. • These above quality may lead to a proactive safety culture.	(2002)
27	Construction industry risk assessment	Risk Mapping in Construction Projects	• This paper shows the preliminary disclosures of a two-year on-going investigation wander entitled as "Change of a Knowledge-Based Risk Mapping Tool for International Construction Projects" which was upheld by the Turkish government and finished in a joint exertion with an accessory improvement association.	• This study proposes a risk mapping process that considers the interdependencies of risk related parameters and speaks to hazard ways that are created from the cause-impact connections among parameters	Yildiz(1999)
28	Construction industry risk assessment	Safety Risk Assessment	• A strategy for continuous risk appraisal (RTSRA) to execute a dynamic assessment of laborer safety states on development site has been proposed in this paper.	• The RTSRA implements a quantitative, Human-Centered, and real-time safety risk assessment. • Factors related to the real-time safety risk of an onsite worker	Miller et al.(1997)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
				have been classified and quantified. The real-time safety risk values and reduction factors are obtained using a proposed reliable formula for quantifying risks. Based on the HMM, the RTSRA gives the real-time probability distributions of different safety consideration and subsequent safety risk values.	
29	Design aspect	• Study of 3D modeling in a complicated building shape. .	• Three case studies out of which two were public projects and one being private project i.e. MIT Center, Eden Project in UK and Yokohama project in Japan. • For each case study geometric specifications, 3D model was organized; organization structure of project was laid and brought all of architects to environmentalists on the given model on one platform.	• Direct involvement of people in project had better coordination while working on projects on contractual basis contrary to non-contractual projects.	• Ku *et al.* 2008
30	Construction safety	• Study the most efficient	• A new method for finding the premium rating for a	• The expert model is quite effective since WCI premium	• Imriyas, 2009

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
		WCI for construction building projects. • Model implementation of the proposed system and cross checking the same.	worker's compensation insurance was proposed which included optimal net premium of WCI to be calculated consisting of risk fee, safety management discount and client control insurance taking hazard and safety index also into consideration. • A system that included database, graphical user interface, inference engine and intermediate processing unit as a part for automation. • Verification of the system was done using truing test, field test and predictive test.	amount to be covered by insurers would constitute the effectiveness of safety management system on site by contractor thus would affect the tenders issued to the contractors. • This system takes client, contractor and insurer into one picture thus ensuring work place safety. • Automation helps in keeping the record for all claims and safety system of contractors for any future reference.	
31.	Construction safety	• Study of the past occupational accidents in the construction field. • Implementatio	• Out of 40000 occupational hazards that were unclassified, 5239 were categorized as construction site accidents of which each was further detailed into severity of the accident (0-10) accident probability (0-	• Study was on tunnel site was done • Major advantages being this method used linguistic ways of expression and the lack of accuracy give a way to this method in construction site.	Gurcanli and Mungen, 2009

S.No	Project involved	Study objective and aspect covered	Gist of Work	Key findings	Reference
		n of expert method in tunneling site and check the risk factor of all accidents that can take place.	100) and present safety conditions (0-10). • The given numbers for each parameter and readable language was converted into values between 0 to 1 with probability of accident having 6 categories, severity of accident having 5 categories and safety level into 5 categories.	• Major drawbacks were found that, reporting of accidents were not as adequate it required which resulted subjective approach and also accidents severity went on higher side.	
32	Construction Safety	• To study the inclusion of safety measures in design stage of the construction elements to avoid any hazard.	• Concept of prevention of hazard via design penned down by NIOSH was studied	• Accountability of safety at site has to include contractors, designers, planners and owners on one platform. • At the initial conceptual stage of design, safety measures are to be included in it to avoid any mishaps in in terms of loss of life or assets.	Lentz,2009
33	Construction Safety	• Method for quantitative	• The quantitative method includes first identifying the	• The risks involved in a particular combination of a	Gangolells *et al*, 2010

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
		analysis of safety in design and its impact on site	risks related to safety at construction sites and then evaluating the risks.	construction method and system was easy to find using the method even for not so experienced people working in designing stage. • Evaluation of the safety and health hazard at site was done to take all proactive measures to avoid any mishap. • An accidents data base needs to be prepared for cause finding or to be lesson learned in future.	
34	Construction safety	• Study the qualitative model for risk assessment over the imprecise system	• Focus of the qualitative system study was on actual data obtained from workers interaction, inspection on site and inspection of all the safety and health documents produced to convert this data using fuzzy methods and then calculate the risks. • A preliminary model was made with the same concept and using fuzzy method, risks were calculated.	• Using a qualitative approach for safety and health risk assessment on construction field provides a more practical approach. • Though the qualitative method needs further improvement for specifying other potential hazards and thus calculating the risks that are involved in it.	Abel Pinto1, Isabel L. Nunes1, and Rita A. Ribeiro, 2009

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
35	Construction Safety	• Study of effectiveness of law in accident prevention in construction site	• Study of the policies that have been framed in European Union keeping safety and health at par with focus on risk elimination at design stage itself. • Study of affect the policies had on the number of incidents at construction site	• It is found that the results are varying with some countries in EU and having 10% lower rates of accidents while the other close to 1-2% only. Even though these regulation are not the only factor that can lead to prevention of incident but surely gives a positive indication. • Major study that further needs to be done is on adaptability of the laws framed and how contented are the official bodies with it.	Ma Dolores Martínez Aires , Ma Carmen Rubio Gámez and , Alistair Gibb, 2010
36.	Metro construction safety	• Risk analysis in metro construction	• Fault tree analysis • Fuzzy set theory and fuzzy fault tree analysis • Fuzzy sensitivity analysis • A step-by-step procedure for decision analysis	During study following observations were noted- • There are several methodologies proposed for risk analysis, such as hazard and operability study (HAZOP), functional hazard analysis, failure modes and effect analysis	Abbasb et al, (2010).

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
				• FTA is a standout amongst the best systems for assessing the recurrence of event of risky occasions in PRA in current fluffy based likelihood investigation, every gathered data is entered for choice examination with no information unwavering quality assessment, bringing about wrong issues in ensuing calculation	
37	Identification of hazard and risk assessment	To improve superintendents hazard recognition and risk perception abilities	• Traditional test procedure using photographs • Virtual test procedure	During study following observations were noted- • The role of the foreman or the supervisor has been identified, both by managers and workers. • Accordingly, improving construction safety supervision, hazard recognition and risk assessment abilities should improve safety at work site. • To assess the risk there were traditional test, the virtual test and ANOVA test.	Abdelhamid, Et al, 2000
38.	Safety	Examination of	• Reviewing various research	During study following observations	Zhou et al,

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
	management	safety management	topic of past present and future on construction safety.	were noted- • Hazard identification, accident cost analysis and other accident analysis is focused by the third party in most of the construction work. • Research gap identified, lack of unsafe condition monitoring, lack of construction safety research at the task level, lack of innovative technology applications in construction safety practice etc.	(2015)
39.	Selection of contractors	Study aims to evaluate the risk management ability of contractors.	• Identifying the qualities and extent for risk management in construction process. • Assessment of current risk management maturity of the contractors	During study following observations were noted- • Fuzzy synthetic evaluation and Questionnaire survey was used to identify the risk management capabilities and maturity level of contractors ▪ Overall risk management maturity level (ORMML) for all the construction establishments suggest that not all construction industry has fully developed risk	(Salawu et al, 2015)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
				management procedures. Only few are of this categories have ORMML and benefited.	
40.	Risk assessment for civil engineering.	Addresses the problems associated with risk acceptance criteria, risk aversion and value of human life and attempts to provide suggestions for the rational treatment of these aspects.	• Discussion of essential parts of risk investigation and evaluation, and additionally endeavoring to depict hazard appraisal as per the current situation with the craftsmanship. • Practical angles, strategies and methods for the execution of risk appraisal in structural building applications are clarified and talked about.	During study following observations were noted- • Brief outline of these standards, and additionally highlighting and talking about the instabilities and constraints of existing practices. • Need for the appropriation of institutionalized risk investigation methods and probabilistic models as this will diminish investigator to-expert variability of results.	(Stewart MG. et al, 1997)
41.	Prevention through Design in Construction	Outlining for development safety involves tending to the security of development specialists in the configuration of the lasting components of a	• Safety constructability during design stage of the project.	• Designers suggested development of security essentials agendas and other requirement during planning phase of the project. • Provide development of awareness among staff by giving security and emergency training at regular interval.	(Gambatese et al, 1997)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
		task			
42.	Occupational and health safety	The objective of the study is to evaluate the cost benefit analysis of occupation and health safety.	• Identifying the cost and incident rate of hazard exposed on workers	During study following observations were noted- • OSH-PRM is developed in focusing the initial stage of project. • The cost benefit analysis of each hazard is assisted by OSH-PRM • The study says that duration exposure of each hazard is determined from the work plan and schedule allotted to workers. • Severity and operational parameters are established based on safety conditions. • The total risk of the project calculated is used to eliminate the risk of occupational safety and health accidents associated with the hazards identified. • The study helps to know the Effective use of available resources to ensure the safety and better implementation of	(V.Sousa et al, 2015)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
				project	
43.	Construction Project	Study aims to manage the risk in construction project by developing a model.	• Identifying the risk impacts of stakeholders and the construction project	During study following observations were noted- • A multi-agent model called SMACC (Stochastic Multi-Agent simulation for Construction project) is used by the risk managers in decision making stage of project • Inspiration of project and identify the risk and impact of the project is one of the importance of SMACC • Project, Initial project Descriptor, Instructions and Risk are the four agent families of SMACC • This model is used in real time construction on GAMA platform • The possibilities how a project can be taken in different direction is noted • There are some limitations of this model however this model is used in some real time projects	(F. Taillandier et al, 2015)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
				to identify the difficulties and resolving it.	
44.	Construction Safety	Study aims to reduce construction industry hazards through design in planning stage	• Studying the role of contractor in safety of construction workplace • Assessing how the design can be made for a safer construction and maintenance	During the study the following observations were noted: • The contractors must properly plan and make decisions on the site avoiding a poor approach to safety • Designers can affect the safety of construction by making a safer design for construction like: • Outline prefab units that can be based on the on the ground and raised set up in order to decrease laborer introduction to fall on the ground and struck by falling articles. • Allowing sufficient gaping between power line and structure so as to avoid accidents while operating cranes • Eliminating fall protection by providing 42” parapet wall, permanent guard rails and anchorage points.	Mroszczyk , 2006

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
				• Specifying coatings not emitting harmful fumes. • Designing cable system for turret structures for eliminating fall protection for future maintenance.	
45.	Construction safety	Study aims to reduce construction industry hazards through design stage	• A panel of experts were selected for reviewing accident cases • 10 fatal accident cases were selected from 224 FACE cases • Each reviewer was given 5 cases and they were asked to study them and conclude whether the design was responsible for the fatal accident or not.	During the study the following observations were noted: • Sloped roof designs should include top anchor points for roofers • Safe entrée to the roof must the anticipated by the designer • In order to avoid working at height the designer should anticipate the sequence and process of erection in his drawings • The installation of beams should take place with safety cables before their leaving the ground which would provide a place of attachment for the safety harness of worker. • One element of designing should be the safety of the construction	Gambatese *et al*,2008

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
				worker in order to reduce the risk of fatal accidents.	
46.	Construction Safety	Study aims to evaluate how fuzzy decision making can help to avert risk in construction site.	• A new model for risk assessment based on fuzzy reasoning techniques and analytic hierarchy process(AHP) is proposed : • An initial phase where a risk assessment group reviews the risk information and data and hence determines the risk criteria • Each one of the factors are then evaluated by members of the group are then as per the agreed score system of the Factor Index (FI) hierarchy. • Risk Severity (RS) and Risk Likelihood (RL) is then measured by the risk assessment group by converting the preferences of individuals to Standardized trapezoidal Fuzzy Number (STFN) by using fuzzy weighted average trapezoidal	During the study the following observations were noted: • The technique can deal with the master information, building judgment and the verifiable information • for risk evaluation in a reliable way • The risk can be assessed specifically utilizing phonetic terms which are utilized in risk evaluation • The introduction of FI empowers chiefs to play out a risk examination of the fundamental development environment so that a more solid result can be acquired.	Zeng *et al*,2007

S.No	Project involved	Study objective and aspect covered	Gist of Work	Key findings	Reference
			operators. Which are then transformed into matching fuzzy sets by analysts . • These sets becomes input to decision making interference system deciding necessary rules for the situation calculating result of Risk Magnitude(RM). • Necessary output modifications are done depending on changes in situation by assembling more information thereby modifying the FI hierarchy and risk parameters.		
47.	Construction Safety	Study aims to reduce construction industry hazards through design by analyzing the perceptions of Western Australia’s	• A survey was conducted where participants was asked to participate in a focus group forum where they discussed about the utilities of safe design • 5 Point Likert Scale were used in the survey • Normality test were carried	During the study the following observations were noted: • Survey showed that the Legislation for Building construction are sensible and should be followed for safe construction • Advancement can take out risks instead of simply relieve it,	Behm and Culvenor, 2011

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
		engineers	for dependent variables using Kolmogrov Smirnoff Test • Dependent variables were not normally distributed therefore Mann-Whitney Test was carried out • Means were calculated to interpret the results.	amid undertaking development • The best possible environment is expected to guarantee a positive state of mind among the design community. The appropriate environment for idea reception must be made before controls are looked for. • Early champions of the industry can provide guidelines so as to make others aware of what to follow and what not to. • There is more scope for thorough research for understanding the relation between design and safety of a construction	
48.	Construction Safety	Study aims to assess how the design can affect the fatalities of a construction workplace	• A good amount of data (230 cases) relating to the fatalities in workplace was collected from NIOSH FACE • Each case was investigated for 3 main question: • If the long lasting features of the project was a reason for the fatality?	During the study the following observations were noted: • Obeying the construction rules is of utmost importance for the contractors. • The concept of safe design not only can reduce risk in the construction but also in the maintenance periods.	Behm,2005

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
			• Are the previous design suggestions are reducing the threat of fatalities? • Could the accident be avoided if new design process was modified? • The answers can be either a yes or a no. If any of the answer be affirmative then it would have established the relation between design and fatality. • For clarity of understanding hypothesis were developed and tests were conducted for reaching to conclusions • After determining the sample size Chi-Square tests were conducted to determine the the presence of a relation between design and fatalities	• The fatalities are related to the element of design that is constructed therefore permanent features can be incorporated in the design so as to reduce the risk • The safety of the construction is very much influenced by the discipline of the designer.	
49.	Construction Safety	Study aims to assess how the health and safety of contractor can	• A sample of 55 shell contractors was selected and they were sent questionnaire through mail by researcher.	During the study the following observations were noted: • Client's interference can result in timely completion	Smallwood,2004

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
		be influenced by a client.	• Descriptive statistics were calculated.	of work, improved productivity and minimization of accidents. • Client should make sure that the contractor has made adequate provisions for safety.	
50.	Construction Safety	Study aims to assess how the design can affect the fatalities of a construction workplace	• A sample of 40 designers were selected out of which 19 responded • Respondents were questioned about • their background • ideas that can bring improvement in construction with safety • barriers to safety in design • Any predicted self-design limitations • The designers were given an improved design based on past research and were asked to comment on it.	During the study the following observations were noted: • Barriers to safe design include • Less knowledge and fact acceptance • Proper training of designing • Lack of motivation for execution of the topic. • Owners of the project can motivate to inculcate safe design in construction • The implementation of safe design may initially become costly but will result in long term benefits.	Gambatese *et al*,2005
51.	Identifying and	Fuzzy analytic hierarchy process	• After distinguishing all risk variables, fluffy AHP is	During study following observations were noted-	(Sotoodeh *et al*, 2012)

S.No	Project involved	Study objective and aspect covered	Gist of Work	Key findings	Reference
	Evaluating Risks of Construction Projects	(AHP) approach to manage the risk of construction .	connected to decide the need of risk elements. • The proposed strategy connected the fluffy AHP approach such that it covers vulnerability present in the specialists' assessments.	• Evaluating and dissecting the risks of an undertaking and wanting to oversee them are the most basic strides ought to be done in the task definition stage. • Risk assessment and examination were overlooked. Simply after event of unfavorable outcomes of risks, administrators of ventures could comprehend the significance of risk administration. • The hazard administration is the documentation procedure of the last choices, recognizing and applying criteria which are utilized to lessen the risk to the satisfactory level.	
52.	Exploring the relationship between major hazard, fatal	Study aims to analyze that occupational accidents.	• Assessment of Causes of fatal versus non-fatal occupational accidents and underlying causes of	During study following observations were noted- • Less severe accidents draw less attention and happen regularly and mostly not	(Linda J. Bellamy et al, 2014)

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
	and non-fatal accidents through outcomes and causes.		catastrophic accidents	taken seriously which resulted into severe accidents. This happens due to ill identification or assessment of risk and its prioritization.	
53.	Construction safety	Study aims to reduce the construction hazards through proactive behavior based safety	• Identification of location-based behavior of workers through PBBS	During study following observations were noted- • Location-based practices were automatically checked by PBBS system • Safety precautions to enhance safety mindfulness or culture for best practices at work place. Safety training and awareness required on the alarming areas. • Activity based PBBS effective for safety management system. • No comparison between older BBS and latest PBBS.	(H.Li et al. 2015)
54.	Construction and risk	Identification of the latest top major	• Primary data was collected using	• Political unrest leads to economic unrest and	Laila Mohammed

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
	safety	risk probabilities in construction projects in Egypt according to political and economic variables.	questionnaires and in depth interviews • Secondary data was collected with the aim of providing multiple sources of data for comparison • The questionnaire had two main sections. First was the general information about the respondents and the second carried a total of 65 risks associated with construction projects.	decrease in investments which simultaneously affects the currency process and therefore has major effects on imported materials. • The change of rules on taxes done by the government affects the prices of materials, equipment and even salaries of the workers working in the project. • Safety and unsecured roads, made the project heads transport their engineers in airplanes especially between cities.	Khodeir, et al 2014
55.	Risk assessment	Systemic decision support approach for safety risk analysis .	• Bayesian network systems (BNs) are a blend of two distinctive scientific ranges, chart hypothesis and likelihood hypothesis, which comprises of a coordinated non-cyclic diagram (DAG) and a related joint	• Fuzzy number-based probabilities are utilized to direct FBN based risk investigation under vulnerability, since it is fit for ascertaining the framework unwavering quality and recognizing the most suitable	Limao Zhang, et al 2014

S.No	Project involved	Study objective and aspect covered	Gist of Work	Key findings	Reference
			likelihood conveyance (JPD). • When developing a BN model, experts are faced with insufficient information concerning probabilities of root hubs. • Under such questionable circumstances, it is observed wrong to utilize routine BN for figuring the framework failure & its likelihood.	causes creating the event of safety violation.	
56.	Design aspects	Accident triangles and differences in lethality ratio.	• Proposed oil storage depot explosion, where there was a fire explosion while filling the tank. • The tank was provided with	• The Heinrich patterns showed different hazards make different potential outcome • Accidents can also be caused by barrier measures and exposure.	Linda. J. Billami

S.No	*Project involved*	*Study objective and aspect covered*	*Gist of Work*	*Key findings*	*Reference*
			two types of level control, where one valve was not functioning properly and the other vale would stop working once the tank was full.	Fixing the barrier potentials with high severity potential can help in prevention of bigger accidents.	

CHAPTER 3

3 Hazard Identification and Risk Assessment

3.1 Overview:

The components of proactive OH&S management system identifies hazard, assessing risk and determination of control mechanisms. Though there is no general guidelines for the usage of terms for the practices like - HIRA, and decide Control mechanism in occupational health & safety management system (OH&S) however for consistency's sake OHSAS 18001:2007 (Sousa, Almeida et al. 2012) defined terminologies will be used. Different terminologies from BS8800: 2004(namely hazard prevention), OHSAS 18001:2007(Risk assessment, hazard assessment are used in ILO-OHS: 2001 which deals the three processes separately and similar to OHSAS 18001:2007.Similarly HSG 65:1997 describes the entire process of controlling risk and health in three steps namely "risk assessment" , "risk control", and "hazard identification", which is the same as defined by OHSAS 18001:2007 (OHSAS 2007). On the other hand, BS 8800:2004 all the processes are combined under the term "risk assessment (British Standard 2004).

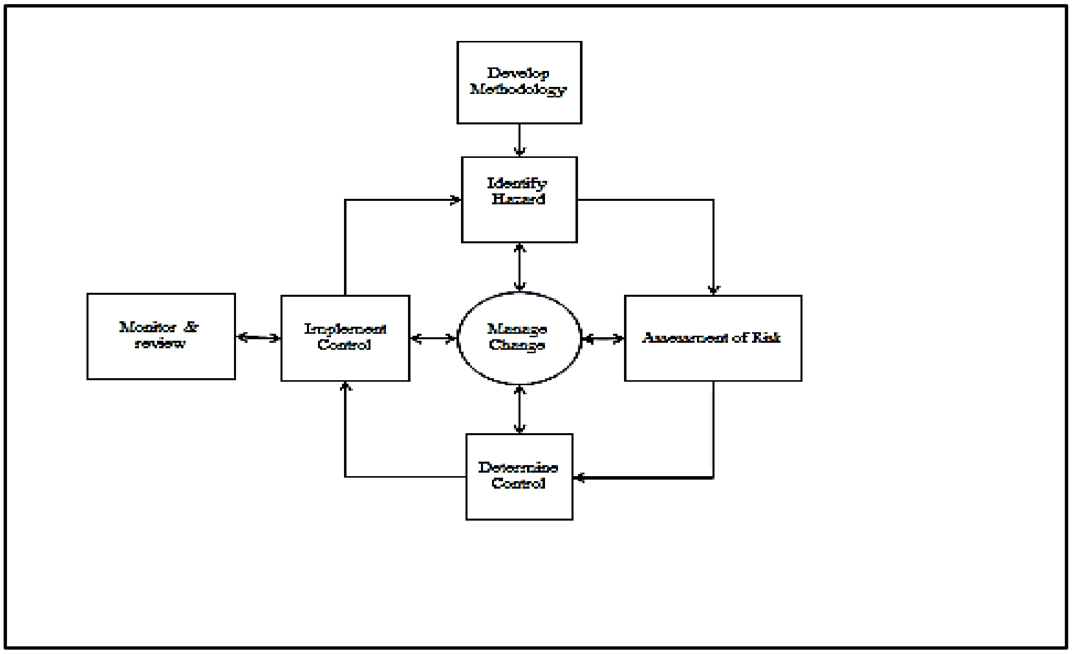
ILO-OHS: 2001, OHSAS 18001:2007 and BS8800: 2004, defines hazard as impairment to human with respect to ill health or injury or amalgamation of those two. However under HSG 65:1997 the possibility to cause harm to plant, environment, property or the product (Health Safety Executive 2013) is termed as hazard. There is a difference in the definition of terminologies like "incident" and "accident". There is some variation in the guidelines and standards (Saldaña, Herrero et al. 2003, Hughes and Ferrett 2013).

As per OHSAS 18001:2007; HSG 65:1997, ILO-OHS: 2001 and BS 8800:2004, defines "incident" discriminately as events causing no harm, and " accident" as which causes ill health, injury or fatality. OHSAS 18001:2007 has replaced the term “acceptable risk” with “tolerable risk”(Özgen 2012).

While S.D., P., Kampmann.J, Tengborg, Eskesen, Veicherts T.H.:2004 in guidelines for tunneling risk management : International Tunneling Association (ITA), Working Group No.2 follows a middle way in between BS 8800:2004 and OHSAS 18001:2007 , it combines identification of hazard and assessment of risk processes under the term of risk assessment and mitigation (Özgen 2012). The organizations need to recognize, implement and sustain the processes of “Risk assessment” “Hazard identification”, and “determining controls” for general understanding of the hazards caused due to its workplace activities in workplace, and being positive that any risks pertaining from the hazard is reduced to or is at a tolerable level (Asbury and Ball 2016).

The items of instituting, executing and adopting effective process of HIRA process (Hester and Harrison 1998) are achieved mainly by:

- Adopting processes measures to identity hazard and risk assessment,
- Hazards are classified as per the activity or place,
- Evaluate the threats related to common hazards by assessing and defining the levels of risk as per their acceptability,
- Evaluating the tolerable risk control mechanisms, which are important and conforms legitimately to other necessities and the requirements, which are necessary as per OH&S objectives and policy



Fgure 1: Outline of the identification of hazard and assessment of risk process (Adopted from OHSAS 18002:2008)

This addresses the execution of controls, observing and review. So, the “implementation of controls” and “ review monitoring” procedures displayed in Figure 1 are those key processes of the organization’s OH&S management system and are hence performed accordingly (Lu, Yao et al. 2005).

3.2 Qualitative Hazard Identification

3.2.1 Past Accident Analysis

In the area of safety it very challenging to execute controlled tests in a cost efficient and harmless manner unlike other specializations of science and engineering where it is easy to conduct cost effective tests to obtain results (Badawy 1995). Therefore, past accident analysis becomes a crucial tool for documentation of the origins, result and various hazardous factors that led to the mishaps and hence to evade the recurrence of accident in the future (Badawy 1995). Past accident analysis provides instrumental result which can help to mitigate unavoidable mishaps (Aini, Fakhru'l-Razi et al. 2005). Past accident analysis helps in identifying various hazards (Vinnem, Aven et al. 2006). The contributing factors will be known by evaluating previous incidences or near misses or accident incidents (Sagberg 1999). Careful analysis of previous accidents can help in outlaying the unsafe and safe condition of the working site and as a result will help in developing corrective measures for evading so (Reason 2016) .

Accident analysis is the process to determine the route of an accident or succession of accidents by assessment of all sorts of evidence through past records interviews, on-site inspection, etc. so as to analyze further episodes of same kind (Behrent 2010). After a mishap occurs, all related important facts that may have contributed to the occurrence and understanding of the accident is gathered by an accident analysis team (Larsen and Kines 2002). After the completion of the forensic process or at least if a wrong idea of the cause of the mishap is drawn, the bits of facts are put together to give a bigger and better view of the actual scenario (Schofield, Noond et al. 2002). The suitable information can be drawn from the history of the accident, conclusions can be drawn about causative factors. Then the counter measures for dodging these mishaps are formulated and they are recorded for future references (Green 1995).

Accident analysis refers to the investigation of accidents by collecting all sorts of information through interviews, on-site inspections and past records, etc. to determine the causes of an accident or chain of accidents to avoid the additional incidents (Sorooshian, Teyfouri et al. 2014). After an accident, the accident investigation is begun to assemble all the conceivable important realities that add to comprehend the mischance (Banić). On the way reference of finishing the scientific procedure or at least delivering some results, the facts are put together to draw a conclusion (Dewey 1958). Consistency and plausibility are checked and reconstructed from the history of the accident (Lowe 1987). Causation and contributing factors can be drawn if the accident history is sufficiently informative (Lowe 1987). The improvement of counter-measures sometimes is wanted or proposals must be issued for anticipating further mishaps of the same kind. These conclusions are archived and recorded for future (Spiers 1986).

Understanding and awareness of things that went wrong, and perhaps may go wrong again can be predicted from the analysis of past accidents (Reason 2016).The past occurrences encounters are interpreted into cautious measures; later on an association can counteract episodes and the requirement for suppressive activities at time of need (Rothblum 1992). Acquaintance from these episodes are required for comparing and the frameworks and own circumstance and empowers us to build an investigation assessment and minimize time to organize the activities (Ganz 2006).

Though, after an occurrence is happened in an activity or process, promptly the circumstances changes. The time to consider (Brockhoff 1967), when the knowledgeable personnel is being there, based on the past accidents, can take optimal and immediate actions to lessen the damages caused by the accidents. Experienced personnel like him can also prevent the accidents that can initiate an incident in the future, by identifying the hazards (Crowl and Louvar 2001).

3.2.2 Preliminary hazard analysis

3.2.2.1 Overview:

Before starting a job the methods which are practiced, where the risks involved and hazards are discussed and the way outs are provided is called the Preliminary hazard analysis (Harms-Ringdahl 2003). After evaluating the possibilities and the consequence of foremost hazards, the risks allied are estimated and is solved prior to the consequences cause harm (LaGrega, Buckingham et al. 2010).

The following are some of the fundamental points taking into account the preliminary hazard investigation and the qualities of the preliminary hazard analysis:

- Expert opinion and questionnaire based on brainstorming to identify types of hazards and provide a risk ranking, helps in prioritizing recommendations to reduce risks (Thaheem and De Marco 2014).
- Basically it is performed by a group of people who have proficient about the kind of action being referred to. Field inspections and verification of documents are on priority analyzing available system (Hassan 1981).
- Define activity or process
- High level analysis of activity or process
- Qualitative hazard analysis will be carried out based on available procedure.
- Corrective measures will remain in place minimizing level of hazard and continuing process further. (Renn, Burns et al. 1992).
- The effectiveness of assessment depends on the involved team and their experience and also if they have been involved in same activity or process earlier(Robinson and Sellschopp 2002).

3.2.2.2 Detailed procedure:

Steps for carrying out a preliminary hazard analysis are as follows:

3.2.2.2.1 Define the action or arrangement of interest.

Define clearly and particularly the restrictions of the framework or action for which preparatory hazard information are required (Ferrier and Haque 2003).Define the accident classifications of interest and the accident severity classes.

Recognize the issues of interest that the risk evaluation will take in consideration like environmental issues, health and security concerns and so forth. Stipulate risk and its severity classes of the incident which is utilized to organize assets for risk control (Covello, Sandman et al. 1988).

3.2.2.2.2 Conduct audit.

Recognize the related area of the major hazards that will result in unwanted consequences. Besides, identify the alternatives or design criteria that could dispense with the associated risk (Frenkel, Hommel et al. 2005).

3.2.2.2.3 Use the outcomes in drawing a basic conclusion.

Audit the corrective and preventive measures and its benefits that are proposed. The common format used for primary hazard analysis is as Table 2.

Table 2: Primary Hazard Analysis worksheet

Example Primary Hazard Analysis Worksheet				
Area : ________________________________ Meeting Date :______________________________ Drawing Number:________________________ Team Member:______________________________				
Hazard: Potential Accident	Curse	Major Effects	Accident Severity Category	Corrective / Preventive Measure Suggested

3.2.2.3 Advantages of PHA:

- Makes sure that the system is protected
- Carrying out in early stage of the design and therefore, changes are less expensive
- Reduces the number of changes thus decreases the design time

3.2.2.4 Disadvantages of PHA:

- The analyst must for recognizes the hazards
- The consequences of the hazards in a pertinent process are not easily predicted.

3.2.3 *What if* analysis

What–If Analysis is an organized conceptualizing method of defining the an action that can go wrong and assessing the probability and consequence of those circumstances (Tichy, Tushman et al. 1979). The competent assessors of an audit tem genuinely identify the problem in a process or activity. Each individual from the audit group joins in finding what can turn out badly based on their previous accident of past similar circumstances (Wang, Chen et al. 2011).

With the help of Piping and Instrument Diagram (P&ID) or operating procedure, the group surveys the process (Venkatasubramanian, Zhao et al. 2000). Operating and maintenance personnel are usually included by the team members, operating engineers, design engineers, specific skilled personnel as safety and necessary personnel. At every step in the process or procedure, *What-If* questions are asked and consequently answers are developed. After that the review team works to get an approval on every question and answer (Clampitt 2009). A listing of recommendations is developed from the answers, identifying the requirement for additional revision or action. Along with the recommendations, the list of questions and answers, become the major components of the hazard assessment report (Kletz 1999). To lessen the chances of ignoring the probable problems, moving to proposals are done in anticipation of the greater part of the potential risks are perceived (Organization 2002).

When staffs are experienced the *What-If* Analysis technique becomes more effective and easy procedure. No specific devices or strategies are required (Huber 1984). The people with a preparation of little risk investigation can take part in a full and significant way. This can be practiced whenever interested like at the time of debugging, at the time of construction, amid maintenance or amid operations. The consequences of the study can be applied quickly and are immediately available (Kranzlmüller 2000). This is factual if the review team members also maintain or operate the system being assessed.

3.2.4 Hazard and Operability Study (HAZOP)

3.2.4.1 Introduction:

A Hazard and Operability (HAZOP) study is an accurate and organized assessment of hazard associated to an existing operation (Wang and Ruxton 1997). It enquires how the plant or system deflects from the design stop and forms risk for equipment, personnel and operability problems. HAZOP have been used with great success within multiple construction, chemical and the petroleum industry to obtain safer, more efficient and more reliable plants

To analyze this chemical processes, the HAZOP method was principally created.

3.2.4.2 History of HAZOP

The report of HAZOP involves systematic as well as organized work of a operation or existing or preset to establish (Cagno, Caron et al. 2002) and assess problems which may indicate peril to equipment or personnel or might disrupt an effective operation.

This method was formerly developed to examine process systems of chemicals, but it was later extended (Toola 1992) to various systems from software to complex systems. This subjective technique has its roots on guide words being performed by a multidisciplinary group (Kennedy and Kirwan 1998) in meetings.

3.2.4.3 When to execute:

The study of HAZOP should be taken up as soon as possible during early phase of designing to have an impact on the design. But then to go forward with HAZOP we require a completed design. At the time of when design is completed, we check HAZOP (Taylor 2007).

The report of HAZOP might as well be considered on an already established facility to determine any changes that needs to be done in order to reduce risk and operability (Bahr 2014).

Studies of HAZOP might also be extended further which includes:

- At the conception stage of design when outlines are readily accessible.
- At the time when finalized instrumentation and piping diagrams are ready
- At the time of installation and construction to make sure that suggestions are implemented(Meyer 1988).
- At the time of commissioning
- During regular operations so that emergency and operational procedures of plant are timely reviewed and modified as necessary (Kyriakdis, 2003).

3.2.4.4 Background of HAZOP:

- HAZOP was constituted in 1963 by ICI based on techniques of “critical examination”
- HAZOP guidelines was the first lead from Chemical Industries Association Ltd and ICI, 1977 (Rossing, Lind et al. 2010)B.
- HAZAN and HAZOP - Assessment and identification of hazards in the process industry (Malfatti 1809).

3.2.4.5 *Guidelines and Standards:*

- HAZOP - Best practices guidelines for the chemical and process industries (Crawley and Tyler 2015).

- (Commission 2001) IEC - 61882: "Hazard and Operability Studies (HAZOP studies).

  Detailed guide of HAZOP in CSIRO, National Safety Council of Australia, 2003 (Gupta and Charan).

3.2.4.6 Various forms of HAZOP:

- Process HAZOP: This form of HAZOP was formerly developed to evaluate process and plant mechanisms.
- Human HAZOP: It includes particular special HAZOPs which focus on human mistakes rather than any breakdown in operation.
- Procedure HAZOP: Safer Operation Study often denoted as SAFOP which reviews the operational or procedural sequences
- Software HAZOP: It is a form of HAZOP that help identify the errors during the software development.

3.2.4.7 Team Members

- Member of HAZOP team;
- Basically, a plant process team would have:
- Electrical/Instrument Engineer
- Process Engineer
- Project Engineer
- Manger for Commissioning
- Safety Engineer
- On basis of the actual operations, the team may constitute:
- Suppliers Representative
- Maintenance Engineer
- Operating Team Leader
- Any other experts as required

3.2.5 Process HAZOP:

Necessary Conditions: To facilitate HAZOP study, we need following information to be readily available:

- PFD (Process Flow Diagrams)
- MSDS (Material Safety Data Sheet)
- Temporary instruction for operation
- Layout of a design
- Instrumentation and piping diagrams
- Data of equipment, Start up and procedures for emergency shutting down equipment.

3.2.5.1 Procedure:

- The system has to be divided into various sections like storage, reactors.
- A node of study has to be chosen which might be line, pump, vessel, operating instructions
- Purpose of the design needs to be described
- Particular parameter of process is selected.
- Guide word is applied
- The causes are determined
- Assess problems or consequences
- Suggestion for actions on time, reason, responsibility
- Information record
- The procedure from Step 2 has to be repeated

3.2.5.2 Operational Modes:

The following operational modes of the plant need to be considered for individual node:

- Regular Operations

- Reduction in throughput of a operation
- Normal Start up procedure
- Normal Shutdown
- Shutdown in case of emergency
- Commissioning
- Any operating modes that needs special attention

3.2.5.3 HAZOP recording

The findings are recorded during the meeting(s) using a HAZOP work-sheet, either by filling in paper copies, or by using a computer connected to a projector (recommended).

3.2.5.4 Worksheet entries

A. Node

The design/process intensions are evaluated in a process at specific location called a node.

Heat exchangers, Separators, Interconnecting pipes with equipment, Scrubbers, Pumps, and Compressors are few examples.

B. Design Intent

The outline expectation is a depiction of how the procedure is relied upon to carry on at the hub/node; this is subjectively portrayed as an action (example: encourage, response, sedimentation) and/or quantitatively in the process parameters, similar to temperature, stream rate, weight, creation, and so forth (Tribus and McIrvine 1971) .

C. Deviation

An approach of heading off from process targets is called deviation.

D. Parameter

It is the significant factor for certain conditions. (E.g. weight, temperature, synthesis).

E. Guideword

It is to make the creative energy of a deviation of the process/outline plan. The most regularly utilized arrangement of assistant words is: no, all the more, less, and in addition, a portion of, other than, and reverse (Alesina and Weder 1999) . Also, guidewords like too soon, past the point of no return, rather than, are utilized; the last essentially for bunch like procedures (Buxton 2010).

F. Cause

It is the clarification why the deviation could happen. A few causes might be distinguished for one deviation. It is regularly prescribed to begin with some of the causes that may bring about the most exceedingly terrible conceivable outcome (Hayek 1932).

G. Consequence

In case if a consequences occurs, it is the outcome of the deviation. Outcomes may both involve process risks and operability issues, similar to plant close down or lessened nature of the item (Jespen 2016).

A few results may take after from one cause and, thusly, one outcome may include few other causes.

H. Safeguard

It is to moderate the event occurrence and consequences. There are five types of safeguards in which

- Deviation is identified (e.g., human operator detection, and alarms and detectors)

- Recompense for the deviation (e.g., if there should arise an occurrence of packing a programmed control framework diminishes the food to a vessel (Hines 1966). These are regularly incorporated into part of the procedure control)
- Occurring of deviation is prevented (e.g., blankets of an idle gas in stockpiles of combustible material)
- Deviation is further prevented from escalation Mitigate the procedure from risky divergence (e.g., Processt safety valves (PSV) and vent frameworks)

3.2.5.5 Process parameters

3.2.5.5.1 Parameters:

Flow, Pressure, Temperature, Level, Composition, pH, Viscosity, Speed, Voltage, Frequency, Addition, Mixing, Separations, Reaction, Time, Control, Sampling, Inspection, Maintenance

3.2.5.5.2 Guide Words:

None, More of, As Well As, Other than, Less, A part of etc.

3.2.5.6 HAZOP Procedure

The system about HAZOP will be the examination from claiming a surviving or illustrated operation (work) technique on risk assessment and reasons for operational issues, technical issues & human errors(Cameron and Raman 2005). To give a chance to be connected with every one successions of operations.

- Best suited for accurate assessments, but can also be used for common preliminary assessments
- Adaptable approach with admiration to utilization of guide-words. Breaking down of operation process to suitable steps
- Characterize intention for every venture.
- Constitute limit states else as accepted procedure HAZOP.

- Relegate guide-words should proposition and limit states to every venture.

3.2.5.6.1 Advantages:

- Systematic examination
- Can be assigned to every sequences of operations
- Multidisciplinary studies
- Considers operational procedures
- Covers all safety as well as operating conditions
- The Solutions to most of all problems that are identifiable are indicated
- Covers all human errors
- The Study can be conducted by independent personnel.
- All the results are then recorded

3.2.5.6.2 Disadvantages:

- Methodical examination
- Utilizes operational experience
- Considers operational procedures

3.2.6 FMECA

FMECA inclines to be favored over FMEA in space as well as in North Atlantic Treaty Organization (NATO) military uses.

3.2.6.1 Application and Benefits of FMECA:

1. It is a documented technique can be used to ensure the proper design and safely completion of job. It is being in used to assess potential failure in a system, mode of failure and its impact during operation.
2. It helps identifying probable failure and their causes before it could be converted critical. It is helpful in evaluation of changes made in design or

other operational procedures within time and helps maintaining safety at work place.

3. It helps in orderly evaluation of process or system which keeps maintaining proactive safety culture at work place.

3.2.6.2 Limitations FMECA:

While identifying hazard, it may not be comprehensive due to which assessment will be limited. It is used as top down tool in which FTA is comparatively best. In top down tool, FMEA identify the major failure although in the case of bottom up analysis it is slightly better than FTA. Assessment of risk value may be reversed because risk ranking are ordinal scale and its multiplication is not defined in ordinal numbers.

3.2.7 Job Safety Analysis:

Job Safety Analysis (JSA), which is also called Job Hazard Analysis, is an effective tool for hazard identification and risk assessment applicable in all industries but most effective in construction industry. At work place where working environment changes constantly and workers moves throughout of day. It is very difficult to identify hazard and risk at work place and to address this type of problem and evaluate risk , (Azadeh, Fam et al. 2008).

JSA is one of the most effective way which helps in minimizing accidents, injuries at workplace. It is tool for training, investigating near misses and accidents (Reese 2011).

A process or activity will be selected to start JSA and potential hazard will be identified. All the way, each and every step will be considered for analysis. After JSA completed, it will be ensured that work had planned properly and ensured safety of workers at workplace(Phoya 2012).

Steps in involved in JSA:

I. List out steps involve in JSA

The moment work activity decided and understanding of work is clear, the work activity need to divide into various parts or steps. These activity or sub-activity is not just specific to the job but also suitable for the work areas. When there are changes in work areas, possibly there is a need to change the sub activity or steps involved.

II. Identification of hazards associated with each step.

Hazard identification in an activity or process is key elements of JSA. Each sub activity will have associated hazard and could lead to failure. Therefore, it will be recommended that how an activity or process, people, material and environment can lead to different hazards. Assessment of activity and identifying hazards are by the following

- From past accidents analysis
- Legal requirements
- Instruction given by manufacturer
- Surrounding work near to the specified work areas.

III. Determine controls for each hazard.

All identified hazard in an activity or sub activity will be having a control by which risk level of hazard can be minimized.

IV. Discuss the JSA with your workers.

Completing all these three steps, JSA will be framed to reduce the risk level at work place. The same information has to share with the workers or employee involved so that any adverse action can be avoided. Before starting the work, JSA review will be done by crew members and ensured that everyone familiar how to do the job. Review of JSA will be done once the same task extended for another day.

3.2.8 Fault tree analysis

3.2.8.1 History

The Beginning Years (1961 – 1970)

- Watson & Mearns (1961), built up the strategy for the Air Force for assessment of the Minuteman Launch Control System.
- Dave Haasl (1963) of Boeing as a critical framework safety investigation device.
- First real utilize when connected by Boeing (1964 – 1967, 1968-1999) on the whole Minuteman framework for safety assessment.
- The first specialized papers on FTA were introduced at the primary System Safety Conference, held in Seattle, June 1965 Boeing started utilizing FTA on the configuration and assessment of business air ship, around 1966
- Boeing built up a 12-stage issue tree reenactment program, and an issue tree plotting program on a Cal comp move plotter
- Adopted by the Aerospace business (air ship and weapons)

The Early Years (1971 – 1980)

- Adopted by the Nuclear Power industry
- Power industry upgraded codes and calculations

The Mid Years (1981 – 1990)

- Usage began getting to be global, essentially by means of the Nuclear Power industry
- More assessment calculations and codes were produced

- A vast number of specialized papers were composed on the subject (codes and calculations)
- Usage of FTA in the product (security) group
- Adopted by the Chemical business

The Present (2000)

- Continued use on numerous frameworks in numerous nations
- High quality flaw tree Commercial codes built up that works on PC's

3.2.8.2 Overview:

Fault Tree Analysis (FTA) is an innovative technique which is commonly used to recognize the events which may occur in order to realize a desired or undesired result. The technique uses a deductive approach to event analysis as it moves from the general to the specific. FTA provides great utility in its ability to distinguish between those events which must occur and those that simply can occur in order for the top event to occur. The information charted on a fault tree provides a qualitative analysis by demonstrating how specific events will affect an outcome (Ramzali, Lavasani et al. 2015). The basic strategy includes the utilizing a mix of generally basic rationale gates (AND, OR ,NOT) to build a disappointment model. The Top Event recurrence or likelihood, is figured from information identifying with less complex or more fundamental Activity , An essential hypothesis in FTA is that all framework disappointments are paired in nature, i.e. a segment or administrator either performs effectively or fizzles totally (Purba, Sony Tjahyani et al. 2015). Construction of Fault Trees

For undertaking the procedures of FTA, 5 steps are involved

- Description of system, including system boundary.
- Identification of Hazard, and determination of top event.

- Construction of fault tree.
- Subjective assessment and examination of the fault tree.

Step One: System description:

A key step in FTA is that a knowledge of the causes of Untimely events is conceivable only by a thorough idea of how the system works (McNelles, Zeng et al. 2016). The initial stage is basically open and it's the responsibility of the individual building the fault tree (the analyst), where boundaries and data needs can be found out (Matuzas and Contini 2015). A portion of the data that might be required are process description, hazardous materials, specifications of equipment's, operating and maintenance procedures, so on (Makajic-Nikolic, Petrovic et al. 2016).

Step Two: Hazard identification

Various activities for example, site reviews, checklist, HAZOP studies and examination of incidents can be utilized to find out top events (Lower, Magott et al. 2016). Top events are generally very major incidents for example, fire, equipment failure, other incident and huge explosions.

Step three: Fault tree construction

There are no such rules what events and gates to be used in fault tree construction. Fault tree show how a specific event occurs by logic diagrams.

A specific undesired outcome is selected and it becomes the event. The causes of the event are identified with their logical link, then an analyst asks queries as "How it can happen?" and "what are the causes which led this event to occur?". The queries continues till the analyst is fully clarified that the model which was failed describes the process under the study (Liu, Yang et al. 2015). Moreover, the process of queries could continue and issues coming outside the boundary of study are not mentioned. As a result, definition of boundary is essential for the success of fault tree analysis(Lavasani, Ramzali et al. 2015).

Fault trees which are made manually are comprehensively subjective and may be incomplete, but, allows the analyst reviewing the system, some errors that may occur in a fault tree are:

- Rapid building of a branch of a tree without deliberately processing level by level along the entire fault tree (Komal 2015).
- Omission of a fundamental failure framework or cause, or a wrong supposition of irrelevant contribution.
- Incorrect blends of probability and frequency into logic gates.
- Improper balance between equipment sort causes and human blunders.
- Non-recognition of dependence of events.

Step Four: Qualitative examination of structure

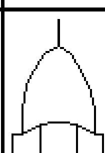
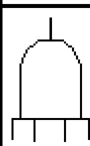
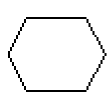
The structure of the fault tree can be qualitatively analyzed after being built, to understand the mechanisms. The things which are highlighted are, the subjective significance of occasions, safeguards effectiveness and the helplessness to regular mode failures (Kabir, Walker et al. 2016). Inspection becomes difficult for more complex fault trees and to tackle this more simplified way as Boolean analysis must be applied. For defining the top events in terms of a summation of all lower events, fault trees has to be converted into equivalent Boolean expression (Ju 2016). This expression is expanded with the help of laws of Boolean algebra, until the top event as the sum of minimal cuts sets.

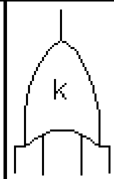
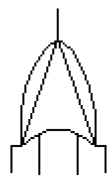
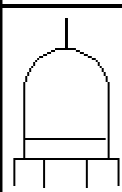
When a single event affects the basic events, common failures are caused which are independent in fault tree (Huang, Fan et al. 2016). The common causes are maintenance error miscalibrating all sensors and power failure disabling several electrical safely systems. For instance, if there is a power failure in any of the two branches of a fault tree attached by an AND gate, and the gate by gate method is followed, the final result will have an error (Huang, Fan et al. 2016). Boolean analysis addresses this problem by identifying the errors. However, there are other elements also which are not included could result in common failure, for example, Common manufacture, common location and so on (Deng, Wang et al. 2015).

Step Five: Quantitative evaluation of fault tree

The top event frequency can be calculated once the last structure of fault tree has been resolved and a recurrence has doled out to each of the essential events. The gate by gate technique is being followed up to the top event. Before calculating the gate output, all inputs must be defined. Before continuing to the more elevated level, all lower gates must be computed. In OR gates, addition occurs and in AND gates, multiplication occurs (Choi and Chang 2016). A number of additional studies possible once a fault tree has been calculated which includes, uncertainty and Sensitivity analysis. Uncertainty analysis gives us a measure of the error bounds of the top event whereas Sensitivity analysis is utilized to decide the affectability of the top event recurrence (Cheshmikhani and Zarandi 2015). The various minimal cut sets are ranked by Importance analysis in order of their contribution to the failure frequency.

Table 3: Classic Fault Tree Gates (Ruijters and Stoelinga 2015)

Name of Gate	**Classic FTA Symbol**	**Causal relation**
OR		If both inputs are "No," then the output is "No."
AND		Output is "Yes" when both inputs are "Yes." Otherwise, "No."
Inhibit		If all input occurs along with an additional conditional event occur, then output will occur.

Name of Gate	**Classic FTA Symbol**	**Causal relation**
Voting OR (*k-out-of-n*)		The yield event happens if k or a greater amount of the information (Input) events happen.
XOR		If both inputs are either “false” or “true”, then the output is false.
Dependency AND	In FTA it is not used.	If all the inputs are “true” and the inputs are dependent upon each other, then the output is true.
Priority AND		If all the input occurs in a particular grouping, then only the output occurs.

3.2.9 Event Tree Examination

3.2.9.1 Overview

- It is a type of risk assessment that depends upon binary logic. In this tree examination an event either is being or being not taking place or a constituent is or is not diminished.
- It is used in recognizing as well as analyzing the consequences take place from a failure or unwanted event. It is a forward bottom-up approach (Ayav and Sözer).
- It is a dominant tool that will categorize all features of a system that includes a chance of taking place later on, when the initiating event is to

be applied to extensive range of systems such as nuclear power plants, chemical industries etc.

- An event tree begins through initiating event, with pivoted events in between as well as ends with Accident situation. Probabilities of Events are acknowledged for each and every situation

Initiating Event:

- Collapse or unwanted event that initiates the start of an accident series.
- Fire, Explosion or a release of a hazardous substance are the examples of initiating event

Pivotal events-

- These are the mediator events between IE as well as the final accident.
- These are the (Failure/success) events of design safety techniques
- Fire alarm works, Sprinkler system, Fire detection system are some examples of Pivotal events

Accident scenario –

- Series of events that are eventually result in an accident.
- The sequence of event usually starts with initiating event as well as is followed by one or more pivotal events that leads to unwanted circumstances

3.2.9.2 Steps that are involved in event tree examination

- Recognize the Initiating event
- Recognize the commas well ass, which are assigning with the primary event like as automatic ty systems, alarms on operator actions.
- Create the event tree starting with the initiating event as well as proceeding through collapse of the safety functions.
- Build the resulting accident sequence.

- Recognize the substantial elements which are to be linked

3.2.9.3 Advantages of Event Tree Examination

- It unites the hardware, software, environment, as well as human interface
- It allows probability evaluation
- Business-related software is available
- Can be performed on various levels of details
- No need to look forward to end events
- Comparatively easy to learn as well as implement

3.2.9.4 Disadvantage of Event Tree Examination:

- Addresses only one initiating event at a time
- Success or failure probabilities are very difficult to discover
- an analyst is needed with practical training as well as experience
- The initiating challenge must be recognized by the analyst

3.2.10 Cause-Consequence Analysis (CCA):

It is a method used for analyzing consequence of chain or any activity. It can be used independently and for individual and also it is helpful for other analysis methods (Ylijoki-Sørensen, Boldsen et al. 2014).

By this method, unwanted events, their consequence and probabilities gets identified. It can be done by merging or combining two different tree events together. In this methods, it examine the primary event and its follow or intermediate events might lead to any failure(Reinholds, Bartkevics et al. 2015). The primary event and follow events cause and probabilities analyzed by top to down tree and it describes failures in this tree only which normally called as fault trees. Cause and consequence tree forms a chain which clarifies the relation between cause and consequence and probably leads to damages. CCA includes:

1. Identify damaged chain or event
2. Identify primary event
3. Identify follow up events
4. Recognize the consequence damage
5. Clarifies cause of failure events
6. Set up probabilities for the cause identified in primary and follow up events.

It is an effective tool which ensures the execution or operation of any activities for which consideration would have been taken in design phase. It is helpful in evaluating complex events which have many altered consequence even in primary events

3.2.11 Decision tree analysis

It is a tool used in tree - form graph or model of all decisions and their consequences. It includes the outcomes, cost & utility and represented in flow chart in which each branch represents the outcomes.

It has three nodes:

1. Decision nodes
2. Chance nodes
3. End nodes

It helps in identifying the causes of failure or consequence coming during operational safety. Once failure identify, suitable control measures remains in place.

Decision trees are as of now a standout amongst the most mainstream strategies utilized for data modeling of data or information displaying. Decision trees are ordinarily utilized as a part of operations examination, particularly in choice investigation, to recognize a methodology well on the way to achieve an objective. They have the edge of being reasonably straightforward, and have been appeared to perform well on an assortment of issues. Decision trees have numerous utilizations, for example, for instance, anticipating a likely result, helping with the examination of issues, and supporting in deciding.

3.2.12 Monte Carlo simulation

It is a mathematical technique in which risk assessment done in quantitative form. This technique is suitable for project management, finance, energy, oil & gas, environment, manufacturing and R& D sectors. It allows decision makers to set possible outcomes and their probabilities of occurrences at any point. A range of outcomes and their occurrences comes out of it and it helps in decision taking.

This technique was used by scientists during working on the atom bomb and during second world war it has been used in many physical and conceptual system.

Monte Carlo techniques are basically utilized as a part of three particular issue classes: enhancement, numerical reconciliation, and creating draws from likelihood dissemination.

The probabilistic way of incident frequencies and adverse behavior makes the Monte Carlo strategies a perfect tool for risk assessments.

3.2.13 Hazard Identification and Risk Assessment (HIRA):

Whenever we talk about hazard, we assume a source or situation which could able to harm and may turn into Ill health, loss of property, loss of environment and injury etc. or amalgamation of these. Although, hazard identification is a process of recognizing the hazards that exists in any activity and defining its characteristics (Lees 2012). While risk is a result of any miss happening in which it signifies the likelihood of consequences of any hazard and severity of an injuries.

But when we take the considerations of risk assessment then we call it as process in which risk will be evaluated from the available hazard for the purpose of further control measure. There are numbers of standard which gives guidelines in which it is assume that work place hazard can be identified in any activities or sub activities and their associated risk can be determined (Kennedy and Kirwan 1998). The determined risk will be evaluated based on the risk matrix available for the further control.

OHSAS tells about the identification of risk in significant categories where it is required to classify the risk in a range where further control will be taken by special attentions or based on the control operating procedures(Labodová 2004) . The identification of risk is the judgement made by the competent person and person involve in project management and those knows the trend of occurrences of any hazard or risk in past.

The OH&S hazard are the behavior of any process unit, activity, product and procedures which adverse as an impacts inline to the concern activity or process or procedures. Therefore, if impact noticed before and a suitable control applies at right time, the risk coming out from these activities or process will be under control or not able to touch its significant range.

Therefore, it is important for an organization to identify hazard in each and every process or activity and assessing its risk for suitable control measures. The control measure suggested should be impartial and should be applied without any interference.

Whenever risk assessment is done, it is always the combination or multiplication of likelihood of any hazard and its severity. In mathematical way, the risk can be calculated by

Risk (R) = Likelihood (L) of an event x Severity (S) of any outcome

Where, Likelihood (L) is an occurrence of any event in a specified time or in specified circumstances while severity is a result or outcome from that event in terms of injury/ health of people, properties damage, damage or adverse on environment or may be combination of these.

3.2.13.1 Purpose of HIRA

- Identification of the purposes which cause harm to employee
- Possibility of that cause of harm to the employee and its severity.
- An organization should able to plan, introduce necessary preventive measures controlling risk.

3.2.13.2 Planning for HIRA

a. It can be planned for a situation
   - Where there is a significant hazard available
   - Where control measures not adequate
   - In which corrective and preventive measures are need to be implemented

b. An organization which is intended to improve safety management system

3.2.13.3 Process of HIRA

HIRA has certain steps to do at work site and they are as follows

- Identification of activity or sub activity hazards
- Assessing the risk related to each hazard (tolerable or non-tolerable)

- Control measure for risk categorized under non tolerable and its monitoring
- Verify adequate health and safety objective and action plan to reduce risk identified and follow up monitoring reduction of risk.
- Training needs identification for the adequate risk control measures and adequate control measures should be a part of operational control

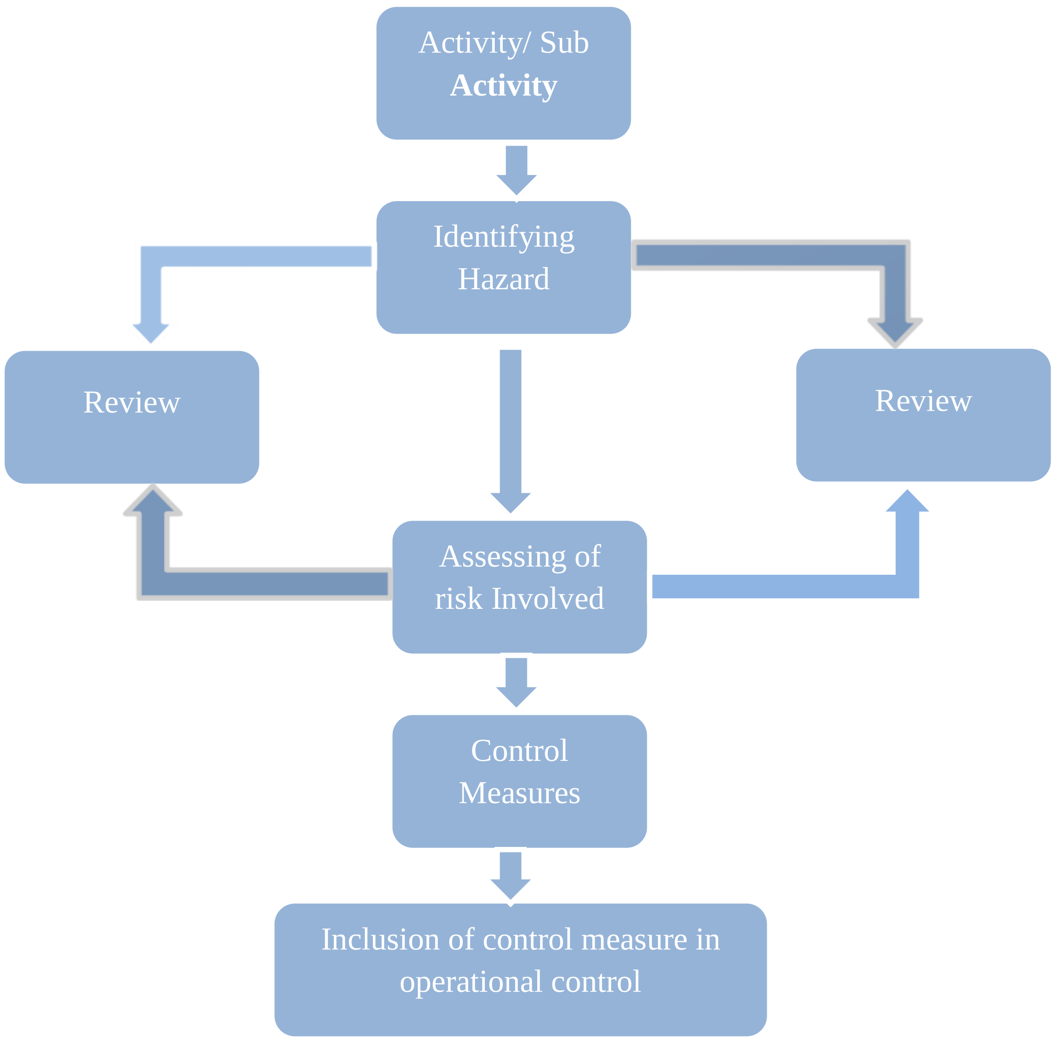


Figure 2: Steps involve in HIRA

3.2.13.4 Assessment of probability and severity

Table 4: Probability Rating (PR)

High (H)	When it occurs frequently or Chances approx. more than 50%
Medium (M)	When it occurs occasionally or Chances between 10% to 50%
Low (L)	When it has never occurred before or chances less than approximately 10%

Table 5: Severity Rating (SR)

High = H	When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000
Medium = M	When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000
Low = L	When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000

3.2.13.5 Risk Matrix:

Table 6: Risk analysis matrix

Probability	H	**3**	**4**	**5**
	M	**2**	**3**	**4**
	L	**1**	**2**	**3**
		L	M	H
Severity				

Table 7: Risk level

Risk Level (RL)	Trivial	Tolerable	Moderate	Substantial	Intolerable
Number	1	2	3	4	5

CHAPTER 4

4 Methodology

4.1 Research framework

4.1.1 Theoretical framework:

Viaduct construction sites have being selected for research study. The main focus of the research is the techniques – job safety analysis (JSA), group risk assessment, What-if analysis and inherent safety approaches – used for hazard identification and risk assessment.

Job safety analysis is the technique which is specifically chosen for construction work. Due to the nature of construction work activities, which keep changing on day to day basis, it is difficult to fix the risk level of any particular activity. JSA is helpful in identifying the hazards associated with activities which keep changing on day to day basis. During execution of work, certain changes in activities or any unplanned activities can be assessed using JSA. JSA is relevant in most of the cases if the recommendations given during assessment are considered.

The most exhaustive concept or technique which we use at construction site hazard identification and risk assessment is the group risk assessment. Hazard identification and risk assessment (HIRA) is broadly used in construction industry to identify the hazard, risk and based on it control measures can be taken place. Team from execution, safety, planning etc. carry HIRA and assess relevant hazard and risk for particular activities since design to execution stage of work. What-if analysis is also helpful while planning and designing or work activities. We take consideration of experience people at work place and they really help out in deciding the hierarchy of control for hazard and risk inherently available in some of activities.

The expertise required for doing safety analysis is gained through years of experience at construction sites. The expert studies the nature of the work and behavior and skill of the person involved in execution of concerned activities. The expert takes into consideration many factors or challenges faced during execution. Years long involvement in construction work execution, system implementation and worked as core team member of risk assessment, many favorable and unfavorable considerations were identified which gives a scope of working in these areas and to bring improvement in it.

For this research total 58 method statements, and 20 health safety and environment manuals were studied and critically analyzed for different types of activity at viaduct construction sites. Similarly state-of-the-art review of hazard and risk present at construction work activities has been done.

4.1.2 Data Collection:

4.1.2.1 Source of data

To complete research work, data collection has been done. Approach of using data collection is via both the mode. i.e. Primary and secondary data source.

4.1.2.2 Primary Data:

i. Site observations
ii. Audit reports
iii. Accident analysis
iv. Method statements
v. HSE plan/ Manual
vi. Questionnaire

4.1.2.2.1 Site Observations

Over last 5 years, various site inspections were done with different companies engaged in viaduct construction works. Site inspections have been done by various levels of employee for different activities. Site inspection included as daily inspection, weekly and biweekly inspection. Physical condition of work place has been determined and evaluated through various site inspections. Normally a walk through with project head, client representative along with head of verticals had been a part of particular weekly or biweekly inspection assessing the work place with respect to standard condition laid down in legal requirements or condition or contract by the client. More than 500 observations have been taken into record that has been done for different activities.

4.1.2.2.2 Audit reports:

Over past five years, more than 20 external audits and more than 50 internal audits has been done and taken into consideration for research work. Audit work has been done at various construction sites confirming safety management system and assessing work site conditions for further improvements. Audit work has been done at certain periodic interval of time so that same activities could be assessed confirming the kind of improvement or failure may coming in during execution. Similarly, during auditing, it had also tried to cover activities different from previous one and reconfirm again in further audits. During audit, each and every scope of project has been covered and analyzed. Not only the current scope but it also focuses on previous scope what had been covered and their conformities. Even different agencies have engaged in doing external audit so that partiality of same can be neglected.

There are three types of audit has been conducted at site and they are (1) Internal Audit (2) External Audit.

Internal audit has been conducted by the competent employee of an organization in two modes. One is by self and another along with client and hired competent person. Internal audit has been conducted by internal audit team in presence of concern department head or in-charge. The issues which has come is being addressed with concern in charge and a target date is set to close out the non-conformance raised during auditing process. Similarly, external audit has planned throughout the year at certain interval followed by surveillance. It has been tried to analyze the nature of nonconformities and its impacts during execution.

4.1.2.2.3 Method Statements:

58 method statements, listed in Table 5, pertaining to different construction activity were analyzed. The key findings of the analysis are summarized in section 4.1.3 & 4.1.5.

Table 8: Different types of method statements

S. No	*Method statement for construction activity*
1.	Method statement for 30MT Gantry crane assembly and erection (Rev-2)
2.	Method statement for construction of road crossing duct outfall of dewatering at Location 1(Rev-2)
3.	Method statement for construction of road crossing duct outfall of dewatering at Location 2 (Rev-4)
4.	Method statement for construction of deep lined wells (Rev-3)
5.	Method statement of excavation and support of main station and switch box (Rev-2)
6.	Method statement of excavation and support of main station and switch box (Rev-3)
7.	Method statement of station void investigation (Rev-2)
8.	Method statement of dewatering system (Rev-3)
9.	Method statement of production and installation of steel reinforcement (Rev-4)
10.	Method statement of demolition and reconstruction of existing boundary wall location

S. No	*Method statement for construction activity*
	1 (Rev-3)
11.	Method statement of construction of temporary slab at location 1 underpass (Rev-3)
12.	Method statement of basement foundation slab construction (Rev 3)
13.	Method statement of construction of workers accommodation and facilities (Rev-1)
14.	Method statement of earthing and bonding of station switch box (Rev-2)
15.	Method statement of erection of stairs tower and switch box (Rev-1)
16.	Method statement of rail track and gantry track erection (Rev-2)
17.	Method statement of tower cranes erecting and dismantling (Rev-6)
18.	Method statement of design, production and erection of formwork (Rev-2)
19.	Method statement of construction of elevations (Walls & columns), intermediates slab and rood slab for station and switch box (Rev-2)
20.	Method statement of station box temporary head wall reconstruction and backfilling at location 1 (Rev-2)
21.	Method statement of construction of road crossing ducts for outfall of dewatering with horizontal directional drilling (HDD) methods. (Rev-2)
22.	Method statement of permanent concrete repairs work (Rev-3)
23.	Method statement of installation commissioning and operation of batching plant. (Rev-2)
24.	Method statement of production and erection of structured steel (Rev-2)
25.	Method statement of monitoring and instrumentation (Rev-3)
26.	Method statement of survey and setting out (Rev-3)
27.	Method statement of installation & relocation of fence/ hording at project sites. (Rev-2)
28.	Method statement of site areas preparation works, earthworks, roads and parking (Rev-3)
29.	Method statement of cast in-situ manhole at location 1 (Rev-2)
30.	Method statement of dewatering discharge manhole (Rev-2)
31.	Method statement for initial pile load test (Rev-1)

S. No	*Method statement for construction activity*
32.	Method statement for installation of elastomeric bearing. (Rev-0)
33.	Method statement for parapet lifting and stitching (Rev-01)
34.	Method statement for parapet lifting and stitching (Rev-02)
35.	Method statement for parapet lifting and stitching (Rev-02)
36.	Method statement for erection of I girder (Rev-0)
37.	Method statement for erection of I girder (Rev-0)
38.	Method statement for casting of I Girder (Rev-0)
39.	Method statement for erection of I Girder (Rev-1)
40.	Method statement for production of concrete (Rev-0)
41.	Method statement for prost tensioning work (Rev-2)
42.	Method statement for parapet erection (Rev-0)
43.	Method statement for casting of pier (Rev-0)
44.	Method statement for casting of pier cap (Rev-0)
45.	Method statement for survey work (Rev-0)
46.	Method statement for geotechnical investigation (Rev-0)
47.	Method statement for bentonite use and handling (Rev-0)
48.	Method statement for parapet erection (Rev-0)
49.	Method statement for construction of column work (Rev-1)
50.	Method statement for pier cap (Rev-0)
51.	Method statement for pier cap (Rev-1)
52.	Method statement for pier cap (Rev-2)
53.	Method statement for erection of gantry cranes (Rev-0)
54.	Method statement for casting of pre-tensioned I Girder (Rev-1)
55.	Method statement for erection of I Girder (Rev-0)
56.	Method statement for erection of I girder (Rev-1)
57.	Method statement for erection of steel span (Rev-0)
58.	Method statement for pre-tensioning of I girder (Rev-0)

4.1.2.2.4 HSE Manual:

20 different HSE manual/ Plan of 14 companies as listed in Table 6, pertaining to different- different construction projects were analyzed. The key findings of the analysis are summarized in Section 4.1.4 & 4.1.5.

Table 9: HSE manual plan

S. No	*HSE manual/ plan*	*No. of HSE Manual/Plan*
1.	Safety, Occupational Health & Environmental Management Systems Manual (SHE MSM)	6
2.	Safety, Occupational Health & Environmental Operational Manual (SHE OM)	6
3.	Occupational Health & Safety Management System Manual	1
4.	HSE Manual	3
5.	HSE Apex Manual	1
6.	HSE & Fire Plan	1
7.	HSE Plan	1
8.	Manual on construction risks, damage to the works and advanced loss of profits (ALOP)	1
	Total	**20**

4.1.2.2.5 Accident statistics data:

More than 100 reportable accidents and more than 500 first aid cases has been analyzed and mentioned in result discussion. Considered accidents were analyzed critically and root cause of accidents or first aid cases has been considered in questionnaire survey and framework development.

4.1.2.2.6 Questionnaire:

A set of questionnaire was been prepared seeing the need of evaluation area, aspect required. The questionnaire is based on review of site conditions, method statements, health and safety plan, and many more factors e.g. Design considerations, Social concern, environmental concern, job satisfaction, financial constraint, Legal issues, availability of skilled manpower etc. The format for questionnaire given in appendixes and the result outcome of doing this survey is in result and discussion sections.

4.1.3 Data Analysis:

Fact finding has been done while conducting site inspection (Daily, weekly or bi-weekly or specific). The purpose of routine or daily inspection was to look at the gaps or lack in implementation of safety health & environment as suggested or legal and other requirements.

While inspection day to day activities or hourly activities, non-compliance or casual attitude towards implementation of HSE has found. While comparing with months data or observations, it has also found that majority of observations nature is repeated and action taken is not proactive. There is lots of similarity between these site inspection and audits in terms of site safety implementation and number of observations are same. This shows the lenient approach of implementation of safety. Similarity in observations once compared daily or weekly inspections. Repeated observations and action is not proactive. While analyzing these various inspection and audits, it has found that, majority of observations are due to negligence of execution person, lack of interest of line management. Aspect & impact analysis done at site is not appropriate or only done for paper work. Lack of resources is one of the major finding during inspection and audit of various construction site. Engineers or management concern were lenient towards safety.

HSE issues or concern is not adequately addressed in planning stage of project. This brings instability in execution of project safely. It has also found, legal laws are known to management but it is not enforced at site in reality. This again, brings instability of execution of projects. Environmental concerns were again major issues at constriction site where implementation is partial. Management attention towards legal concern is also partial and they keep focusing on project production as their priority.

While inspection and analysis done at site among site workers, engineers or managers it has been concluded that cost saving is prime concern and for this, sub-standard material, inadequate material is being used which contains inherent risk in them or it impacts project safety directly or indirectly.

It was also noticed during observations, designer role is limited up to certain extent, they need to focus on design which can be executed safely and likelihood of risk is minimum.

Interacting with engineers and managers, they showed their concern towards difficulties of design which suggest the following:

1. Most of the activities are covered thoroughly in MS with their referencing and detailed step wise activity.
2. Although MSs mentions prior activates but it does not cover the criticalities associated with prior activities or other challenges, thereby opening avenue to address the associated problems a prior.
3. Some of the MSs have detailed coverage of the step wise execution of work details whereas in most of the MS it is done partially. Major safety considerations or execution hurdles are not highlighted in any of the MS.
4. The HSE issues related to individual activities or sub activities are not mentioned. Only generic HSE control measures appear in every MS.
5. In spite of multiple reviews no changes have been incorporated in MS to address the safety concerns.
6. The role of designer in preparing MS is limited.
7. Risk assessment included in MS covers most of the activities and sub activities. Whereas, a few MS identify only limited activities.

8. None of the MS present separate discussion on existing and proposed control measures. In most of risk assessments (RA) only proposed control measures are in place. The proposed control measures are satisfactory sometime in few RA. Majority of proposed control measures are very common and limited which directly influenced the risk values of risk assessments.
9. A thorough analysis of risk assessment studies shows that majority of the RA studies are qualitative in nature with a few exceptions. It has been observed that, minimization of risk is claimed through cosmetic changes thereby rendering the risk management ineffective. In some of the risk assessment studies, probability and severity of existing hazard has not been considered.
10. In majority of risk assessment, significant risk or critical risk areas have not been identified.

4.1.4 Observations based on thorough study of HSE manuals.

I. Majority of HSE manual are project specific.

II. Management system manual are based on ISO 14001 and OHSAS 18001. Some of the HSE manuals have been compiled based only on general safety measures.

III. Only some of operational manuals detail about safe procedure to be followed during execution.

IV. Critical activities have not been identified in most of the HSE manual. Even though these HSE manuals are project specific, critical activities, their hazard and risk have not identified. In some of operation manual, control operating procedures are included but it has not adequately covered about nature of activity for which these control operation procedures is made.

V. The role of designer and consultant is not listed and HSE management systems are mute about it.

VI. Safe procedures are well versed in most of operational manual and it gives guidelines to execute the work safely. In addition, it is required to discuss individual steps of an activity and their hazards and risk.

VII. No guidelines have been given to assist in hazard identification and risk assessment. In some of the HSE manuals, RA procedure is given but no mention is made of the adherence to hierarchy of control.

VIII. Emergency preparedness plan is elaborated well in some of the manuals and a few HSE manuals emphasize on the need to improve individual emergency scenarios action plan.

IX. A parent team has been assigned to handle all type of emergencies without mention of emergency specific roles.

X. Neither mock drill guidelines have been defined nor any time frame has being fixed for safe evacuation or control depending on the level of emergency.

4.1.5 Summary of MS & Manual:

A total 58 method statement and 20 HSE manuals were studied to identify their shortcomings in terms of scope of work, prior activities details, detailed work procedures, HSE management systems & risk assessments etc. (As given in tabular form)

I. Subjectivity of MS should be eliminated and core team, expert opinion, idea or proposals shall be in considerations.

II. Whenever any work activity details given, should be analyzed by expert team consisting designer, planner, project management team, safety experts and other HOD's. Based on expert opinion, activity should be highlighted if it consist critical risk while performing the work.

III. Step wise work details with expected difficulties to be mentioned so that control measures can be suggested accordingly. Every activity shall have their HSE aspects and based on that HSE control measures should be in place.

IV. Risk assessment methodologies used in method of statement lack thoroughness, as it is highly subjective, and no specific framework exists for the steps to be followed while doing risk assessment.

V. Safety design considerations are an effective way to reduce construction accidents but lack of expertise and confidence on part of designer has resulted in many accidents in the past and management are somewhere responsible to give importance of competent designer with their competent core team to give their inputs reducing construction accidents.

VI. Therefore, common guidelines are to be prepared for quantitative risk assessment by which each and every considerations of construction project shall be taken into account.

VII. While analyzing various risk assessment of construction projects it has found that, various considerations which somehow influence partially or fully to the project execution cycle, social well-being of workers or accidents statistics are not into considerations.

VIII. Construction projects HSE manuals needs to be incorporated based on expert opinion or suggestions and all different considerations which partially or fully influence execution cycle of projects. HSE manual (management system and operational manual). Critical activity or sub activity working procedures should be highlighted with adequate HSE control measures and probable hazard and risk should be scrutinized at the time of execution of that particular activity. Any changes coming into execution should be highlighted from onwards communication system and thorough discussion required from expert team including structural and functional safety experts.

IX. In India, we lack of dedicated structural safety expert and this responsibility is on designer at this time therefore, it is required to take his considerations all the time whenever any changes coming in or while incorporating HSE manuals.

4.1.6 Framework Development:

Framework is being developed based on the Inspection/ observation work done at work site, analyzing method statement, study and analysis of HSE manual or plan, accidents statistics and based on relevant questionnaire. In this framework, some of considerations has been added which quantification will add on to the previous method of doing risk assessment. It has been develop a technique that is helpful in identify constraint by which any failure could be assisted and when it is likely to be happen, before necessary action can be taken place. The way it has been done, the chances of occurrence of accidents or any miss happening could be minimized if properly assessed and control measures suggested. It could be easier to raise the alarm immediately once identify any one of the consideration below their set levels or requirements. This will be helpful in controlling adverse scenario or impact in shorter or longer terms. Study and analyzing risk assessment of different project site involved in viaduct and other construction works, it has observed that at many projects or activity chooses for execution, HIRA is most generic and doesn't consider many of the essential considerations.

Based on the study done with the help of various methods, there are 12 considerations which have been included in HIRA which is to be looked at during conducting group risk assessment. HIRA will be conducted at initial stage to final stage of construction work and competency of each section will be included identifying various hazards at work site.

During risk assessment, these considerations will be analyzed and quantified separately and its criticality will be added advantage for the existing model available for risk assessment and each consideration and quantification will be evaluated separately

4.1.7 Different Considerations of risk assessment:

These considerations are-

i. Environmental consideration
ii. Social considerations
iii. Economic considerations
iv. Design consideration
v. Consultant consideration
vi. Client consideration
vii. Contractor consideration
viii. Safety consideration
ix. Resource mobilization consideration
x. Manpower consideration
xi. Legal Concern consideration
xii. Adverse concern consideration

Decision analysis of this consideration: All these considerations have their importance and impacts in project life cycle. Every consideration has 6 categories and every category of each consideration has been quantified based on the review, legal requirements, site observations, experience and expert advice.

CHAPTER 5

5 Result and discussion

5.1 Site inspection and observations:

Inspections reports from three different construction sites, over the period Feb 2013 - July 2014 was taken into considerations for data analysis purposes. Following are activities have been considered for trend analysis and gaps identified:

- Housekeeping
- Barricading
- Electrical work
- Work at height
- Hot work
- Mechanical work
- Excavation work
- Hand rails/ Edge protection
- Material handling/ Lifting
- Hand tool & power tool
- PPE's
- Fire
- Others

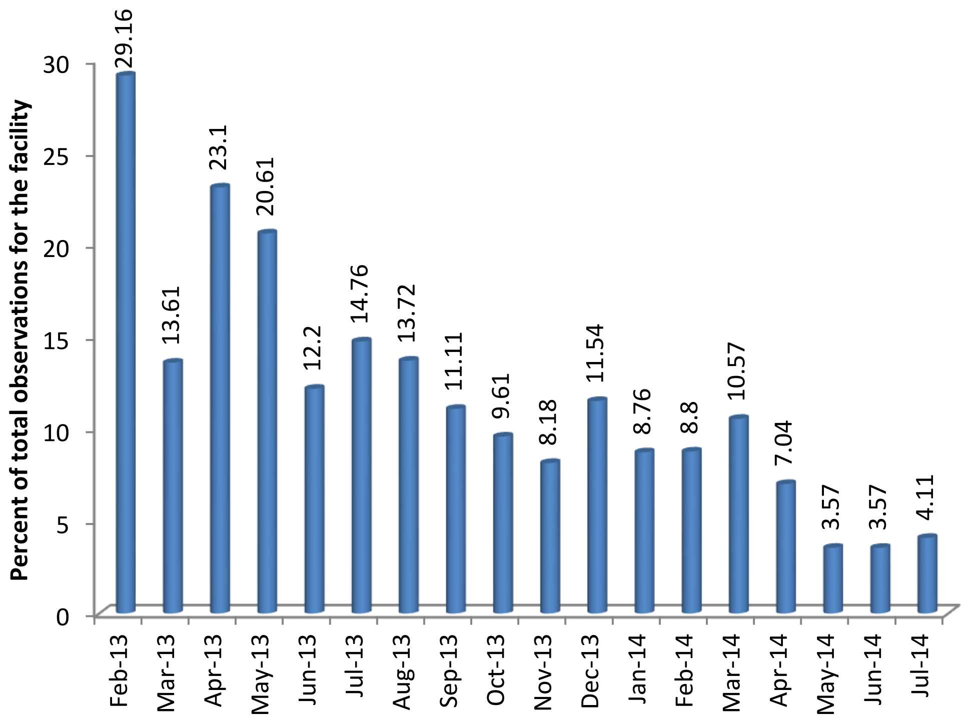


Figure 3: HSE inspection for Housekeeping

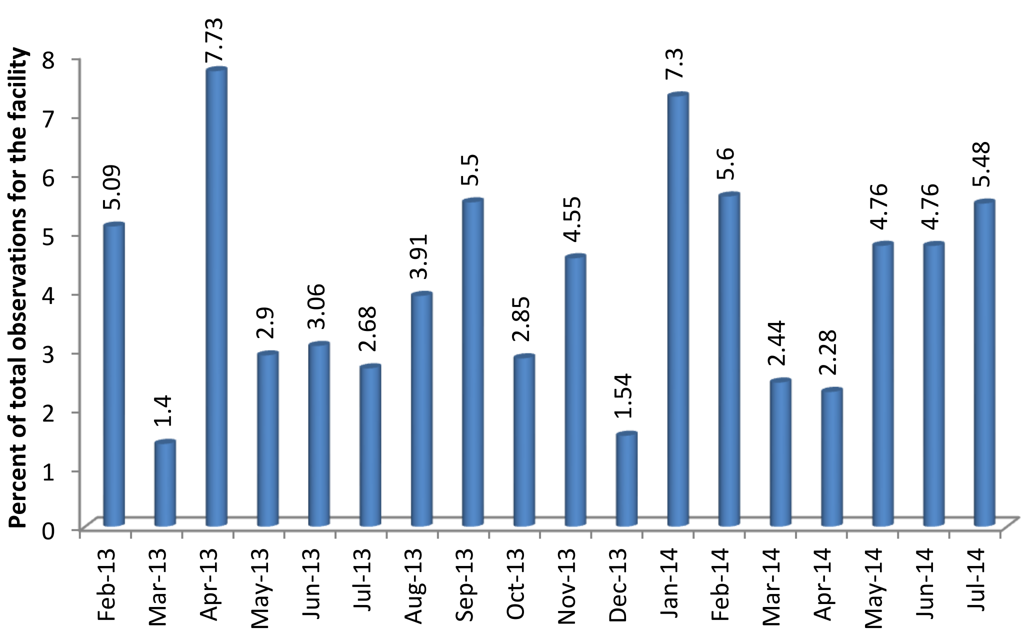


Figure 4: HSE inspection for Barricading

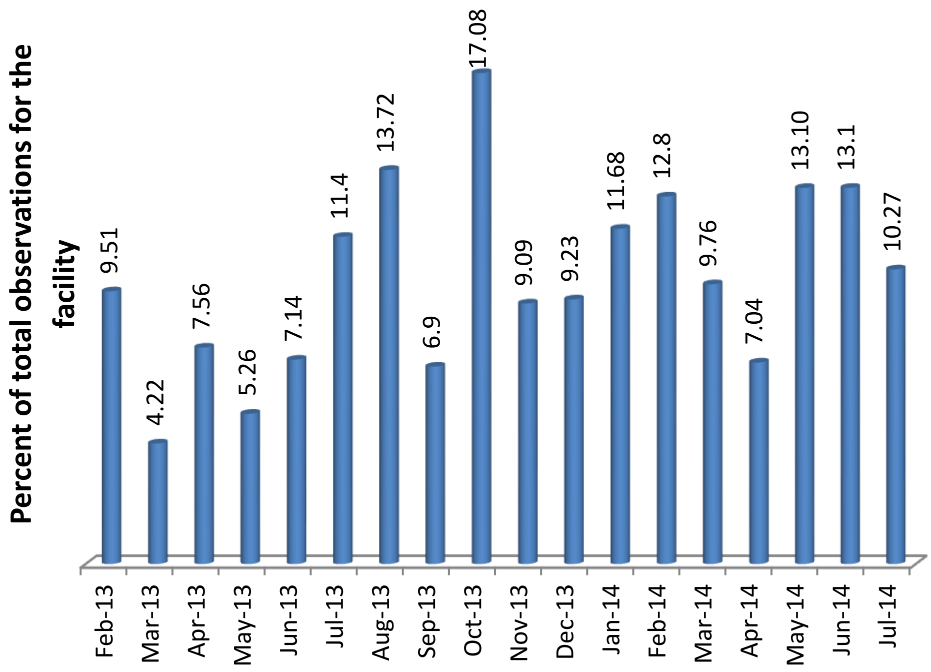


Figure 5: HSE inspection for Electrical Work

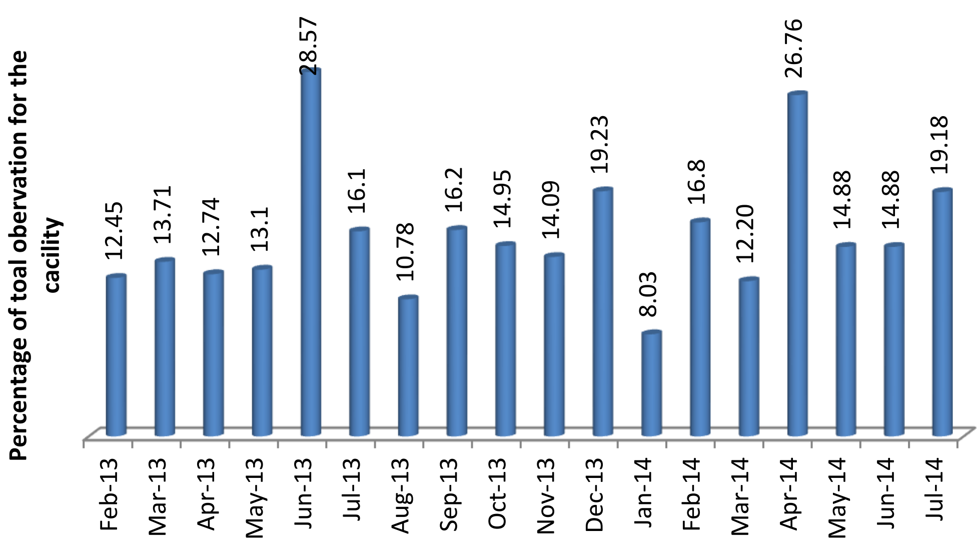


Figure 13: HSE inspection for Work at height

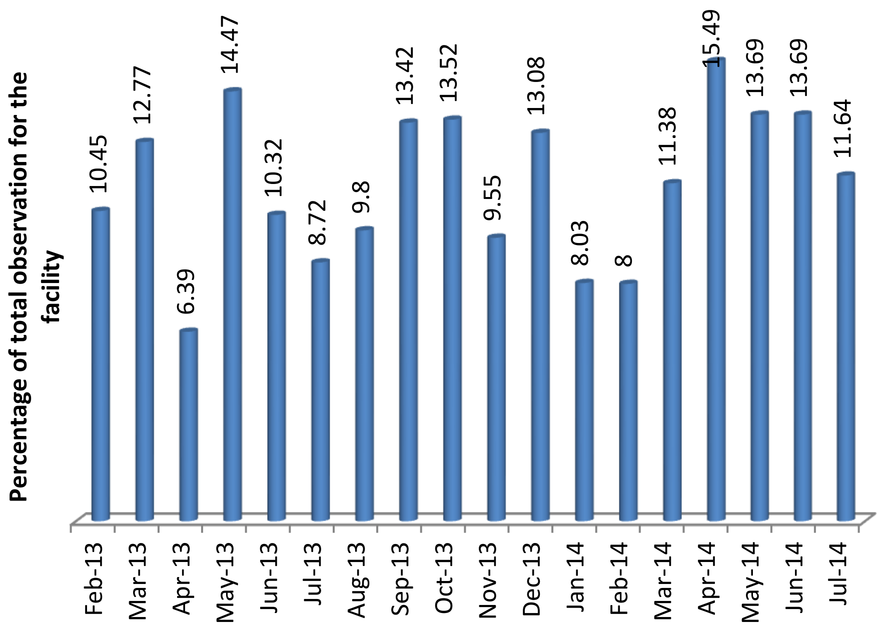


Figure 6: HSE inspection for Hot Work

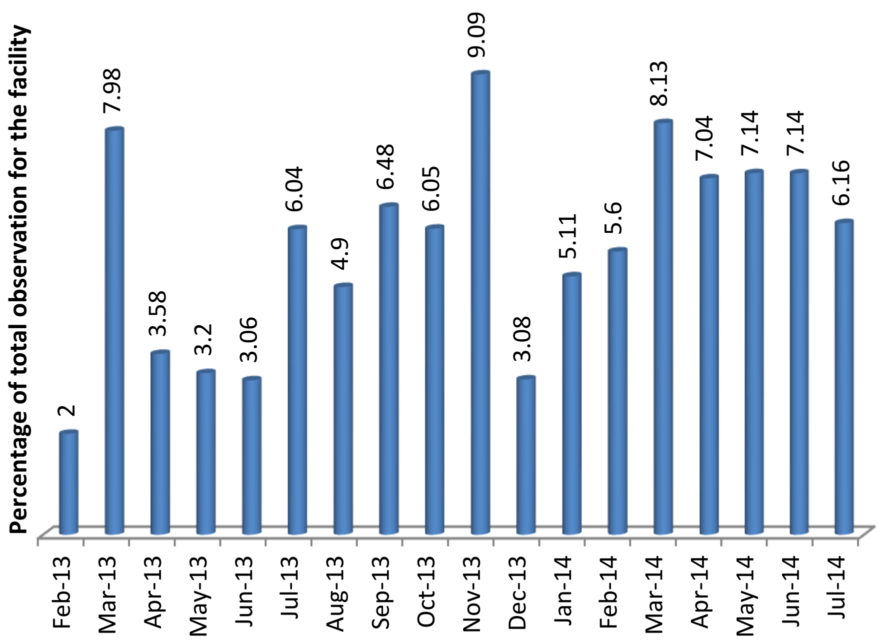


Figure 7: HSE inspection for Mechanical Work

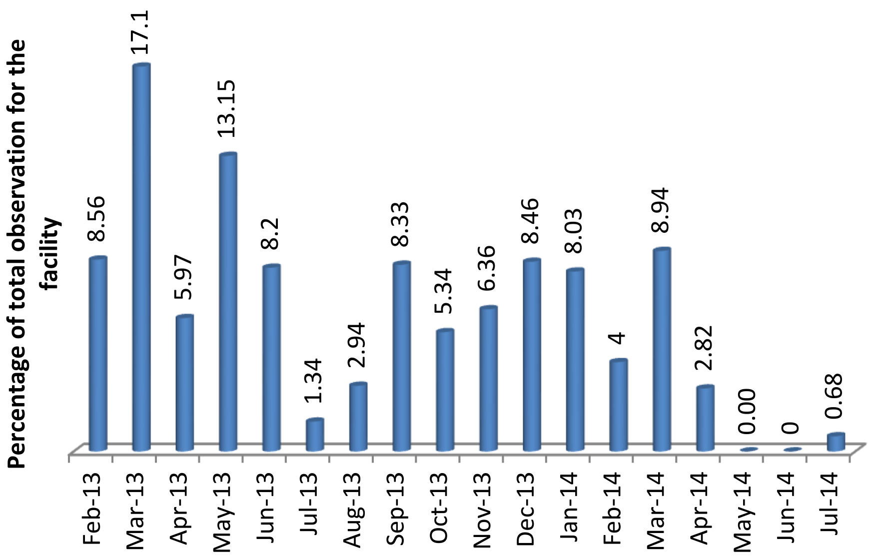


Figure 8: HSE inspection for Excavation Work

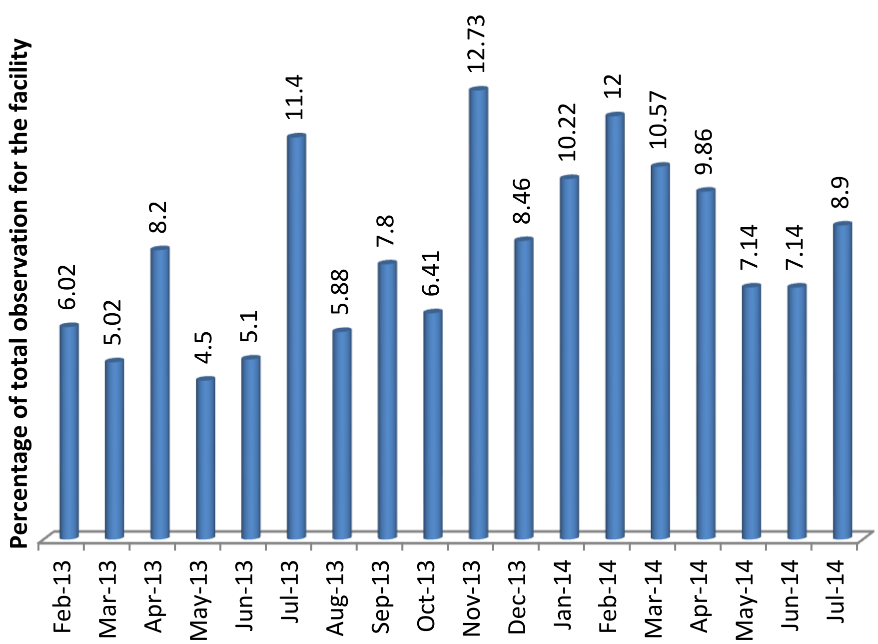


Figure 9: HSE inspection for Hand rails / Edge protection

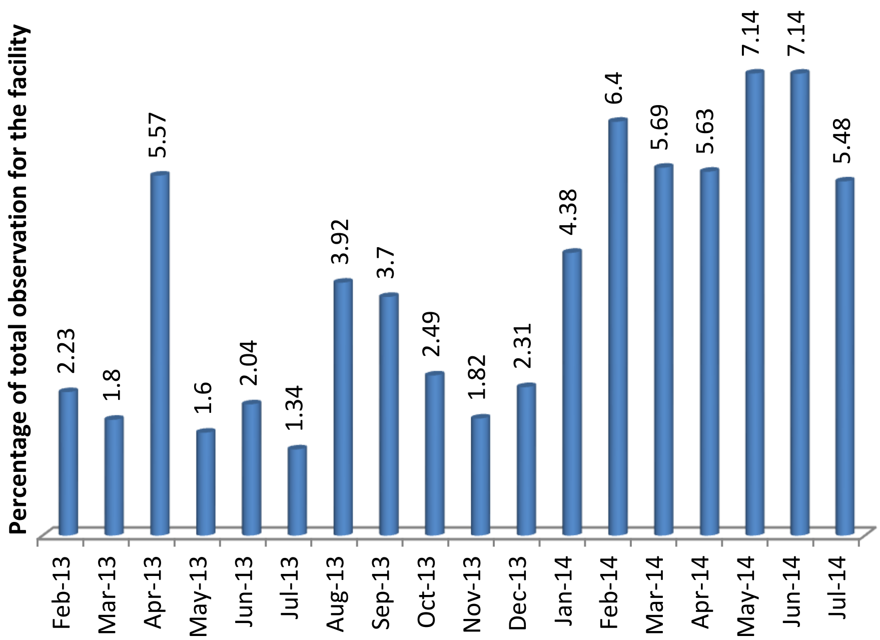


Figure 10: HSE inspection for Material Handling / Lifting

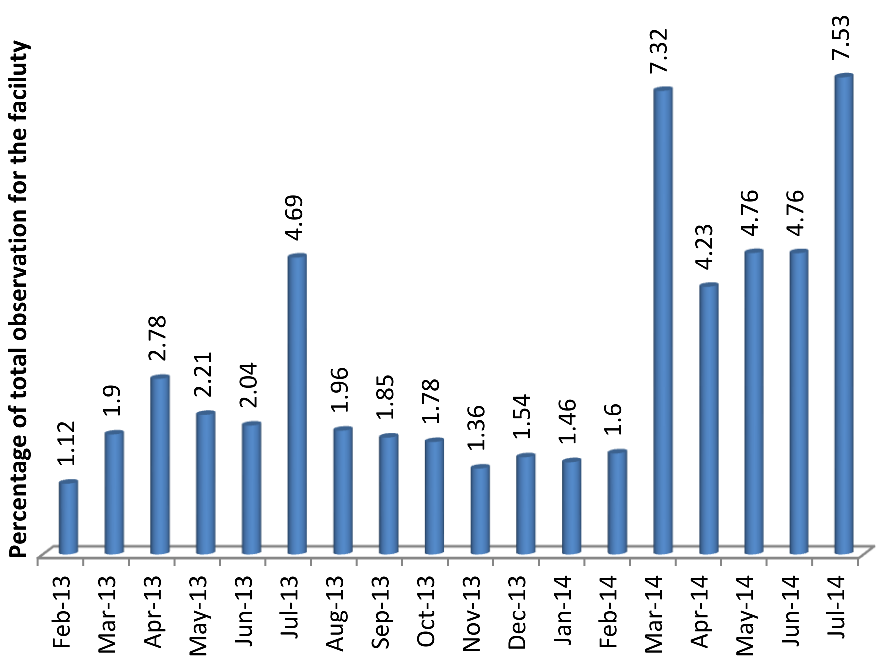


Figure 11: HSE inspection for Hand tool & Power tools

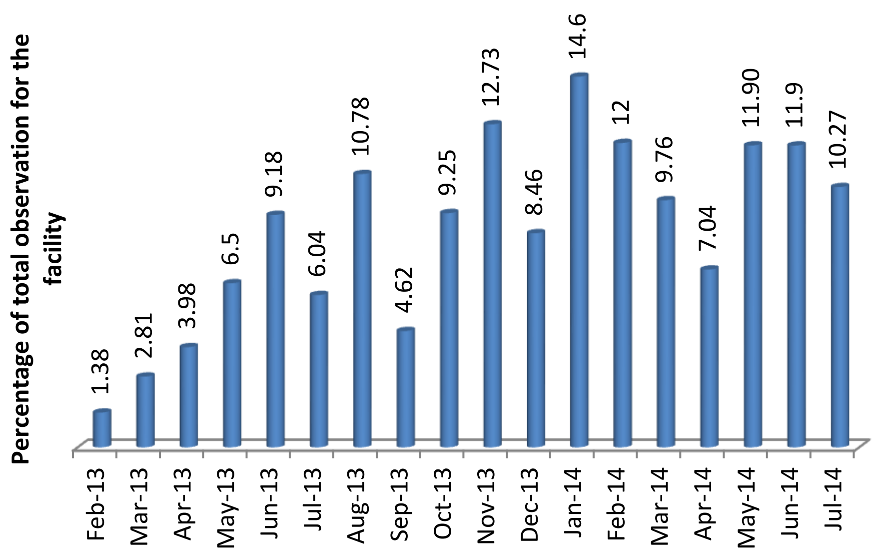


Figure 12: HSE inspection for PPE's

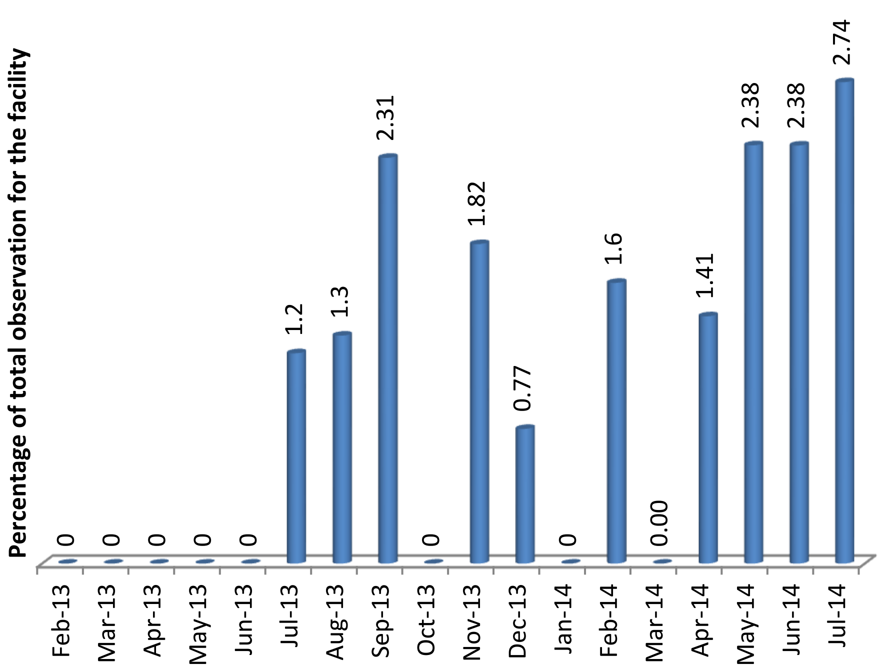


Figure 13: HSE inspection for Fire

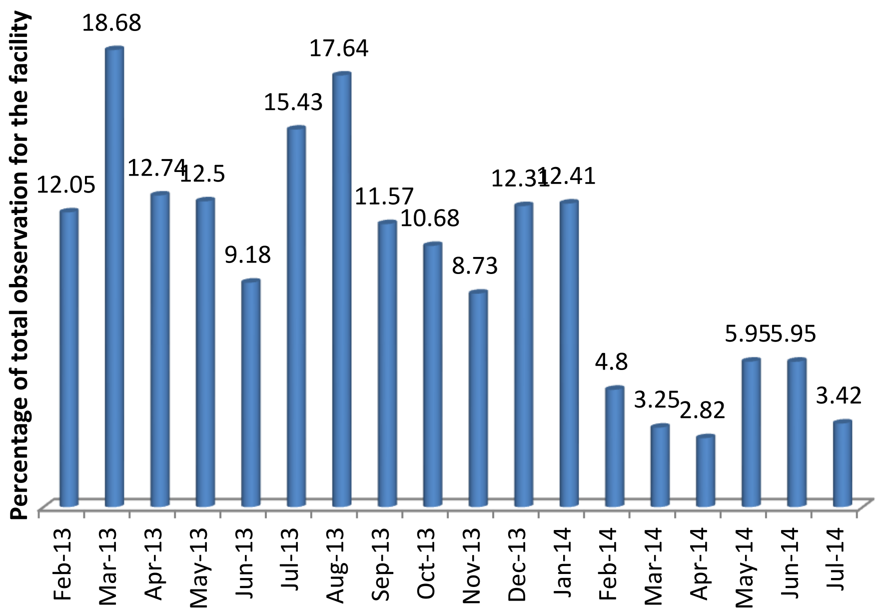


Figure 14: HSE inspection for others

5.2 Site Inspection analysis:

An analysis of the trend in each category shows that, rectification of concerns raised in connection with housekeeping has resulted in significant improvement over time. Compare to housekeeping, no other activity has shown any improvement despite several reminders at the site as well as management level but appropriate actions were not initiated. The reason for the lapse in compliance with the observations were the lax attitude of site engineers; site supervision and also due to resource unavailability.

Slight improvement was noticed in some of activities such as excavation, barrication, hand tool and power tools, but this improvement was not observed consistently over the entire inspection period. It has also been observed that sometimes management forced site engineers to execute the work in a stipulated time without access to adequate resources (man, machine and material). Under these circumstances the supervisor of location has no option but to violate standard operating procedure (SOP) at work place. Under normal circumstances the work has to be carried out as per SOP but when taking short cuts and without access to proper resources, the quality of work and safety of workers is compromised.

During analysis, it has also been found that excessive work pressure at work place affects the behavior of workers or staffs towards safety and they tend to overlook safety during work. As the time passes this behavior becomes a habit that results in increased number of non-compliances at work place.

The final conclusion for these observations is:

- Lack of interest of top and site management towards HSE implementation.
- Daily observation, other non-compliances recorded during site inspection were not taken seriously by site as well as top management.
- The first priority of the management is work progress and then comes HSE. Even if HSE is considered it is not done consistently.
- Sometime, site engineers/ managers either hesitate to convey their concern to the top management or they find the top management unapproachable. These communication gaps results in HSE issues not given the due importance by the top management.
- Engineers find themselves helpless in implementing safety because of the lack of interest of seniors, cost involved and the requirement to adhere to strict deadlines.
- Sometime, site management taken HSE as a separate issue delinked from the work progress.
- Sub-contractor attitude, during execution, was found unsatisfactory and sometime they don’t listen to engineers instructions. Sometimes, engineers find themselves helpless because of the monopoly of the sub-contractors or the lack of interest on part of top management to penalize the erring sub-contractor.

- It was found that, engineers or other staffs involved in site activity are, sometimes not confident and they work under fear or some kind of insecurity. This lack of morale affects their performances.
- Lack of interest on management's part towards compliance with legal requirements at site resulted in non-conformities felt unaddressed. Sometime it was found that personal effects of some concerned authority resulted in rectification of non-conformities but lack of interest by higher management resulted in reappearing of the same non-conformities again.

5.3 Audit Analysis:

Table 10: Audits and Non-Conformities raised in every section.

External Audit (Period 2010 to 2014)															Total
Number of Companies Audited		*A*	*A*	*A*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*C*	*C*	
S. No	**Audit No / Area/section**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
1	**General**	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2	**SHE targets and goals**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	**Compliance**	4	1	0	2	0	0	0	0	0	0	0	0	0	1	8
4	**Contractor SHE policy and plan**	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2
5	**Designer's role**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	**Contractor SHE organization**	2	2	0	1	0	0	1	1	1	1	0	1	1	1	12
7	**Contractor SHE committee**	2	0	1	0	0	0	0	0	0	0	0		0	0	3
8	**Id card and first day at work, SHE**	2	1	1	1	0	0	0	0	1	1	0	0	0	1	8

External Audit (Period 2010 to 2014)																Total
Number of Companies Audited		*A*	*A*	*A*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*C*	*C*	
S. No	**Audit No / Area/section**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
	orientation training															
9	**SHE training**	3	4	1	4	0	0	0	0	0	0	0	0	0	2	14
10	**SHE inspection**	0	0	0	1	0	0	0	0	0	0	0	0	0	2	3
11	**SHE audit**	2	0	0	2	0	0	0	0	0	0	0	0	0	2	6
12	**SHE communication**	2	0	1	2	1	0	0	0	0	0	0	0	0	1	7
13	**SHE submittals to the employer**	1	0	0	1	0	0	1	1	1	1	0	0	0	0	6
14	**Accident reporting & investigation**	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2
15	**Emergency preparedness plan**	2	0	0	0	0	0	0	0	0	0	0	0	0	1	3
16	**Experts/agencies for SHE services**	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
17	**Housekeeping**	2	3	4	3	2	2	1	0	2	0	0	0	0	1	20
18	**Working at height**	0	4	10	0	5	8	5	3	5	5	5	5	8	5	68
19	**Overhead protection**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	**Slipping tripping cutting drowning & falling hazards**	0	1	0	1	0	1	1	0	0	0	0	0	4	0	8
21	**Lifting appliances**	3	0	0	0	1	4	3	2	2	3	5	0	2	3	28

External Audit (Period 2010 to 2014)																Total
Number of Companies Audited		*A*	*A*	*A*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*C*	*C*	
S. No	**Audit No / Area/section**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
	and gear															
22	**Launching operation**	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
23	**Construction machinery**	2	0	0	0	0	0	0	0	0	0	0	1	0	0	3
24	**Machine and general area guarding**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	**Manual lifting and carrying excessive weight**	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4
26	**Electrical safety**	5	4	2	2	0	2	7	7	5	5	2	2	4	6	53
27	**Lighting**	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
28	**Hand tools and power tools**	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
29	**Welding, gouging and cutting operations**	2	0	1	3	1	1	5	2	5	2	2	2	0	2	28
30	**Dangerous and harmful environment**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	**Fire prevention, protection and**	2	0	0	0	0	0	1	0	0	1	0	0	0	0	4

External Audit (Period 2010 to 2014)																Total
Number of Companies Audited		*A*	*A*	*A*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*C*	*C*	
S. No	**Audit No / Area/section**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
	fighting system.															
32	**Corrosive substances**	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
33	**Demolition**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	**Excavation and tunneling**	2	0	0	2	2	4	3	1	1	3	0	0	3	3	24
35	**Work permit system (PTW)**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
36	**Traffic management**	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
37	**Work adjacent to railways**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	**Batching plant and casting yard**	3	3	0	0	3	2	0	0	0	0	0	0	0	0	11
39	**Personal protective equipment (PPE)**	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2
40	**Visitors to site**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	**Physical fitness of workmen**	0	1	0	6	1	0	0	0	0	0	0	0	0	0	8
42	**Medical facilities**	0	1	0	0	2	0	0	0	0	0	0	0	0	4	7
43	**Noise**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	**Ventilation and**	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2

External Audit (Period 2010 to 2014)																Total
Number of Companies Audited		*A*	*A*	*A*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*C*	*C*	
S. No	**Audit No / Area/section**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
	illumination															
45	**Radiation**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	**Welfare Measures for Workers**	2	0	0	5	1	0	0	0	0	0	0	0	0	1	9
47	**Air quality**	2	0	0	1	1	0	0	0	0	1	0	0	0	0	5
48	**Water quality**	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
49	**Archeological and historical preservation**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	**Landscape and greenery**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	**Felling of trees**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	**Fly ash**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	**Waste**	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
54	**Hazardous waste management**	5	3	2	1	5	0	5	0	0	0	0	0	2	1	24
55	**Energy management**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
56	**Penalty**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	**Stoppage of Work**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	**Awards**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	**Miscellaneous**	0	0	1	0	0	0	0	0	1	2	1	0	0	0	5
TOTAL NC		56	33	24	43	27	24	34	18	24	26	18	12	24	40	

During the study total 15 external audits over the period of 2010 to 2014 were analyzed .Specific study for different areas has been analyzed and cataloged with every step of the process. The outcome of the analysis is reported below:

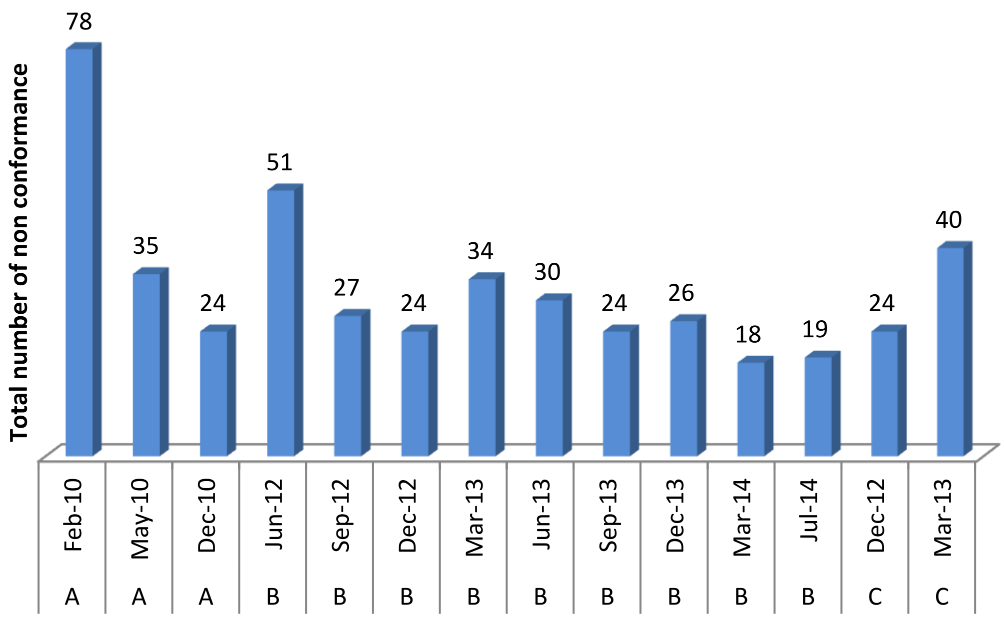


Figure 15:Non-compliance from external audit for three companies (A, B and C) (2010-2014)

The audit reports, for three companies – *A*, *B* and *C*– were prepared by independent agencies with expertise in these areas. All these three companies were engaged in viaduct construction work in a reputed firm which vows to follow considerable safety culture in their organization.

As per graph, for company *A*, only three audits, which were conducted, have been considered for the analysis. It is observed that the number of non-compliances in their first audit, Feb 2010, was 78, during May 2010 it was 35 and during Dec 2010 it was 24. One observes continuous improvement, as reflected by the audit reports.

Company *B* total of consecutive 09 external audit (June 2010- July 2014) are conducted and considered for analysis. The number of non- compliances among all these nine audits are comparatively improved but it was consistent after certain period of time. Although it was required to improve further. The non-conformities raised by auditor few sections are repeated and almost ignored by contractor. In some of sections, non-compliance was closed during action taken by responsible person but again it has repeated after certain period of time.

As per graph, for company *C*, only two consecutive audits were considered for analysis (Dec 2012- Mar 2013). The number of non-conformities has increased from 24 to 40 from first audit to second audit. As work activities increased, the number of non-conformities also increased.

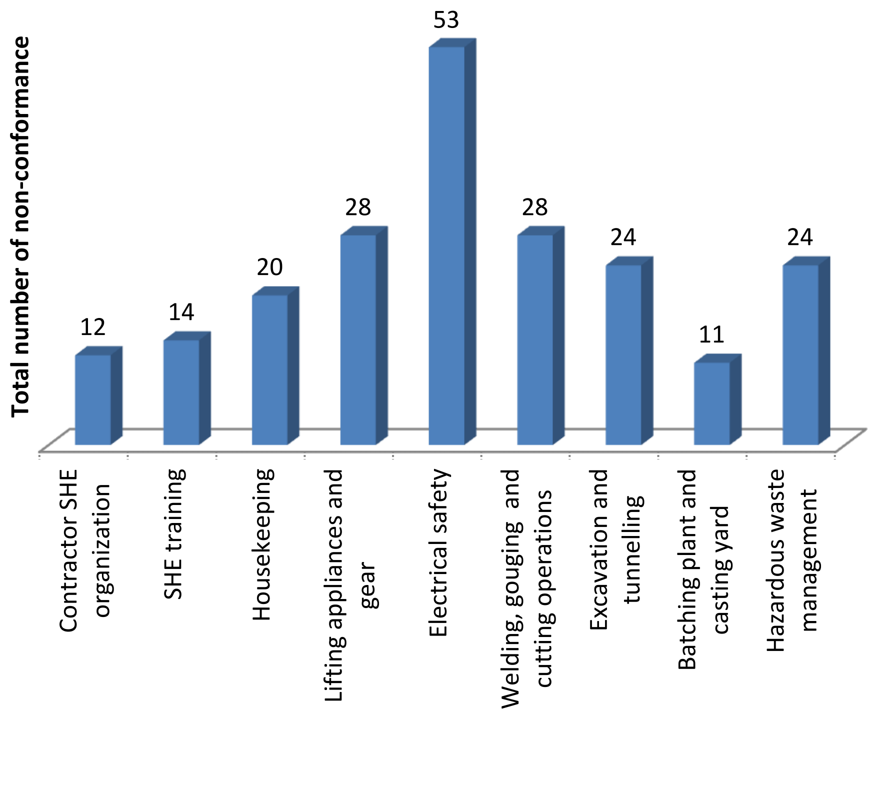


Figure 16: Critical areas at company A B & C (2010-2014)

Total of 59 different areas in Table 10 was identified for audit by agencies involved. 18 out of 59 areas were required special attention although 9 out of these 59 required immediate attentions. Company *A*, *B* and *C* all three had numbers of non-compliances in these sections which showed that these areas have been neglected since the start of the project.

5.3.1 Analysis and conclusion of audits:

The outcome of the analysis is summarized below:

- Identified hazard were not brought to the attention of management for remedial measures.
- Budgeting for SHE organization not done.
- Inadequate number of SHE staffs/ officers.
- Lack of required training for target audience.
- Lack of training calendar and even if the calendar was available, training was not given. In some of the cases, management did not deem it necessary to give proper training or no training was given at all.
- Most critical activity – Lifting, for viaduct work has number of non-compliances due to incompetent supervision, resource management, lack of awareness and training, hiring cost etc.
- Shortage of staff, task allocation or prioritization of work activities is also a problem with project management and majority of accidents happens due to these gaps. Housekeeping at work place is everyone’s responsibility but due to work load constraint it was ignored most of the time. Proper schedule and responsibility was not fixed for housekeeping.
- Concerns regarding, electrical safety, proper gas welding-cutting were repeatedly raised but no remedial measures were initiated, which is an alarming trend. The major reasons behind these observations were indifference, due to improper training, of the management as well as that of operations. Number of required staffs in electrical section, substandard

material, inadequate equipment, and improper maintenance of equipment were major concerns.

- Contractor management and ensuring legal compliance were major concern in batching plant and casting yards. Contractor performance evaluation was not in place, neither their track record was scrutinized for their selection. Organizations, sometimes intentionally, do not hire contractors with proper training due to cost concerns.
- Environmental concerns are not given due importance because of lack of strict enforcement by the concerned agencies. Companies also do not invest in environment conservation activities due to lack of proper knowledge and also to do cost cutting without realizing the harm such approach may do to the environment. SOPs telling the procedure to be adopted at work site are ignored in maximum number of cases.

5.4 Major/ fatal accident analysis:

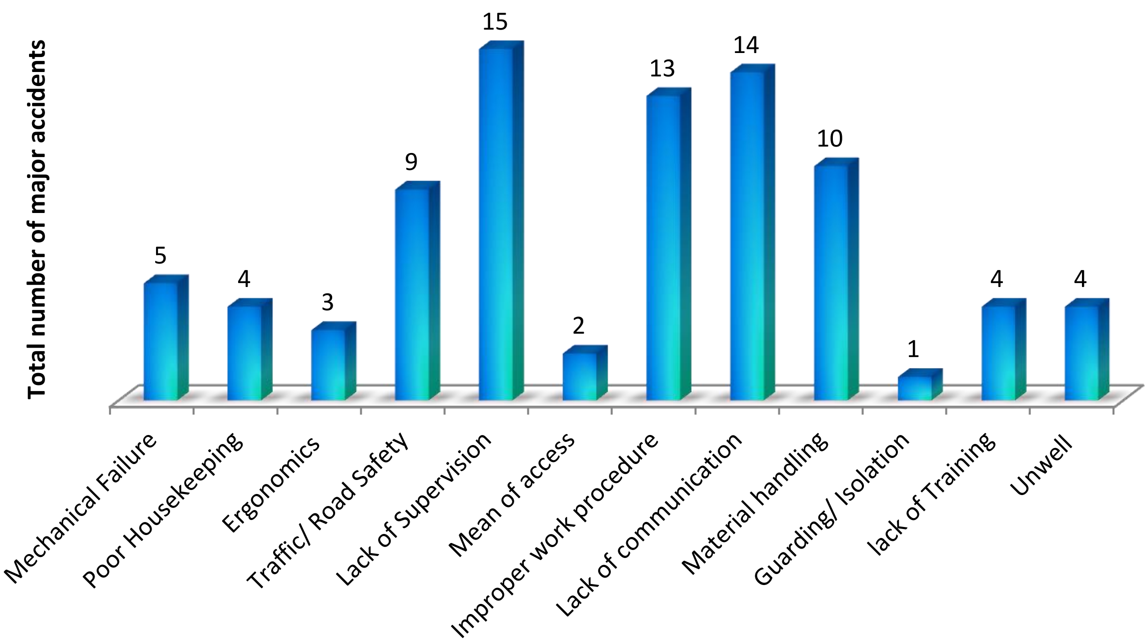


Figure 17: Total number of major accident (2007 – 2014) at three construction site

Analysis of 84 major/fatal accidents, during the period 2007 – 2014 was done at three construction sites. Out of 84 major accidents, 6 fatal accidents happened during this period. Out of these six fatal accidents the accident records were available only for 4 accidents. Analysis of those concern in which accidents has happened is analyzed. An analysis of the accidents shows that the maximum number of accident happened due to lack of supervision, lack of communication, improper work procedure, material handling and traffic / road safety.

5.4.1 Root-cause analysis of accidents and its conclusion:-

5.4.1.1 Lack of supervision:

It is observed that, workers were engaged at work place either without proper supervision. It is also observed that management assigned person without adequate competency to with the task of meeting the deadline. Due to work pressure, supervisors compel the workmen at finish a given task in time while overlooking the safety. Therefore, the pressure of meeting deadline and incompetency in supervision resulted in a number of accidents. In a few cases, it was observed that the supervisor did not know how to finish the work safely or he ignored the guidelines given by his superior. Wrong and inadequate instructions given to workmen by such a supervisor resulted in accidents.

5.4.1.2 Lack of communication:

During accident investigation and analysis it was found that, 17 % of accidents had happened due to lack of communication or improper communication between project managers and site engineer or concern person, or between site engineer and workmen and vice versa. Some of accidents had happened due to confusion created by lack of proper communication. In some cases major accident happened because work continued even if there was shortage of material or resources. In some of the cases, workers overlooked the instruction given by his supervisor.

Unplanned work or activities have also been identified as the reason for some of the accidents.

5.4.1.3 Improper work procedure:

15 % of the accidents had resulted because of improper work procedure. The execution of work was not done as required. In some of the cases, proper procedure were not in place which consequently resulted in laps in putting proper control measures in place. In a few cases control measures were missing even if work procedure was in place. In some cases it was found that the supervisor was not aware of correct action.

5.4.1.4 Material handling:

12 % of accidents are recorded and analyzed fall under the category of material handling activities. Overloading, improper coordination, and lack of knowledge of right way of doing work were main reasons for accidents during manual material handling activities. Some of the major accidents happened during mechanical loading or unloading of material. Wrong posture, overloading, inadequate work procedure, hurriedness in finishing job, and incompetent supervision were some of the leading causes that resulted in accidents.

5.4.1.5 Road Safety/ Traffic:

During analysis it was found that 11 % of accidents had happened due to frequent use of machinery on road and not following road safety rules and regulation. In some of cases, construction equipment, material got in contact with workers or civilians. Some of incidents were resulted from drunk driving. Project management also failed to take action resulting in repetition of such accidents. A few of the incidents, which could have been avoided, happened because safety measures were overlooked by management due to economic constraints.

5.4.1.6 Mechanical failure:

Failure of machinery again was a major cause which resulted in 6 % of accidents. Age of machinery, maintenance and its operation were identified as main reasons for accidents. Compromising with quality of machinery due to financial constraints, incompetent operator, inadequate supervision, etc. played a huge role in these accidents.

5.4.1.7 Lack of training:

Lack of awareness or training also resulted in some of the major incidents at work site. Analysis of these incidents revealed the fact that work was not executed as per the standard operating procedure and workers were not aware of it. The concern engineer or supervisor had not instructed the workers on the safe method of operation. Financial constraints also resulted in lack of initiative by the management in deploying training agencies to give proper safety training. In some of the cases even if provision for undergoing safety training was available, the line management was not ready to spare time for training.

5.4.1.8 Poor housekeeping:

Poor housekeeping, material keeping at work site had resulted in 5% of the accidents. Site engineer/ manager have also shown negligent approach towards good housekeeping. Analysis indicate that, spending time on housekeeping or material keeping was not given priority by the site execution officers and they wanted to finish the work, meeting deadlines. It was also found that, while working at site, proper housekeeping after a job was finished was not practiced resulting in some of the reported incidents. Ill-defined responsibilities also resulted in some of the accidents related to poor housekeeping.

5.4.1.9 Unfit worker

During accident investigation, it was found that some of the accidents had happened due to engagement of unfit workers leading to accidents. In such cases it was found that the site supervisor was negligent in ensuring physical fitness of the engaged workforce. Although in some cases lack of awareness had also played an import role in these types of accidents.

5.4.1.10 Mean of access:

Safe work site access is critical, especially when working at height. It was found that some of the accidents happed due to improper access or negligence toward providing proper access due to hurriedness in finishing the work. In some of the cases even though the engineers or managers was aware of the importance of providing safe access, he overlooked this safety aspect due to pressure of meeting project deadline. In a few cases, resource availability was the reason for not providing safe access at work site.

5.4.1.11 Ergonomics issues:

In 4% of the accidents, improper way of executing work or working with unsuitable equipment led to major incidence. Workers engaged at work place beyond working hours and odd timing also contributed to such accidents.

5.4.1.12 Isolation / Guarding

Unrestricted entry or isolation at work place resulted in 1% of the accidents, despite the fact that it is an earmarked concern at work place. Working with improperly or unguarded machinery during maintenance also contributed to a number of such accidents.

5.5 Minor Accident Analysis:

A total of 149 minor accidents, over a period of 23 months (Aug 2012 to July 2014), were considered for the analysis. Figure shows 17 different areas, where accidents have happened. Out of all the areas considered for the analysis, a few areas were identified as critical – in which percentage of accidents was high e.g. bar bending, work at height, material handling, shuttering and D shuttering etc. The reason behind majority of accidents in these areas was found to be lack of proper supervision, negligence of supervisor in providing effective control measures, deployment of unskilled workmen, deployed workmen not well trained, resource shortage, hurriedness to finish the job while overlooking safety considerations, etc. Some others reason were also noted which directly or indirectly resulted in accidents e.g. design constraint, resource availability, inadequate staffs or workmen, working hours, health and hygiene, lack of resources, co-ordination etc.

Table 11: No. of minor injured cases

S. No	Month	No. Of injured cases
1	Aug-12	10
2	Sep-12	9
3	Oct-12	8
4	Nov-12	10
5	Dec-12	8
6	Jan-13	6
7	Feb-13	8
8	Mar-13	5
9	Apr-13	5
10	May-13	6
11	Jun-13	6
12	Jul-13	5
13	Aug-13	6
14	Sep-13	5
15	Oct-13	5
16	Nov-13	5
17	Dec-13	7
18	Jan-14	7
19	Feb-14	6
20	Mar-14	5
21	Apr-14	6
22	May-14	3
23	Jun-14	4
24	Jul-14	4
Total		**149**

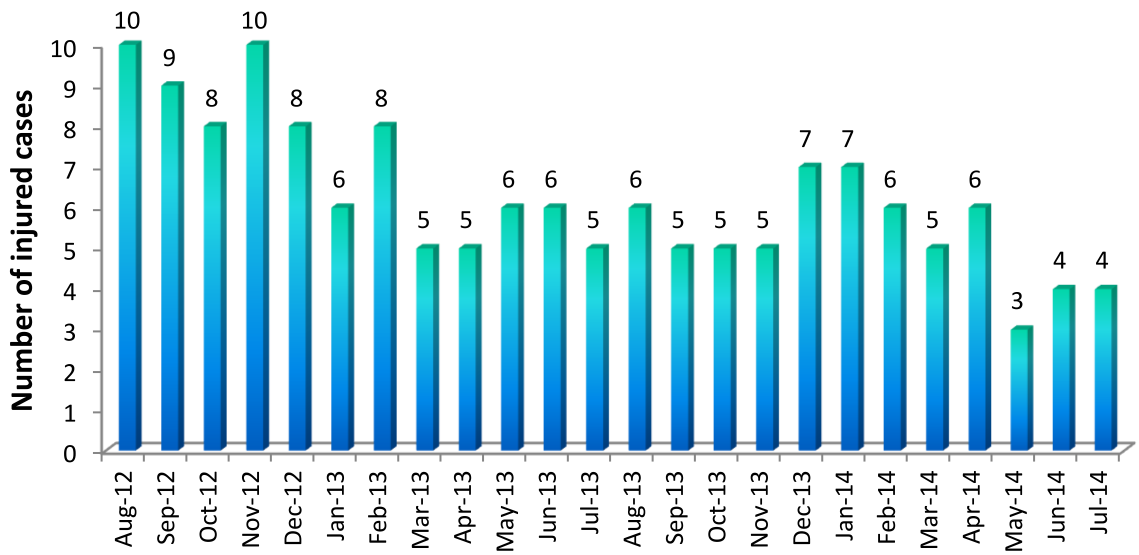


Figure 18: Injured case (month wise)

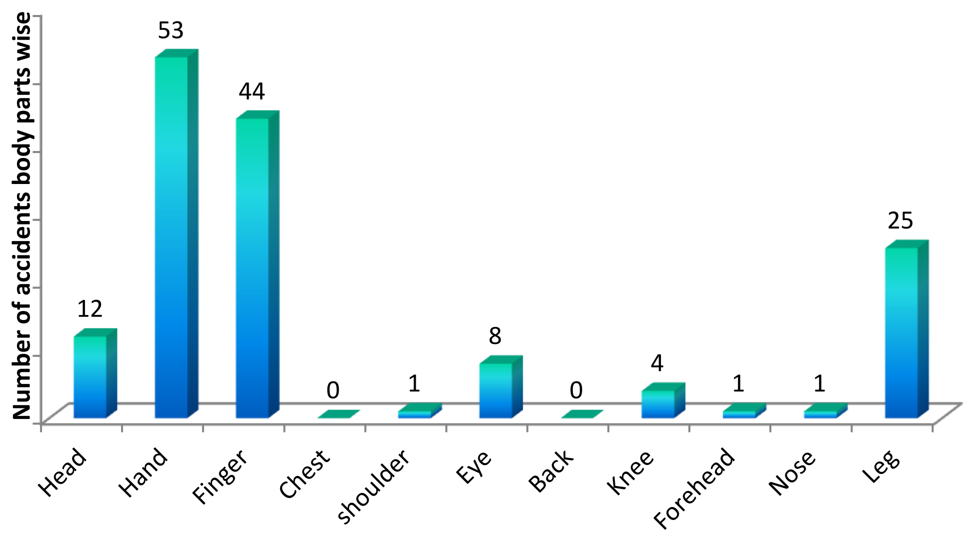


Figure 19: Injured case (Body part wise)

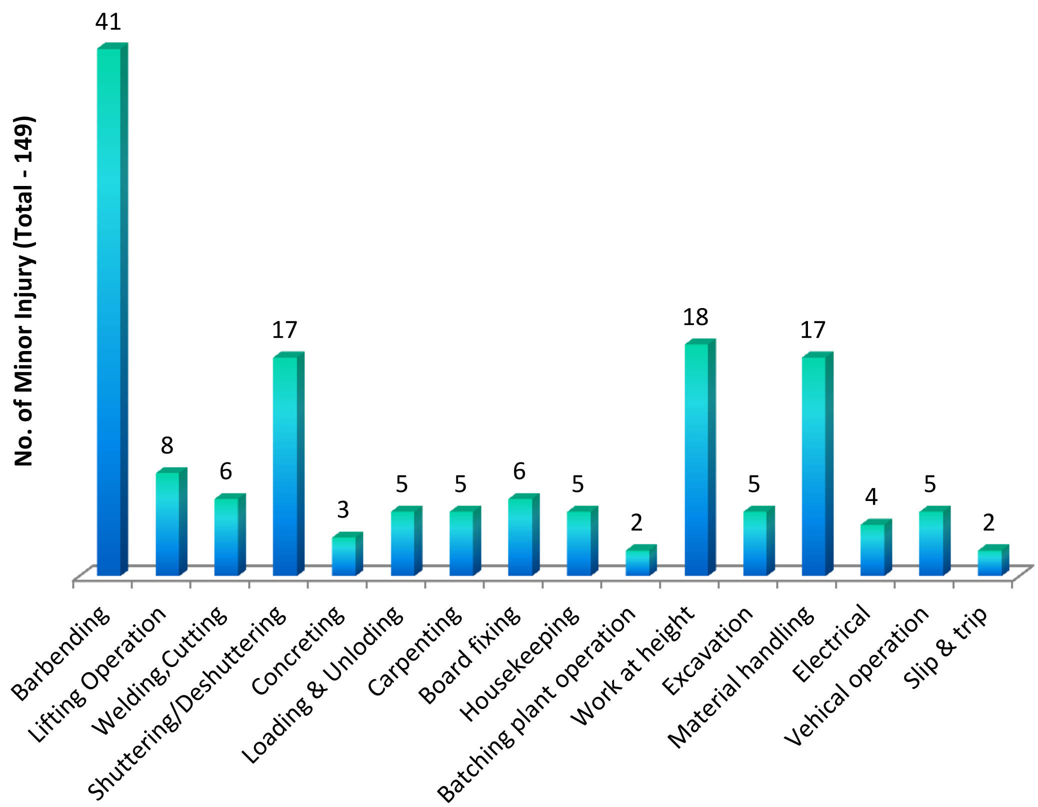


Figure 20: Activity wise injury analysis

5.6 Internal Audit Analysis:

Monthly internal audits are a part of analysis and 15 internal audits were done since May 2013- July 2014 for the three companies considered for the study. The 20 different areas considered for the audit were as under:-

I. SHE Administration
II. SHE Training & SHE Communication
III. SHE Inspection & Audit
IV. Hazard Identification & Risk Assessment and Emergency Preparedness
V. Reporting of Accidents and Dangerous Occurrence and Investigation

VI. Housekeeping
VII. Working at Height
VIII. Lifting Appliances & Gear
IX. Construction Machinery / Hand tools and power tools
X. Site Electricity
XI. Fire Prevention
XII. Welding and Cutting
XIII. Excavation and Trenching
XIV. Tunneling Operation and Work in confined Space
XV. Traffic Management
XVI. Personnel Protective Equipment
XVII. Industrial health & Hygiene (Lighting and Ventilation)
XVIII. Welfare Measure
XIX. Environmental Management
XX. Batching Plant & Casting Yard

Each consideration was audited on monthly basis. The following section presents analysis of such audits, done over a period of 15 months.

Each of the 20 different areas, considered for the study, has various components and minimum of 10 sub areas have been quantified.

Each audit summary included full inspection report was submitted to management for review and for action. Analysis of audits done between 2013- 2014 shows that despite the recommendations as documented in audit report little improvement was noticed in the areas where non-compliance were observed. Some improvements were observed in the areas of housekeeping, work at height, lifting appliances and gear, construction machinery, welding cutting, site electricity, excavation and trenching, and batching plant and casting yard but this trend was not consistent over the period analyzed in this study. The course of action which was proposed during meetings or at other platform improving the situation were not implemented effectively. This let to repetition of same observations in subsequent audits but still no action was taken to rectify them.

The reason behind repeated observations and poor improvement record are as follows:

- Hurriedness to finish the work on time
- Project duration
- Mentality of site engineers or managers towards HSE implementation.
- Lenient approach in compliance with safety issues unless work was affected and stopped.
- Contractor selection not done on the basis of their professionalism.
- New contractor in lead role which make them ineffective and think safety as hurdle in work progress.
- Resource un-availability and resource management. Contracting company has a trend to execute the job in available resource and don’t want to invest more which result in compliances in many forms.
- Cost saving concept matters these days and mainly in the case where project undertaken is under budget.
- Allocation of role and responsibility. Many of site engineers or managers are not up to the performances they are being allocated to.
- Due to some reason, company also doesn’t hire competent staffs may be knowing how to execute the work safely.
- Management doesn’t bother in their safety statistics or performances.

5.7 Questionnaire feedback:

Survey was conducted at two construction sites with more than 1,700 employees. The level of employees included in this survey was from top management to worker from different verticals e. g. site workers, supervisors, foremen, site engineer, managers, design coordinators, safety personnel, and project managers etc. The questionnaire was prepared based on site inspection, audits conducted and incidents reports from different sites in past few years.

5.8 Outcome of the survey:

Outcome of the survey is summarized below:

1. Environment: The environmental awareness and its implementation at construction work site are not satisfactory and most of the workers are unaware of these issues. Although, legal requirements are known at the management level but these are not implemented at work site. Training and education on environmental issues and control measure to improve environmental compliances not common among every employee which creates a gap between standard requirements and its implementation.

2. Social aspect: The answer given by the workers and engineers at work site regarding approach of employer towards social concern and societal risk was not satisfactory. Employer had focused on project execution, ignoring workers suitability. Even during on holiday workers are asked to work on site. They are not being paid as per minimum wages fixed by the government. Both the contractor had only limited issues with nearby residents and that has addressed properly except some of cases. Nearby residents used to support contractor in executing project in many ways but contractor have least interest for nearby residents increasing social well-being or other CSR activities. The effective, efficient and hurdle free work can be achieved by increasing social awareness or by involving residents during many occasions.

3. Economy: Companies financial status, project cost matters a lot for establishing and maintaining safety culture at work place. There is direct linkage of safety with financial constraint of any company or project. Quality of work and safety culture can improve if companies are positive about spending money on safety and quality. If financial status of company is good they can hire

experienced and effective employee and deploy effective contractor for their projects thereby improving safety culture, while also finishing project on time.

4. Design: Role of designer is foremost in project management. Role of designer can be influenced by contracting companies that impacts project in many ways. Therefore, selection of competent self-reliance designer and their freedom is essential for safe execution of any job. As of now, designers show little concern for operational challenges and ignore the safety concerns. It is required, that the designer to do risk assessment during design stage of project minimizing operational inherent safety risks.

5. Role of consultant: Consultant role in execution and maintaining safety at work place is significant. The survey shows that self-reliance consultant can help contracting companies in establishing and maintaining proactive safety culture at work place. Therefore, their role is quite essential during execution and also during design of project.

6. Role of client: Client role is very important in project management process and safety performances and other issues majorly depend on client. If client is strict about project safety management, surely a proactive culture can be established. If a client is focused on progress, ignoring safety, then implementation of safety can be adversely effected.

7. Role of contractor: Contractors plays a major role in safe execution of any job. Risk levels of an activities or project depend directly on the competence of the contractor.

8. Safety: To ensure a proactive safety culture, safety considerations of a project are essential and should be looked at each and every stage or activity of a project. Weightage should be given to effective and adequate number of safety staffs, supervision of work, motives of top management or contractor towards safety etc. since beginning of project.

9. Resource availability and management: Resource availability and resource management is of prime concern in project management. Safety at work place is directly influenced by resource availability and quality of resources. Ownership of resources, proper distribution, and availability of resource is directly linked to work performance and implementation of safety.

10. Quality of manpower: Handing over of a project on time, while maintaining safety and qualities depends on types or manpower recruited by a contractor. As per survey, attrition and availability of skill workers can influence safety performances at site. Therefore, companies should have a retention plan for workers or employee association with the organization. Inadequate number of required workers influence risk level of any project.

11. Legal considerations: Implementation of proper legal consideration helps in reducing risk level of any projects. Compliance with legal requirements results in enhanced safety culture at site. A company should have a competent legal advisor to keep the company informed about the legal laws or other applicable laws. Therefore, legal concerns should be taken up on priority basis for smooth execution of project with proper safety.

12. Adverse Consideration: Failure in design, bankruptcy of client, contractor or consultant is adverse case which will have significant effect on project progress and on safety at site. Natural calamities, occupational emergencies are the situation which needs to be taken care of and companies shall have preparedness plan to cop up with all these emergencies. Safety performances are directly linked to it and these issues can't be ignored at any point of time. Therefore, probable all adverse condition or situation should be addressed, analyzed and preparation should be in place.

5.9 Framework Development:

Based on inspections, audits, accidents analysis, study and analysis of method statement, HSE manuals and survey conducted at site, a risk assessment framework has been developed in which 12 considerations are implemented. The salient features of the developed framework are:

1. 12 considerations that have been identified in the survey exercise have been implemented in the developed framework
2. Each consideration has 6 areas of concern which has been identified and quantified based on analysis of data.
3. Risk quantification has done for each of the area in these considerations.
4. Risk for each of these areas has quantified as 1, 3 & 5. The significance of these values is taken from the input received from all sources & data.
5. Number significance for the risk level is as follows-

   1- *Satisfactory* ***3-*** *Attention required* ***5-*** *Immediate review required.*

Red	Review Required	
Yellow	Attention Required	
Green	Satisfactory	

Green Zone (Satisfactory): –The maximum risk rating for an individual consideration, for it to fall under green zone, is 6. Risk rating coming under this range will be satisfactory and safe execution of work can be ensured based on existing control measure at work site.

Yellow Zone (Attention required): If the risk rating for an individual consideration is in the range of 7 to 18, that consideration require proper attention before proceeding to execution of work at site.

Red Zone (Review Require): If the risk rating for an individual consideration falls in the range of 19 to 30, immediate review, stopping all activities, is required.

Cumulative risk rating and legend:

Color	***Legend***	***Cumulative Range***
Red	Review Required	217 - 360
Yellow	Attention Required	73 - 216
Green	Satisfactory	1 - 72

Figure 21: Cumulative risk rating and legend

Similarly, if cumulative risk rating of all consideration is under 73 then it will be in **“green zone”** (satisfactory level). **“Yellow zone”** is assigned for cumulative risk rating of all considerations between 73 to 216. Risk rating under this range will require attention and efforts will be made to bring down risk rating under green zone. Finally, when cumulative risk rating of all twelve considerations is between 217 to 360, then it will be under “**red zone**”. Risk rating under this zone will require immediate review by experts and efforts will be taken to bring down that level to green zone. Red zone will be alarming zone and advised not to execute the job any case unless risk rating has brought down to satisfactory level. Risk multiplication factor is obtained by diving sum of risk value by cumulative risk value. The risk multiplication factor will be in the range of ***0.2 to 1***.

If the risk multiplication factor is in the range of 0 to 0.2, it can be assumed that work undertaken for a particular activity is safe and can be executed under proper supervision.

If risk multiplication factor is in the range of 0.2 to 0.6, immediately action is required and it is advised not to precede work further unless action is taken to minimize the risk factor. Risk multiplication factor above 0.6 indicate high risk and execution of all work should be stopped and design should be reviewed.

6. Finally, modified risk level (MRL) or residual risk level (RRL) can be obtained by multiplying risk multiplication factor (RMF) with initial risk level (RL).

5.9.1 Quantification of modified risk level

Quantification of modified risk level or Residual risk level and its range:
Individual risk rating (0 to 72) is taken as safe in which risk multiplication factor will have a maximum value of 0.2. RMF value in the range 0.2 to 1

may arise from deficiencies observed in numbers of areas under considerations.

Therefore, modified risk level (MRL) or residual risk level (RSL) will be as follows:

RL Category	Initial RL	Risk Multiplication Factor (RMF)	MRL	MRL range
Intolerable	5	0.2	1	MRL > 0.8
Substantial	4	0.2	0.8	0.6 < MRL ≤ 0.8
Moderate	3	0.2	0.6	0.4 < MRL ≤ 0.6
Tolerable	2	0.2	0.4	0.2 < MRL ≤ 0.4
Trivial	1	0.2	0.2	MRL ≤ 0.2

Figure 22: Modified risk level (MRL)

5.9.2 Proposed action on MRL or RRL:

When MRL lies in the range of 0.2 to 0.4, it will be assumed that work execution is safe as per stated defined procedure and under proper supervision with proper SOP and other codes of requirements. But if MRL is above 0.4, it requires reviewing each consideration in which their risk rating is higher than acceptable.

Management has to define or set their limitations over control measures in place for all areas under considerations taken during assessment. Based on decision, SOP will be prepared tackling all different scenarios analysed during risk assessment.

Table11 *: Existing risk assessment techniques								
Risk Assessment of Column Work **(Page 118 of 200)**	**SR = Severity Rating** - When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	**PR = Probability Rating** - When it occurs frequently or Chances approx. more than 50%	H	**3**	**4**	**5**
	- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	**2**	**3**	**4**
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable	- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	**1**	**2**	**3**
					L	M	H

SL. No.	**Activity, Product, Service**	**Hazard, Concern**	**Severity Explanation**	**Severity Rating H/M/L**	**Probability Explanation**	**Probability Rating H/M/L**	**Risk Level 1/2/3/4/5**	**Risk Controls**		**Responsibility**
1	Use of material transporting vehicles	Hit/ trap during movement of vehicles	Minor/ Major	M	May Happen	L	2	✓ Any machineries or vehicle will be exposed to road will be complying all traffic safety requirements. ✓ Inspected and approved machineries will be in use ✓ Machinery will have all relevant documents as per site. ✓ Movements of machineries will be only at marked location under proper supervision. ✓ Helper will be available with machinery. ✓ Wearing of all appropriate PPE's	✓ Work shall be under competent supervision ✓ Engineer in-charge of location should ensure specified jobs are being doing by right machineries.	Engineer In-charge
2	Scaffold Erection & Dismantli									

Table11 *: Existing risk assessment techniques

Risk Assessment of Column Work **(Page 119 of 200)**	**SR = Severity Rating** - When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	**PR = Probability Rating** - When it occurs frequently or Chances approx. more than 50%	H	**3**	**4**	**5**
	- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	**2**	**3**	**4**
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable	- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	**1**	**2**	**3**
					L	M	H

SL. No.	Activity, Product, Service	Hazard, Concern	Severity Explanation	Severity Rating H/M/L	Probability Explanation	Probability Rating H/M/L	Risk Level 1/2/3/4/5	Risk Controls		Responsibility
	ng									
	Manual material handling	Hit/ slips/ trip and crush during handling	Minor/ Major	M	May Happen	L	2	✓ Use of only experiences workers. ✓ Access way will be clear. Stacking of material will be proper. ✓ Coordination among workers will be good enough to carry the load. ✓ Work under proper supervision of foreman/ supervisor or engineer. ✓ Wear all appropriate PPE's.	✓ Ensure clear access way. Avoid running during handling of material. ✓ Stacking of material should be only at designated place. ✓ Wet or slippery surface shall be avoided.	Engineer In-charge
	Erection & Dismantling of Scaffold	Fall/ hit/ Crush during erecting the scaffold pipes	Minor/ Major/ Fatal	H	May Happen	M	4	✓ Only competent workers will be engaged in this activity. ✓ Inspection of ledge/ standard before in use. Compaction of firm ground will be ensured before starting the work. ✓ Medical fitness will	✓ Work shall be under competent person. ✓ During erection and dismantling of scaffold, engineer in-charge or foreman should remain on duty	Engineer In-charge

Table11 [*]: Existing risk assessment techniques

Risk Assessment of Column Work **(Page 120 of 200)**	**SR = Severity Rating** - When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	**PR = Probability Rating** - When it occurs frequently or Chances approx. more than 50%	H	**3**	**4**	**5**
	- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	**2**	**3**	**4**
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable	- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	**1**	**2**	**3**
					L	M	H

SL. No.	**Activity, Product, Service**	**Hazard, Concern**	**Severity Explanation**	**Severity Rating H/M/L**	**Probability Explanation**	**Probability Rating H/M/L**	**Risk Level 1/2/3/4/5**	**Risk Controls**		**Responsibility**
								be there for all workers. ✓ Proper access will be given. Fall protection arrangement will be in place. ✓ During dismantling, throwing of pipes will be avoided. ✓ All area will be cautioned. Workers having proper platform/ support to stand and work. ✓ It will be ensure none will stand underneath during dismantling of scaffold. ✓ Use of Use of all required PPE's	and ensure the safety of person. ✓ Training must be given to the workers engaged in this. ✓ Ensure all fall protection arrangement and in good condition.	
3	Work at height	Fall/ hit/ slips During Survey work,	Minor/ Major/ Fatal	H	May Happen	M	4	✓ Work as per methods statements. ✓ Work under competent person. ✓ Workers will be medically fit	✓ Training shall be given to the workers engaged in this activity. ✓ None of	Engineer Incharge

Table11 *: Existing risk assessment techniques

Risk Assessment of Column Work **(Page 121 of 200)**	**SR = Severity Rating** - When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	**PR = Probability Rating** - When it occurs frequently or Chances approx. more than 50%	H	**3**	**4**	**5**
	- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	**2**	**3**	**4**
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable	- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	**1**	**2**	**3**
					L	M	H

SL. No.	Activity, Product, Service	Hazard, Concern	Severity Explanation	Severity Rating H/M/L	Probability Explanation	Probability Rating H/M/L	Risk Level 1/2/3/4/5	Risk Controls		Responsibility
		scaffold erection/ dismantling, shutter / D shutter work, other work						involved in this work. ✓ Only authorized workers will be able to perform the work. ✓ Engineer in-charge of location will ensure the safety of all people. ✓ Allowance of work only when all edge/ fall protection will be in place. ✓ Briefing of work details before starting the work. ✓ Ensure stability of structure if workers work at height. ✓ Suitable mean of access will be given. ✓ Avoidance of work at sharp edge. ✓ Proper platform will be given with handrails/ toe guard once exposed to edge work. ✓ Wearing of all required PPE's.	workers will be workers without PPE's. Use of safety harness will be mandatory for everyone. ✓ Ensure all edge and fall protection is as per standard. ✓ Safety harness use in this should be of standard quality and inspection done every day before in use. ✓ Don't use if it is damaged or found wear & tear.	

<table>
<tr><td colspan="14">Table11 *: Existing risk assessment techniques</td></tr>
<tr><td colspan="3" rowspan="2">Risk Assessment of Column Work

(Page 122 of 200)</td><td colspan="2">SR = Severity Rating
- When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000</td><td>High = H</td><td colspan="3">PR = Probability Rating
- When it occurs frequently or Chances approx. more than 50%</td><td>H</td><td>3</td><td>4</td><td colspan="2">5</td></tr>
<tr><td colspan="2">- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000</td><td>Medium = M</td><td colspan="3">- When it occurs occasionally or Chances between 10% to 50%</td><td>M</td><td>2</td><td>3</td><td colspan="2">4</td></tr>
<tr><td colspan="3">RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable</td><td colspan="2">- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000</td><td>Low = L</td><td colspan="3">- When it has never occurred before or chances less than approximately 10%</td><td>L
</td><td>1
L</td><td>2
M</td><td colspan="2">3
H</td></tr>
<tr><td>SL. No.</td><td>Activity, Product, Service</td><td>Hazard, Concern</td><td>Severity Explanation</td><td>Severity Rating H/M/L</td><td>Probability Explanation</td><td>Probability Rating H/M/L</td><td>Risk Level 1/2/3/4/5</td><td colspan="5">Risk Controls</td><td>Responsibility</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td><td colspan="3"></td><td></td></tr>
<tr><td>4</td><td>Bar bending & cutting</td><td>Hit/ trap/ crush/slips/ trip during bending/ cutting / handling</td><td>Minor/ Major</td><td>M</td><td>May Happen</td><td>L</td><td>2</td><td colspan="2">✓ Use of only authorize and trained person.
✓ Machine use in this operation will be of standard quality and inspection done by mechanical and electrical in-charge.
✓ Electrical connection will be ensured safe during this operation.
✓ Working place will be clean and clear. Material handling as per standard.
✓ Wearing of all required PPE’s.</td><td colspan="3">✓ Earthing of all electrically operated equipment.
✓ Avoid loose and multiple connections.
✓ Regular inspection of equipment’s should be done.</td><td>Engineer Incharge/ Electrical In-charge</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td><td colspan="3"></td><td></td></tr>
<tr><td>5</td><td>Shuttering and D Shuttering</td><td>Hit/ trip/ crush/ fall of or by the materi</td><td>Minor/ Major/ Fatal</td><td>H</td><td>May Happen</td><td>L</td><td>3</td><td colspan="2">✓ Workers engaged in this activity will be trained.
✓ Work as per method statement. Material lifting/ shifting as per engineer</td><td colspan="3">✓ Shutter handling as per standard.
✓ Inspection of anchorage point.
✓ Use tag line</td><td>Engineer In-charge</td></tr>
</table>

Table11 *: Existing risk assessment techniques

Risk Assessment of Column Work (Page 123 of 200)	SR = Severity Rating		PR = Probability Rating				
	- When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	- When it occurs frequently or Chances approx. more than 50%	H	3	4	5
	- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	2	3	4
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable	- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	1	2	3
					L	M	H

SL. No.	Activity, Product, Service	Hazard, Concern	Severity Explanation	Severity Rating H/M/L	Probability Explanation	Probability Rating H/M/L	Risk Level 1/2/3/4/5	Risk Controls		Responsibility
		al during handling						instruction. ✓ Tying arrangement will be good enough to withstand the load. ✓ Handling of shutter in away stuck of hand or other body parts avoided. ✓ None will be stand in front of or in a way it may not harm during D-shutter. ✓ Shutter handling carrying by crane/hydra will be as per requirements. ✓ Wearing of all required PPE's	while shift/ handle it mechanically. ✓ Avoid throwing of shutter during D shuttering.	
6	Use of Cranes/ hydra	Hit/ Fall from material/ mechanical failure	Minor/ Major/ Fatal	H	May Happen	L	3	✓ Use of crane/ hydra as per DMRC requirement. ✓ Operator will be trained and having competency certificate. ✓ Use of crane only when ensured	✓ Crane shall be tested by third party approved by DMRC. ✓ Only competent and authorized operators will be operating	Engineer In-charge/ Mechanical In-charge

Table11 *: Existing risk assessment techniques

Risk Assessment of Column Work **(Page 124 of 200)**	**SR = Severity Rating** - When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	**PR = Probability Rating** - When it occurs frequently or Chances approx. more than 50%	H	**3**	**4**	**5**
	- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	**2**	**3**	**4**
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable	- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	**1**	**2**	**3**
					L	M	H

SL. No.	Activity, Product, Service	Hazard, Concern	Severity Explanation	Severity Rating H/M/L	Probability Explanation	Probability Rating H/M/L	Risk Level 1/2/3/4/5	Risk Controls		Responsibility
								compacted firm ground. ✓ Only inspected tool & tackles will be in use. Rigger / banksman will be deployed for signaling. ✓ Before lifting it is to be ensure the load is tied properly and none is available underneath. ✓ Use of all required PPE's.	the crane/ hydra. ✓ Use tag line tying the load.	
7	Concreting	Hit by boom placer, Concrete flow/ pump/ eye / skin irritation,	Minor/ Major	M	May Happen	L	2	✓ Deployment of only trained person for this work. ✓ Inspection of hydraulics or boom placer piping or pump pipelines before in use. Use of only competent operators having similar experience. ✓ None will stand infront of delivery of	✓ Caution the boom placer placing areas. ✓ Inspection of pipeline before in use. It is to be ensure that pipe line are not rupture neither and not older than of its suggested working hours.	Engineer In-charge/ Bathing plant In-charge

Table11 *: Existing risk assessment techniques

Risk Assessment of Column Work **(Page 125 of 200)**	**SR = Severity Rating** - When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	**PR = Probability Rating** - When it occurs frequently or Chances approx. more than 50%	H	**3**	**4**	**5**
	- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	**2**	**3**	**4**
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable	- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	**1**	**2**	**3**
					L	M	H

SL. No.	**Activity, Product, Service**	**Hazard, Concern**	**Severity Explanation**	**Severity Rating H/M/L**	**Probability Explanation**	**Probability Rating H/M/L**	**Risk Level 1/2/3/4/5**	**Risk Controls**		**Responsibility**
								concrete through pipelines. ✓ Use of all required PPE's.	✓ Use traffic rules while moving via live roads.	
8	Surface Finishing	Fall, slip/ trip & eyes irritation	Minor/ Major	M	May Happen	L	2	✓ Work will be carried out under competent supervision. ✓ Arrangement will be done if finishing at height as per work at height standard. ✓ Edge protection will be given. ✓ Use of all required PPE's.	✓ Safety precautions shall be adopted as per work requirements and work procedures.	Engineer In-charge
9	Surveying work	Slips/fall during walking and taking alignment	Minor/ Major	M	May Happen	L	2	✓ Access way will be given for easy movement of surveyors. ✓ Necessary precautions will be taken during work at height or while taking coordinates at height.	✓ Ensure the approach and access during surveying work.	

Table11 *: Existing risk assessment techniques

Risk Assessment of Column Work **(Page 126 of 200)**	**SR = Severity Rating** - When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	**PR = Probability Rating** - When it occurs frequently or Chances approx. more than 50%	H	**3**	**4**	**5**
	- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	**2**	**3**	**4**
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable	- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	**1**	**2**	**3**
					L	M	H

SL. No.	**Activity, Product, Service**	**Hazard, Concern**	**Severity Explanation**	**Severity Rating H/M/L**	**Probability Explanation**	**Probability Rating H/M/L**	**Risk Level 1/2/3/4/5**	**Risk Controls**		**Responsibility**
11	Use of hand tools & power tools	Cut/wound/ electrocution or any foreign parts exposed to the workers	Minor/ Major	M	May Happen	L	2	✓ Use of only experienced person. ✓ Work under proper supervision. ✓ All electrical moving equipment's will be inspected and tagged by electrical engineer. ✓ Only tested and authorized equipment/tools will be in use.	✓ Power operating equipment will be power off immediately after finish the job. ✓ Engaged workers should be trained.	Concern In-charge/ Electrical Engineer

		Framework of Risk Assessment						Individual Risk Rating						Total RR
1	**Environmental Consideration**	Air pollution	Water pollution	Noise pollution	Illumination non compliance	Soil issues	C&D waste generation							
		☐ < 10%	☐ < 10%	☑ < 10%	☑ < 10%	☐ < 10%	☐ < 5%							
		☑ Between 10% - 20%	☑ Between 10% - 20%	☐ Between 10% - 20%	☐ Between 10% - 20%	☑ Between 10% - 20%	☑ Between 5% - 15%	3	3	1	1	3	3	14
		☐ > 20 %	☐ > 20 %	☐ > 20 %	☐ > 20 %	☐ > 20 %	☐ > 15 %							
2	**Social Consideration**	Communalism	Traffic	Gender discrimination	Impacts on society	Local interference	Identified issues resolved							
		☑ No	☐ < 5 %	☑ < 5 %	☐ < 5 %	☐ No	☐ 100%							
		☐ Up to 5 %	☑ Between 5% - 10%	☐ Between 5% - 10%	☑ Between 5% - 10%	☑ Up to 5 %	☑ Beteeen 99-95 %	1	3	1	3	3	3	14
		☐ > 5 %	☐ > 10 %	☐ > 10 %	☐ > 10 %	☐ > 5 %	☐ < 95 %							
3	**Economic Consideration**	Project cost	Manpower cost	Resource cost	Cost liabilities for safety implimentation	Expected loss/ Profit	Company condition							
		☑ High end	☐ High end	☐ High end	☐ 100%	☐ Profit	☑ Sound							
		☐ Lumpsum	☑ Average	☑ Average	☐ Beteeen 99-90 %	☐ At par	☐ Average	1	3	3	5	5	1	18
		☐ Less value	☐ Low	☐ Low	☑ < 90 %	☑ Loss	☐ Poor							
4	**Design Consideration**	Deadline	Material cosideration	Site condition	Cost	Safety consideration during design	Contractor/ client responsibility							
		☐ Realistic	☑ Standard material	☐ Non-residential	☑ Not effected	☑ Effective	☐ Client							
		☑ Tight	☐ Mix	☑ Low density	☐ Marginally effected	☐ Average	☐ Consultant	3	1	3	1	1	5	14
		☐ Unrealistic	☐ Cheap	☐ Highly populated	☐ Significantly effected	☐ Least	☑ Contractor							
5	**Consultant Consideration**	Expertise	Leadership skill	Self reliance	Financial status	Similar project exp	Adequate number of staff							
		☐ Very high	☑ High	☐ 100%	☑ 100%	☑ >95%	☐ 95%							
		☑ High	☐ Average	☑ 95%	☐ 95%	☐ Between 95-90%	☑ Between 95-90%	3	1	3	1	1	3	12
		☐ Average	☐ Low	☐ 90%	☐ 90%	☐ < 90%	☐ < 90%							
6	**Client Consideration**	Progress/ Safety oriented	Competency	Financial Status	Leadership Skill	Number of staffs	Self reliance							
		☑ Both	☐ 100%	☑ 100%	☑ 100%	☐ 100%	☐ 100%							
		☐ Safety	☑ Between 99-80%	☐ 95 %	☐ Between 99-90%	☑ Between 99-90%	☑ 95%	1	3	1	1	3	3	12
		☐ Progress	☐ <80%	☐ 90%	☐ < 90%	☐ < 90%	☐ 90%							
7	**Contractor Consideration**	Progress/ Safety oriented	Competency	Financial Status	Number of staffs	Similar Project exp	Accident records (FR)							
		☐ Both	☑ > 90%	☐ Very good	☐ > 95 %	☐ > 90%	☑ < 0.01							
		☐ Safety	☐ Between 90 - 70%	☑ Average	☑ Between 95-80%	☑ Between 90 -60	☐ Between 0.01 - 0.1	5	1	3	3	3	1	16
		☑ Progress	☐ < 70%	☐ Low	☐ < 80%	☐ < 60%	☐ > 0.1							

8	**Safety Consideration**	Legal cosideration	Work as per HSE plan	Sufficient number of staffs	Trained& experienced execution staff	Employer concern	Management approach							
		☐ Full compliance	☐ > 90%	☐ >90 %	☐ > 90%	☑ High	☐ >90 %							
		☑ Partial compliance	☑ Between 90 - 70%	☑ Between 90-60%	☑ Between 90 -60	☐ Average	☑ Between 90-60%	3	3	3	3	1	3	16
		☐ No compliance	☐ < 70%	☐ < 60%	☐ < 60%	☐ Less	☐ < 60%							
9	**Resource Consideration**	Resource availability	Resouce Management	Quality of resource	Ownership of resource	New or older	Economic issue							
		☐ >95%	☑ > 90%	☐ As required	☐ 100 %	☐ >80 %	☐ No							
		☑ Between 95-80%	☐ Between 90 -60	☑ Average	☑ Between 99-60%	☐ Between 80-50%	☑ 10 %	3	1	3	3	5	3	18
		☐ < 80%	☐ < 60%	☐ Low	☐ < 60%	☑ < 50%	☐ > 10%							
10	**Manpower**	Number	Experienced	Permanent employee status	Efficient	Migration in staff	Competent manpower in society							
		☑ >95%	☑ > 90%	☐ > 90%	☐ > 90 %	☐ < 5 %	☐ > 95 %							
		☐ Between 95-90%	☐ Between 90-60%	☑ Between 90 -60%	☑ Between 90-60 %	☑ Between 5-20 %	☑ Between 95-70%	1	1	3	3	3	3	14
		☐ < 90%	☐ < 60%	☐ < 60%	☐ < 60%	☐ > 20 %	☐ < 70%							
11	**Legal Concern**	Applicable Legal laws	Management commitment	Approval from concerned authority	Free from disputes	Competency of legal Advisor	Re-assessment of legal laws							
		☐ > 95 %	☐ 100 %	☐ > 95 %	☑ > 95 %	☐ > 95 %	☑ > 95 %							
		☑ Between 95-80%	☑ Between 99-90%	☑ Between 95-90%	☐ Between 95-90%	☑ Between 95-85%	☐ Between 95-90%	3	3	3	1	3	1	14
		☐ < 80%	☐ < 90%	☐ < 90%	☐ < 90%	☐ < 85%	☐ < 90%							
12	**Adverse concern**	Financial	Safety issues	Natural clamity	Occupational emergencies	Quality issues	Management change							
		☑ No issue	☑ No issues	☑ No issues	☐ No issues	☐ No issues	☑ No Change							
		☐ Bearable	☐ Severe	☐ Bearable	☑ Upto 5%	☑ Bearable	☐ Partial	1	1	1	3	3	1	10
		☐ Bankrupt	☐ Significant	☐ Unbearable	☐ >5%	☐ Unbearable	☐ Major	Risk Multiplication Factor						**0.48**

Figure 23: Framework of risk assessment

Table 12: Assessment of risk level

SR = Severity Rating		**PR = Probability Rating**				
- When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000	High = H	- When it occurs frequently or Chances approx. more than 50%	H	3	4	5
- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000	Medium = M	- When it occurs occasionally or Chances between 10% to 50%	M	2	3	4
- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000	Low = L	- When it has never occurred before or chances less than approximately 10%	L	1	2	3
RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable				L	M	H

Table 13: Risk Assessment after inclusion of framework model

Risk Assessment after inclusion of framework model												
S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/ 4/5**			**Risk Control**		**Responsi-bility**
								Risk multipli -cation factor	**Modi-fied risk level**	**Existing**	**Required**	
1	Use of material transporting vehicles	Hit/ trap during movement of vehicles	Minor/ Major	M	May Happen	L	2.00	0.48	0.96	• Any machineries or vehicle will be exposed to road will be complying all traffic safety requirements. • Inspected and approved machineries will be in use • Machinery will have all relevant documents as per site. • Movements of machineries will be only at marked location under proper supervision. Helper will be available with machinery. Wearing of all appropriate PPE's	• Work shall be under competent supervision • Engineer in-charge of location should ensure specified jobs are being doing by right machineries.	Engineer In-charge

Risk Assessment after inclusion of framework model												
S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/ 4/5**	**Risk multipli -cation factor**	**Modi-fied risk level**	**Risk Control**		**Responsi-bility**
										Existing	**Required**	
2	Scaffold Erection & Dismantling											
	Manual material handling	Hit/ slips/ trip and crush during handling	Minor/ Major	M	May Happen	L	2	0.48	0.96	• Use of only experiences workers. • Access way will be clear. Stacking of material will be proper. • Coordination among workers will be good enough to carry the load. • Work under proper supervision of foreman/ supervisor or engineer. • Wear all appropriate PPE's.	• Ensure clear access way. Avoid running during handling of material. • Stacking of material should be only at designated place. • Wet or slippery surface shall be avoided.	Engineer In-charge

Risk Assessment after inclusion of framework model												
S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/ 4/5**	**Risk multipli -cation factor**	**Modi-fied risk level**	**Risk Control** Existing	**Risk Control** Required	**Responsi-bility**
3	Erection & Dismantling of Scaffold	Fall/ hit/ Crush during erecting the scaffold pipes	Minor/ Major/ Fatal	H	May Happen	M	4	0.48	1.92	• Only competent workers will be engaged in this activity. • Inspection of ledge/ standard before in use. Compaction of firm ground will be ensured before starting the work. • Medical fitness will be there for all workers. • Proper access will be given. Fall protection arrangement will be in place. • During dismantling, throwing of pipes will be avoided.	• Work shall be under competent person. • During erection and dismantling of scaffold, engineer in-charge or foreman should remain on duty and ensure the safety of person. • Training must be given to the workers engaged in this. • Ensure all fall protection arrangement and in good.	Engineer In-charge

Risk Assessment after inclusion of framework model												
S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/ 4/5**			**Risk Control**		**Responsi-bility**
								Risk multipli -cation factor	**Modi-fied risk level**	**Existing**	**Required**	
4	Bar bending & cutting	Hit/ trap/ crush/slips / trip during bending/ cutting/ handling	Minor/ Major	M	May Happen	L	2	0.48	0.96	• Use of only authorize and trained person. • Machine use in this operation will be of standard quality and inspection done by mechanical and electrical in-charge. • Electrical connection will be ensured safe during this operation. • Working place will be clean and clear. Material handling as per standard. • Wearing of all required PPE's.	• Earthing of all electrically operated equipment. • Avoid loose and multiple connections. • Regular inspection of equipment's should be done.	Engineer Incharge/ Electrical In-charge

Risk Assessment after inclusion of framework model

S. No	Activity, Product, Service	Hazard , Concern	Sevirity Explan-ation	Sevirity rating H/M/L	Probab-ility Explan-ation	Proba-bility rating H/M/L	Risk level 1/2/3/ 4/5			Risk Control		Responsi-bility
								Risk multipli -cation factor	Modi-fied risk level	Existing	Required	
5	Shuttering and D Shuttering	Hit/ trip/ crush/ fall of or by the material during handling	Minor/ Major/ Fatal	H	May Happen	L	3	0.48	1.44	• Workers engaged in this activity will be trained. • Work as per method statement. Material lifting/ shifting as per engineer instruction. • Tying arrangement will be good enough to withstand the load. • Handling of shutter in away stuck of hand or other body parts avoided. • None will be stand in front of or in a way it may not harm during D-shutter.	• Shutter handling as per standard. • Inspection of anchorage point. • Use tag line while shift/ handle it mechanically. • Avoid throwing of shutter during D shuttering.	Engineer In-charge

Risk Assessment after inclusion of framework model												
S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/ 4/5**	**Risk multipli -cation factor**	**Modi-fied risk level**	**Risk Control** Existing	**Risk Control** Required	**Responsi-bility**
6	Use of Cranes/ hydra	Hit/ Fall from material/ mechanical failures	Minor/ Major/ Fatal	H	May Happen	L	3	0.48	1.44	• Use of crane/ hydra as per DMRC requirement. • Operator will be trained and having competency certificate. • Use of crane only when ensured compacted firm ground. • Only inspected tool & tackles will be in use. Rigger / banksman will be deployed for signaling. • Before lifting it is to be ensure the load is tied properly and none is available underneath. • Use of all required PPE's.	• Crane shall be tested by third party approved by DMRC. • Only competent and authorized operators will be operating the crane/ hydra. • Use tag line tying the load.	Engineer In-charge/ Mechanical In-charge

Risk Assessment after inclusion of framework model

S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/ 4/5**			**Risk Control**		**Responsi-bility**
								Risk multipli -cation factor	**Modi-fied risk level**	**Existing**	**Required**	
7	Concreting	Hit by boom placer, Concrete flow/ pump/ eye / skin irritation,	Minor/ Major	M	May Happen	L	2	0.48	0.96	• Deployment of only trained person for this work. • Inspection of hydraulics or boom placer piping or pump pipelines before in use. Use of only competent operators having similar experience. • None will stand infront of delivery of concrete through pipelines. • Use of all required PPE’s.	• Caution the boom placer placing areas. • Inspection of pipeline before in use. It is to be ensure that pipe line are not rupture neither and not older than of its suggested working hours. • Use traffic rules while moving via live roads.	Engineer In-charge/ Bathing plant In-charge

Risk Assessment after inclusion of framework model

S. No	Activity, Product, Service	Hazard , Concern	Sevirity Explan-ation	Sevirity rating H/M/L	Probab-ility Explan-ation	Proba-bility rating H/M/L	Risk level 1/2/3/ 4/5	Risk multipli -cation factor	Modi-fied risk level	Risk Control		Responsi-bility
										Existing	Required	
8	Surface Finishing	Fall, slip/ trip & eyes irritation	Minor/ Major	M	May Happen	L	2	0.48	0.96	• Work will be carried out under competent supervision. • Arrangement will be done if finishing at height as per work at height standard. • Edge protection will be given. • Use of all required PPE's.		Engineer In-charge

Risk Assessment after inclusion of framework model												
S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/ 4/5**			**Risk Control**		**Responsi-bility**
								Risk multipli -cation factor	**Modi-fied risk level**	**Existing**	**Required**	
9	Surveying work	Slips/fall during walking and taking alignment	Minor/ Major	M	May Happen	L	2	0.48	0.96	• Access way will be given for easy movement of surveyors. • Necessary precautions will be taken during work at height or while taking coordinates at height. • Handling of surveying equipment as per acceptable methods. .	• Ensure the approach and access during surveying work.	

Risk Assessment after inclusion of framework model												
S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/4/5**	**Risk multipli -cation factor**	**Modi-fied risk level**	**Risk Control**		**Responsi-bility**
										Existing	**Required**	
10	Site Illumination	Electrocution/ Shock	Minor/ Major/ Fatal	H	May Happen	L	3	0.48	1.44	• Proper lighting (as per DMRC requirements) will be available at work place. • Only competent electrician will be deployed for all lighting arrangements. • Use of double insulated cables. • Equipment will be connected via ELCB/RCCB/MCB etc. • Use of all appropriate PPE's.	• None of else rather than electrician or electrical engineer will be permitted to work with electricity. • Only standard quality of light/ or equipment's will be in use. • Earthling/ grounding to every equipment's shall be given.	Electrical Engineer/ Concern Site In-charge

Risk Assessment after inclusion of framework model													
S. No	**Activity, Product, Service**	**Hazard , Concern**	**Sevirity Explan-ation**	**Sevirity rating H/M/L**	**Probab-ility Explan-ation**	**Proba-bility rating H/M/L**	**Risk level 1/2/3/ 4/5**	**Risk multipli -cation factor**	**Modi-fied risk level**	**Risk Control**		**Responsi-bility**
										Existing	**Required**	
11	Use of hand tools & power tools	Cut/wound/ electrocution or any foreign parts exposed to the workers	Minor/ Major	M	May Happen	L	2	0.48	0.96	• Use of only experienced person. • Work under proper supervision. • All electrical moving equipment's will be inspected and tagged by electrical engineer. • Only tested and authorized equipment/tools will be in use. • Inspection of equipment will be done before in use as per its standard checklists. • Wearing of required PPE's.	• Power operating equipment will be power off immediately after finish the job. • Engaged workers should be trained. • Work shall be carried in presence of competent supervisor.	Concern In-charge/ Electrical Engineer

Table 14: Proposed Control measures for “use of machineries during material handling (Sample)

Activity / Sub-Activity	Considerations	Proposed Control Measures
Use of machineries for material handling in column work	Environmental Consideration	✓ Good conditions machinery will be in used followed by other requirements. ✓ Speed limitations have to be ensured. ✓ Wheel washing bay is required before vehicles are allowed to go on road. ✓ For limited vehicles, wheel wash (dry) facilities should be available at site. ✓ During wheel wash, wastage of water will be avoided. Water jet can be used minimizing wastage of water. ✓ Used water shall be collected in a pit from which supernatants water will be used for sprinkling purposes on road minimizing air pollution or can be used in other forms which is accepted. ✓ Other waste e.g. Oil, used oil, cotton waste, grease, filters, leather etc. will be stored and disposed as required or mentioned in SOP.
	Social Consideration	✓ Avoid construction machineries on road very frequently. ✓ Task team members availability during movement of vehicles on road. ✓ In the case of road closing, proper permission from concern authority, information given during closer to concern authority, traffic rules to be followed, adequate arrangement needed avoiding any problem to the concern public. ✓ Public issues or concern or any litigation handled on priority ✓ SOP for machineries operation & maintenance, working near or on live roads etc. ✓ Towing van and its team round of clock at work site. ✓ Record of periodic maintenance of machineries used. ✓ Permit to work only from concern authority ✓ Condition verified before issuance of PTW.
	Economic Consideration	✓ Purchase of new machineries ✓ Deployment of good condition machineries ✓ Cost doesn’t matter for suitable and required machineries ✓ Adequate number of machineries available. ✓ Documents verified before deployment of

Activity / Sub-Activity	Considerations	Proposed Control Measures
		machineries at work site. ✓ Fitness certificate ensures before deployment. ✓ Competent staffs for verification available or hired where cost is not a problem.
	Design Consideration	✓ Designer recommendation deploying suitable equipment's for completion of project. ✓ Availability of machineries ensured in project or in market. ✓ Has given all specification as per requirements. ✓ Site is approachable to use machineries. ✓
	Consultant Consideration	✓ Issued guidelines from consultant have given priority in deploying and operation of machineries. ✓ Each and very machineries information given to consultant. ✓ Machineries verified by consultant. ✓ Consultant adequate enough to verify all machineries. ✓ Inspection and check done by consultant and continues to do so randomly. ✓ Ensures SOP ✓ Ensures valid documents ✓ Ensures operators competency ✓ Ensures same type or machineries he recommended etc.
	Client Consideration	✓ Has given detailed guidelines for suitable machineries. ✓ Has given freedom to client inspecting and validating deployed machineries. ✓ Client is self-reliance in validating machineries. ✓ Ensures all machineries are equipped with safety features and comply legal requirements. ✓ MS has detailed description of machineries and approved by client. ✓ Daily check or inspection done for involved machineries. ✓ Has adequate number of employee for close monitoring of machineries. ✓ Ensures competent operators, banksman, rigger and other staffs. ✓ Ensures legal permission and validity of equipment as per rules.

Activity / Sub-Activity	Considerations	Proposed Control Measures
		✓ Remain present during road closer. ✓ Ensures litigations and issues raised by public has addressed on time. ✓ Closely involve in risky operation by machineries ✓ For hurdle free work, ensures if separate route can be provided for smooth work. ✓ Have control over contractor machineries and staffs for any emergency situation.
	Contractor Consideration	✓ Short cuts will be avoided to finish the job. ✓ Site team supports in smooth running of machineries. ✓ Only competent staffs will be deployed in this operation. ✓ Inspection of machineries will be done every day or as recommended. ✓ Cost will not be a matter in any case for deployment of required and suitable machineries. ✓ Changes in process or work methodology will be updated in case any near misses or incidents are noticed previously in similar activities. ✓ PTW will be issued by concern person. ✓ Verification done before issuance of PTW. ✓ Valid documents available at site with every individual machinery. ✓ In case of hired machineries, guidelines given by client and consultant have followed. ✓ P& M in-charge is competent and readily available whenever required. ✓ During any alteration and changing of machineries, information has shared to client and consultant. ✓ Written procedure available (stage wise) for activity ✓ Inspection and testing done as recommended and records available.
	Safety Consideration	✓ Complying required legal laws. ✓ Compliance record available. ✓ Detail working procedure available. ✓ SOP for critical activity available. ✓ Employer/ client/ consultant recommendation has taken on priority for execution. ✓ Competent and required number of staffs available for executing and monitoring the work. ✓ Employee involve in machinery operation are trained enough.

Activity / Sub-Activity	Considerations	Proposed Control Measures
	Resources Consideration	✓ Required number of machinery available. ✓ Machineries are in use as it is made up. ✓ Proper maintenance schedule available for machineries available at site. ✓ Ownership of machinery is defined and made responsible. ✓ Maintenance record available and checked. ✓ Ensure old aged machineries are not in use. ✓ Updated machineries are in use. ✓ In the case of hired machineries, term and condition clear with owner of machineries as it is needed. ✓ Ensure the usage of machineries on higher side. ✓ Site planning available for usage of machineries.
	Manpower Consideration	✓ Required number of staffs available ensuring safe work at site. ✓ Competent & experienced employee available to ensure site activity as defined in work procedure. ✓ Weightage has given in deployment of staff (permanent or temporary) Stability of staff will be ensured. ✓ Award and upgradation system available for competent and effective employee.
	Legal Consideration	✓ All site engineer and top management are aware of all required legal legislation applicable in case of machineries. Legal advisor competent enough and received legal permission applicable for smooth running on machineries at work site. ✓ Record of permission available. ✓ Importance of applicable legal laws briefed by legal advisor to top management. ✓ Top management ensures compliances and responsibility given to all individuals. ✓ Valid permission from concern authority is readily available with machineries. ✓ Disputed equipment can't be bear at site ✓ Legal advisor ensures the updating of legal laws time to time and informs to top management or person concern.
	Adverse Consideration	✓ Emergencies plan available and updated with individual operation. ✓ All necessary steps have taken to avoid any emergencies due to machinery operation.

Activity / Sub-Activity	Considerations	Proposed Control Measures
		✓ Monetary issues are not a constraint at all in deployment of staffs or machineries for smooth operation. ✓ Cost on safety has no problem and deployment of required number of employee ensured. ✓ No changes has made in SOP.

CHAPTER 6

6 Summary & Conclusion:

Viaduct construction activity is crucial to take off the pressure from the already stressed transport infrastructure. Construction activities at ground level are hazardous, this hazard increases manifold for construction activities done at height.

Various principle/theories exist for analyzing hazard and risk − Job Safety Analysis, What-If analysis, preliminary hazard analysis (PHA), checklist analysis, past accidents analysis, HAZOP, FMECA, FTA, ETA, cause consequence analysis, Human Error Analysis etc. – use of which can help identify and minimize the risk involved. But most of these hazard and risk analysis technique have not be designed for evaluation of risk in construction activities which make calls for great caution while applying these techniques.

Risk assessment methodologies used in method of statement lack thoroughness, as it is highly subjective, and no specific framework exists for the steps to be followed while doing risk assessment. Safety design considerations are an effective way to reduce construction accidents but lack of expertise and confidence on part of designer has resulted in many accidents in the past.

The situation becomes grave because of the lack of knowledge of safety consideration by the personnel involved in the design stage. This lack of awareness of safety considerations is present even at the highest level of management. In maximum cases, which were analyzed, assigned activity was done by foreman and supervisor who are not competent. In most of the cases discrepancy is found in implementation of recommendations of the method statement.

In order to address this problem and we have developed a comprehensive framework to assist in risk assessment for viaduct construction activities. Subjectivity of the user has been eliminated or minimized by assigning specific hazard values that have been arrived at after thorough analysis of the collected data. Further effect of subjectivity has been minimized with the inclusion of all the relevant sub-activities and assignment of a weightage factor for each activity.

Validation of the developed framework was performed by asking various construction companies to use and implement the recommendations and provide feedback. It has been found that the implementation of the developed framework resulted in reducing the accident.

Case studies: Implementation of developed framework at two construction sites.

Two construction sites were considered for the implementation of developed framework.

The two sites selected for the case study, were both engaged in viaduct construction activities and both have very good safety tract record. The construction companies engaged for the construction activity have QMS, EMS and OHSAS certification, and also have very good track record in India and overseas. The sites chosen for the implementation of developed framework were functioning for more than a year before implementation of the modified risk levels. Chief safety reviewed the effect of implantation of the findings of developed framework over a period of four months. The effectiveness of this framework was evaluated by analyzing previous four months incident record. Significant improvement, as reported in Table 15 & 16 and Figure 24 & 25, was observed at the two sites.

Table 15: Analysis of previous four months incident record Site -A

ACTIVITY	*Incident Percent reduction*	*No of accidents (Jan 15-Apr 15)*	*No of Incidences (May 15- Aug 15)*
Barbending	28	21	15
Lifting Operation	12	5	4
Welding,Cutting	14	5	4
Shuttering/Deshuttering	21	13	10
Concreting	10	8	7
Loading & Unloding	30	16	11
Carpenting	8	6	6
Board fixing	5	6	6
Housekeeping	15	9	8
Batching plant operation	5	3	3
Work at height	21	16	13
Excavation	16	7	6
Material handling	26	6	4
Electrical	5	6	6
Vehical operation	12	7	6

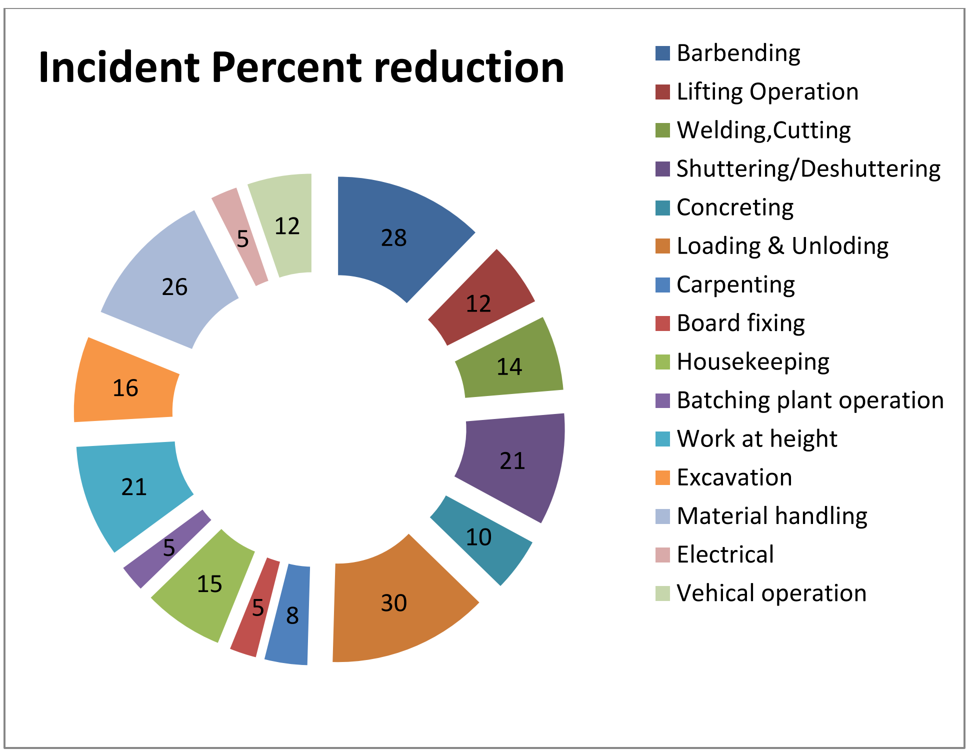


Figure 24: Analysis of previous four months incident record Site A

Table 16: Analysis of previous four months incident record Site B

ACTIVITY	***Incident Percent reduction***	***No of accidents (Jan 15-Apr 15)***	***No of Incidences (May 15- Aug 15)***
Barbending	20	15	12
Lifting Operation	8	7	6
Welding,Cutting	10	4	4
Shuttering/Deshuttering	19	16	13
Concreting	6	11	10
Loading & Unloding	14	13	11
Carpenting	18	3	2
Board fixing	20	4	3
Housekeeping	10	11	10
Batching plant operation	6	5	5
Work at height	17	14	12
Excavation	8	9	8
Material handling	21	8	6
Electrical	20	4	3
Vehical operation	15	4	3

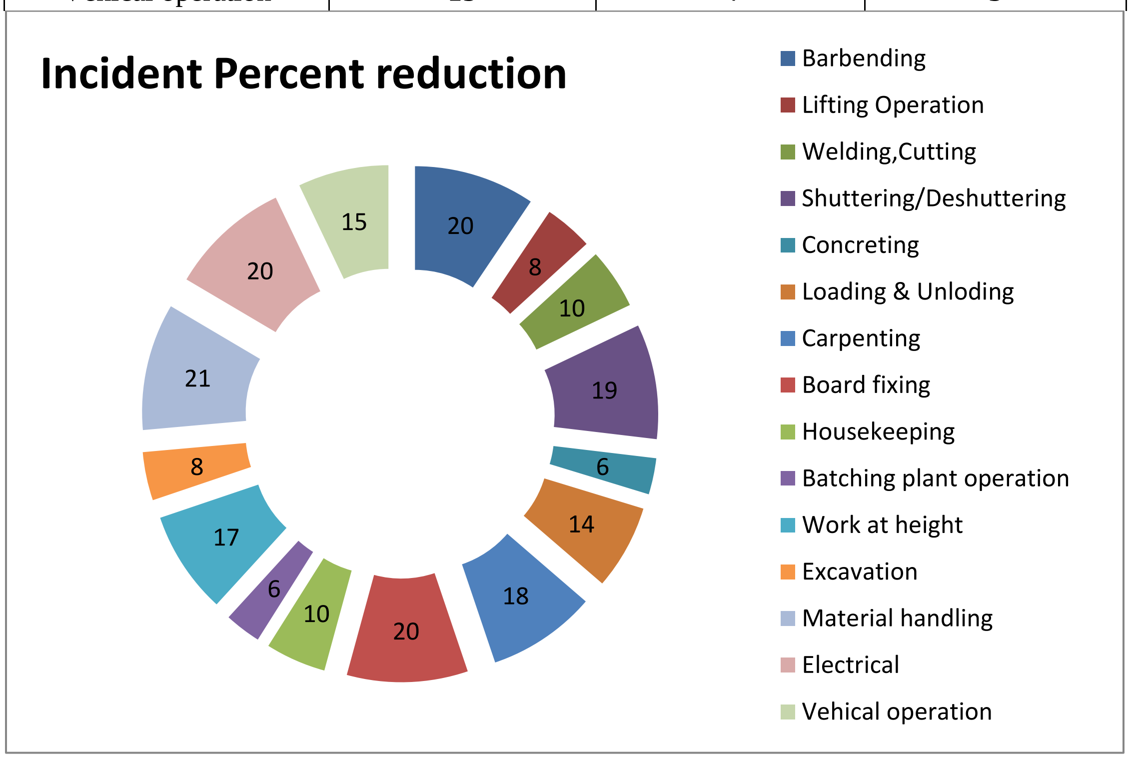


Figure 25: Analysis of previous four months incident record Site B

CHAPTER 7

Scope of future work

Generation of list of corrective measures, as indicated in Chapter 6, can be incorporated in the developed framework. Additionally, the developed framework can also be extended to incorporate considerations for other industry type as well.

The framework can also be modified to incorporate case studies that can be used to train safety officers and other concerned authorities about the effect of neglecting various safety parameters/considerations.

References:

Aini, M., A. Fakhru'l-Razi, M. Daud, N. Adam and R. Abdul Kadir (2005). "Analysis of royal inquiry report on the collapse of a building in Kuala Lumpur: implications for developing countries." Disaster Prevention and Management: An International Journal **14**(1): 55-79.

Alesina, A. and B. Weder (1999). Do corrupt governments receive less foreign aid?, National bureau of economic research.

Asbury, S. and R. Ball (2016). The Practical Guide to Corporate Social Responsibility: Do the Right Thing, Routledge.

Ayav, T. and H. Sözer "Identifying critical architectural components with spectral analysis of fault trees." Applied Soft Computing.

Azadeh, A., I. M. Fam, M. Khoshnoud and M. Nikafrouz (2008). "Design and implementation of a fuzzy expert system for performance assessment of an integrated health, safety, environment (HSE) and ergonomics system: The case of a gas refinery." Information Sciences **178**(22): 4280-4300.

Badawy, M. K. (1995). Developing managerial skills in engineers and scientists: Succeeding as a technical manager, John Wiley & Sons.

Bahr, N. J. (2014). System safety engineering and risk assessment: a practical approach, CRC Press.

Banić, M. "INCIDENT REPORTING AND NETWORK EVENT ANALYSIS."

Behrent, M. C. (2010). "Accidents happen: François Ewald, the “antirevolutionary” Foucault, and the intellectual politics of the French Welfare State." The Journal of Modern History **82**(3): 585-624.

British Standard, B. (2004). "8800: 2004." Occupational health and safety management systems-Guide. in: BSI British Standards **70**.

Brockhoff, K. (1967). "A test for the product life cycle." Econometrica, Journal of the Econometric Society: 472-484.

Buxton, B. (2010). Sketching user experiences: getting the design right and the right design, Morgan Kaufmann.

Cagno, E., F. Caron and M. Mancini (2002). "Risk analysis in plant commissioning: the Multilevel Hazop." Reliability Engineering & System Safety **77**(3): 309-323.

Cameron, I. T. and R. Raman (2005). Process systems risk management, Academic Press.

Cheshmikhani, E. and H. R. Zarandi (2015). "Probabilistic analysis of dynamic and temporal fault trees using accurate stochastic logic gates." Microelectronics Reliability **55**(11): 2468-2480.

Choi, I.-H. and D. Chang (2016). "Reliability and availability assessment of seabed storage tanks using fault tree analysis." Ocean Engineering **120**: 1-14.

Clampitt, P. G. (2009). "The questionnaire approach." Auditing Organizational Communication: A Handbook of Research, Theory and Practice: 55.

Commission, I. E. (2001). "IEC 61882: Hazard and operability studies (HAZOP studies)-Application guide." Geneva: Author.

Covello, V. T., P. M. Sandman and P. Slovic (1988). Risk communication, risk statistics, and risk comparisons: A manual for plant managers, Chemical Manufacturers Association Washington, DC.

Crawley, F. and B. Tyler (2015). HAZOP: Guide to best practice, Elsevier.

Crowl, D. A. and J. F. Louvar (2001). Chemical process safety: fundamentals with applications, Pearson Education.

Deng, Y., H. Wang and B. Guo (2015). "BDD algorithms based on modularization for fault tree analysis." Progress in Nuclear Energy **85**: 192-199.

Dewey, J. (1958). Experience and nature, Courier Corporation.

Ferrier, N. and C. E. Haque (2003). "Hazards risk assessment methodology for emergency managers: A standardized framework for application." Natural Hazards **28**(2-3): 271-290.

Frenkel, M., U. Hommel and M. Rudolf (2005). Risk management: challenge and opportunity, Springer Science & Business Media.

Ganz, M. (2006). Organizing: People, power and change, Harvard: Harvard University Press.

Green, P. (1995). Measures and methods used to assess the safety and usability of driver information systems, Citeseer.

Gupta, N. V. and H. Charan "Hazard Operability Analysis (HAZOP): A Quality Risk Management tool."

Harms-Ringdahl, L. (2003). Safety analysis: principles and practice in occupational safety, CRC Press.

Hassan, A. M. (1981). "An investigation of the learning projects among adults of high and low readiness for self-direction in learning."

Hayek, F. A. (1932). Prices and production, Ludwig von Mises Institute.

Health Safety Executive (2013). Managing for health and safety. UK, Health Safety Executive.

Hester, R. E. and R. M. Harrison (1998). Risk assessment and risk management, Royal Society of Chemistry.

Hines, N. W. (1966). "Nor Any Drop to Drink: Public Regulation of Water Quality Part I: State Pollution Control Programs." Iowa L. Rev. **52**: 186.

Huang, W., H. Fan, Y. Qiu, Z. Cheng and Y. Qian (2016). "Application of fault tree approach for the causation mechanism of urban haze in Beijing—Considering the risk events related with exhausts of coal combustion." Science of The Total Environment **544**: 1128-1135.

Huang, W., H. Fan, Y. Qiu, Z. Cheng, P. Xu and Y. Qian (2016). "Causation mechanism analysis for haze pollution related to vehicle emission in Guangzhou, China by employing the fault tree approach." Chemosphere **151**: 9-16.

Huber, G. P. (1984). "Issues in the design of group decision support sytems." MIS quarterly: 195-204.

Hughes, P. and E. Ferrett (2013). International Health and Safety at Work: For the NEBOSH International General Certificate, Routledge.

Jespen, T. (2016). Risk Assessment and Risk Reduction Methodologies. Risk Assessments and Safe Machinery, Springer**:** 213-241.

Ju, W.-h. (2016). "Study on Fire Risk and Disaster Reducing Factors of Cotton Logistics Warehouse Based on Event and Fault Tree Analysis." Procedia Engineering **135**: 418-426.

Kabir, S., M. Walker, Y. Papadopoulos, E. Rüde and P. Securius (2016). "Fuzzy temporal fault tree analysis of dynamic systems." International Journal of Approximate Reasoning **77**: 20-37.

Kennedy, R. and B. Kirwan (1998). "Development of a hazard and operability-based method for identifying safety management vulnerabilities in high risk systems." Safety Science **30**(3): 249-274.

Kletz, T. A. (1999). HAZOP and HAZAN: identifying and assessing process industry hazards, IChemE.

Komal (2015). "Fuzzy fault tree analysis for patient safety risk modeling in healthcare under uncertainty." Applied Soft Computing **37**: 942-951.

Kranzlmüller, D. (2000). Event graph analysis for debugging massively parallel programs, na.

Labodová, A. (2004). "Implementing integrated management systems using a risk analysis based approach." Journal of cleaner production **12**(6): 571-580.

LaGrega, M. D., P. L. Buckingham and J. C. Evans (2010). Hazardous waste management, Waveland Press.

Larsen, L. and P. Kines (2002). "Multidisciplinary in-depth investigations of head-on and left-turn road collisions." Accident Analysis & Prevention **34**(3): 367-380.

Lavasani, S. M., N. Ramzali, F. Sabzalipour and E. Akyuz (2015). "Utilisation of Fuzzy Fault Tree Analysis (FFTA) for quantified risk analysis of leakage in abandoned oil and natural-gas wells." Ocean Engineering **108**: 729-737.

Lees, F. (2012). Lees' Loss prevention in the process industries: Hazard identification, assessment and control, Butterworth-Heinemann.

Liu, P., L. Yang, Z. Gao, S. Li and Y. Gao (2015). "Fault tree analysis combined with quantitative analysis for high-speed railway accidents." Safety Science **79**: 344-357.

Lowe, D. G. (1987). "The viewpoint consistency constraint." International Journal of Computer Vision **1**(1): 57-72.

Lower, M., J. Magott and J. Skorupski (2016). "Analysis of Air Traffic Incidents using event trees with fuzzy probabilities." Fuzzy Sets and Systems **293**: 50-79.

Lu, J., J. E. Yao and C.-S. Yu (2005). "Personal innovativeness, social influences and adoption of wireless Internet services via mobile technology." The Journal of Strategic Information Systems **14**(3): 245-268.

Makajic-Nikolic, D., N. Petrovic, A. Belic, M. Rokvic, J. A. Radakovic and V. Tubic (2016). "The fault tree analysis of infectious medical waste management." Journal of Cleaner Production **113**: 365-373.

Malfatti, J. (1809). Entwurf einer Pathogenie aus der Evolution und Revolution des Lebens.

Matuzas, V. and S. Contini (2015). "Dynamic labelling of BDD and ZBDD for efficient non-coherent fault tree analysis." Reliability Engineering & System Safety **144**: 183-192.

McNelles, P., Z. C. Zeng, G. Renganathan, G. Lamarre, Y. Akl and L. Lu (2016). "A comparison of Fault Trees and the Dynamic Flowgraph Methodology for the analysis of FPGA-based safety systems Part 1: Reactor trip logic loop reliability analysis." Reliability Engineering & System Safety **153**: 135-150.

Meyer, B. (1988). Object-oriented software construction, Prentice hall New York.

OHSAS, B. (2007). "18001 (2007) Occupational Health and Safety Management Systems. Requirements." British Standards.

Organization, W. H. (2002). The world health report 2002: reducing risks, promoting healthy life, World Health Organization.

Özgen, C. (2012). degree of Master of Science in Civil Engineering Department, Middle East Technical University by, Citeseer.

Phoya, S. (2012). "HEALTH AND SAFETY RISK MANAGEMENT ON BUILDING CONSTUCTION SITES IN TANZANIA: The Practice of Risk Assessment, Communication and Control."

Purba, J. H., D. T. Sony Tjahyani, A. S. Ekariansyah and H. Tjahjono (2015). "Fuzzy probability based fault tree analysis to propagate and quantify epistemic uncertainty." Annals of Nuclear Energy **85**: 1189-1199.

Ramzali, N., M. R. M. Lavasani and J. Ghodousi (2015). "Safety barriers analysis of offshore drilling system by employing Fuzzy Event Tree Analysis." Safety Science **78**: 49-59.

Reason, J. (2016). Managing the risks of organizational accidents, Routledge.

Reese, C. D. (2011). Accident/incident prevention techniques, CRC Press.

Reinholds, I., V. Bartkevics, I. C. J. Silvis, S. M. van Ruth and S. Esslinger (2015). "Analytical techniques combined with chemometrics for authentication and determination of contaminants in condiments: A review." Journal of Food Composition and Analysis **44**: 56-72.

Renn, O., W. J. Burns, J. X. Kasperson, R. E. Kasperson and P. Slovic (1992). "The social amplification of risk: Theoretical foundations and empirical applications." Journal of social issues **48**(4): 137-160.

Robinson, A. R. and J. Sellschopp (2002). Rapid assessment of the coastal ocean environment. Ocean Forecasting, Springer**:** 199-229.

Rossing, N. L., M. Lind, N. Jensen and S. B. Jørgensen (2010). "A functional HAZOP methodology." Computers & chemical engineering **34**(2): 244-253.

Rothblum, A. M. (1992). "KEYS TO SUCCESSFUL INCIDENT INQUIRY1." Safety: 329.

Ruijters, E. and M. Stoelinga (2015). "Fault tree analysis: A survey of the state-of-the-art in modeling, analysis and tools." Computer Science Review **15–16**: 29-62.

Sagberg, F. (1999). "Road accidents caused by drivers falling asleep." Accident Analysis & Prevention **31**(6): 639-649.

Saldaña, M. A. M., S. G. Herrero, M. A. M. del Campo and D. O. Ritzel (2003). "Assessing definitions and concepts within the safety profession." The international Electronic Journal of Health Education **6**: 1-9.

Schofield, D., J. Noond, L. Goodwin and J. March (2002). Interactive evidence: new ways to present accident investigation information. Proceedings of Workshop on the Investigation and Reporting of Incidents and Accidents, University of Glasgow, Citeseer.

Sorooshian, S., A. Teyfouri and S. A. M. Ali (2014). Technology & Management, Lulu. com.

Sousa, V., N. Almeida and L. Alves Dias (2012). "Risk management framework for the construction industry according to the ISO 31000: 2009 standard." Journal of Risk Analysis and Crisis Response **2**(4): 261-274.

Spiers, E. M. (1986). Chemical warfare, Springer.

Taylor, J. R. (2007). "Understanding and combating design error in process plant design." Safety science **45**(1): 75-105.

Thaheem, M. J. and A. De Marco (2014). "Sustainable Repair & Maintenance of Buildings in the Developing Countries: A Risk Management Perspective and Proposal of Customized Framework." Journal of **1**(1): 14-23.

Tichy, N. M., M. L. Tushman and C. Fombrun (1979). "Social network analysis for organizations." Academy of management review **4**(4): 507-519.

Toola, A. (1992). "Plant level safety analysis." Journal of loss prevention in the process industries **5**(2): 119-124.

Tribus, M. and E. C. McIrvine (1971). "Energy and information." Scientific American **225**(3): 179-188.

Venkatasubramanian, V., J. Zhao and S. Viswanathan (2000). "Intelligent systems for HAZOP analysis of complex process plants." Computers & Chemical Engineering **24**(9): 2291-2302.

Vinnem, J. E., T. Aven, T. Husebø, J. Seljelid and O. J. Tveit (2006). "Major hazard risk indicators for monitoring of trends in the Norwegian offshore petroleum sector." Reliability Engineering & System Safety **91**(7): 778-791.

Wang, J. and T. Ruxton (1997). "A review of Safety analysis methods applied to the design process." Journal of Engeering Design **8**(2): 131-152.

Wang, Y., K. Chen, Y. Ci and L. Hu (2011). "Safety performance audit for roadside and median barriers using freeway crash records: case study in Jiangxi, China." Scientia Iranica **18**(6): 1222-1230.

Ylijoki-Sørensen, S., J. L. Boldsen, K. Lalu, A. Sajantila, U. Baandrup, L. W. T. Boel, L. H. Ehlers and H. Bøggild (2014). "Cost–consequence analysis of cause of death investigation in Finland and in Denmark." Forensic Science International **245**: 133-142.

Appendix

I. Environmental Consideration					
S.No.	**Questions**	***1−4*** *(Disagree)*	***5−7*** *(Agree)*	***8−10*** *(Strongly Agree)*	*can't say*
1	Awareness among workers or employees to the noise pollution at site.	192	207	51	3
2	Do they know the permissible level of environmental pollutions at construction site	317	67	65	2
3	Control measures adopted for all environmental hazards.	181	227	40	3
4	Management approach towards environmental issues at work site	181	227	45	0
5	All environmental hazards is being identified and addressed time to time among all employees.	272	136	45	0
6	Client focus on reducing or minimizing of environmental pollution.	64	326	59	4
7	Are legal requirements considered and implemented on priority by management.	37	280	130	6

II. Social Consideration					
S.No	**Questions**	***1−4*** *(Disagree)*	***5−7*** *(Agree)*	***8−10*** *(Strongly Agree)*	*can't say*
1	Does focus given on personal issues of an employee or workers during working time.	402	63	33	2
2	Does project has any pending issues for land allocation or other social issues for that location	421	45	29	5
3	Management concern about nearby people concern and brings improvements.	165	200	134	1
4	Have CSR team of company organizes activities to the nearby people.	463	23	11	3

5	Have company top management or client gives priority to the people	165	43	36	0
6	A welfare measure of company provided by organization is adequate enough and employee satisfied with that.	60	250	185	5
7	Does site location is sensitive and efforts are being made to control over that.	444	50	6	0

III. Economic Consideration

S.No.	Questions	***1–4*** *(Disagree)*	***5–7*** *(Agree)*	***8–10*** *(Strongly Agree)*	*can't say*
1	Is project cost is as per original cost quote during tendering.	54	131	306	11
2	Project is being taken below original tender value	64	135	297	6
3	Does project execution or HSE implementation affected on project cost	32	121	345	4
4	Is there any direct or indirect effect on project execution if project is under quote?	29	118	348	7
5	HSE implementation effected directly when company thinking about profit and loss in project cycle due to safety expenditure.	31	154	314	3
6	Have safety expenditure taken into consideration during quoting of project.	33	155	313	1
7	Allocation of additional amount on safety can improve safety culture at site	30	119	353	0

IV. Design Consideration

S.No	Questions	***1–4*** *(Disagree)*	***5–7*** *(Agree)*	***8–10*** *(Strongly Agree)*	*can't say*
1	Does design of a project affects the deadline of project.	33	100	300	11
2	Does designer focus on material specification while execution of project and If yes, then material purchased with expectation of designer.	298	100	36	10
3	Designer has taken consideration of all societal, environments & adverse consideration while designing the project.	111	292	33	8
4	Does cost of project priorities in front of	33	111	288	12

	designer to design the project.				
5	Does nature of execution, time and employment affected due to designer consideration	56	310	67	9
6	Have designer recommends appropriate safety considerations during execution of project.	109	298	32	5
7	Have designer designed the project based on available resources	59	269	101	15
8	Do you think designer independently design the project without any influence	105	298	34	7
9	How employer gives freedom to the designer if hired	113	295	30	6

V. Consultant Consideration					
S.No	**Questions**	***1−4*** *(Disagree)*	***5−7*** *(Agree)*	***8−10*** *(Strongly Agree)*	*can't say*
1	Does consultant is experienced and have his own team.	60	199	249	2
2	Does HSE implementation improves if consultant is competent and gives suitable recommendation	55	194	261	0
3	HSE culture will be influenced if consultant is not self-reliant	57	193	259	1
4	Does consultant financial status affects ensuring safety at work place	59	200	248	3
5	Consultant role in maintaining healthy safety culture at work place .	21	51	236	2

VI. Client Consideration					
S.No	**Questions**	***1−4*** *(Disagree)*	***5−7*** *(Agree)*	***8−10*** *(Strongly Agree)*	*can't say*
1	Does client is safety oriented and not partial or liberal	53	219	181	5
2	Clear guidelines given by client to contractor establish and maintain safety culture at work site	60	212	180	6
3	Client competency matters to implement healthy safety culture at site	38	68	350	2

4	Client more focused on progress rather than HSE implementation.	58	181	218	1
5	Safety implementation and supervision effected if client is not self-reliant	30	54	370	4

VII. Contractor Consideration

S.No	Questions	***1−4*** *(Disagree)*	***5−7*** *(Agree)*	***8−10*** *(Strongly Agree)*	*can't say*
1	Safety implementation effects due to contractor attitude towards safety	14	25	379	2
2	Does a safety performance or implementation gets affected due to deployment of incompetent execution staff.	16	25	376	3
3	Does financial status of contactor affects safety implementation directly or indirectly.	12	22	381	5
4	Does safety performances or implementation at work site may decline due to shortage of manpower.	15	30	374	1
5	Contractor level of concern about accidents statistics	17	379	20	4

VII. Safety Consideration

S.No	Questions	***1−4*** *(Disagree)*	***5−7*** *(Agree)*	***8−10*** *(Strongly Agree)*	*can't say*
1	Has construction work is being planned as per legal requirements recommendations.	31	70	390	9
2	Have safety procedures developed as per requirements approved by top management.	29	71	392	8
3	Sufficient number of HSE staffs available as per project requirement.	30	74	394	2
4	Does deployed HSE staff are experienced and competent in their job	31	73	393	3
5	Safety concern of individual activities is taken in considerations while preparing SOP.	24	288	184	4
6	Does safety at work place influenced due to lack inadequate supervision of work	14	65	414	7
7	Had legal requirements influence safety management system	14	63	420	3

8	How much management approach is essential tochange mind set for safety culture at work site.	11	66	419	4
9	Do you believe, lenient or casual attitude of top management may leads to inadequate SHE management system at work place.	15	66	415	4

IX. Resource Consideration

S.No	**Questions**	***1–4*** *(Disagree)*	***5–7*** *(Agree)*	***8–10*** *(Strongly Agree)*	*can't say*
1	Resource availability influences the execution of project and may effects safety implementation?	30	64	374	5
2	Resource management plays key roles in minimizing accident / injury at work site.	29	223	218	3
3	Do you think quality of material helps maintaining safety culture?	10	64	394	5
4	Ownership of resource has linked with utilization of resource on time?	13	59	395	6
5	Does age of material has significance on safety at work.	14	61	390	8
6	Does financial constraint of any company affects the availability of resource required and impacts on safe execution at work site.	2	49	410	12

X. Manpower Consideration

S.No	**Questions**	***1–4*** *(Disagree)*	***5–7*** *(Agree)*	***8–10*** *(Strongly Agree)*	*can't say*
1	Does availability of manpower required for proper execution of work site safely.	30	53	389	3
2	Nature of employment has significance to do the job and maintain proper safety.	35	52	382	6
3	Skilled and experienced manpower is favorable to safe execution at work place.	29	55	385	6
4	Migration of manpower affects or impacts on safety at work place.	75	190	204	6
5	Does effective or efficient workmen availability in society has concern to the work place and linked to safe work execution?	65	196	206	8

6	Retention of workmen should be ensured by employer and may lead to effective work	37	53	376	9
7	Does contractor wish to deploy number of workers less than required and force available workmen to complete the job	62	193	213	7
8	Does workmen hygiene matters for effective execution of job	40	49	379	7

XI. Legal Consideration

S.No.	**Questions**	***1−4*** *Disagree*	***5−7*** *(Agree)*	***8−10*** *(Strongly Agree)*	*can't say*
1	Management aware of applicable legal requirements	52	98	280	19
2	Management committed to ensure all required legal requirements	27	211	200	11
3	Does legal advisor available to the company and competent	27	190	223	9
4	Company management committed to start the work or activity only if ensures the compliance?	26	192	223	8
5	Legal laws help in maintaining safety culture at work place	16	202	225	6
6	Smooth running of project can’t be affected even if HSE applicable laws are not adequately followed	230	199	6	14
7	Company is sincere about updation in legal requirements and asks his legal advisor to comply as soon as possible.	26	200	202	21

XII: Sample format for risk assessment

<table>
<tr><td rowspan="2"></td><td rowspan="2">Risk Assessment
Column Work
(Page 162 of 200)</td><td>SR = Severity Rating
- When it can lead to fatality or permanent disability Or when Property Loss is more than Rs 100,000</td><td>High = H</td><td>PR = Probability Rating
- When it occurs frequently or Chances approx. more than 50%</td><td>H</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>- When it can lead to temporary disability or doctor visit is required Or when Property Loss is more than Rs 10,000 but less than Rs 100,000</td><td>Medium = M</td><td>- When it occurs occasionally or Chances between 10% to 50%</td><td>M</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td colspan="2" rowspan="2">RL = Risk Level, 1 = Trivial, 2 = Tolerable, 3 = Moderate, 4 = Substantial, 5 = Intolerable</td><td rowspan="2">- When it can lead to First aid Injury Or when Property Loss is less than Rs 10,000</td><td rowspan="2">Low = L</td><td rowspan="2">- When it has never occurred before or chances less than approximately 10%</td><td>L</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td></td><td>L</td><td>M</td><td>H</td></tr>
</table>

SL. No.	**Activity, Product, Service**	**Hazard, Concern**	**Severity Explanation**	**Severity Rating H/M/L**	**Probability Explanation**	**Probability Rating H/M/L**	**Risk Level 1/2/3/4/5**	**Risk Controls**		**Responsibility**
								Existing	**Required**	

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

Methos statement Number	Description of scope and works	Referen-ce & backgro-und of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment							Over all risk assessme-nt done (1/2/3/4)
			Prior work details given	Hazard informat ion raised (1/2/3/4)	Critical activities risk identified & discussed (1/2/3/4)	Steps wise description (1/2/3/4)	Methods of execution (1/2/3/4)	Vulnerability of work identified (1/2/3/4)	Resource description (1/2/3/4)	Identification of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measures suggested (1/2/3/4)	All activities / Subactivi-ties covered (1/2/3/4)	Any Critical activities/ Sub-activities mentioned (1/2/3/4)	Hazard identified (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Proposed control (1/2/3/4)	Risk Level quantifie-d (1/2/3/4)	
1	Method statement for 30MT Gantry crane assembly and erection (Rev-2)	3	4	2	1	4	4	1	4	1	2	1	4	1	3	3	3	1	3	1	3
2	Method statement for construction of road crossing duct outfall of dewatering at Location 1(Rev-2)	4	4	2	1	3	3	1	3	1	3	1	3	1	4	4	3	1	3	1	3
3	Method statement for construction of road crossing duct outfall of dewatering at Location 2 (Rev-4)	4	3	1	1	4	4	1	3	1	1	1	3	1	4	4	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

			Prior activities details			**Detailed procedure**				**HSE Management System**			**Risk assessment**								
Methos statement Number	**Description of scope and works**	**Referen-ce & backgro-und of project**	**Prior work details given**	**Hazard informat-ion raised (1/2/3/4)**	**Critical activities risk identified & discussed (1/2/3/4)**	**Steps wise description (1/2/3/4)**	**Methods of execution (1/2/3/4)**	**Vulnerability of work identified (1/2/3/4)**	**Resource description (1/2/3/4)**	**Identification of critical areas (1/2/3/4)**	**Activity based control measures proposed (1/2/3/4)**	**General safety measures suggested (1/2/3/4)**	**All activities / Subactivi-ties covered (1/2/3/4)**	**Any Critical activities/ Sub-activities mentioned (1/2/3/4)**	**Hazard identified (1/2/3/4)**	**Severity & Probability identified (1/2/3/4)**	**Risk Level (1/2/3/4)**	**Exist control (1/2/3/4)**	**Proposed control (1/2/3/4)**	**Risk Level quantifie-d (1/2/3/4)**	**Over all risk assessme-nt done (1/2/3/4)**
4	Method statement for construction of deep lined wells (Rev-3)	4	4	1	1	4	3	1	4	1	3	2	3	1	4	4	3	1	1	1	3
5	Method statement of excavation and support of main station and switch box (Rev-2)	3	3	1	1	4	3	1	3	1	3	2	3	1	3	4	3	1	1	1	3
6	Method statement of excavation and support of main station and switch box (Rev-3)	3	4	1	1	3	3	1	3	1	2	2	4	1	3	4	3	1	1	1	3
7	Method statement of station void investigation (Rev-2)	4	3	1	1	4	4	1	3	1	3	1	4	1	3	1	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant | 2= Information available but not relevant | 3= Partially covered | 4= Adequately covered

Methos statement Number	Description of scope and works	Reference & background of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment								Over all risk assessment done (1/2/3/4)
			Prior work details given	Hazard information raised (1/2/3/4)	Critical activities risk identified & discussed (1/2/3/4)	Steps wise description (1/2/3/4)	Methods of execution (1/2/3/4)	Vulnerability of work identified (1/2/3/4)	Resource description (1/2/3/4)	Identification of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measures suggested (1/2/3/4)	All activities / Subactivities covered (1/2/3/4)	Any Critical activities/ Sub-activities mentioned (1/2/3/4)	Hazard identified (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Proposed control (1/2/3/4)	Risk Level quantified (1/2/3/4)	
8	Method statement of dewatering system (Rev-3)	3	3	1	1	3	4	1	3	1	2	3	3	1	3	1	3	1	3	1	3
9	Method statement of production and installation of steel reinforcement (Rev-4)	4	4	1	1	3	4	1	3	1	2	3	3	1	3	1	3	1	3	1	3
10	Method statement of demolition and reconstruction of existing boundary wall location 1 (Rev-3)	3	3	1	1	3	4	1	4	1	2	3	4	1	3	1	3	1	3	1	3
11	Method statement of construction of temporary slab at location 1 underpass (Rev-3)	4	3	1	1	3	3	1	4	1	2	3	4	1	3	1	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

Methos statement Number	Description of scope and works	Referen-ce & backgro-und of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment								Over all risk assessme-nt done (1/2/3/4)
			Prior work details given	Hazard information raised (1/2/3/4)	Critical activities risk identified & discussed (1/2/3/4)	Steps wise description (1/2/3/4)	Methods of execution (1/2/3/4)	Vulnerability of work identified (1/2/3/4)	Resource description (1/2/3/4)	Identification of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measures suggested (1/2/3/4)	All activities / Subactivi-ties covered (1/2/3/4)	Any Critical activities/ Sub-activities mentioned (1/2/3/4)	Hazard identified (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Proposed control (1/2/3/4)	Risk Level quantified (1/2/3/4)	
12	Method statement of basement foundation slab construction (Rev 3)	4	4	1	1	3	4	1	3	1	2	3	3	1	3	1	3	1	3	1	3
13	Method statement of construction of workers accommodation and facilities (Rev-1)	4	4	1	1	4	4	1	4	1	2	3	4	1	3	1	3	1	3	1	3
14	Method statement of earthing and bonding of station switch box (Rev-2)	4	4	1	1	3	4	1	3	1	2	3	3	1	3	1	3	1	3	1	3
15	Method statement of erection of stairs tower and switch box (Rev-1)	4	4	1	1	4	3	1	3	1	2	3	4	1	3	1	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

Methos statement Number	Description of scope and works	Reference & background of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment								Over all risk assessment done (1/2/3/4)
			Prior work details given	Hazard information raised (1/2/3/4)	Critical activities risk identified & discussed (1/2/3/4)	Steps wise description (1/2/3/4)	Methods of execution (1/2/3/4)	Vulnerability of work identified (1/2/3/4)	Resource description (1/2/3/4)	Identification of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measures suggested (1/2/3/4)	All activities / Subactivities covered (1/2/3/4)	Any Critical activities/ Sub-activities mentioned (1/2/3/4)	Hazard identified (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Proposed control (1/2/3/4)	Risk Level quantified (1/2/3/4)	
16	Method statement of rail track and gantry track erection (Rev-2)	4	4	1	1	3	3	1	4	1	2	3	4	1	3	1	3	1	3	1	3
17	Method statement of tower cranes erecting and dismantling (Rev-6)	4	3	1	1	4	3	1	3	1	2	3	3	1	3	1	3	1	3	1	3
18	Method statement of design, production and erection of formwork (Rev-2)	3	4	1	1	4	4	1	3	1	2	3	4	1	3	1	3	1	3	1	3
19	Method statement of construction of elevations (Walls & columns), intermediates slab and rood slab for station and switch box (Rev-2)	4	4	1	1	4	3	1	4	1	2	3	4	1	3	1	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

			Prior activities details			Detailed procedure				HSE Management System			Risk assessment								
Methos statement Number	Description of scope and works	Referen-ce & backgro-und of project	Prior work details given	Hazard information raised (1/2/3/4)	Critical activities risk identified & discussed (1/2/3/4)	Steps wise description (1/2/3/4)	Methods of execution (1/2/3/4)	Vulnerability of work identified (1/2/3/4)	Resource description (1/2/3/4)	Identification of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measures suggested (1/2/3/4)	All activities / Subactivi-ties covered (1/2/3/4)	Any Critical activities/ Sub-activities mentioned (1/2/3/4)	Hazard identified (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Proposed control (1/2/3/4)	Risk Level quantifie-d (1/2/3/4)	Over all risk assessme-nt done (1/2/3/4)
20	Method statement of station box temporary head wall reconstruction and backfilling at location 1 (Rev-2)	3	4	1	1	4	4	1	3	1	2	3	4	1	3	1	3	1	3	1	3
21	Method statement of construction of road crossing ducts for outfall of dewatering with horizontal directional drilling (HDD) methods. (Rev-2)	3	4	1	1	4	3	1	3	1	2	3	4	1	3	1	3	1	3	1	3
22	Method statement of permanent concrete repairs work (Rev-3)	4	4	1	1	3	4	1	3	1	2	3	4	1	3	1	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

			Prior activities details			Detailed procedure				HSE Management System			Risk assessment								
Methos statement Number	**Description of scope and works**	**Referen-ce & backgro-und of project**	**Prior work details given**	**Hazard informat ion raised (1/2/3/4)**	**Critical activities risk identifie d & discusse d (1/2/3/4)**	**Steps wise descripti on (1/2/3/4)**	**Methods of executio n (1/2/3/4)**	**Vulnera bility of work identifie d (1/2/3/4)**	**Resource descripti on (1/2/3/4)**	**Identif ication of critical areas (1/2/3/ 4)**	**Activity based control measures proposed (1/2/3/4)**	**General safety measure s suggeste d (1/2/3/4)**	**All activities / Subactiv i-ties covered (1/2/3/4)**	**Any Critical activities/ Sub-activities mentione d (1/2/3/4)**	**Hazard identifie d (1/2/3/4)**	**Severity & Probability identified (1/2/3/4)**	**Risk Level (1/2/3/ 4)**	**Exist control (1/2/3/4)**	**Propose d control (1/2/3/4)**	**Risk Level quantifie -d (1/2/3/4)**	**Over all risk assessme -nt done (1/2/3/4)**
23	Method statement of installation commissioning and operation of batching plant. (Rev-2)	4	4	1	1	3	3	1	4	1	2	3	3	1	3	1	3	1	3	1	3
24	Method statement of production and erection of structured steel (Rev-2)	4	3	1	1	3	3	1	3	1	2	3	3	1	3	1	3	1	3	1	3
25	Method statement of monitoring and instrumentation (Rev-3)	3	4	1	1	4	4	1	4	1	2	3	4	1	3	1	3	1	3	1	3
26	Method statement of survey and setting out (Rev-3)	3	4	1	1	4	3	1	4	1	2	3	3	1	3	1	3	1	3	1	3
27	Method statement of installation & relocation of fence/ hording at project sites. (Rev-2)	4	4	1	1	3	3	1	3	1	2	3	4	1	3	1	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

	1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered	

Methos statement Number	Description of scope and works	Referen-ce & backgro-und of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment								Over all risk assessme-nt done (1/2/3/4)
			Prior work details given	Hazard informat ion raised (1/2/3/4)	Critical activities risk identifie d & discusse d (1/2/3/4)	Steps wise descripti on (1/2/3/4)	Methods of executio n (1/2/3/4)	Vulnera bility of work identifie d (1/2/3/4)	Resource descripti on (1/2/3/4)	Identif ication of critical areas (1/2/3/ 4)	Activity based control measures proposed (1/2/3/4)	General safety measure s suggeste d (1/2/3/4)	All activities / Subactiv i-ties covered (1/2/3/4)	Any Critical activities/ Sub-activities mentione d (1/2/3/4)	Hazard identifie d (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/ 4)	Exist control (1/2/3/4)	Propose d control (1/2/3/4)	Risk Level quantifie -d (1/2/3/4)	
28	Method statement of site areas preparation works, earthworks, roads and parking (Rev-3)	3	4	1	1	4	3	1	3	1	2	3	4	1	3	1	3	1	3	1	3
29	Method statement of cast in-situ manhole at location 1 (Rev-2)	4	3	1	1	3	4	1	4	1	2	3	4	1	3	1	3	1	3	1	3
30	Method statement of dewatering discharge manhole (Rev-2)	3	4	1	1	3	3	1	4	1	2	3	4	1	3	1	3	1	3	1	3
31	Method statement for initial pile load test (Rev-1)	4	1	1	1	3	3	1	1	1	2	1	3	1	3	1	3	1	3	1	3
32	Method statement for insallation of elastomeric bearing. (Rev-0)	3	4	1	1	4	4	1	4	1	2	3	4	1	4	3	3	1	3	1	3
33	Method statement for parapet lifting and stitching (Rev-1)	4	4	1	1	4	3	1	4	1	2	3	3	1	3	1	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

Methos statement Number	Description of scope and works	Referen-ce & backgro-und of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment								Over all risk assessme-nt done (1/2/3/4)
			Prior work details given	Hazard informat ion raised (1/2/3/4)	Critical activities risk identifie d & discusse d (1/2/3/4)	Steps wise descripti on (1/2/3/4)	Methods of executio n (1/2/3/4)	Vulnera bility of work identifie d (1/2/3/4)	Resource descripti on (1/2/3/4)	Identif ication of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measure s suggeste d (1/2/3/4)	All activities / Subactiv i-ties covered (1/2/3/4)	Any Critical activities/ Sub-activities mentione d (1/2/3/4)	Hazard identifie d (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Propose d control (1/2/3/4)	Risk Level quantifie -d (1/2/3/4)	
34	Method statement for parapet lifting and stitching (Rev-2)	4	3	1	1	3	4	1	4	1	2	3	3	1	3	3	3	1	3	1	3
35	Method statement for parapet lifting and stitching (Rev-2)	4	4	1	1	4	3	1	3	1	2	3	3	1	4	1	3	1	3	1	3
36	Method statement for erection of I girder (Rev-0)	4	3	1	1	3	3	1	3	1	2	3	3	1	4	3	3	1	3	1	3
37	Method statement for erection of I girder (Rev-0)	3	1	1	1	3	4	1	3	1	2	3	3	1	3	1	3	1	3	1	3
38	Method statement for casting of I Girder (Rev-0)	4	1	1	1	4	4	1	1	1	2	3	3	1	4	3	3	1	3	1	3
39	Method statement for erection of I Girder (Rev-1)	4	1	1	1	4	3	1	4	1	3	3	3	1	3	3	3	1	3	1	3
40	Method statement for production of concrete (Rev-0)	3	1	1	1	4	4	1	1	1	2	3	3	1	3	3	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

Methos statement Number	Description of scope and works	Referen-ce & backgro-und of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment								Over all risk assessme-nt done (1/2/3/4)
			Prior work details given	Hazard informat ion raised (1/2/3/4)	Critical activities risk identifie d & discusse d (1/2/3/4)	Steps wise descripti on (1/2/3/4)	Methods of executio n (1/2/3/4)	Vulnera bility of work identifie d (1/2/3/4)	Resource descripti on (1/2/3/4)	Identif ication of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measure s suggeste d (1/2/3/4)	All activities / Subactiv i-ties covered (1/2/3/4)	Any Critical activities/ Sub-activities mentione d (1/2/3/4)	Hazard identifie d (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Propose d control (1/2/3/4)	Risk Level quantifie -d (1/2/3/4)	
41	Method statement for prost tensioning work (Rev-2)	3	1	1	1	3	3	1	3	1	3	3	3	1	3	3	3	1	3	1	3
42	Method statement for parapet erection (Rev-0)	3	1	1	1	4	4	1	4	1	2	3	3	1	3	3	3	1	3	1	3
43	Method statement for casting of pier (Rev-0)	4	1	1	1	3	3	1	1	1	3	3	3	1	3	3	3	1	3	1	3
44	Method statement for casting of pier cap (Rev-0)	4	1	1	1	4	3	1	4	1	3	3	3	1	3	3	3	1	3	1	3
45	Method statement for survey work (Rev-0)	3	1	1	1	3	4	1	4	1	2	3	3	1	3	3	3	1	3	1	3
46	Method statement for geotechnical investigation (Rev-0)	3	4	1	1	3	3	1	3	1	2	3	3	1	3	1	3	1	3	1	3
47	Method statement for bentonite use and handling (Rev-0)	3	4	1	1	3	4	1	3	1	2	3	3	1	3	4	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant | 2= Information available but not relevant | 3= Partially covered | 4= Adequately covered

Methos statement Number	Description of scope and works	Referen-ce & backgro-und of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment								Over all risk assessme-nt done (1/2/3/4)
			Prior work details given	Hazard information raised (1/2/3/4)	Critical activities risk identified & discussed (1/2/3/4)	Steps wise description (1/2/3/4)	Methods of execution (1/2/3/4)	Vulnerability of work identified (1/2/3/4)	Resource description (1/2/3/4)	Identification of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measures suggested (1/2/3/4)	All activities / Subactivi-ties covered (1/2/3/4)	Any Critical activities/ Sub-activities mentioned (1/2/3/4)	Hazard identified (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Proposed control (1/2/3/4)	Risk Level quantifie-d (1/2/3/4)	
48	Method statement for parapet erection (Rev-0)	3	4	1	1	4	4	1	4	1	2	3	3	1	3	4	3	1	3	1	3
49	Method statement for construction of column (Rev-1)	3	4	1	1	4	3	1	4	1	2	3	3	1	3	4	3	1	3	1	3
50	Method statement for pier cap (Rev-0)	3	4	1	1	3	4	1	3	1	2	3	3	1	3	3	3	1	3	1	3
51	Method statement for pier cap (Rev-1)	3	4	1	1	3	4	1	4	1	2	3	3	1	3	3	3	1	3	1	3
52	Method statement for pier cap (Rev-2)	3	4	1	1	3	3	1	3	1	2	3	3	1	3	4	3	1	3	1	3
53	Method statement for erection of gantry cranes (Rev-0)	3	4	1	1	3	3	1	3	1	2	3	3	1	3	3	3	1	3	1	3
54	Method statement for casting of pretension I Girder (Rev-1)	3	4	1	1	3	4	1	4	1	2	3	3	1	3	4	3	1	3	1	3

XIII: Study and analysis of method statements and SHE manuals

1= Not at all relevant	2= Information available but not relevant	3= Partially covered	4= Adequately covered

Methos statement Number	Description of scope and works	Referen-ce & backgro-und of project	Prior activities details			Detailed procedure				HSE Management System			Risk assessment								Over all risk assessme-nt done (1/2/3/4)
			Prior work details given	Hazard information raised (1/2/3/4)	Critical activities risk identified & discussed (1/2/3/4)	Steps wise description (1/2/3/4)	Methods of execution (1/2/3/4)	Vulnerability of work identified (1/2/3/4)	Resource description (1/2/3/4)	Identification of critical areas (1/2/3/4)	Activity based control measures proposed (1/2/3/4)	General safety measures suggested (1/2/3/4)	All activities / Subactivi-ties covered (1/2/3/4)	Any Critical activities/ Sub-activities mentioned (1/2/3/4)	Hazard identified (1/2/3/4)	Severity & Probability identified (1/2/3/4)	Risk Level (1/2/3/4)	Exist control (1/2/3/4)	Proposed control (1/2/3/4)	Risk Level quantifie-d (1/2/3/4)	
55	Method statement for erection of I Girder (Rev-0)	3	3	1	1	3	4	1	4	1	2	3	3	1	3	4	3	1	3	1	3
56	Method statement for erection of I girder (Rev-1)	3	4	1	1	4	4	1	3	1	2	3	3	1	3	3	3	1	3	1	3
57	Method statement for erection of steel span (Rev-0)	3	4	1	1	4	3	1	4	1	2	3	3	1	3	3	3	1	3	1	3
58	Method statement for pretensioning of I girder (Rev-0)	3	4	1	1	4	4	1	4	1	2	3	3	1	3	3	3	1	3	1	3

XIV. Published Paper

Review Article

STATE OF ART REVIEW OF HAZARDS & RISK ASSOCIATED WITH VIADUCT WORK AND SUGGESTION TO IMPROVE SAFETY

Bikarama Prasad Yadav[1*], Dr.N.A.Siddiqui[2], Dr Ashutosh Gautam[3]

Address for Correspondence

[1*,2] University of Petroleum & Energy Studies, Dehradun, Uttarakhand, 248007

[3]India Glycols Ltd Kashipur, Uttarakhand India

ABSTRACT

Most Indian metro cities are facing the problem of traffic congestion, arising from indiscriminate use of personal vehicles, due to lack of an effective transport system to meet the demands of increasing population. An effective public transport system can not only ease the traffic flow but also improve the air quality of a region by taking personal vehicles off the road in large numbers.

Providing an effective rail or road transport system requires construction of viaducts for safe and congestion free movement of traffic. Viaducts also facilitate connecting existing network over otherwise difficult terrain and optimized use of available land. Construction of rail and road network requires working in hazardous environment. Rail and road construction work at ground level is hazardous but this hazard increases manifold for work above ground level.

As per estimates given by Occupational Safety Administration (OSHA), UK more than 10 % of the workers involved in viaduct construction meet accidents ranging from minor injuries to fatality. Therefore, the importance of reviewing the existing safety measures and suggestions to improve the existing safety record cannot be undermined.

This paper reviews the existing safety practices and standards followed by viaduct construction industries. The causes of high accident rate are identified and suggestions are given to improve the safety of workers involved in viaduct construction, thereby, drastically bringing down the number of injuries.

KEYWORDS: Hazardous environment, construction Safety, Viaduct hazards, Risk in construction etc.

INTRODUCTION

Expanding existing network of rail and road via viaducts is being used to provide for smooth movement of public, private and good carriers. The viaduct concept was started in 18th century and improvements were done during late 19th to 20th century thereby popularizing this concept in urban infrastructure. In ancient times, the same concept was in used while crossing over river or canal by putting wooden plank but in 21st century drastic changes came and use of viaduct based on modern concept was promoted.

The majority of work carried in viaduct work involves working at height where life of working personnel remains in danger and majority of accidents are due to fall during work at height. There are numerous hazard associated with performing viaduct work and even in 21st century we have failed to control the accidents in viaduct work.

Compared to other construction works accidents leading to injury and even death happen more frequently in viaduct because of the nature of work. From inception of construction project till it is finished, inherent hazard and underlying hazard are considerable.

As per bureau of labour statistics (BLS) 150,000 workers are injured every year and majority of workers are injured due to fall, while injury due to contact with the equipment was also identified as a major for work at height accidents. One out of every ten workers gets injured in a year (OSHA, Year) and they have also identified fall hazards as the main reason behind majority of accidents at construction site. There are various activities in construction which keep changing all of sudden or on routine basis which makes the work place unstable in nature and due to which special attention is required round the clock.

Hazard identification and assessment is the technique use by site execution personnel to designer analyzing the consequences before execution of a job. There are two steps involved in the identification of risk in construction through interviewing the personnel involved from design to execution stage. The first stage is knowledge acquisition and the second stage is participation of core design team (Chapman 2001). Limited research has been done to minimize and control the risk due to inherent hazard associated with construction work. Although, from time to time, concerns regarding safety in construction industry have being raised but still it remains the most hazardous industry. In Spain 30% of all the industrial accidents were reported in the construction industry between 2000 to 2006 mainly (Gangolells, Casals et al. 2010). The goal of proactive risk assessment is to minimize the risk during construction without compromising quality and safety at work place and avoiding a project from missing the set deadline.

SAFETY CULTURE IN CONSTRUCTION INDUSTRY

Improving behavioral based safety (BBS) is the most effective way by which risk is can be effectively managed. It is the most effective tool which has been implemented since 1980 in Europe and North America and today it is the most popular tool worldwide (Li, Lu et al. 2015). Improved risk management is seen by applying BBS concept. A large number of illiterate migrated workers are involve in construction industry thereby bringing instability and increasing inherent risk but this can be controlled by applying or implementing proactive behavioral based safety approach. Risk management is total human control system which is applicable since initiation of projects till its completion. BBS can change the mind set of personnel and management towards safety and likewise towards audit, identification of hazard and risk assessment and its control measures. BBS helps to minimize and control risk with participation from all level of management.

Even though safety aspects in construction get finalized even before mobilization of workmen, equipment but its implementation is rarely realized(Behm 2005). Behm (2005) revealed that 40% of fatalities in construction happen due to ill approach of designer, architect, & structural engineers. Identification of hazard during design and planning stage in construction industry is done casually. Even though there are consensuses noted while considering inherent hazard and risk which are present in construction industries but these are generally overlooked by the architects, designer or planner. Risk in construction projects are uncertain and it effect at least one of the objective of the project e.g. cost, scope, schedule etc. (Rezakhani 2012). To avoid such risk identification of hazard and effective risk management is necessary. Therefore, assessment of risk, which may effects its scope or work or objective of projects, is required by the construction companies. Managing risk at project sites can benefit to the project manager not only in the safety related incidents but also in many financial issues and also increase the confidence in achieving project objectives (Rezakhani 2012). As per international labour organization (ILO) about 60000 fatal accidents or almost 30-40% of total accidents occurred in construction globally and 7% -10% of global workforce works in construction industry (Lew and Lentz 2010). Many initiatives and many control measures have been suggested to address these problems in the construction industry. Different organizations are actively addressing the hazards in construction globally and workers engaged in construction industry are better trained and aware than before.

Investigation of work based accidents highlights the poor performances of involved working personal as well as that of contractor. Achieving the objective zero accidents is not possible unless owner, designer and other parties shoulder the well-defined responsibilities. Individual worker, supervisor, manager, designer or consultant cannot enforce zero tolerance for accidents or reduce the accident in significant way. Change in the trends and level of safe execution of construction projects can be achieved only when proactive involvement can be seen from all - workers to owner.

A number of risk assessment methodologies are available to assess the site conditions and help minimize the identified risks. (Haight 2001).

The risk corresponding to body parts wise was measured using fuzzy reasoning and fuzzy analytic hierarchy process. The overall risk of project was calculated as using sum of product methods. In the above study, author has used fuzzy numbers and linguistic terms for input value of each input parameters because of unavailability of precise and exact data of body part wise injury.

BACK GROUND ON HAZARD AND RISK MINIMIZATION IN CONSTRUCTION

Identification of hazard and its analysis in construction are often a traditional methods normally used in various forms. Due intrinsic uncertainty of construction and traditional approach of identification of hazard and risk assessment, there are certain limitation which has been raised by various researchers in this filed. These limitations are based on the hazard vulnerability of construction project and its unstable work nature. It is difficult to assess and advice the safety behavior which meets accidents due to involvement of operation procedure, human error and decision taken by designer and management. Since majority of assumptions, opinions are involved then risk assessment process should be more strict and reviewed by safety experts. In this situation it is difficult to quantify the adverse effect of hazard and its consequences because of involvement of high level of uncertainty, limited ability of humans which believed in holistic approach. Considering by above statements, it is clear that risk analysis methods in the construction business is uncontrolled with deficient information and/or uncertain, not well characterized, and inadequate data, especially in the outline stage, for which traditional or conventional methodologies don't give sufficient answers. A step ahead fuzzy techniques characterize methods of subjective analysis or assessments of all inborn unclearness and also for human creativity, intuition which is main component of risk analysis methods (Pinto, Nunes et al. 2010).

Fuzzy linguistic parameters were in used to deal with uncertain and inadequate data (Gürcanli and Müngen 2009). He has considered the cost of health care, trainings, machines upgradation and various tools used in construction. He derived the parameters of accident and likelihood for different types of construction and based on the activity. The data was collected by past accidents records and government data logged by governmental agencies. This approach may be used in various fields but it has specifically used for construction industries. (Beriha, Patnaik et al. 2012) has given characterization and expectation model in view of registering strategy for the surveying the chief to investigate the word related wounds and making arrangements for budgetary costs to enhance safety performances in Indian construction industries. (Blockley 1975) He has considered probability of basic mishaps in basic introducing so as to design fuzzy ideas. He has likewise dissected the accident evaluation system for underground construction utilizing a model in fuzzy concept. Further, likelihood of structural accidents was analyzed by using fuzzy sets. (Blockley 1980) has mentioned various methods assessing the failure of structure and structural safety measures. (Faber and Stewart 2003) addresses the issues connected with risk acceptance criteria, hazard avoidance and estimation of human life and endeavors to give proposals to the judicious treatment of these viewpoints. He has also highlighted the problematic areas and the requirements for further training, examination and spread are pushed. (An, Lin et al. 2006) In the system, fuzzy reasoning approach is adopted to calculate the risk level of all different hazards and its failure frequency, its consequence and probability. (An, Lin et al. 2006) Statistics shows the number of accidents includes not only the workers but also from non-employee side, public etc. Authors describes the dangerous nature of construction industry mainly railways where he identified the need of increasing awareness to bring proactive safety management system. He observed that causes of accidents are fundamental milestone to control accidents can be achieved by risk analysis. In last few years risk analysis plays central role identifying the hazards e.g. Derailment hazard, Collision Hazards, Fire Hazards, Electrocution hazards, fall hazards, train strike, slip trip etc.

ACCIDENT PREVENTION THROUGH DESIGN CONSIDERATIONS:

Design considerations are the most important factor that has the potential to minimize and control construction accidents. Aires, Gámez et al. (2010)

Based on reviews, suggestions were given to develop some methodical approach to implementation and adding safety in design considerations. As per Mroszczyk (2006) majority of construction accidents happens during the initial phase of work when project gets allocated. Mroszczyk (2006) has suggested that including the safety design consideration since its beginning would help decrease the number of accidents. Zhou, Whyte et al. (2012) used digital data in implementing safety in construction. Virtual Reality, CAD and building information modelling, sensing warning technology are helpful to develop tools for hazard identification and safe project delivery.

CONCLUSION:

A state-of-the-art literature review revealed the fact that majority of accidents happened in construction industry during the initiation phase due to ill approach of designer, architect and engineers. Although only 7-10 % global workforce works in construction industry more than 30-40 % of global industrial accidents are from construction industry.

Analysis of a number of accidents indicates that holistic approach of hazard identification and risk assessment, which is largely ignored by the construction designer, helps improve the on time project delivery, mobility of workforce. Active engagement of concerned and competent person and implementation of legislation strictly would also help improve the safety in construction industry. Significant improvements were noticed in accident prevention when enforcement had been seen on standard and other legislation.

Although construction safety design protocols have been set quite long ago in construction, but lack of proactive implementation results in areas specific accidents. Even as various tools have being developed for risk management, implementation of these risk management tools adapter for site specific needs is required.

Allocation of hazard in any activity and evaluating its risk value is not a solution until consideration includes well construction safety design and planning strategy. Many initiatives taken by experts, to reduce accidents during initial stages of construction have resulted in decrease in number of accidents. To further improve the safety in construction, various tools have been made. One such tool is based on fuzzy logics which has the capability to take into consideration uncertain and inadequate data.

REFERENCES:

1. Aires, M. D. M., M. C. R. Gámez and A. Gibb (2010). "Prevention through design: The effect of European Directives on construction workplace accidents." Safety science 48(2): 248-258.
2. An, M., W. Lin and A. Stirling (2006). "Fuzzy-reasoning-based approach to qualitative railway risk assessment." Proceedings of the Institution of Mechanical Engineers, Part F: Journal of rail and rapid transit 220(2): 153-167.
3. Behm, M. (2005). "Linking construction fatalities to the design for construction safety concept." Safety Science 43(8): 589-611.
4. Beriha, G., B. Patnaik, S. Mahapatra and S. Padhee (2012). "Assessment of safety performance in Indian industries using fuzzy approach." Expert Systems with Applications 39(3): 3311-3323.
5. Blockley, D. (1975). Predicting the likelihood of structural accidents. ICE Proceedings, Thomas Telford.
6. Blockley, D. I. (1980). The nature of structural design and safety.
7. Chapman, R. J. (2001). "The controlling influences on effective risk identification and assessment for construction design management." International Journal of Project Management 19(3): 147-160.
8. Faber, M. H. and M. G. Stewart (2003). "Risk assessment for civil engineering facilities: critical overview and discussion." Reliability engineering & system safety 80(2): 173-184.
9. Gambatese, J. and J. Hinze (1999). "Addressing construction worker safety in the design phase: Designing for construction worker safety." Automation in Construction 8(6): 643-649.
10. Gambatese, J. A. (1998). "Liability in designing for construction worker safety." Journal of Architectural Engineering 4(3): 107-112.
11. Gambatese, J. A., M. Behm and J. W. Hinze (2005). "Viability of designing for construction worker safety." Journal of construction engineering and management 131(9): 1029-1036.
12. Gambatese, J. A., M. Behm and S. Rajendran (2008). "Design's role in construction accident causality and prevention: Perspectives from an expert panel." Safety Science 46(4): 675-691.
13. Gangolells, M., M. Casals, N. Forcada, X. Roca and A. Fuertes (2010). "Mitigating construction safety risks using prevention through design." Journal of safety research 41(2): 107-122.
14. Gürcanli, G. E. and U. Müngen (2009). "An occupational safety risk analysis method at construction sites using fuzzy sets." International Journal of Industrial Ergonomics 39(2): 371-387.
15. Haight, F. A. (2001). "Risk and misfortune: the social construction of accidents. Judith Green. UCL Press, 1 Gunpowder Square, London EC4A 3DE. 1997 pp x+222. ISBN 1-85728-560-3 (HB), 1-85728-561-1 (PB) (In North America Taylor and Francis, 1900 Frost Road, Bristol PA 19007-1598. $26.95." Accident Analysis & Prevention 33(5): 697.
16. Hecker, S., J. A. Gambatese and M. Weinstein (2004). Designing for safety and health in construction: Proceedings from a Research and Practice Symposium, University of Oregon Press.
17. Hinze, J. and F. Wiegand (1992). "Role of designers in construction worker safety." Journal of construction engineering and management 118(4): 677-684.
18. Ku, K., S. Pollalis, M. Fischer and D. Shelden (2008). "3D model-based collaboration in design development and construction of complex shaped buildings." Journal of Information Technology in Construction 13(258-285): 26.
19. Lew, J. and T. Lentz (2010). Designing for safety–applications for the construction industry. Proceedings of the 18th Special Track CIB World Building Congress, CIB W099-Safety and Health in Construction.
20. Li, H., M. Lu, S.-C. Hsu, M. Gray and T. Huang (2015). "Proactive behavior-based safety management for construction safety improvement." Safety Science 75(0): 107-117.
21. Mroszczyk, J. W. (2006). "Designing for construction worker safety." American Society of Safety Engineers 5(3): 3.
22. Pinto, A., I. L. Nunes and R. A. Ribeiro (2010). Qualitative Model for Risk Assessment in Construction Industry: A Fuzzy Logic Approach. DoCEIS, Springer.
23. Rezakhani, P. (2012). "A review of fuzzy risk assessment models for construction projects." Slovak Journal of Civil Engineering 20(3): 35-40.
24. Smallwood, J. (1996). The influence of designers on occupational safety and health. First International Conference of CIB Working Commission W.
25. Smallwood, J. (2008). The Influence of Clients on Contractor Health and Safety (H&S). Proceedings of the CIB W99 Rinker 14th International Conference Evolution of and Directions in Construction Safety and Health, Gainesville, Florida.
26. Torghabeh, Z. J. and S. S. Hosseinian (2012). "Designing for construction workers' safety." Int. J. Adv. Eng. Technol: 2231-1963.
27. Zhou, W., J. Whyte and R. Sacks (2012). "Construction safety and digital design: A review." Automation in Construction 22: 102-111.

analyzed accidents data from 10 countries and found that more than 10% reduction in work place accidents was noticed when safety design considerations were in place. Design safety must be considered during the design phase, before execution of construction work approval of work procedure, as indicated in design is necessary. Workforce engaged in construction is neither consistent nor they are permanent; therefore establishing workforce competency is a ever present problem for employer. Statistics show that implementation of safety design considerations result in reduction in accidents (Lew and Lentz 2010). Decrease in the number of accidents and injuries in construction through implementation of safety design considerations will not only save lives but also improves the work quality and life. It also results in reduction in number of accidents claims and other financial expenditure for employers or contractors (Ku, Pollalis et al. 2008). Role of designer, extent of distribution of accountability, allocation of responsibility during construction based on technical capability of architect & engineers has shown significant reduction in accident rates in building projects. Implementing the concept of safe design and 3D models enhances the feasibility of executing the project on time. UK (Hecker, Gambatese et al. 2004) mandated prevention through design in construction along with other European nations in 1995. Builders, construction companies and consultants were persuaded to implement safety design in construction which resulted in noticeable improvement in safety performance. Many design professionals raised the concern over implementation of prevention through design as it may result in framing of harsh and impractical regulations against designers in case of any construction injury. Hecker, Gambatese et al. (2004) have shown that designers lack safety design knowledge. Construction project allotted through bidding process constraints the constructor in implementing design safety considerations during execution of the project. Gambatese, Behm et al. (2005) have developed an outline for the implementation of safety design considerations, implementation of which resulted in considerable enhanced safety, wellbeing and health of construction workers. Gambatese, Behm et al. (2005) are of the view that designing of safety is quite possible and can have positive impact on safety of construction workers, safe execution, cost effectives at end and on time delivery of the project. Gambatese (1998) argue that role of designer in construction safety is encompasses construction design safety. A number of cases have been brought to the court where designer mistakes and their ill approach resulted in accidents. It has been seen (Gambatese 1998) that unless safety is incorporated through contractual binding on designer during bid-build process, they do not bother much in incorporating safety features in the structure thereby enhancing construction workers safety. Role of contractor in ensuring safety during construction exercise is well defined and the role or participation of designer in enhancing construction safety must be increased. Increased participation of designer in ensuring construction safety will improve the implementation of the concept of inherent safety in construction projects. Design engineers must be held accountable and liable for safety hazards arising from design even if no legal bindings are stated. Once the concept of design safety is implemented, decrease in number of accidents, injuries and associated cost would reduce. According to Hinze and Wiegand (1992) designer plays an important role in development of a project and same time he/she play an important role in implementing safety in design. Traditionally construction worker safety has been regarded as the sole responsibility of the construction contractor. Only one third of contractor, companies or designer follow the design content helpful for workers safety (Hinze and Wiegand 1992). Some of the impractical aspects of prevention through design have resulted in legal cases against contractors and have discouraged the design contractors. Torghabeh and Hosseinian (2012) gave the design and planning concept of construction safety design. They through the implementation of design safety were able to reduce the number of accidents for workers engaged in construction. There have been a number of legal cases where the construction safety was compromised because of the lack of knowledge legal standards by designer or it was found that the information provided by the contractor was inadequate. Generally it is found the lack of safety data hampers hazard identification and incorporation of safety features into design. Contractors engaged in design built projects have been seen to go for cost cutting at the expense of worker safety. Gambatese, Behm et al. (2008) studied relationship between design and construction site safety. It was found that there is a definite link between design decision and construction safety as they directly influence accident causation. Occupational diseases are not the part of design resulting in injuries and accidents. Smallwood (2008) highlighted the inclusion design and construction safety issues in project specific Quality Health Safety and Environment (QHSE) plan. Pressure of cost cutting from the contractor influences the engineering designer resulting in compromised HSE requirements thereby diverts from holistic approach in implementation of health safety issues in construction. Smallwood (1996) studied data more than 75 contracting company and found that 50% of companies identified the design as an aspect or factor, which if not done properly negatively effects the health and safety of construction workers. He also revealed that almost 90% of contractors suggested that safety of the construction can be improved through design and along with it; architects and engineers should learn construction safety as part of their curriculum during colleges. Behm (2005) studied 230 fatality cases in US between 1990 to 2003. Out of the 230 cases only 224 cases were used for the study as for the other 6 cases sufficient information was not available. Review was done to access whether any design is linked to the incidents. Based on the assessed data and review Behm (2005) observed, 42% of accidents were having design content issues for which more than 40 suggestion were given to improve the workers design safety. Gambatese and Hinze (1999) reviewed many design firms and constructing company regarding advice and implementation of safety in design. They found the lack of skills in designers to implement safety features in order to avoid or to reduce the safety risk or lack of confidence in implementing the safety in design.

XV: Curriculum Vitae

CURRICULUM VITAE

BIKARAMA PRASAD YADAV

Assistant Professor (SG)
Department of Health Safety & Environment
University of Petroleum and Energy Studies, Dehradun. India
Contact No: - +91-7055044111
Email Id: - bikarama@gmail.com; bpyadav@ddn.upes.ac.in

CAREER OBJECTIVE:

Employ the knowledge and skills to gain or contribute my organization's success in a significant way as an individual and as a member of the corporate family. To provide quality of outcome based education in the field of health safety, fire and environment and to enriching students knowledge theoretically, practically and application based.

PERSONAL OBJECTIVE:

My desire is to create a truly competitive arena wherever I work. I want to bring my enthusiasm and sense of confidence to the organization and to the people I work with. My involvement in various areas of activities at college, industries has taught me crucial lessons on leadership and teamwork. My regular endeavour is to work for my pupil knowledge enhancement.

ACADEMIC QUALIFICATION:

- **PhD (Engineering/ Health Safety & Environment)** – (Pursuing)
  University- University of Petroleum & Energy Studies, Dehradun
- **M Tech (HSE)**
  University- University of Petroleum & Energy Studies, Dehradun
- **B. Tech (Safety & Fire Engineering)**
  University- Cochin University of Science & Technology, Kochi
- **Intermediate Science**
  Board/University- Bihar Intermediate Educational Council. Patna
- **Matriculation (All Subjects)**
  Board/University- Bihar Secondary Examination Board, Patna

EXPERIENCES:

1. **Organization Name**: University of Petroleum & Energy Studies, Dehradun.
   Assistant Professor (Selection Grade) - HSE
   Area of interest: Construction Safety. Fire Engineering. Hazard Evaluation & Assessment, Process safety etc.

2. **Organization Name**- J Kumar Infra Projects Limited (February 2012 to till date)
   Designation- Chief SHE Manager
   Scope of Work - Part Design & Construction of Viaduct work including two stations
   Client- Delhi Metro Rail Corporation Ltd (CC-02)

3. **Organization Name**- SGS India Private Ltd (Sept 2011 to Feb 2012)
   Designation- Assistant Manager
   Work Details- Lead North India Industrial HSE Services
   Location- Gurgaon (Regional Office)

4. **Company Name**- B L Kashyap & Sons Ltd (Feb 2010 to May 2011)
   Designation- Chief SHE Manager
   Scope of Work- Part Design & Construction of viaduct of length 1897.71m on the extension up to Vaishali (Ghaziabad) of Yamuna bank – Anand Vihar Corridor of Delhi MRTS project
   Client- Delhi Metro Rail Corporation Ltd [BC 37(1) R]

5. **Company Name**- Soma Enterprise Ltd (May 2007 to Jan 2010)
   Designation- Sr. SHE Manager
   Scope of Work- Design and construction of Tunnel by shield TBM & station by cut and cover method between Udyog Bhawan & Green park station (both excluding) for underground works on central Secretariat to Qutab Minar Corridor of Phase II of Delhi MRTS project
   Client-Delhi Metro Rail Corporation Ltd (BC-16)

6. **Company Name-** Navayuga Engineering Company Ltd (May 2006 to May 2007)
   Designation- SHE Manager
   Scope of Work- Part Design & Construction of Viaduct work including three stations of Delhi Metro Rail Projects
   Client-Delhi Metro Rail Corporation Ltd (BC-06)

ROLE & RESPONSIBILITY AT PRESENT:

- Involved in learning & teaching of assigned subjects for B Tech (Fire & Safety Engineering students) and M Tech (Health Safety and Environment)
- Developing course plan for assigned subjects and preparation of question papers of subject taught.
- Evaluation and submission of answer sheet on time.
- Assisting HOD/ career services for placement related works and placing students in companies. Actively arrange students summer internship and project work.
- Actively work for semester, curriculum planning for the subjects such as Fire Engineering (IV) Risk Assessment & planning, Fire Engineering III, Safety in process industry, Fire

Fighting Appliances & Operation, Concept of Fire Safety in Building structure & installations, Safety in Construction , Fire Engineering Lab , Fire Risk & Control.

- Coordination between students and career services for internship and placements
- Enhancing student skill in Fire Engineering Lab with practical experience and knowledge
- Active participation as Coordinator in National & International Seminars.
- Mentor & Guide for student projects from Bachelors and Master degree in Fire Safety and HSE.
- Planning and coordinating industrial training and guest lectures by calling up industrial professionals for the students.

ROLE & RESPONSIBILITY OF PAST ORGANIZATIONS:

- ✓ Conducted Industrial Audits (HSE/Safety Audits, Electrical Safety Audits, Fire Safety Audits, and Process Safety Audits). Technical/HSE Trainings. Managing Safety Management and Supervision at Construction sites. Carrying HAZOP Studies, Quantified Risk Assessment (QRA), Risk Based Inspection. HSE Documentation Services to all industries.
- ✓ Assisting in developing business, Business meeting with clients for all kind of HSE services, Tendering of HSE Projects
- ✓ Conducting HSE training programs for project personnel
- ✓ Organizing Induction training, Behavioral based training, Specific training (welder training, fire protection training, general safety awareness training etc.) and reviewing Safety tool box talks
- ✓ Develop and supervise the implementation of Project HSE Plans in a project or facility as per ISO 14001:2004 and OHSAS 18001:2007 requirements, Monitoring of work practices utilized by contractor or sub-contractor of the project or facility.
- ✓ Evaluates & Monitor the Health Safety and Environmental programs on projects or facilities. Analyse occupational safety & health hazards and develop methods of control.
- ✓ To stop the work in imminent danger situations or conditions having imminent adverse Safety Health & Environmental impact. Recommends corrective action and give advices to the engineer/supervisor and responsible management for necessary actions
- ✓ Active Participation along with engineers/managers in departmental personnel planning and development. Conducting employee's performance evaluation (oral/written) related to HSE issues
- ✓ Carrying accident investigations, documents causative factors and prepare reports
- ✓ Guide site HSE Supervisor in preparing specific reports as outlined in the site specific HSE Procedures Manual. Develops and implements the Worker Safety and Health Program and the corresponding procedure/documents.
- ✓ Monitors hazardous waste management, soil erosion and sedimentation control and other environmental issues as directed. Prepare and maintain WMP outlined in HSE plan
- ✓ Reporting and receiving technical direction and functional supervision from the most senior HSE representative on the project
- ✓ Maintaining working relationships with personnel in Construction, Engineering, Procurement, Quality Assurance/Quality Control, and Contracts group to ensure compliance of the Project HSE Execution Plan
- ✓ Maintain contact with external counter part's community and/or client furnished emergency response services to ensure their familiarization with the layout of the Project Emergency Response Requirements

- ✓ Safety walks with Project Leader/Manager, Establishing and maintain HSE culture, Looking Fire protection system & Carry out Mock drill practices at site
- ✓ Member of monthly Safety audit (internal) conducted by safety team for all dept. based on or in guidance of condition of contract SHE (version 1.2),Delhi Metro Rail Corporation
- ✓ HeadedHSE meetings while communicate HSE programmes or issues to the project management team.
- ✓ Monitoring project compliance with project Construction Environmental Control Plan (CECP).

TRAINING & EDUCATION:

Trainer for NEBOSH (IGC), Internal & External Auditor, Trainer for various HSE Training (e.g. Construction Safety Trainings, Safety while Working at height, Hazard Evaluation process/technique, Excavation & Confined space, Crane Safety, EMS, SMS, Electrical Safety, Legal Laws, HIRA, JSA & Fire Protection System, Welding cutting Safety, Hazard Evaluation & Assessments Methods, Process Safety, BBS etc.

INTERESTS & EXPERTISE:

Safety Management System, Risk Assessment, Hazard Evaluation Techniques (e.g. Hazop, Hazan, FTA, ETA, JSA, FMEA & FMECA, Consequence Analysis, What If Analysis), Safety in Construction, Safety Audit, Safety in Petroleum and Petrochemical Industry, Fire Protection Systems, Accident Investigation Analysis, NBC (Part IV) and other legal legislations.

PROJECTS:

- ✓ A brief Study on HAZOP, Risk Assessment, and Fire Protection System on blast furnaces department in Tata Steel, Jamshedpur (5 Weeks)
- ✓ Safety Management in Chlor-Alkali Industry in Travancore Cochin Chemical Ltd, Udyodmandal, Cochin (2 Weeks)

SEMINARS & WORKSHOP

- ✓ One day national seminar on "Traffic safety" organized by Institution of Engineers (I), Delhi.
- ✓ Attended work shop on, Environment awareness, fire safety in industries during many occasions organized by Institution of Engineers (I) , Delhi.
- ✓ National Fire Safety Seminar
- ✓ Atmosfair 1, Atmosfair 2 and Atmosfair 3.
- ✓ Global HSE Conference 2016, New Delhi, India

ACHIEVEMENT & AWARDS:

- ✓ Received 2nd best project award for year 2006-2007 for condition of contract on SHE from **Delhi Metro Rail Corporation for BC-06 Project**
- ✓ Excellent contribution for successfully accreditations of **ISO: 14001** and **OHSAS: 18001** by **BSI** (NEC Ltd, Year 2006-2009)
- ✓ Excellent contribution for successfully accreditations of **ISO: 14001** and **OHSAS: 18001** by **Vexil Business Process Services Private Ltd** (Soma Enterprise Ltd, Year 2008-2011)

- ✓ **“Best Safety staff”** of the year 2008- 2009

TRAINING & CERTIFICATES:

- ✓ Lead Auditor Training OHSAS 18001:2007
- ✓ Internal Auditor Training by **EQMS**
- ✓ Confined Space Training by Authorized/ Competent Person
- ✓ General Construction Safety Awareness training by **BVQI**
- ✓ Certificate in **Disaster Management** from IGNOU
- ✓ Certificate in **First Aid** from St. John Ambulance
- ✓ Attended FDP organized by NITTTR, Bhopal. (2016).
- ✓ Attended FDP organized by IIT Mumbai. (2015).

MEMBERSHIP & OTHER ACTIVITIES

- ✓ Active member of **ASFE** (Association of Safety and Fire Engineers), CUSAT
- ✓ Member of **National Safety Council** (NSC) Mumbai
- ✓ Member of **Society of Fire Protection Engineers** (Bethesda, MD, USA)
- ✓ Worked as active member of many activities like seminar, quiz, awareness programmes on the occasion of **National Safety Day Celebration** under **Division of Safety and Fire Engineering, CUSAT** during college tenure

RESEARCH & PUBLICATION:

- Bikarama Prasad Yadav, Dr.N.A.Siddiqui, Dr Ashutosh Gautam “State of art review of hazards & risk associated with viaduct work and suggestion to improve safety” Int J Adv Engg Tech/Vol. VI/Issue IV/Oct.-Dec.,2015/22-2
- Prasenjit Mondal, Abhishek Nandan, Dr.Nihal Anwar Siddiqui, B.P Yadav,“ Impact of Soak pit on Ground Water Table”, Environmental Pollution Control Journal: Vol 18: No 1: Nov-Dec 2014. ISSN 0972-1541.
- Prasenjit Mondal, Abhishek Nandan, Dr.N.A.Siddiqui and B.P.Yadav, “Removal of fluoride from water by suitable low cost environmental friendly methods”, Environmental Pollution Control Journal”: Vol 17, No 6: Sep-Oct 2014. ISSN 0972-1541
- Construction Safety Climate in Developing Country

COMPUTER SKILLS & PROFICIENCY:

- ✓ Knowledge of Ms-Office, Excel, Internet

HOBBIES & INTEREST:

- ✓ To Know about humans values & their behaviour
- ✓ Astro, Palmistry, Writing Books & Articles

PERSONAL PROFILE:

Name	: Bikarama Prasad Yadav
Father's Name	: Mr. Sudish Prasad Yadav
Mother's Name	: Mrs. Sukeshwar Devi
Date of Birth	: 01/03/1978
Nationality	: Indian
Marital Status	: Married
Passport No	: F5652200
Language Known	: Hindi (RWS), English (RWS)
Current Address	: H. No 20, Vyom Prast Phase-1, GMS Road, Dehradun- 248001
Permanent Address	: Village-Ghoghraha, Po- Maharani, Dist- Gopalganj, Bihar, Pin- 841409

I hereby declare the details furnished above are true of my knowledge & belief and I will responsible for any discrepancy.

Place: Dehradun, Yours Truly,

Date:……………… (Bikarama Prasad Yadav)