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HAZARD IDENTIFICATION AND RISK ANALYSIS IN MINING INDUSTRY

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mining Engineering

By

AMOL PAITHANKAR

107MN026

nit rourkela

Engineering the future

DEPARTMENT OF MINING ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA-769008

2010-2011

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National Institute of Technology, Rourkela

C E R T I F I C A T E

This is to certify that the thesis entitled "**Hazard Identification and Risk Analysis in Mining Industry**" submitted by Sri Amol Paithankar (Roll No. 107MN026) in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not formed the basis for the award of any Degree or Diploma or similar title of any University or Institution.

Date:

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ABSTRACT

For any industry to be successful it is to identify the Hazards to assess the associated risks and to bring the risks to tolerable level. Mining activity because of the very nature of the operation, complexity of the systems, procedures and methods always involves some amount of hazards. Hazard identification and risk analysis is carried for identification of undesirable events that can leads to a hazard, the analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects. It is widely accepted within industry in general that the various techniques of risk assessment contribute greatly toward improvements in the safety of complex operations and equipment.

Hazard identification and risk analysis involves identification of undesirable events that leads to a hazard, the analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects. The objective of hazards and risk analysis is to identify and analyze hazards, the event sequences leading to hazards and the risk of hazardous events. Many techniques ranging from simple qualitative methods to advanced quantitative methods are available to help identify and analyze hazards. The use of multiple hazard analysis techniques is recommended because each has its own purpose, strengths, and weaknesses.

As the part of the project work, hazard identification and risk analysis was carried out for an iron ore mine and a coal mine and the hazards were identified and risk analysis was carried out. The different activities were divided in to high, medium and low depending upon their consequences and likelihood. The high risks activities have been marked in red colour are un-acceptance and must be reduced. The risks which are marked in yellow colour are tolerable but efforts must be made to reduce risk without expenditure that is grossly disproportionate to the benefit gained. The risks which are marked in green have the risk level so low that it is not required for taking actions to reduce its magnitude any further.

For the iron ore mine the high risk activities which were recorded were related to face stability and the person blasting the shots. In the coal mine there was problem of fly rocks,

roads were not proper for haulage purpose, inappropriate use of personal protective equipment and inrushes of water into the mine causing inundation.

Hazard identification and risk assessment can be used to establish priorities so that the most dangerous situations are addressed first and those least likely to occur and least likely to cause major problems can be considered later. From the study carried out in the iron ore and coal mine and the risk rating which were made and analyzed shows that the number of high risks in the coal mine was more than that of iron ore mine and same goes for the events in medium risk.

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION

For any industry to be successful it should meet not only the production requirements, but also maintain the highest safety standards for all concerned. The industry has to identify the hazards, assess the associated risks and bring the risks to tolerable level on a continuous basis. Mining being a hazardous operation has considerable safety risk to miners. Unsafe conditions and practices in mines lead to a number of accidents and causes loss and injury to human lives, damages the property, interrupt production etc. Risk assessment is a systematic method of identifying and analysing the hazards associated with an activity and establishing a level of risk for each hazard. The hazards cannot be completely eliminated, and thus there is a need to define and estimate an accident risk level possible to be presented either in quantitative or qualitative way.

Because of the existing hazards of mining as an activity and the complexity of mining machinery and equipment and the associated systems, procedures and methods, it is not possible to be naturally safe. Regardless of how well the machinery or methods are designed, there will always be potential for serious accidents. It is not possible for an external agency to ensure the safety of an organisation such as a mining company nor of the machinery or methods it uses. The principal responsibility for the safety of any particular mine and the manner in which it is operated rest with the management of that mine. It is widely accepted within industries in general that the various techniques of risk assessment contribute greatly toward improvements in the safety of complex operations and equipment. In many industries there is legislative requirement for risk assessment to be undertaken of all hazardous equipment, machinery and operations taking account of the procedures used for operation, maintenance, supervision and management.

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

The objective of hazard and risk analysis is to identify and analyse hazards, the event sequences leading to hazards and the risk of hazardous events. Many techniques ranging from simple qualitative methods to advanced quantitative methods are available to help identify and analyse hazards. The use of multiple hazard analysis techniques are recommended because each has its own purpose, strengths, and weaknesses. Some of the more commonly used techniques for risk assessment include: failure modes and effects analysis (FMEA), hazard and operability studies (HAZOP), fault-tree analysis (FTA), event-tree analysis (ETA) etc.

1.1 NEED FOR RISK ASSESSMENT

Risk assessments will help the mine operators to identify high, medium and low risk levels. Risk assessments will help to prioritise risks and provide information on the probability of harm arising and severity of harm by understanding the hazard, combine assessments of probability and severity to produce an assessment of risk and it is used in the assessment of risk as an aid to decision making. In this way, mine owners and operators will be able to implement safety improvements. Different types of approaches for the safety in mines various tools and appropriate steps have to be taken to make mining workplace better and safer.

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

1.2 OBJECTIVES

Keeping the aforementioned problems in mind, the project work has been planned with the following objectives

- Review of literature on Hazard Identification and Risk Assessment
- Review of accidents in mines and their analysis.
- Study of risk assessment methodologies.
- Application of Hazard Identification and Risk analysis for improvement of workplace safety in mines.

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

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

Qureshi (1987) had done a Hazard and Operability Study (HAZOP) in which potential hazards and identified by looking at the design in a dynamic manner

- To identify the nature and scale of the dangerous substances;
- To give an account of the arrangements for safe operation of the installation, for control of serious deviations that could lead to a major accident and for emergency procedures at the site;
- To identify the type, relative likelihood and consequences of major accidents that might occur; and
- To demonstrate that the manufacturer (operator) has identified the major hazard potential of his activities and has provided appropriate controls.

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

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

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

- To identify accident initiating events and accidental sequence.
- To classify these sequences in to frequency categories

- To determine the related consequences with respect to workers, population and the environments.

Duijm (2001) identified hazards for six different techniques for disposing decommissioned ammunition. Use has been made of functional modelling as a basis for hazard identification. Risk levels are estimated based on general accident rates in the chemical industry. The disposal techniques are “open burning” (OB), “open detonation” (OD), “closed detonation” (CD), “fluidised bed combustion” (FBC), “rotary kiln (RK) incineration”, “mobile incineration” and Comparative risk levels for alternative disposal techniques for ammunition have been derived using hazard identification based on functional modelling of the techniques in combination with the required manpower to perform the operations.

Khan et al. (2001) developed safety weighted hazard index (SWeHI). In quantitative terms SWeHI represents the radius area under moderate hazard (50% probability of fatality/ damage).

In mathematical term it is represented as

$$SWeHI = B/ A$$

Where B = Quantitative measures of damage that can be caused by unit/ plant.

A= credits due to control measures and safety arrangements.

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

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

RISK = HAZARD * CONSEQUENCE * ELEMENT OF RISK

Jelemensky et al. (2003) applied quantitative risk analysis followed by qualitative hazard identification to determine potential event sequences and potential incidents. From quantitative risk analysis risk estimation is done and individual fatality rate was calculated as:

$$IR(x,y) = \sum_{io=1}^{IO} P_{io}(x,y) \sum_{d=1}^{D} P_{io,d} \sum_{i=1}^{I} P_{d,i} f_i$$

Where

IR(x, y) = individual fatality risk at a specific location (x, y)

P_{io}(x, y) = conditional probability of fatality at specific location (x, y) at given outcome incident case io.

IO = total no. of incident event

$P_{io, d}$ = conditional probability that the plant damage state case d will lead to the incident outcome case io.

D = total no. of plant damage states

$P_{d, I}$= conditional probability that the initiating event case I will lead to the plant damage case d.

I = total no of initiating event.

Kecojevic and Radomsky (2004) studied about loader and truck safety and found out the severity and number of accidents involving loader and trucks are higher when compared to other operations. They established fatal categories and causes of accidents and control strategies are discussed and evaluated to increase hazard awareness.

Dziubinski et al. (2006) studied basic reasons for pipeline failure and its probable consequences taking individual and societal risk into consideration and proposed methodology of risk assessment for hazards associated with hazardous substance transport in long pipelines. Taking that methodology as example, subsequent stages of risk analysis were considered paying special attention to the applied techniques and calculation models. A specific feature of this methodology was a combination of qualitative and quantitative techniques which offer a possibility of a full risk assessment for long pipelines.

Laul et al. (2006) identified hazards (chemical, electrical, physical, and industrial) and potential initiators that could lead to an accident. Hazard analysis is used to evaluate identified hazards. Hazard analysis is done by “what if check list”, Hazard and Operability (HAZOP) analysis, Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA) and provided methods together with the advantages and disadvantages, for developing a safety document for chemical, non-nuclear facilities.

Jeong et al. (2007) made a qualitative analysis by Hazard and Operability Method (HAZOP) to identify the potential hazards and operability problems of decommissioning operations and concluded that the decommissioning of a nuclear research reactor must be accomplished according to its structural conditions and radiological characteristics and radiation exposure must be controlled to within the limitation of the regulation to perform the dismantling work under the ALARA principle safely.

Frank et al. (2008) carried out a risk assessment using common risk management tools. In basic tools, they used diagram analysis and risk rating and filtering. In advanced tools they used fault tree analysis (FTA), Hazard and Operability Analysis (HAZOP), Hazard Analysis and Critical Control Points (HACCP), Failure Mode Effect Analysis (FMEA) and established a severity categorization table which divides severity of consequence into noticeable, important, serious, very serious and catastrophic.

Nor et al. (2008) studied risk related to loaders and dozers and were assessed and ranked. The hazards "failure to follow adequate maintenance procedure" and "failure of mechanical / electrical/ hydraulic components" were the most severe and frequent hazards for the loaders and they fell into the category of high risk.

Hassan et al. (2009) carried out a Quantitative Risk Assessment (QRA) into basic steps including system definition, Hazard Identification, Frequency Analysis, Consequence Modelling, Risk calculations and Assessment to determine the safest route for the transportation of hazardous material.

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

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

Orsulak et al. (2010) presented an application of a risk assessment approach in characterising the risks associated with safety violations in underground bituminous mines in Pennsylvania using the Mine Safety and Health Administration (MSHA) citation database. In this study quantitative risk assessment is performed, which allowed determination of the frequency of occurrence of safety violations (through associated citations) as well as the consequences of them in terms of penalty assessments.

CHAPTER 3

ACCIDENTS IN MINES AND THEIR ANALYSIS

3. ACCIDENTS IN MINES AND THEIR ANALYSIS

Mining is a hazardous operation and consists of considerable environmental, health and safety risk to miners. Unsafe conditions in mines lead to a number of accidents and cause loss and injury to human lives, damage to property, interruption in production etc. The following section presents the different hazards in surface and underground mines, their precautions and statistics of accidents in coal and non-coal mines.

3.1 HAZARDS IN DIFFERENT OPERATIONS AND PRECAUTIONS IN SURFACE MINES

The major hazards due to different mining operations and their prevention and control are as outlined below:

I. Surveying

- ❖ Fall from heights.
- ❖ Thrown from overturning vehicle.

  Since hazards are by ground formation it is unlikely to be removed.

  - By the use of good properly constructed scaffolds.

II. Clearance

- ❖ Struck by falling tree and debris from demolition building.
  - Can be avoided by using trained operator.
- ❖ Use of power saw or by other equipment used for removal of top soil.
  - Avoided by wearing full personal protection by operator.

III. Laying out

- ❖ Hazards prevalent during construction of building.
  - Single storey building is less hazardous than a larger higher store building.
- ❖ Hazard during construction of roadways.
  - Roadways on level ground will involve fewer hazards than on inclined terrain.
- ❖ Overhead electricity lines.
- ❖ Falling while working at height.
  - Avoid driving at the edge of roadway under construction.
- ❖ Plant moving out of control.
  - Well maintained plant and equipment reduces risk of injury.

- ❖ Individual struck by moving vehicle.
    - Heavy earth moving equipment and vehicle drivers and those giving signals should be well trained.

IV. Drilling

- ❖ Falling from the edge of a bench.
    - Part of training should include instructions to face towards the open edge of the bench so any inadvertent backward step is away from the edge.
    - Provide suitable portable rail fencing which can be erected between the drilling operations and the edge of the mine.
    - Attachment of a safety line to the drilling rig and provide harness for the driller to wear.
- ❖ Inhalation of dust created during drilling operation.
    - Use water during the drilling operations.
    - Providing a ventilation system on drilling rig with dust filter to remove harmful dust.
- ❖ Noise
    - Risk is higher in older machines.
    - Newer drill machines are provided with cabin which controls noise level within cabins.
    - Providing operators with ear protection.
- ❖ Entrapment of being struck by a moving and revolving part of the drill equipment.
    - Accidents will be lowered by properly guarding dangerous parts of the equipment.
    - Operators must be well trained and supervised.

V. Explosives

- ❖ Poorly designed shots can result in misfires early ignition and flying rock.
    - Safety can be ensured by planning for round of shots to ensure face properly surveyed, holes correctly drilled, direction logged, the weight of explosion for good fragmentation.
    - Blast design, charge and fire around of explosives should be carried out by a trained person.

VI. Face stability

- Rock fall or slide
  - Regular examination of face must be done and remedial measures must be taken to make it safe if there is any doubt that a collapse could take place.
  - Working should be advanced in a direction taken into account the geology such that face and quarry side remain stable.

VII. Loading

- Rock falling on the driver.
- Plant toppling aver due to uneven ground.
- Failure of hydraulic system.
- Fires
- Fall while gaining access to operating cabin.
- Electrocution in Draglines.
- Failure of wire ropes in Draglines.
  - Operator cabin should be of suitable strength to protect he driver in event of rock fall.
  - Electrical supply to dragline should be properly installed with adequate earth continuity and earth leakage protection.
  - Wire rope should be suitable for work undertaken and be examined periodically.
  - Ensure that loaders are positioned sufficiently away from face edges.

VIII. Transporting

- Brake failure
- Lack of all-around visibility from driver position
- Vehicle movements particularly while reversing
- Rollover
- Vibrations
- Noise
- Dust and maintenance
  - Visibility defects can be eliminated by the use of visibility aids such as closed circuit television and suitable mirrors.
  - Edge protection is necessary to prevent inadvertent movement.

- Seatbelt to protect driver in event of vehicle rollover.
- Good maintenance and regular testing necessary to reduce possibility of brake failure.

IX. Processing of mineral

1) **Crushing**
    - ❖ Blockages
    - ❖ High noise
    - ❖ Dust
    - ❖ Vibrations
        - ▪ Use of hydraulic hammers to break up blockages.
        - ▪ Provide noise isolators and provide mechanical ventilation systems designed to remove any harmful dust.
2) **Grinding**
    - ❖ Noise
    - ❖ Dust
    - ❖ Entrapment
    - ❖ Confined spaces
    - ❖ Chemical additives
        - ▪ Noise and dust hazards can be reduced by providing noise isolation devices and air filtration system.
        - ▪ Chemical additives can be reduced by the adaptation of normal preventative measures such as substitution automated pipe feeds personal protection.
3) **Screening**
    - ❖ Dust
    - ❖ Noise
    - ❖ Vibration
    - ❖ Fall from height during maintenance
        - ▪ Protective equipment to safeguard against inhalator of residual dust.

3.2 HAZARDS IN UNDERGROUND WORKING

- ❖ Fall of roof and sides
  - Roof and side of working should be kept secure.
  - Support should be set as per systematic support rules.
  - Fencing should be provided in unauthorised area.
  - Workers should not be permitted to work under unsupported roof.
  - Safety prop with drawers should be used.
  - Temporary supports should be provided before clearing roof.
- ❖ Collapse of pillar in coal mines
  - Stook left in depillaring must be kept of adequate size.
- ❖ Air blast
  - Extensive area of un-collapsed roof should not be allowed to exist.
  - Seams with strong and massive roof rocks more no. of entries should be kept open.
  - Shelters should be provided at suitable sites.
  - Installation of warning system to warn people about imminent air blast.
- ❖ Rock burst and bumps

X. Rope haulage

- ❖ Runaway of tubs due to breakage of rope, failure of attachment to rope, failure of couplings and drawbars.
  - Rope should be selected properly and maintained with care.
- ❖ Non functionality of safety devices.
- ❖ Travelling along haulage roadway.
  - Unauthorised travelling on haulage roadways should be strictly prohibited.
- ❖ Uncontrolled movement of tubs.
- ❖ Derailment of tubs.
  - Bad patches in the track should be corrected.
- ❖ Poor construction of curves.
  - Haulage curves should be properly designed and constructed.

XI. Electrical hazards

- ❖ Electric shock and/or burn.
- ❖ Ignition of firedamp or coal dust.
- ❖ Fire arising from electric defects.
    - Inspect equipment regularly for signs of overheating, partial discharge and mechanical damage.
    - Inspect earthing point regularly.
    - Use of flameproof and intrinsically safe apparatus.
    - Cables should be provided with double wire armouring.

XII. Fire hazard

- No petrol power equipment must be permitted.
- Hard held extinguishers should be provided in various places in mines.
- All underground equipment containing more than 100 litres of flammable hydraulic fluid must be fitted with an automatic suppression system with suitable manual activation.
- Storage of flammable substances must be minimised.

XIII. Inundations

- No working should be done vertically below any river, lake or other reservoir.
- If there is a river nearby entrance into a mine shall be constructed and maintained such that lowest point of its mouth is not less than 1.5m above the highest flood level at that point.
- Shaft sites should be located away from faults and other geological disturbances.
- All abandoned shaft and boreholes not required for any purpose should be filled up with debris and sealing material.
- In case of presence of highly water bearing strata in the vicinity of the proposed working mining should be so planned as not to disturb the water bearing strata.

XIV. Ventilation

- ❖ Failing of cooling system.
- ❖ Oxygen deficiency (<19%)
- ❖ Gas evolution from coal
- ❖ Presence of CO > 50ppm

- Presence of CO_2 > 1%
- Presence of H_2S > 20ppm
- Presence of NO_X
- Increase in temperature due to rock temperature and heats from machines

XV. Illumination

- Insufficient illumination system
    - Permanent lighting should be provided in places where equipment can be hazardous.
    - Separate and independent emergency light source should be provided at all places where a hazard could be placed by failure if light.

3.3 ACCIDENT STATISTICS IN INDIAN MINES

Accident statistics of Indian mines and trend of fatal accidents for coal mine and non-coal mines are shown in Table 3.1 and Table 3.2 respectively followed by graphical representation of coal mine in figure 3.1and 3.2 and of non-coal mine in figure 3.3 and 3.4. A cause wise accident serious and fatal for coal and non-coal mine for a period of 2001 to 2007 are shown in table 3.3 and table 3.4 respectively. The graphical representation for fatal accident in coal and non-coal mine for 2007 are shown in figure 3.5, 3.6 and figure 3.9, 3.10 respectively. The graphical representation of serious accident in coal and non-coal mines for 2007 are shown in figure 3.7, 3.8 and figure 3.11, 3.12 respectively.

Table 3.1: Trend in Fatal Accidents and Fatality in Coal mines (1951-2007)

Year	Coal Mines			
	Average Accidents	**Accident Rate**	**Average Killed**	**Death Rate**
1951-60	222	0.61	295	0.82
1961-70	202	0.48	260	0.62
1971-80	187	0.40	264	0.55
1981-90	162	0.30	185	0.34
1991-2000	140	0.27	170	0.33
2001-2007	87	0.22	112	0.28

Source: *Annual Report, Ministry of Labour, 2007-08*

Table 3.2: Trend in Fatal Accidents and Fatality in Non-Coal mine (1951-2007)

Year	Non coal Mines			
	Average Accidents	**Accident Rate**	**Average Killed**	**Death Rate**
1951-60	64	0.27	81	0.34
1961-70	72	0.28	85	0.33
1971-80	66	0.27	74	0.30
1981-90	65	0.27	73	0.31
1991-2000	65	0.31	77	0.36
2001-2007	54	0.34	62	0.40

Source: *Annual Report, Ministry of Labour, 2007-08*

Table 3.3: Trend of Accidents in Coal Mines – Cause wise (2001-07)

Causes	Number of Fatal Accidents							Number of Serious Accidents						
	2001	2002	2003	2004	2005	2006	2007	2001	2002	2003	2004	2005	2006	2007
Fall of Roof	30	23	18	26	18	13	11	35	45	39	44	38	27	22
Fall of Sides	9	11	5	8	7	4	2	43	38	27	67	45	26	22
Other Ground Movements	0	1	1	0	0	1	0	1	0	0	1	1	0	0
Winding in Shafts	2	0	1	0	0	3	0	6	4	4	5	2	4	1
Rope Haulage	15	6	10	5	12	8	6	116	85	84	127	168	173	84
Dumpers, Trucks, etc.	19	14	21	22	21	18	11	32	28	35	20	34	37	20
Other Transportation Machinery	1	2	2	3	4	5	2	23	19	15	10	16	46	22
Non-Transportation Machinery	10	9	11	7	15	9	8	34	39	43	28	46	47	41
Explosives	2	4	3	5	2	1	1	7	9	6	8	5	0	2
Electricity	4	4	1	4	4	3	4	5	7	3	4	5	5	0
Gas, Dust, Fire etc.	0	0	2	2	0	4	1	0	2	6	2	0	1	1
Fall of Persons	7	4	5	3	7	3	7	191	151	147	307	284	210	161
Fall of Objects	2	2	1	0	6	6	3	83	99	90	183	264	144	105
Other Causes	4	1	2	2	3	8	12	91	103	64	156	198	94	69
Total	105	81	83	87	96	79	81	667	629	563	962	1106	814	550

Table 3.4: Trend of Accidents in Non-coal Mines – Cause wise (2001- 07)

Causes	Number of Fatal Accidents							Number of Serious Accidents						
	2001	2002	2003	2004	2005	2006	2007	2001	2002	2003	2004	2005	2006	2007
Fall of Roof	2	1	1	2	1	0	2	0	1	1	2	2	0	1
Fall of Sides	8	10	7	12	6	10	6	1	1	1	3	0	1	0
Other Ground Movements	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winding in Shafts	0	0	0	0	0	0	0	1	1	0	0	0	0	2
Rope Haulage	0	0	0	0	0	0	0	5	1	1	0	1	0	1
Dumpers, Trucks, etc.	22	10	13	18	12	18	15	14	14	15	11	10	6	2
Other Transportation Machinery	4	3	2	3	1	2	5	2	3	3	2	3	6	3
Non-Transportation Machinery	7	6	6	6	9	4	2	23	23	25	22	15	9	11
Explosives	6	8	5	3	4	3	1	0	2	1	0	1	0	1
Electricity	1	1	3	2	0	0	1	1	4	1	0	0	1	1
Gas, Dust, Fire etc.	3	0	1	0	0	0	0	0	0	0	0	3	0	0
Fall of Persons	11	10	11	6	13	14	2	44	41	23	41	22	20	10
Fall of Objects	2	2	3	3	2	7	1	53	45	45	38	20	16	8
Other Causes	5	1	0	2	1	1	1	55	69	52	69	31	15	18
Total	71	52	52	57	48	59	36	199	205	168	188	108	75	58

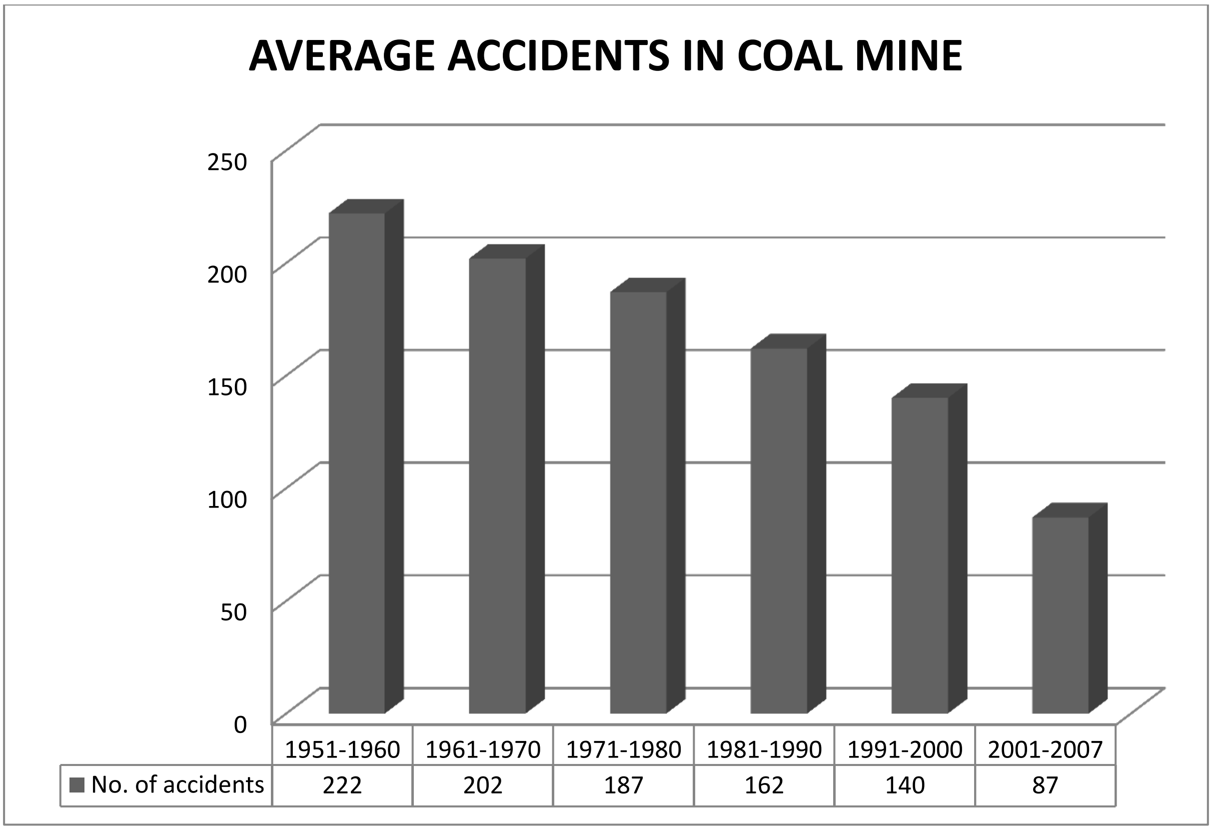

Figure 3.1: Average accidents in coal mines

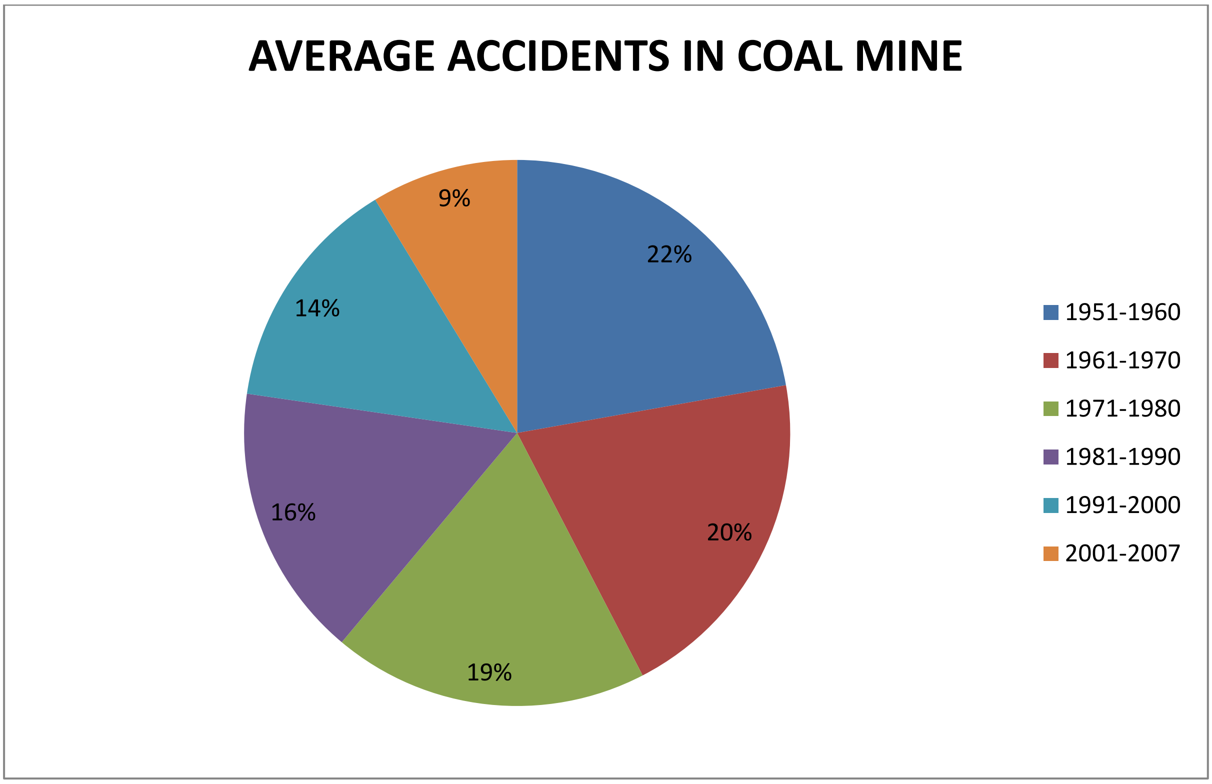

Figure 3.2: Pi Chart representation for average accidents in coal mines

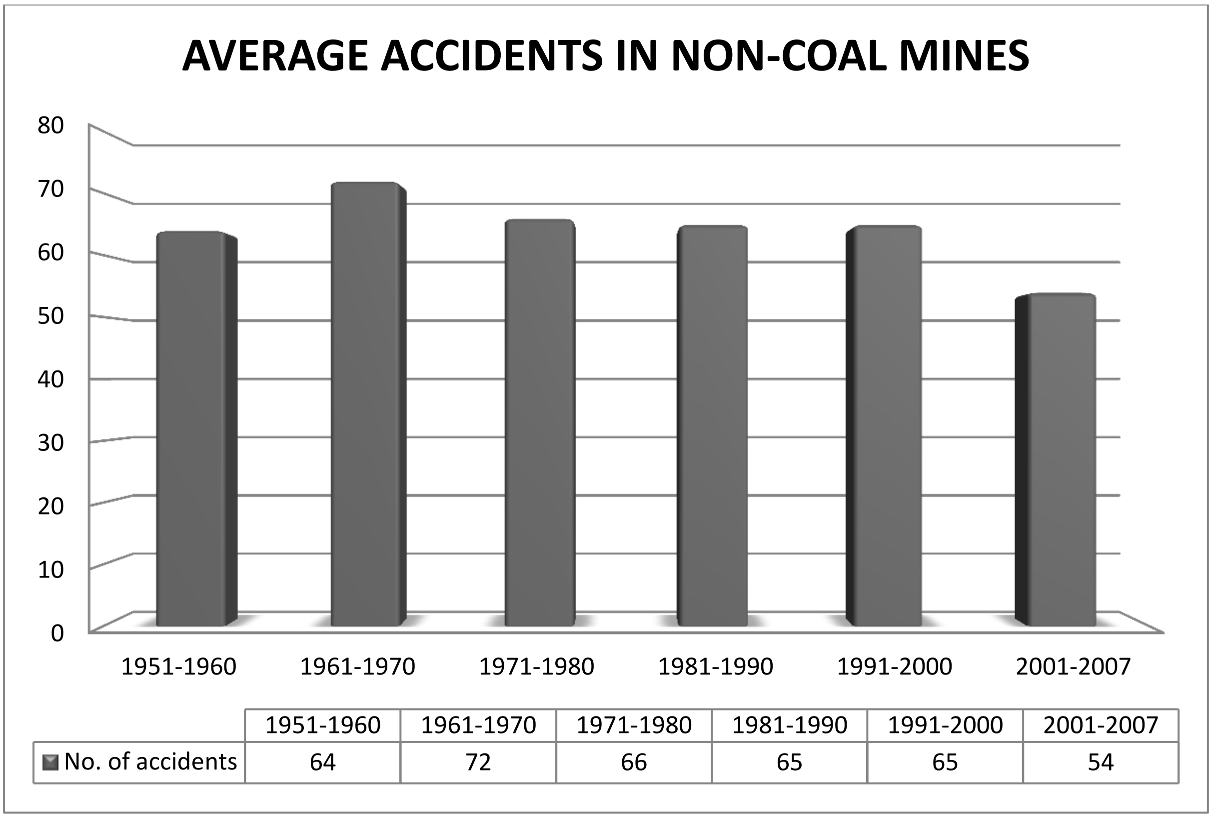

Figure 3.3: Average accidents in non-coal mines

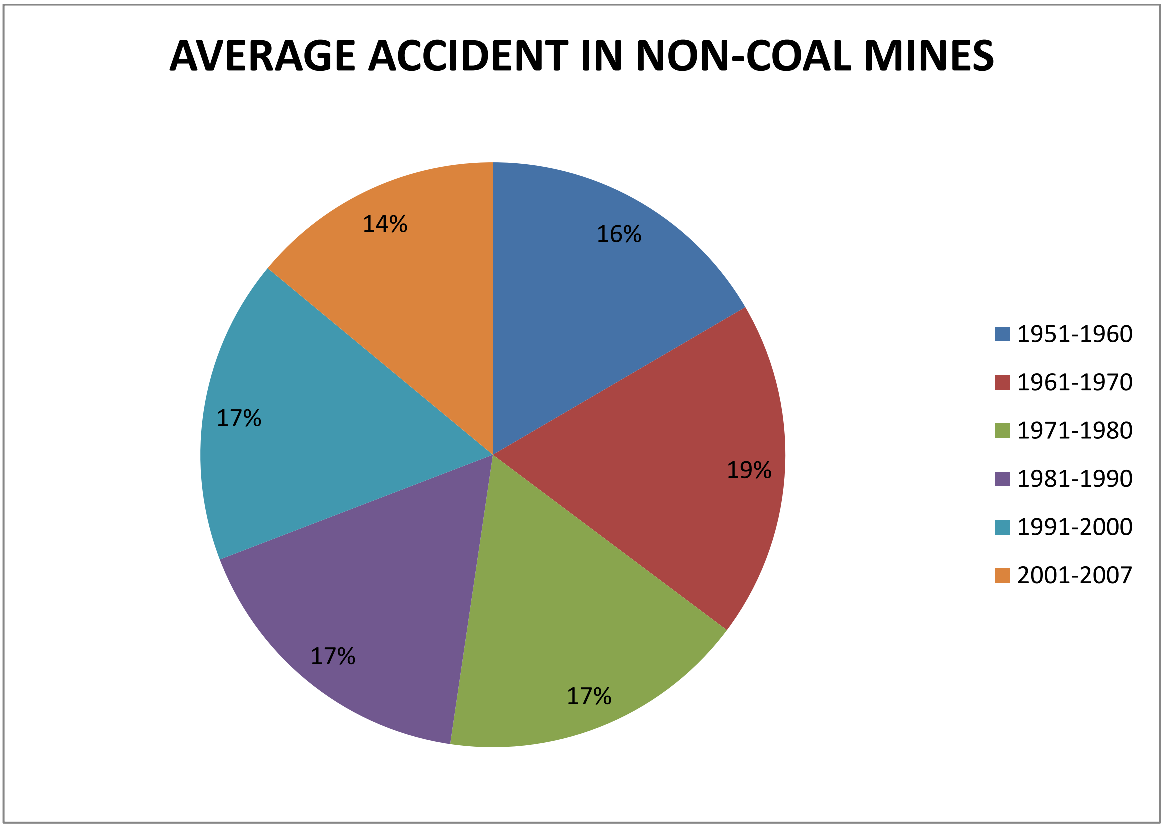

Figure 3.4: Pi Chart representation for average accidents in coal mines

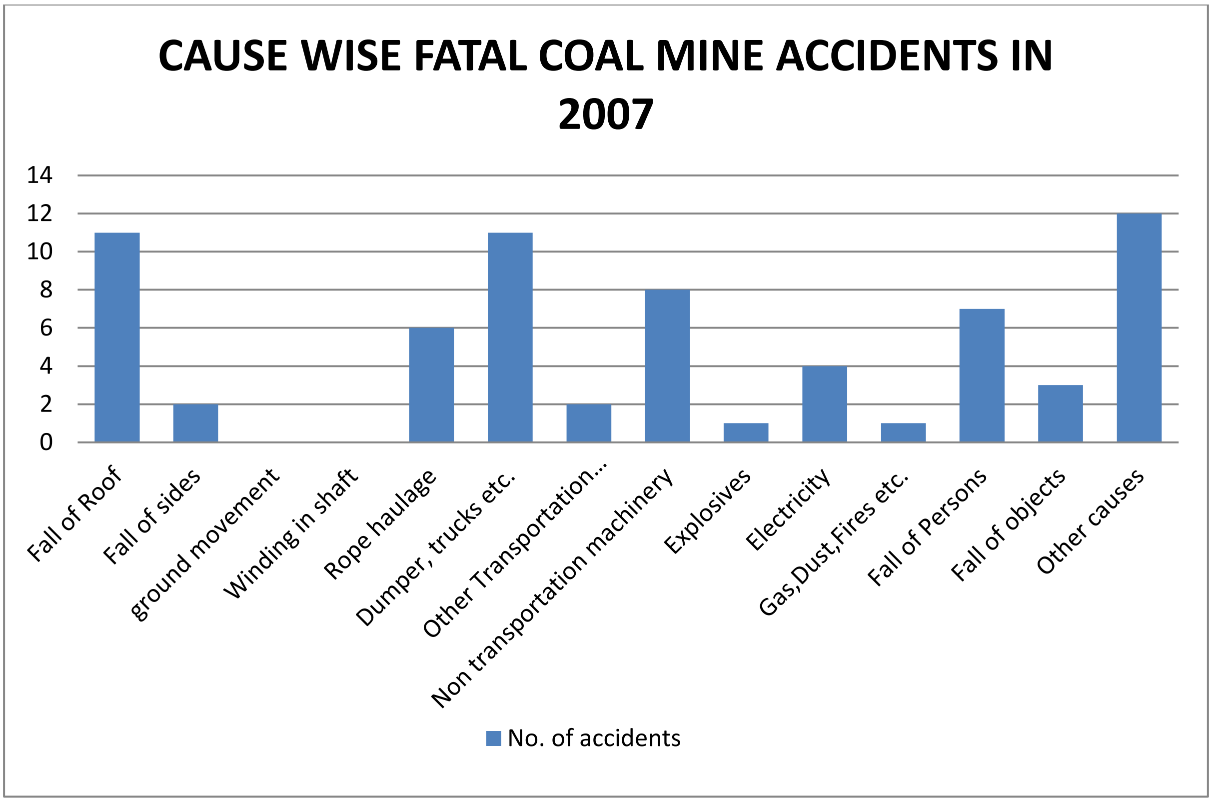

Figure 3.5: Average cause wise fatal accidents in coal mines in 2007

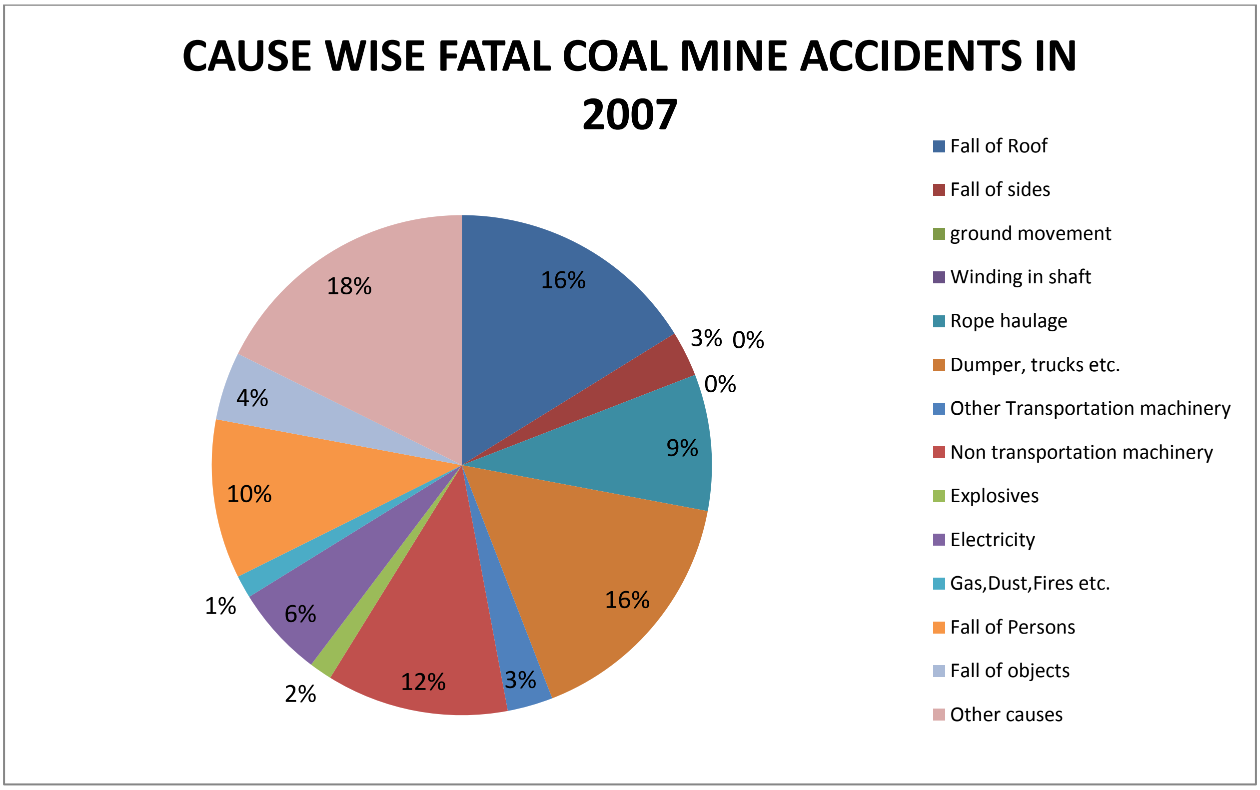

Figure 3.6: Pi chart representation of average cause wise fatal accidents in coal mines in 2007

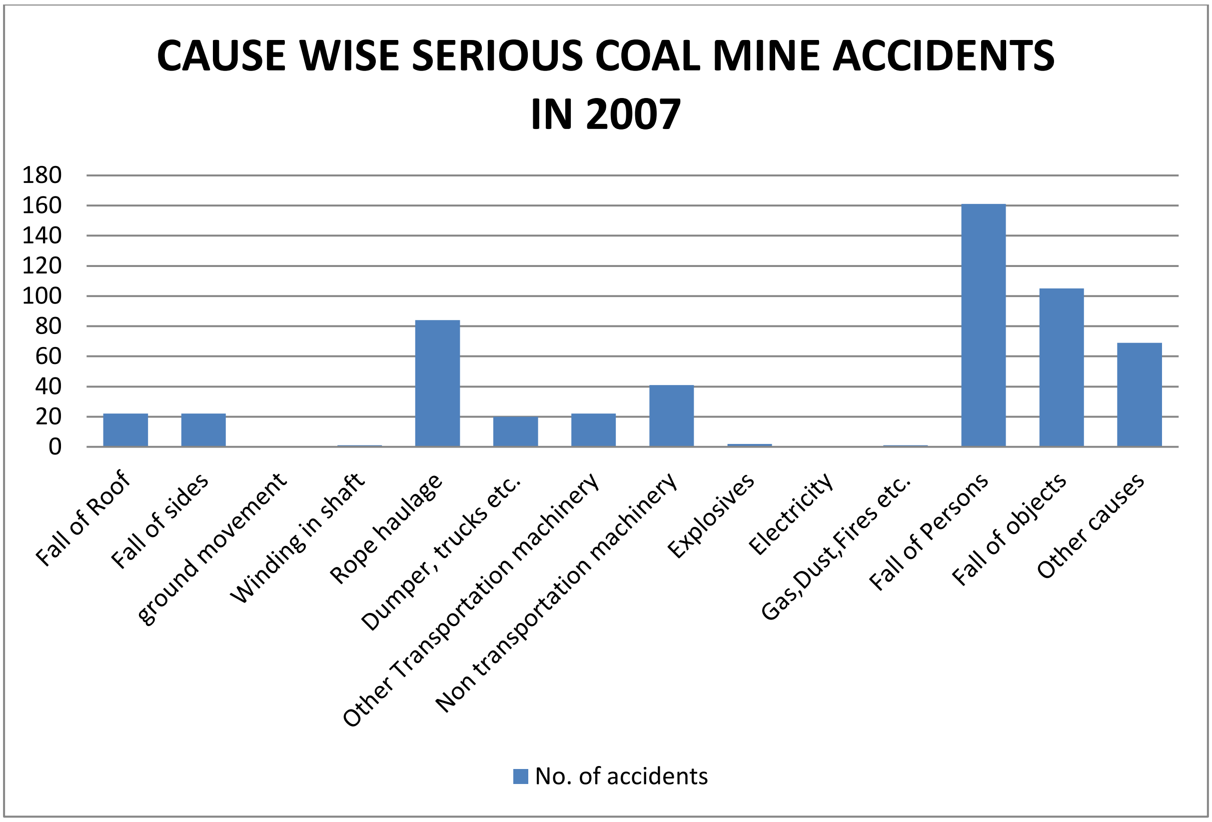

Figure 3.7: Average cause wise serious accidents in coal mines in 2007

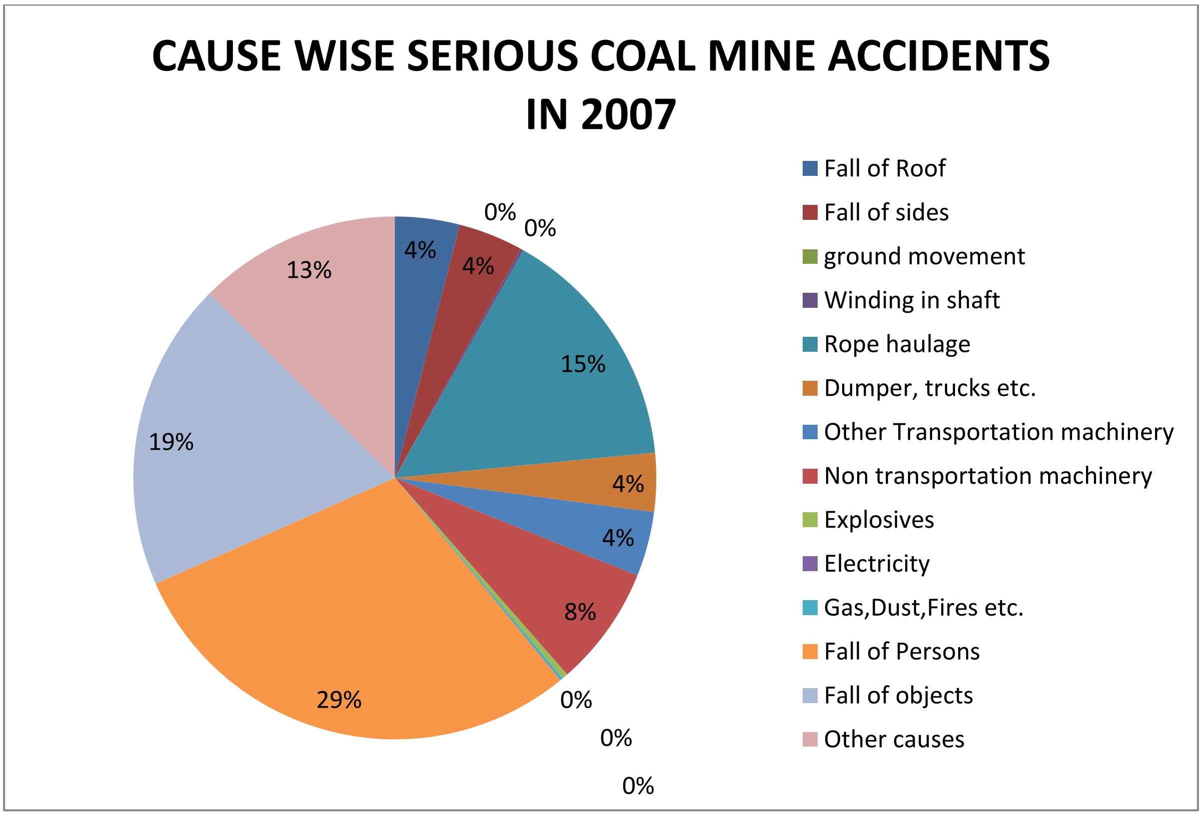

Figure 3.8: Pi chart representation of average cause wise serious accidents in coal mines in 2007

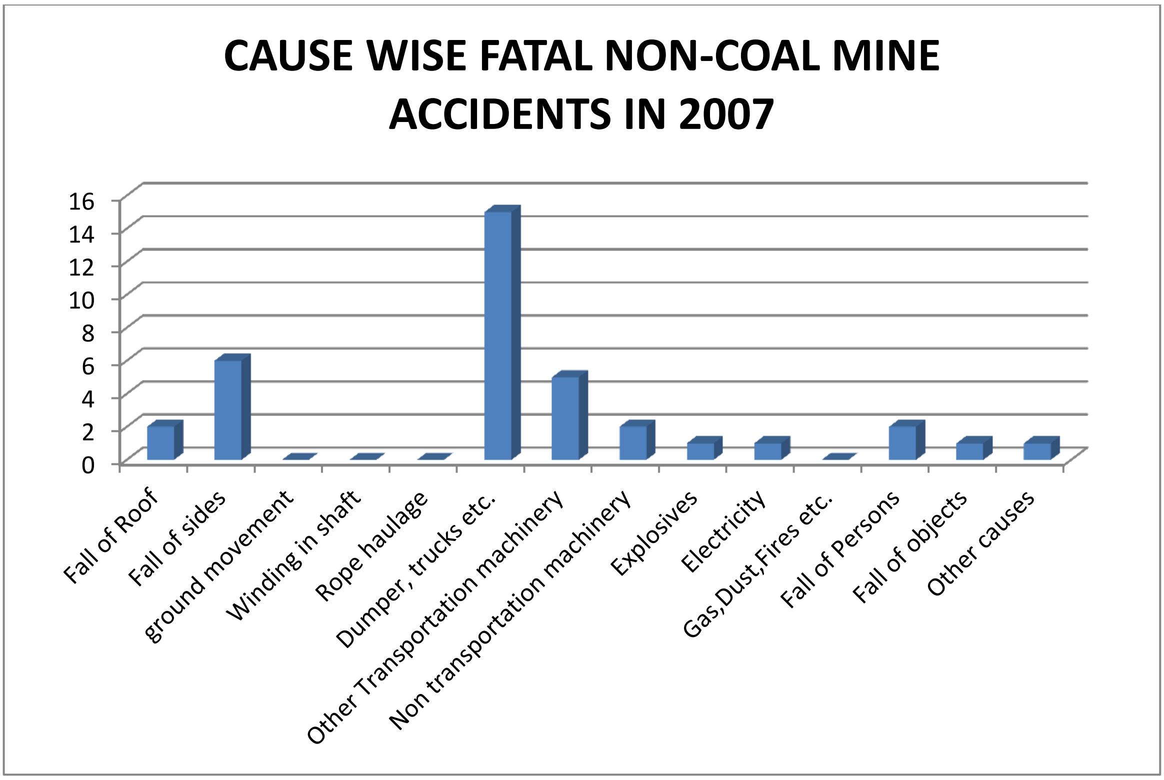

Figure 3.9: Average cause wise fatal accidents in non-coal mines in 2007

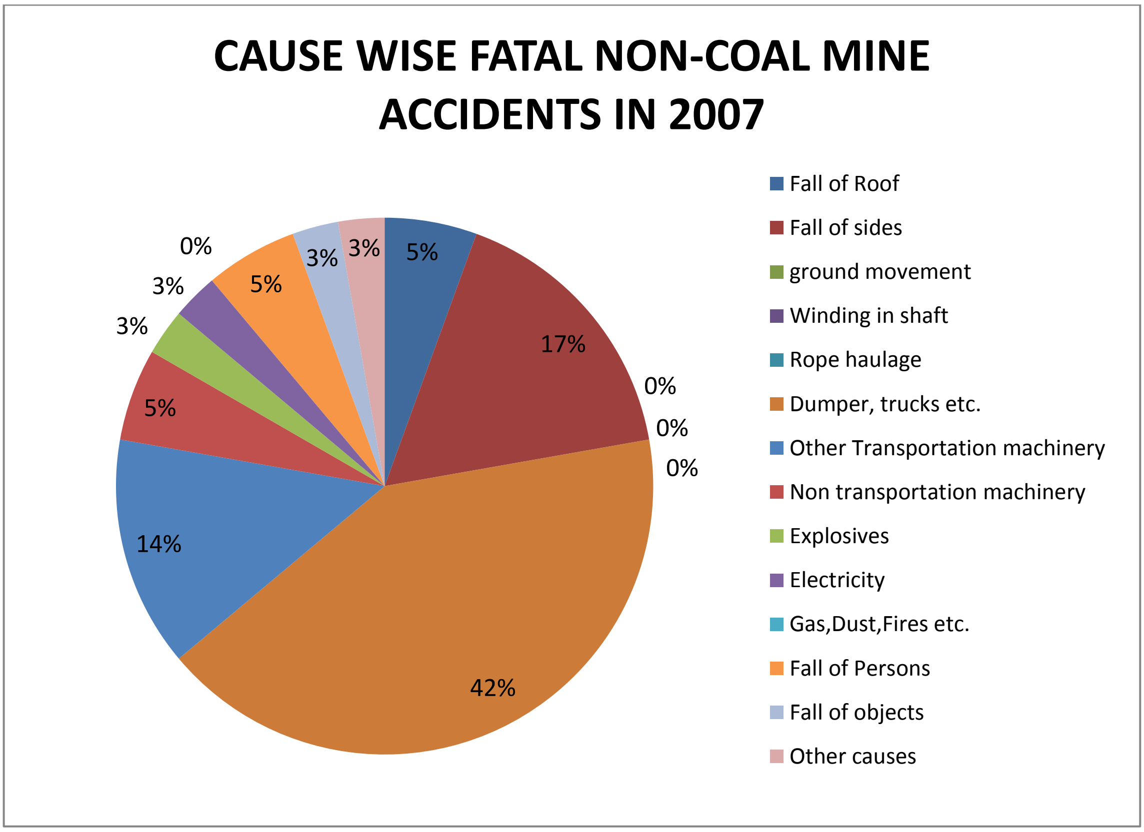

Figure 3.10: Pi chart representation of average cause wise fatal accidents in non-coal mines in 2007

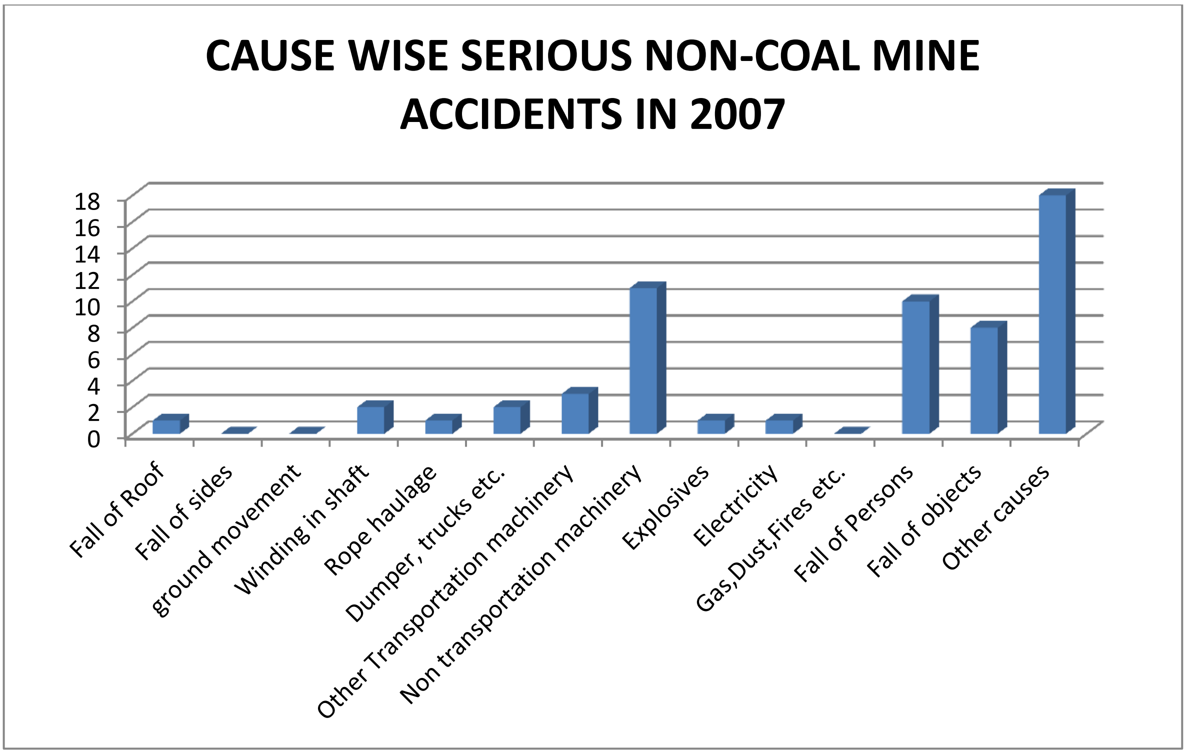

Figure 3.11: Average cause wise serious accidents in non-coal mines in 2007

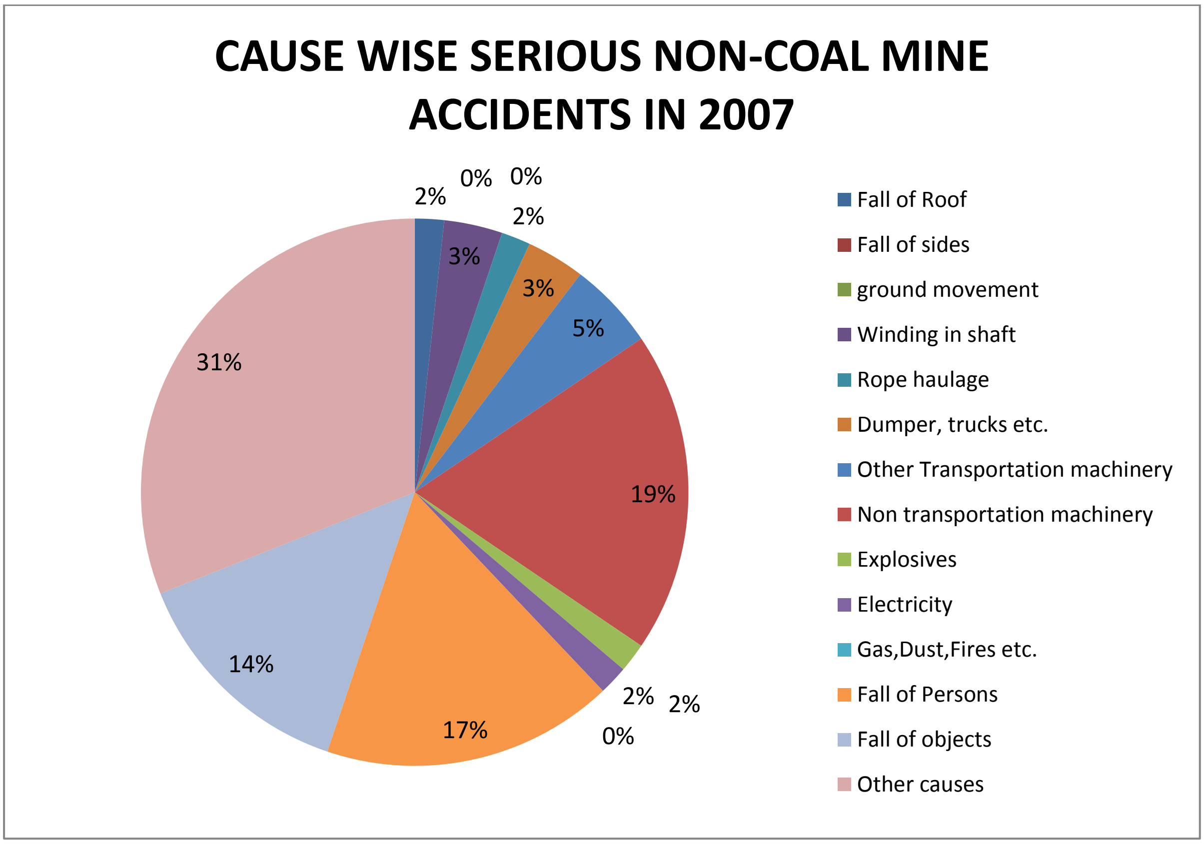

Figure 3.12: Pi chart representation of average cause wise serious accidents in non-coal mines in 2007

It can be seen that the trend of accidents in coal mine is decreasing from 1951-1960 to 2001-2007and the numbers of fatal accidents are almost reduced to less than half from 1951 to 2007 (figure 3.1). The trend of non-coal mine is not as steep as that for coal mine it is increasing in a period of 1961-1970 after that it is gradually decreasing (figure 3.3).

The main factors for fatal accidents of coal mine for the year 2007 (figure 3.6) are roof fall, dumper and truck and others contributing 16%, 16% and 18% respectively. The main factors for fatal accidents of non-coal mine for the year 2007 (figure 3.10) are fall of sides, dumpers and trucks, and non-transportation machinery are 17%, 42% and 14% respectively.

The major contributing factors for serious accidents in coal mines are fall of person, fall of objects and rope haulage contributing 29%, 19% and 16% respectively of the total serious accidents in 2007 (figure 3.8). For non-coal mines the serious accidents are caused by non-transportation machines, fall of person and fall of person contributing 19%, 17% and 14% respectively of the total accidents in 2007 (figure 3.12).

CHAPTER 4

RISK ASSESSMENT

4. RISK ASSESSMENT

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

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

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

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

4.1. DIFFERENT TERMINOLOGIES ASSOCIATED WITH RISK ASSESSMENT

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

Harm: Physical injury or damage to the health of peoples either directly or indirectly as a result of damage to property or to the environment.

Hazard: Hazard is a situation that poses a level of threat to life, health, property or environment. Most hazards are dormant with only a theoretical risk of harm however once a hazard becomes active it can create emergency situation.

Hazardous situation: A circumstance in which a person is exposed to a hazard

Hazardous event: A hazardous situation which results in harm

Accident: An accident is a specific, unidentifiable, unexpected, unusual and unintended eternal action which occurs in a particular time and place with no apparent and deliberate cause but with marked effect.

Risk: Risk concerns the deviation of one or more results of one or more future events from their expected value.

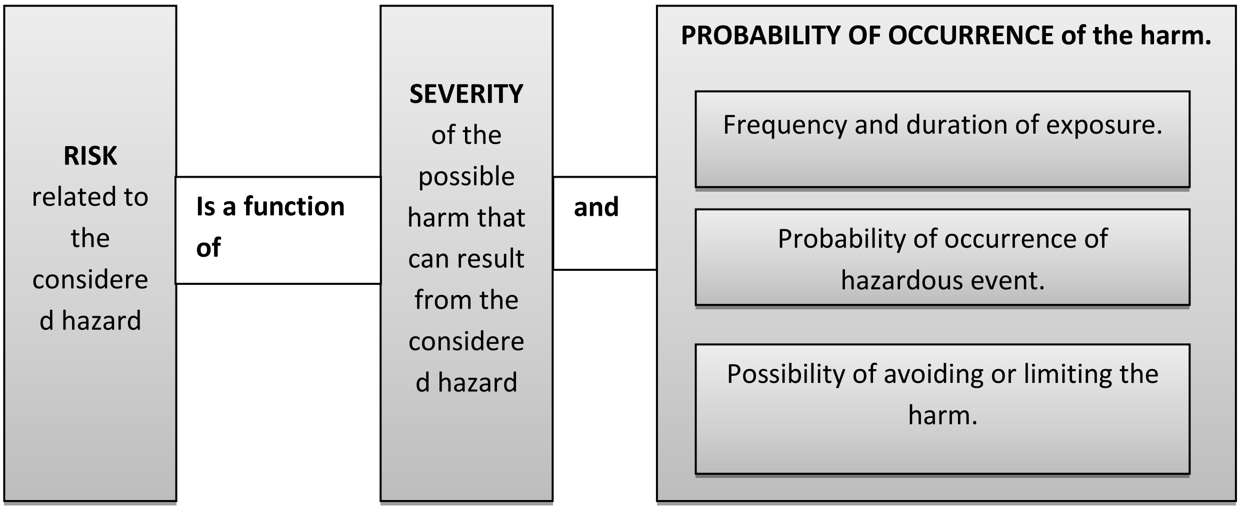

Figure 4.1: The European Community's Definition of Risk.

Tolerable risk: Risk which is accepted in a given context based on the current values of society

Protective measure: The combination of risk reduction strategies taken to achieve at least the tolerable risk. Protective measures include risk reduction by inherent safety, protective devices, and personal protective equipment, information for use and installation and training.

Severity: Severity is used for the degree of something undesirable.

Different Forms of Injury

- Serious Bodily Injury means any injury which involves the permanent loss of any part or section of the body or the permanent loss of sight or hearing or any permanent physical incapability or the facture of any bone or one or more joint or bone of any phalanges of hand or foot.
- Reportable Injury means any injury other than any serious bodily injury, which involves the enforced absence of injured person from work for a period of 72 hours or more.
- Minor Injury means any injury which results in enforced absence from work of the person exceeding 24hrs and less than 72 hours.

Risk Analysis: A systematic use of available information to determine how often specified events may occur and the magnitude of their likely consequences.

Risk Assessment: The process used to determine risk management priorities by evaluating and comparing the level of risk against predetermined standards, target risk levels or other criteria.

Risk Treatment: Selection and implementation of appropriate options for dealing with risk.

4.2 TYPES OF HAZARD IDENTIFICATION AND RISK ANALYSIS

There are three types of hazard identification and risk assessments:

- Baseline Hazard Identification and Risk Analysis;
- Issue-based Hazard Identification and Risk Analysis; and
- Continuous Hazard Identification and Risk Analysis.

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

Baseline Hazard Identification and Risk Analysis

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

Issue-based Hazard Identification and Risk Analysis

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

Continuous Hazard Identification and Risk Analysis

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

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

4.3 THE INTER-RELATIONSHIP BETWEEN TYPES OF HIRA

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

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

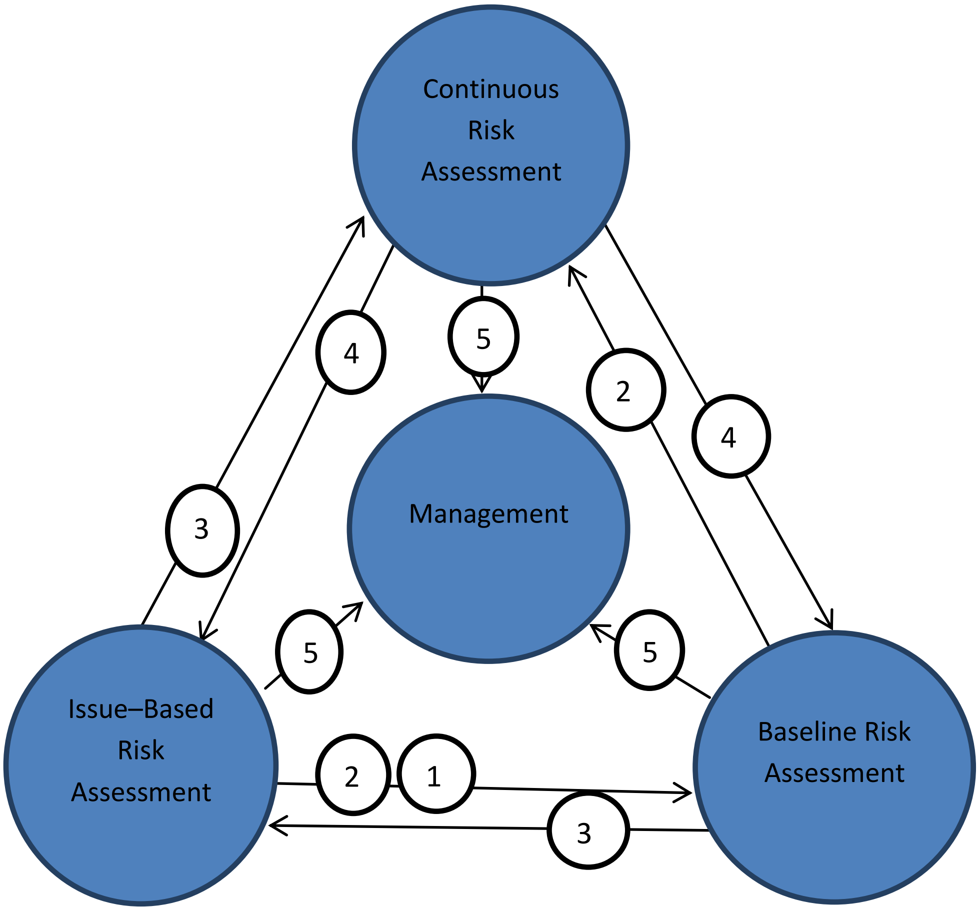

Figure 4.2: The Inter-relationship between Different Types of HIRA.

The different steps of risk assessment procedure are as given below (Figure 4.3):

Figure 4.3: Steps in Risk Assessment

Step 1 Hazard Identification

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

Step 2 Risk Assessment

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

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

Step 3 Risk Control

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

Step 4: Implementation of risk controls

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

The most effective methods of control are:

1. Elimination of hazards
2. Substitute something safer
3. Use engineering/design controls
4. Use administrative controls such as safe work procedures
5. Protect the workers i.e. By ensuring competence through supervision and training, etc.

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

Step 5: Monitor and Review

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

4.4 RISK ANALYSIS

The risk assessment portion of the process involves three levels of site evaluation:

1) Initial Site Evaluation,

2) Detailed Site Evaluation,

3) Priority Site Investigations and Recommendations.

The risk assessment criteria used for all levels of site evaluation take into account two basic factors:

- The existing site conditions
- The level of the travelling public's exposure to those conditions.

The Initial Site Evaluation and Detailed Site Evaluation both apply weighted criteria to the existing information and information obtained from one site visit. The Initial Site Evaluation subdivides the initial inventory listing of sites into 5 risk assessment site groups. The Detailed

Site Evaluation risk assessment is then performed on each of the three highest risk site groups in order of the group priority level of risk. The result of the Detailed Site Evaluation process is a prioritized listing of the sites within each of the three highest risk site groups.

Risk analysis is done for

- Forecasting any unwanted situation
- Estimating damage potential of such situation
- Decision making to control such situation
- Evaluating effectiveness of control measures

4.5 ACCEPTABLE RISK

Risk that is acceptable to regulatory agency and also to the public is called acceptable risk.There are no formally recognized regulatory criteria for risk to personnel in the mining industry. Individual organizations have developed criteria for employee risk and the concepts originally arising from chemical process industries and oil and gas industries.

Because of the uncertainties linked with probabilistic risk analysis used for quantification of the risk levels the general guiding principle is that the risk be reduced to a level considered As Low as Reasonably Practicable (ALARP). The risk acceptability criteria are illustrated in Figure 4.4. It can be seen that there are three tiers:

a. A tolerable region where risk has been shown to be negligible and comparable with everyday risks such as travel to work.
b. A middle level where it is shown the risk has been reduced to As Low As Reasonably Practicable level and that further risk reduction is either impracticable or the cost is grossly disproportionate to the improvement gained. This is referred as the ALARP region.
c. An intolerable region where risk cannot be justified on any grounds. The ALARP region is kept sufficiently extensive to allow for flexibility in decision making and allow for the positive management initiatives which may not be quantifiable in terms of risk reduction.

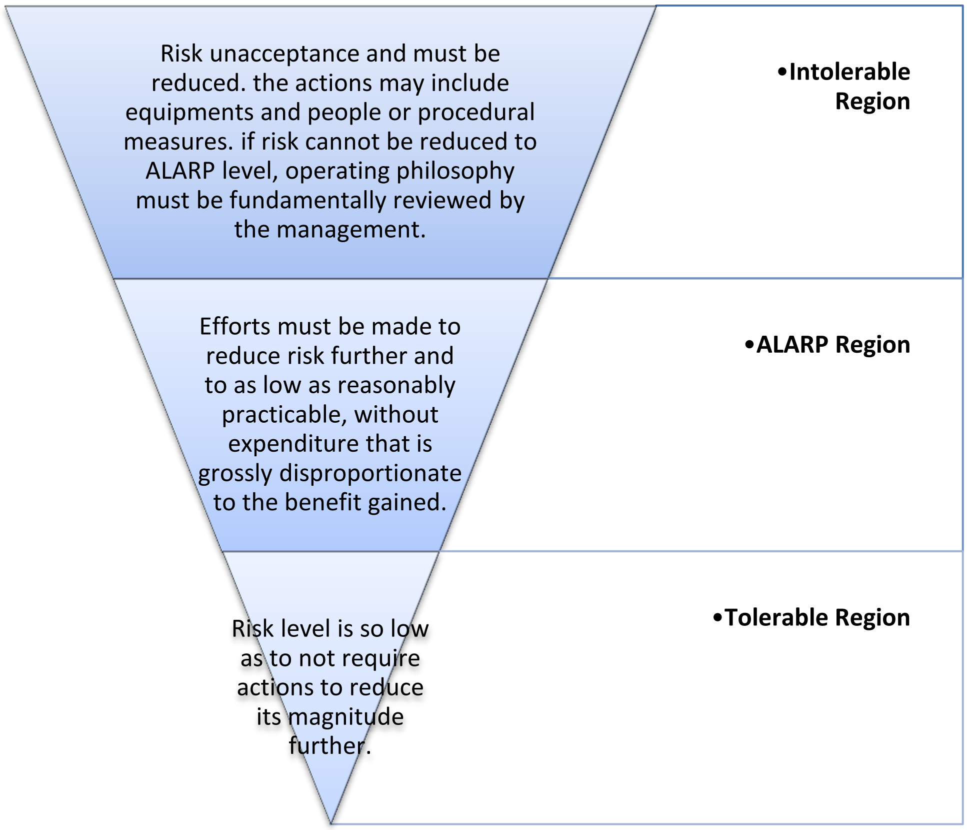

Figure 4.4: The Risk Acceptability Criteria.

4.6 METHODOLOGIES FOR RISK ANALYSIS

The objective of risk analysis is to produce outputs that can be used to evaluate the nature and distribution of risk and to develop appropriate strategies to manage risk. Events or issues with more significant consequences and likelihood are identified as 'higher risk' and are selected for higher priority mitigation actions to lower the likelihood of the event happening and reduce the consequences if the event were to occur.

Qualitative methods use descriptive terms to identify and record consequences and likelihoods of the events and resultant risk. Quantitative methods identify likelihoods as frequencies or probabilities. They identify consequences in terms of relative scale (orders of magnitude) or in terms of specific values (for example estimate of cost, number of fatalities or number of individuals lost from a rare species).

For both qualitative and quantitative methods it is important to invest time in developing appropriate rating scales for likelihood, consequence and resultant risk. The full range of risk situations likely to be encountered within the scope of the exercise should be considered when developing rating scales.

4.6.1 Qualitative methods

Qualitative approaches to risk assessment are the most commonly applied. Qualitative risk assessment methods are quick and relatively easy to use as broad consequences and likelihoods can be identified and they can provide a general understanding of comparative risk between risk events, and the risk matrix can be used to separate risk events into risk classes (ratings).

A logical systematic process is usually followed during a qualitative risk assessment to identify the key risk events and to assess the consequences of the events occurring and the likelihood of their occurrence.

Table 4.1: A qualitative method for the classification of risks

Risk Rank Likelihood x Consequence	L1 Almost certain	L2 Likely	L3 Possible	L4 Unlikely	L5 Rare
1 Catastrophic	1	2	4	7	11
C2 Major	3	5	8	12	16
C3 Moderate	6	9	13	17	20
C4 Minor	10	14	18	21	23
C5 Insignificant	15	19	22	24	25

RISK RATING	
High Risk	1 - 6
Medium Risk	7 - 15
Low Risk	16 - 25

Table 4.2: Risk Likelihood Table for Guidance

Step 1: Assess the Likelihood				Step 2 Assess the Consequences		
L1	Happens every time we operate	Almost Certain	Common or repeating occurrence	**C1**	Fatality	Catastrophic
L2	Happens regularly (often)	Likely	Known to have occurred "has happened"	**C2**	Permanent disability	Major
L3	Has happened (occasionally)	Possible	Could occur or "heard of it happening"	**C3**	Medical/hospital or lost time	Moderate
L4	Happens irregularly (almost never)	Unlikely	Not likely to occur	**C4**	First aid or no lost time	Minor
L5	Improbable (never)	Rare	Practically impossible	**C5**	No injury	Insignificant

Qualitative approaches are best used as a quick first-pass exercise where there are many complex risk issues and low-risk issues need to be screened out for practical purposes.

Qualitative approaches have some shortcomings compared with more quantitative approaches. Key criticisms are that qualitative methods are imprecise it is difficult to compare events on a common basis as there is rarely clear justification of weightings placed on severity of consequences and the use of emotive labels makes it difficult for risk communicators to openly present risk assessment findings.

4.6.2 Semi quantitative methods

Semi-quantitative approaches to risk assessment are currently widely used to overcome some of the shortcomings associated with qualitative approaches. Semi-quantitative risk assessments provide a more detailed prioritised ranking of risks than the outcomes of qualitative risk assessments. Semi-quantitative risk assessment takes the qualitative approach a step further by attributing values or multipliers to the likelihood and consequence groupings. Semi-quantitative risk assessment methods may involve multiplication of frequency levels with a numerical ranking of consequence. Several combinations of scale are possible.

Table 4.3 shows an example of semi-quantitative risk matrix where the likelihoods and consequences have been assigned numbered levels that have been multiplied to generate a numeric description of risk ratings. The values that have been assigned to the likelihoods and consequences are not related to their actual magnitudes but the numeric values that are derived for risk can be grouped to generate the indicated risk ratings. In this example, Extreme risk events have risk ratings greater than 15, High risks are between 10 and 15, and so on.

Table 4.3: Example of a Basic Semi-quantitative Risk Rating Matrix

		Consequence Level				
		1	2	3	4	5
Likelihood level	Descriptor	Insignificant	Minor	Moderate	Major	Catastrophic
5	Almost Certain	5	10	15	20	25
4	Likely	4	8	12	16	20
3	Possible	3	6	9	12	15
2	Unlikely	2	4	6	8	10
1	Rare	1	2	3	4	5

RISK RATING
EXTREME
HIGH
MODERATE
LOW

An advantage of this approach is that it allows risk ratings to be set based on the derived numeric risk values. A major drawback is that the numeric risk values may not reasonably reflect the relative risk of events due to the possible orders of magnitude differences within the likelihoods and consequences classes.

In many cases the approach used to overcome above drawbacks has been to apply likelihood and consequence values that more closely reflect their relative magnitude, but which are not absolute measures. The semi-quantitative risk matrix ofTable4.4 shows the relative risk values that would be derived by replacing the qualitative descriptions of likelihoods and consequences with values that better reflect their relative order of the magnitude and provide more realistic relativity within each class.

Table 4.4: Example of an Alternative, Basic Semi-quantitative Risk Rating Matrix

		Consequence Level				
		1	2	3	4	5
Likelihood level	Descriptor	Insignificant	Minor	Moderate	Major	Catastrophic
1	Almost Certain	1	10	100	1000	10000
0.1	Likely	0.1	1	10	100	1000
0.01	Possible	0.01	0.1	1	10	100
0.001	Unlikely	0.001	0.01	0.1	1	10
0.0001	Rare	0.0001	0.001	0.01	0.1	1

RISK RATING
EXTREME
HIGH
MODERATE
LOW

In this example the risk assessment clearly indicates that there is order of magnitude difference between likelihood classes and also between consequence classes. Using this approach, it is possible to derive numbered risk levels by multiplying likelihood and consequence levels for each cell of the matrix. For example a risk event which is possible (likelihood level = 0.01) and would have a major consequence (consequence level = 1000) would show a risk level of 10. If the issues were comparable then this event would pose same risk as another event which was, for example likely (0.1) but with lower, moderate (100), consequences.

The matrix of Table 4.4 also shows that in this particular case the risk ratings have been weighted to place more emphasis on higher consequence events. This is frequently done to reflect an organisation's lower tolerance of higher consequence events. This step can be difficult to justify and can be misleading in overemphasising some risk events.

Semi-quantitative risk assessments methods are quick and relatively easy to use clearly identify consequences and likelihoods. They usually provide a general understanding of comparative risk between risk events and are useful for comprehensive risk assessments.

4.6.3. Quantitative methods

Quantitative risk assessment is increasingly applied in the mining and minerals industry due to business requirements to support financial decisions, evenly compare financial risks with environmental and social risks, and to demonstrate transparency, consistency and logic of approach. However quantitative risk approaches often are not intuitive and require some up-front learning investment by decision makers.

Quantitative risk assessment is used across the full range of risk applications from deriving preliminary first-pass separation of risk events to much more comprehensive assessments. The comprehensive assessments can derive detailed risk profiles for priority ranking, estimates of the costs that may be incurred due to risk events, input to financial models and a basis for cost-benefit analysis.

Quantitative risk assessment follows basic risk assessment approach to its full extent by attributing absolute values to likelihood and consequences. Estimates of likelihood are made in terms of event frequency or probability of occurrence of the risk event.

Estimates of consequence can be made using any consistent measure selected according to the nature of the application. The risk quotient is used to differentiate on a comparative basis between the risks events using a consistent measure of risk and to identify those events that pose the most risk. Where consequences are expressed in financial terms, the risk quotient is equivalent to the commonly used term ‘expected cost’ or ‘expected value’.

a. Risk maps

A risk map is the quantitative equivalent to risk matrices that are typical outputs from qualitative risk assessments. Like a risk matrix the risk map shows the relationship between likelihood (vertical axis) and consequence level (horizontal axis) for each event and also shows how the events can be rated from low to extreme risk if desired.

The risk map construction recognises that the scales of both likelihood and consequence of risk events are perceived to differ by orders of magnitude. Consequently the diagonal lines represent lines of equal risk. The line showing ‘selected lower limit of extreme risk’ shows that the risk quotient (calculated as likelihood x consequence) is equal to 10 at all intersection points along the line. For example, points (100, 0.1), (1000, 0.01), (10 000, 0.001) all show equal risk. In addition, any events with risk quotients greater than 10 would plot above the selected lower limit and would be considered to pose extreme risk.

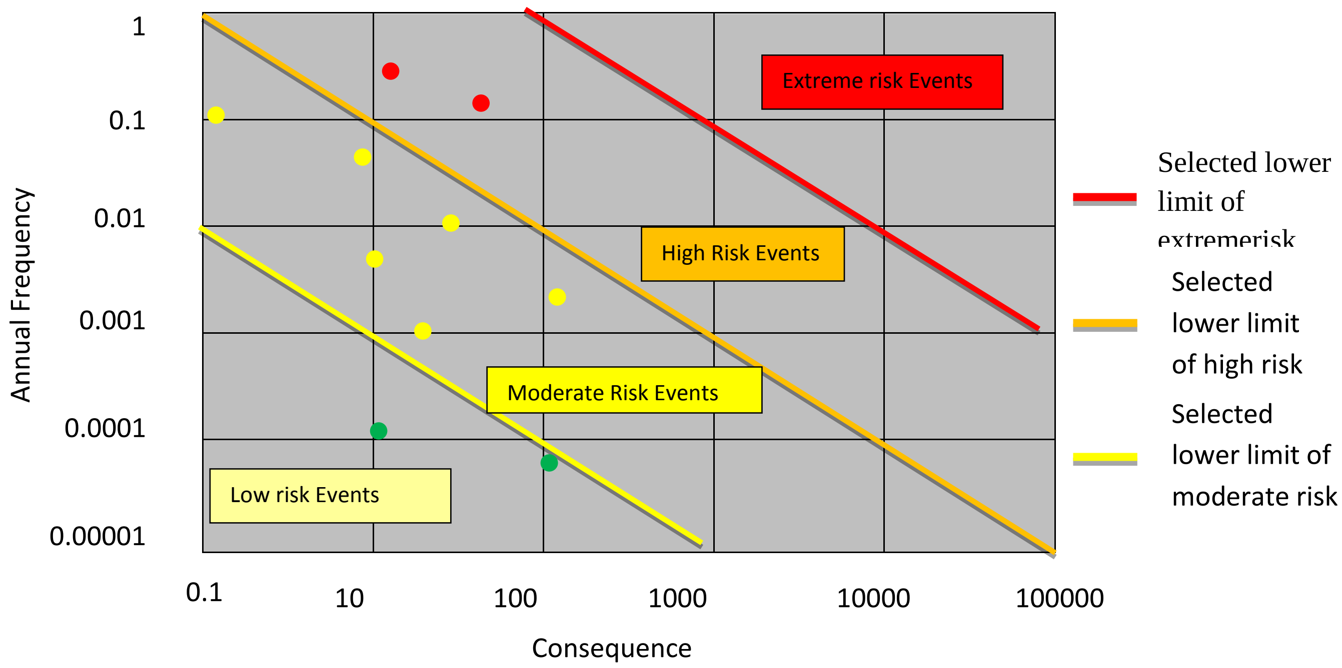

Figure 4.5: An Example of Risk Map

b. Risk profiles

Risk profiles are more commonly used to express the basic outputs of quantitative risk analysis. Figure shows an example of risk profile generated from the same data as the risk map above.

The risk quotient for each potential event is shown on the vertical axis and is calculated from the product of the likelihood of occurrence and the cost if the event occurred. The selected lower limits of each risk rating are also indicated on the profile.

Additional profiles can be generated to assist development of appropriate risk treatment strategies. Exposure profiles that show estimated cost of risk issues clearly indicate both the risk of each event and the potential financial exposure if the event were to occur. Identification of a high-risk, high-cost event, for example, would indicate that priority action should be carried out to address the risk.

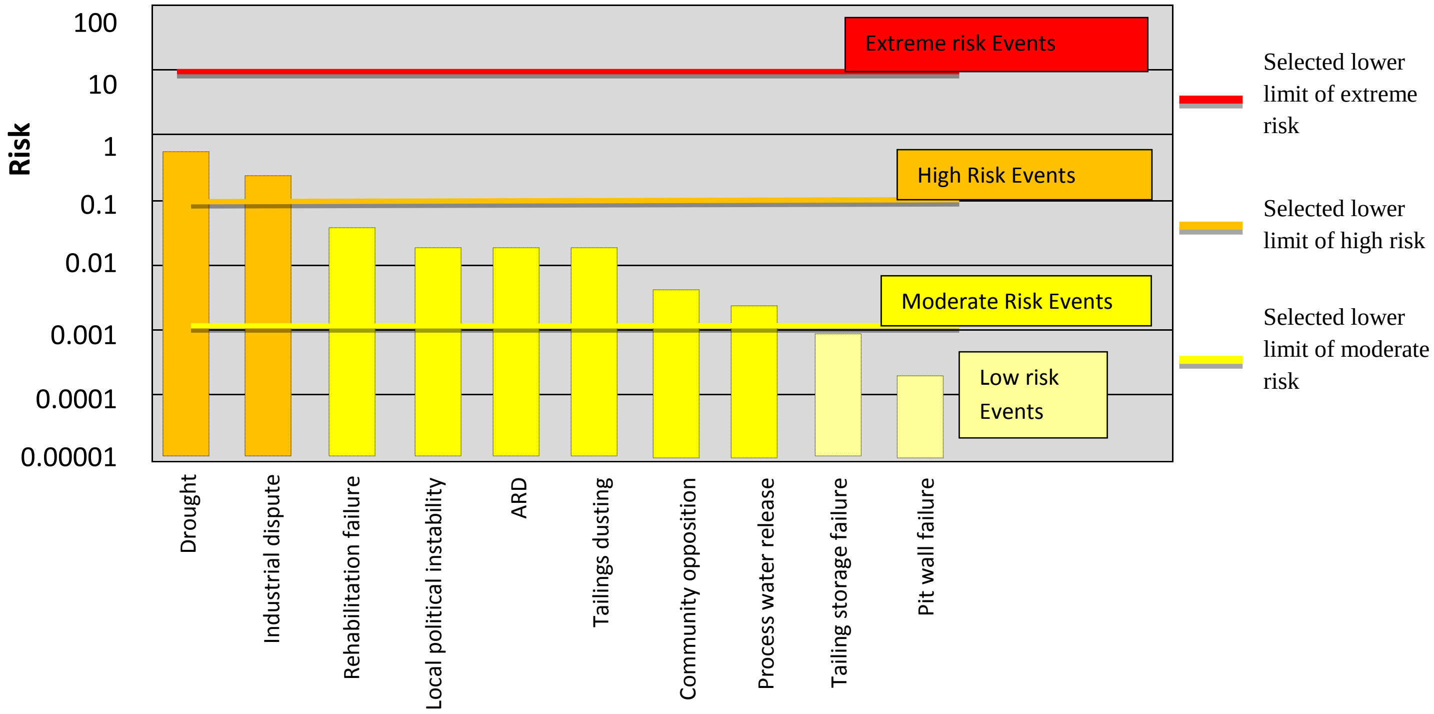

Figure 4.6: An Example of Risk Profile

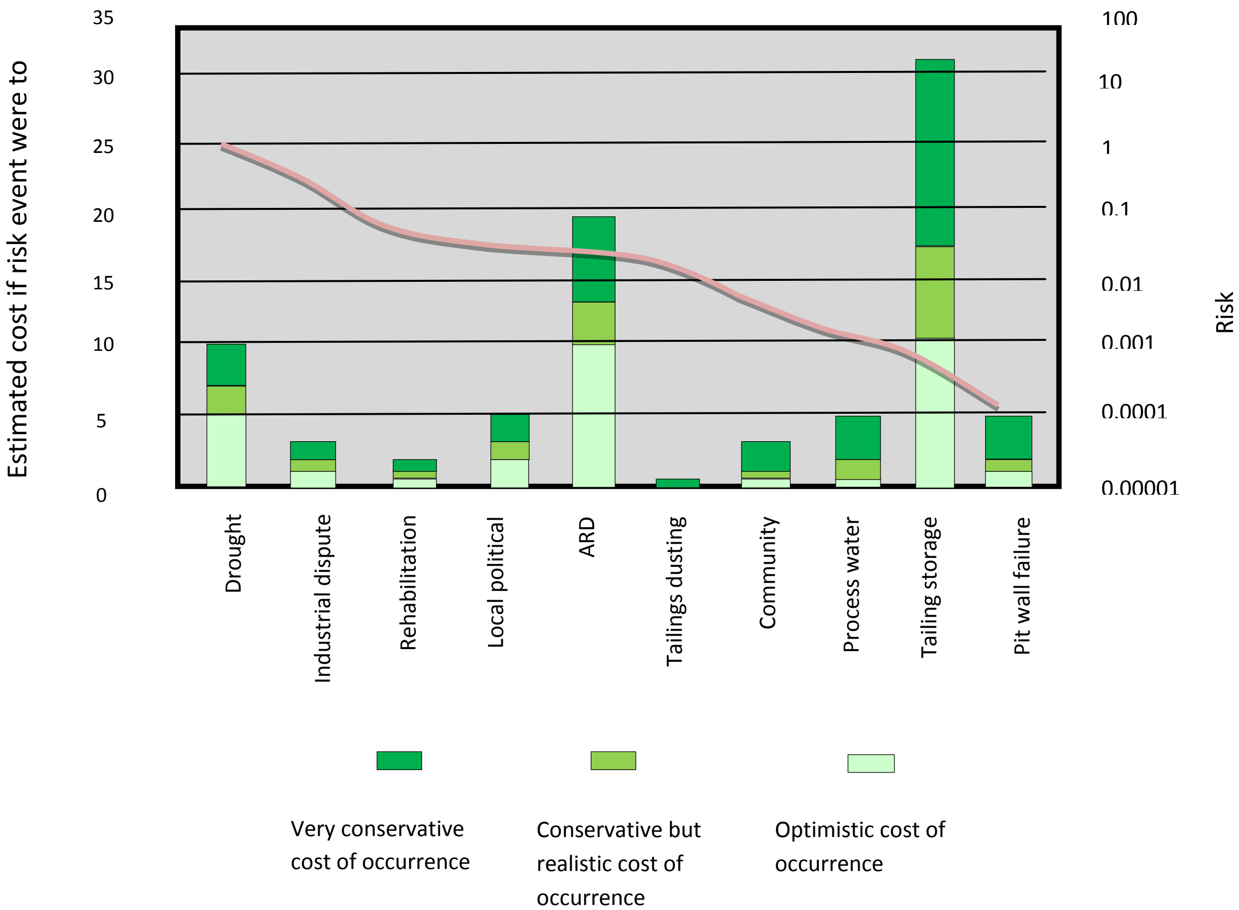

Figure 4.7: Example of Exposure Profile

Additional outputs of quantitative risk assessment that are used to develop and support risk management strategies show profiles of event likelihoods and cost-benefit relationships (progressive costs to implement a risk management strategy versus reduction in risk or reduction in the estimated future cost of risk events).

Fully quantitative risk assessment is not very useful for environmental impact study type risk assessments, where there are many diverse environmental and social issues that need to be evaluated and their risk communicated to the community and other stakeholders.

4.7RISK ASSESSMENT PROCEDURES

4.7.1 Hazard and Operability Analysis (HAZOP)

A HAZOP is an organized examination of all possibilities to identify and processes that can malfunction or be improperly operated.

HAZOP analyses are planned to identify potential process hazards resulting from system interactions or exceptional operating conditions.

Features of HAZOP study are:

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

Advantages:

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

Disadvantages

a. Requires a distinct system of engineering documentation and procedures.
b. HAZOP is time consuming.
c. Requires trained engineers to conduct the study.

d. HAZOP emphases on one event causes of deviations or failures.

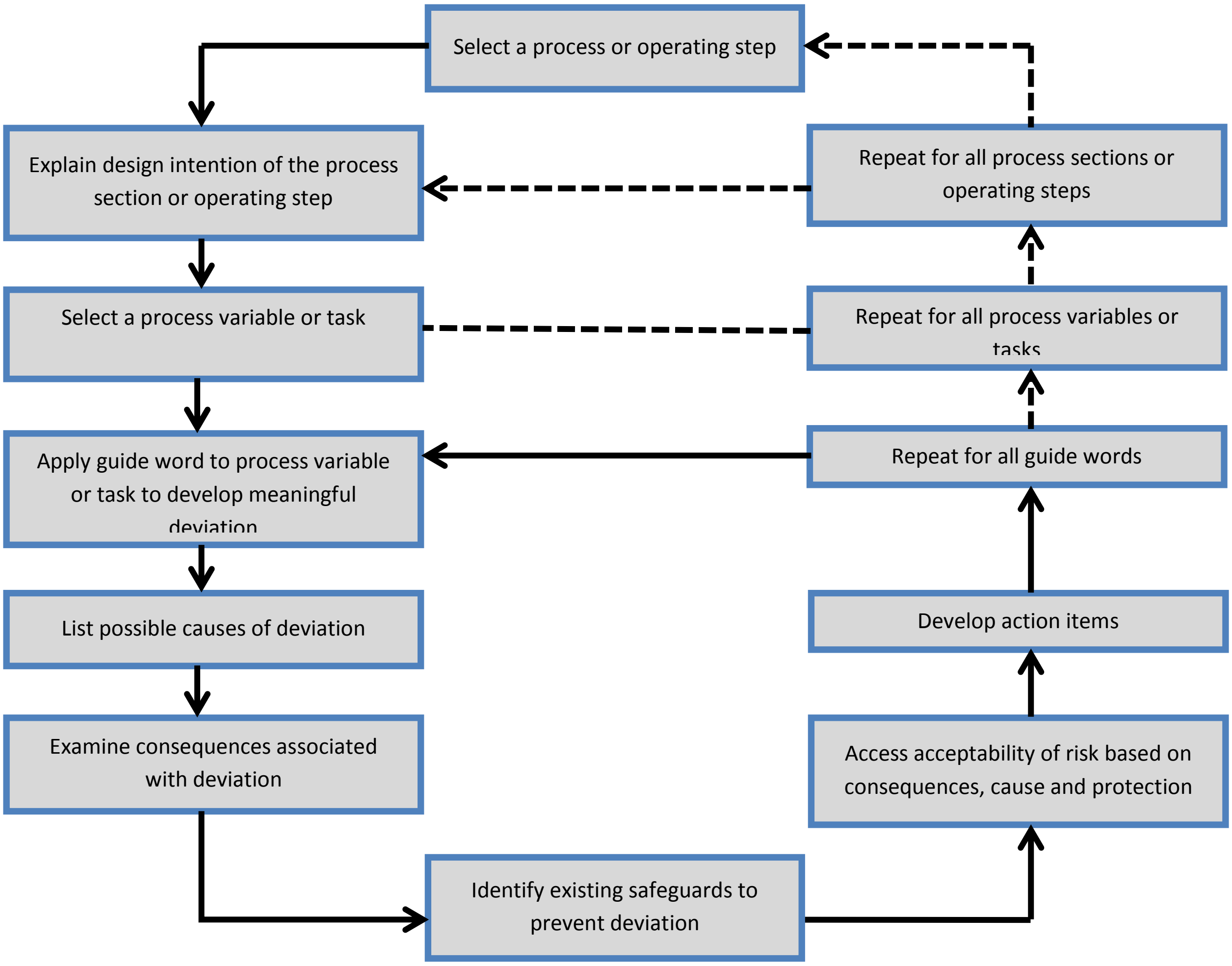

Figure 4.8: HAZOP (Hazard and operability analysis) Concept.

4.7.2 Failure Mode and Effect Analysis (FMEA)

An FMEA is a systematic method for examining the impacts of component failures on system performance. Basically FMEA focuses on failures of systems and individual components and examines how those failures can impact facility and processes.

FMEA is most effective when a system is well defined and includes the followings key steps:

a. Listing of all system components;
b. Identification of failure modes (and mechanisms) of these components;
c. Description of the effects of each component failure mode;
d. Identification of controls (i.e., safeguards, preventive) to protect against the causes and/or consequence of each component failure mode;
e. If the risks are high or the single failure criterion is not met.

Information required for an FMEA includes:

1. System structure;
2. System intimation, operation, control and maintenance;
3. System environment;
4. System modelling;
5. System software;
6. System boundary;
7. System functional structure;
8. System functional structure representation;
9. Block diagrams; and
10. Failure significance and compensating provisions.

FMEA is a qualitative inductive method and is easy to apply. FMEA is supported by the preparation of a list of the expected failure modes in the light of

a. The use of the system,
b. The elements involved,
c. The mode of operation,
d. The operation specification,
e. The time constraints and
f. The environment.

FMEA is an efficient method for analysing elements which can cause failure of the whole, or of a large part, of a system.

Advantages

a. Simple
b. Efficient
c. Cost effective
d. Has quantitative applications

Disadvantages

a. Limited capability to address operational interface and multiple failures
b. Human error examination is limited
c. Missing components are not examined
d. Common-cause vulnerability may be missed

4.7.3 Fault Tree Analysis (FTA)

A fault tree is a detailed analysis using a deductive logic model in describing the combinations of failures that can produce a specific system failure or an undesirable event. An FTA can model the failure of a single event or multiple failures that lead to a single system failure.

FTA is often used to generate:

- Qualitative description of potential problems
- Quantitative estimates of failure frequencies/ likelihoods and relative importance of various failure sequences/contributing events
- Suggested actions to reduce risks
- Quantitative evaluations of recommendation effectiveness

The FTA is a top-down analysis versus the bottom-up approach for the event tree analysis. The method identifies an undesirable event and the contributing elements (faults/conditions) that would initiate it.

The following basic steps are used to conduct a fault tree analysis:

1. Define the system of interest.
2. Define the top event/system failure of interest.
3. Define the physical and analytical boundaries.
4. Define the tree-top structure.
5. Develop the path of failures for every branch to the logical initiating failure.
6. Perform quantitative analysis.
7. Use the results in decision making.

Once the fault tree has been developed to the desired degree of detail, the various paths can be evaluated to arrive at a probability of occurrence.

Advantages

1. It directs the analyst to ferret out failures deductively;
2. It points out the aspects of the system which is appropriate for an understanding of the mechanism of likely failure;

3. It provides a graphical assistance enabling those responsible for system management to visualize the hazard; such persons are otherwise not associated with system design changes;
4. Providing a line of approach for system reliability analysis (qualitative, quantitative);
5. Allowing the analyst to give attention to one particular system failure at a time;
6. Providing the analyst with genuine understandings into system behaviour.

Disadvantages

1. Requires a skilled analyst. It is an art and also a science
2. Focuses only on one particular type of problem in a system, and multiple fault trees are required to address the multiple modes of failure
3. Graphical model can get complex in multiple failures

4.7.4 Event Tree Analysis (ETA)

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

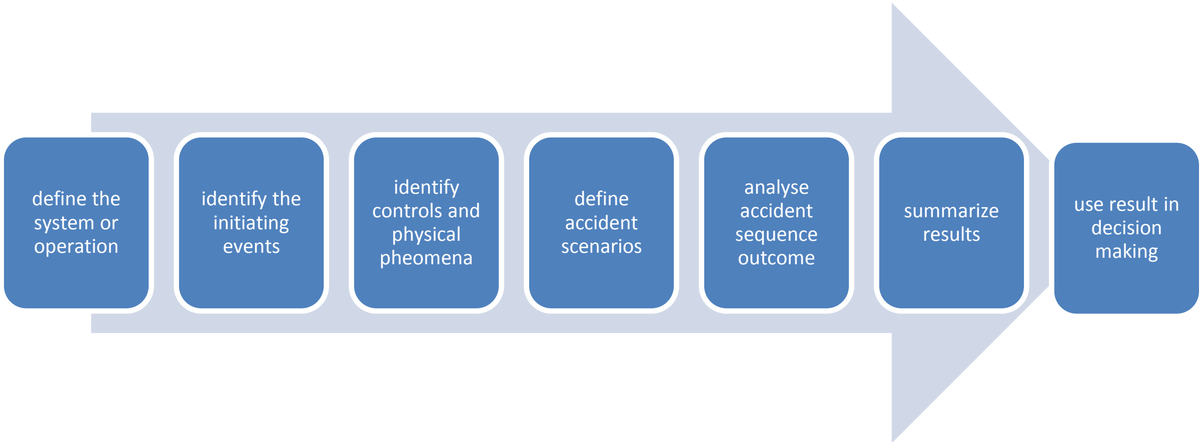

Figure 4.9: Procedure of Event Tree Analysis

An analyst can develop the event tree by inductively reasoning chronologically forward from an initiating event through intermediate controls and conditions to the ultimate consequences.

An ETA can identify range of potential outcomes for specific initiating event and allows an analyst to account for timing, dependence, and domino effects that are cumbersome to model in fault trees.

An ETA is applicable for almost any type of analysis application but most effectively is used to address possible outcomes of initiating events for which multiple controls are in place as protective features.

Advantages

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

Disadvantages

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

The above techniques provide appropriate methods for performing analyses of a wide range of hazards during the design phase of the process and during routine operation. A combination of two or three methods is more useful than individual methods as each method has some advantages and disadvantages.

4.7.5 Failure Mode Effect and Critical Analysis (FMECA)

The FMECA is composed of two separate investigations, the FMEA and the Criticality Analysis (CA). The FMEA must be completed prior to performing the CA. It will provide the added benefit of showing the analysts a quantitative ranking of system and/or subsystem failure modes. The Criticality Analysis allows the analysts to identify reliability and severity related concerns with particular components or systems.

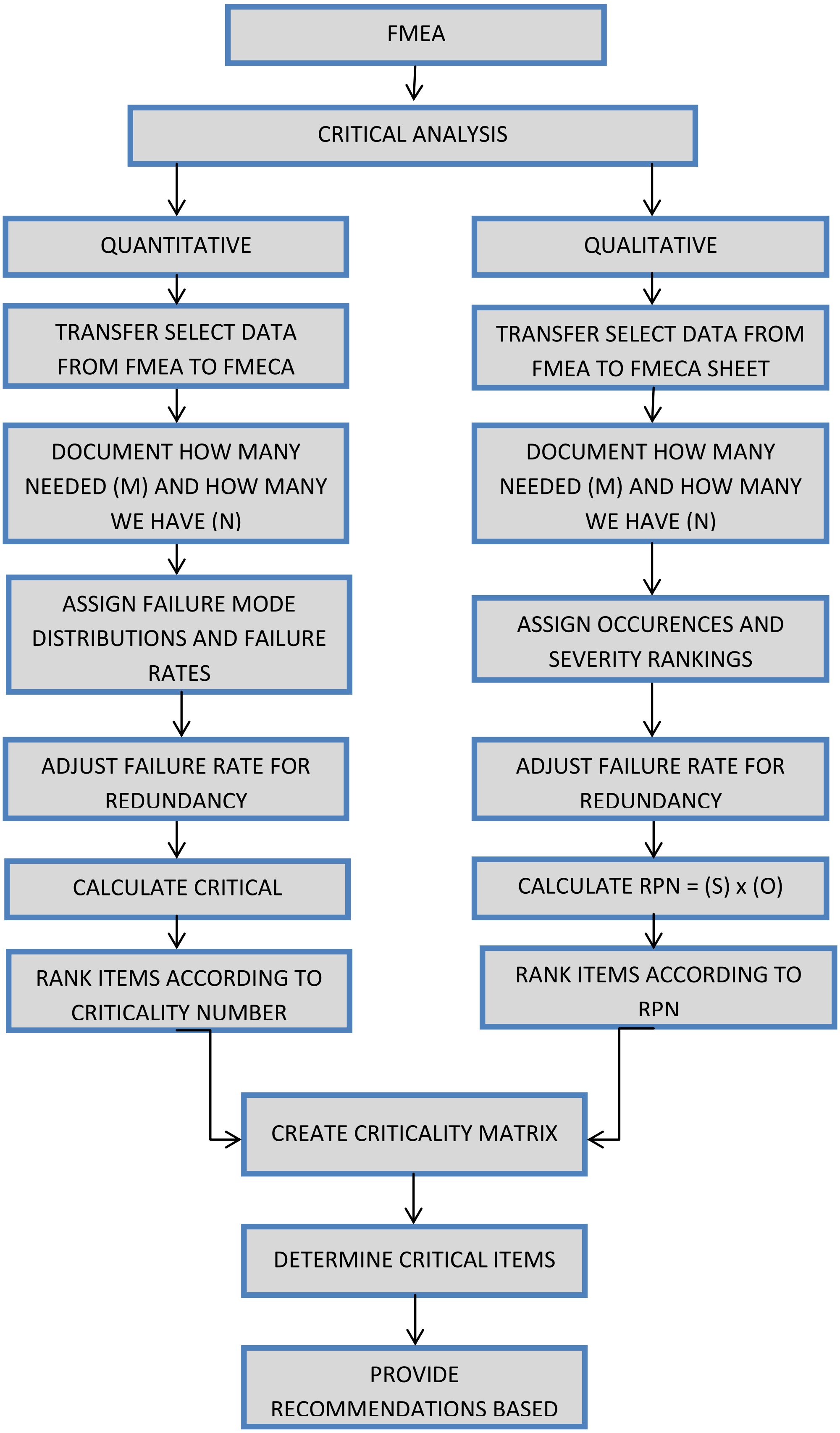

Figure 4.10: The Process for Conducting FMECA using Quantitative and Qualitative Means.

CHAPTER 5

HAZARD IDENTIFICATION AND RISK ANALYSIS - CASE STUDIES

5. HAZARD IDENTIFICATION AND RISK ANALYSIS - CASE STUDIES

5.1 CASE STUDY OF AN IRON ORE MINE

5.1.1 Introduction

The iron ore mine is located in Jharkhand state of India. Mining operations are carried out in a series of 12 meter high benches, 150mm diameter holes are drilled and blasted with explosives; the ore is then shovelled and trucked. The mine has facility for dry processing of rich grade fine ore. The total lease area of the mine is 1160.06 ha and the lease was obtained in the year 1923. Of the total lease area, about 762.43 ha of land is forest area and about 397.63 ha of land is non-forest area. The iron ore mine produces sized ore (-40mm to + 10mm), LD ore (-40mm to +20mm) and blended fines (-10mm). To describe the deposit present there three essential features are topographic data, geological data and location data.

- Topography Data – it is an essential component as it gives an idea about the surrounding environment of the deposit. At Iron mine the entire area is classified as eastern ridge and western ridge that are separated by a small stream. The eastern ridge comprises of 6 distinctly visible hills whereas there are no such prominent hills in the western ridge.
- Geological Data – it gives an idea of the kind of the deposit that is available and the nature of OB on the area and also faults or discontinuities if present any. In the iron mine the eastern ridge has a strike of NNE-SSW and a dip of 20 to 400 west. The rock types of this area are quartzite, banded Haematite jasper, iron ore, shale and lava. The ores found can be broadly classified into the following four types:
    1. Hard Ore – it is steel grey in colour, fine grained, massive and is of homogeneous variety.
    2. Soft Ore – it is soft, spongy, laminated and often porous.
    3. Friable Ore – it is brownish to steel grey in colour and contains kaolinous and shaly material.
    4. Blue Dust – these are natural fines capable of holding powdery haematite.

5.1.2 Mining Method

Iron ore Mine is a fully mechanized Open Cast Mine having a production rate of 7.6 MTPA to 8.5 MTPA (During 2007 to 2011). The ROM from mine is processed in beneficiation plant and finished product (Sized Ore & Fines) is dispatched to Steel Plant. The mining operations are achieved with the help of shovel dumper combination. The bench height of 12m is kept and drilling is done by 150/165 mm diameter drills with 10% sub-grade drilling. Blasting is done by using mostly SME (Site Mixed Emulsion Explosives) with the Nonel system of initiation so as to minimize adverse effect on environment such as ground vibration, noise and fly rock. The blasted material is loaded by shovels of different capacities into 50 / 60 tons dumpers. The ROM ore is hauled by dumpers from different mining faces and dumped in the primary crusher in the pre-determined proportions for blending different qualities of ores.

5.1.3 Machinery Deployed

The detail of the HEMM's used at the iron mine are given below. Earlier 50 – 60T dumpers were used but last year 4 new 90 T dumpers were ordered as the production was increased. The drills used are electrically operated whereas the shovels are diesel operated.

Table 5.1.1: Machinery Deployed in the Iron Ore Mine

Machinery	Capacity of Each Unit	Number of Units
Shovels	5.5 – 5.9 cu m	6
Drills	150 – 165 mm	7
Mining loaders	9 cu. M	1
Dumpers	Rear dump truck (BEML / CAT, 50 / 60 T), Komatsu(90 T)	15+4
Dozers	D-155, CAT-D9R, Wheel Dozer, Komatsu	5
Graders	BEML , Komatsu	2
Loader	Front-End-Loader, 5.75 cu. m.	3
Water sprinkler	28 KL	3
Trucks	10 T	6

5.1.4 Risk Analysis and Risk Management

The steps we would be following for risk assessment and risk management in iron ore mine are as follows:-

- Hazards identification
- Ranking of hazards as per their probability and consequence
- Management of hazards as per their ranking

Major risks that were identified were related to

- Fly-rocks during blasting
- Toppling of heavy equipment
- Explosion in magazine (explosive storage)
- Fire in fuel (HSD) storage /handling
- Waste dump failure
- Fire in mine equipment
- Landslide (Slope failure)
- Electrical Fire

As per the risk analysis carried out in Iron Ore mine few major risks as per the ranking are

- Hanging of unsupported rock mass on the working face of the mine.
- Blasting is not done by an authorised person.

5.1.5 Risk Rating

5.1.5.1. Dust, chemicals and hazardous substances

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Dusts that can effect health such as silica	L4	C3	17
2. Other dusts that can effect operations	L4	C3	17
3. Chemical such as petrol, diesel, oils, degreasers, solvents.	L4	C4	21
4. Chemical fumes such as from welding/ cutting, grinding etc.	L3	C5	22
5. Gases such as H_2S, CO, CO_2 NOX	L4	C5	24
6. Fines or build-up of combustible particles	L4	C5	24

5.1.5.2. Explosives

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Unauthorised person firing shot	L3	C1	4
2. Handling Explosives	L4	C1	7
3. Explosives – general (Fly rock occurrences, noise and vibrations, neighbour)	L4	C1	7
4. Explosives Storage -including detonators	L5	C1	11

5.1.5.3. Gravitational energies

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. High wall / pit wall / stockpiles / berms	L3	C1	4
2. Fall and dislodgement of earth and rock	L4	C1	7
3. Instability of the excavation and adjoining structure	L4	C1	7
4. Floor	L4	C3	17
5. Mine road design and construction	L4	C3	17
6. Objects / structures falling on people	L4	C3	17
7. Fall of things such as components, tools, structures	L5	C3	20
8. Air blasts / wind	L3	C5	22

5.1.5.4. Mechanical Energies

Equipment such as earth moving machinery (trucks, loaders, dozers, etc.), rail, winders, mining equipment such as drills, shovels, excavator, other

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Inappropriate exposure to moving machinery	L4	C2	12
2. Mechanical failure (including critical systems)	L3	C3	13

3. Loss of control of a vehicle or other machinery at the mine	L4	C3	17
4. Road traffic in and out issues	L4	C3	17
5. Interaction between mobile plant and pedestrians	L4	C3	17
6. Unintentional fire or explosion	L4	C3	17
7. Contact of mobile plant with overhead structures	L5	C3	20

Fixed mechanical equipment such as conveyor, crusher, screens, other

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
8. Means of prevention, detection and suppression of fires	L4	C1	7
9. Inappropriate access to operating machinery (e.g. Guards missing)	L4	C2	12
10. Mechanical failure (including critical systems)	L3	C3	13
11. Conditions under which plant is use	L4	C3	17
12. Safe access/procedures	L4	C4	21
13. Blockages and spillage	L4	C5	24

5.1.5.5. Pressure (Fluids/Gases)

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Unusual rain event	L3	C3	13
2. Inrush into/flood intrusion of mine (directly or indirectly)	L5	C3	20

3. Road drainage	L4	C5	24

5.1.5.6.Work Environment

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Noise	L4	C2	12
2. Manual handling hazards	L4	C3	17
3. Wildlife such as snakes, spiders, insects	L4	C3	17
4. Biological, such as exposure to work related diseases	L4	C3	17
5. Slip/trip hazards	L4	C4	21
6. Vibration	L4	C4	21
7. Building maintenance / cleaning	L3	C5	22
8. Effects of Ventilation	L5	C4	23
9. Condition of Buildings / Structures	L4	C5	24
10. Sufficient Hygiene Facilities	L4	C5	24

5.1.5.7.Others

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Use of PPE	L5	C1	11
2. No dust suppression after blasting	L1	C4	10

5.1.6 Risk Treatment

- All safety precautions and provisions of Metalliferous Mine Regulations (MMR) 1961 shall be strictly followed during all mining operations;
- Entry of any unauthorized person into mine and plant areas shall be completely prohibited
- Arrangements for fire fighting and first-aid provisions in the mine's office complex and mining area;
- Provision of all the safety appliances such as safety boot, helmets, goggles, ear plugs etc. shall be made available for the employees
- Mining will be undertaken in coexistence with the requirements of the Mining Plan which shall be updated from time to time
- Mine faces shall be regularly cleaned so as to ensure that the same is safe to work

- Handling of explosives, charging and blasting shall be undertaken only by a competent person
- Adequate safety equipment shall be provided at the explosive magazine
- All the mining equipment shall be maintained as per the guidelines of the manufacturer
- Haul roads shall be water sprinkled in order to suppress dust and other fugitive emission;
- Elevating the awareness of employees, contract workers and public as a whole by celebrating Annual Safety Week which includes various competitions like posters, essay, slogan, quiz etc.

5.2 CASE STUDY OF A COAL MINE

5.2.1 Introduction

The mine is located in Chhattisgarh state of India and the working is done by an opencast method of working. The mine has revealed existence of 8 coal horizons out of which 4 horizons are now workable. Mine was opened on 24 April 2006 and Coal production of mine started on 27th Sept. 2006. Coal production is 12000 TPD and OB removed is 25000m^3 per day. OMS of mine is 95 and Striping ratio of mine is 1: 2.60.

5.2.2 Geology of the Mines

There are 3 seams in the mines. Name of seams are VI, V (top), V (bottom) which produce a grade 'F' ROM of coal. Dip is at an inclination of 1 in 7 and the Extend of mine along dip direction is 1100m, along strike direction is 1100m and along depth is 120m. Thickness of each seam i.e. seam VI is 8.28 – 10.30m, seam V (top) is 2.78 – 3.80m and seam V (bottom) is 7.70 – 15.39m. Thickness of Top Overburden cover is 10 -57 m, Between VI and V top is 39.39 – 47.50m and Between V top and V bottom is 8.79 – 16.94m.Total reserves of mine is 19.82 MT. The rock types of this area are coal, shally coal, carbonaceous shale, grey shale, medium grained sand stone and fine grained sand stone.

5.2.3 Machineries Deployed

The overburden removal is being done with shovel dumper combination, with drilling and blasting. The coal production is done by pay loaders and tippers, with drilling and blasting. For OB removal 35nos of dumpers are working contractually. For coal production 20nos of dumpers are working contractually. The drilling is being carried out by 160mm dia. drill machine contractually. The haul road is 300m in length and 20m in width having a slope of 1in16 with sufficient lighting arrangement. Tipping truck road is 30m wide and its length is 2.5kms having flat slope and ramps of 1 in 12 and are provided with safety berms. In dump yard area height is kept at 30m, sufficient space is provided avoid overcrowdings, for slope natural angle should not be more than 37^0 . For the use of explosives a magazine with license is there having a capacity of explosives 14000kg, fuse 10000kg and detonators 20000. 1 explosive van and 5 blasting shelters are present and blasting density per million tonnes is 279.32 Te.

5.2.4 Risk Analysis and Risk Management

The steps we would be following for risk assessment and risk management in coal mine are as follows:-

- Hazards identification
- Ranking of hazards as per their probability and consequence
- Management of hazards as per their ranking

Major risks that were identified were related to

- Blasting in mines
- Entry of workers
- Dust emission
- Loading in coal faces & OB
- Pay loaders operation at stock yard
- Use of HEMM
- Dumping area of coal and OB
- Inundation

As per the risk analysis carried out in coal mines few major risks as per the ranking are

- Use of PPE was not proper
- Fly rock while blasting
- Absence of footpath for the movement of trucks and tippers
- Accident due to movement of pay loaders
- Overcrowding of vehicles
- Poor supervision at loading faces of coal and OB
- Conflict with the code of work practice. (strikes)
- Sudden inrush of river water

5.2.5 Risk Rating

5.2.5.1. Dust, Chemicals & Hazardous Substances

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Dusts that can effect operations	L2	C3	9
2. Dusts that can effect health such as silica	L4	C3	17
3. Fines or build-up of combustible particles	L4	C3	17
4. Chemical such as petrol, diesel, oils, degreasers, solvents.	L4	C3	17
5. Gases such as H_2S, CO, CO_2 NO_X	L3	C5	22

5.2.5.2. Electrical Energies

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Electricity(High voltage installation)	L4	C3	17
2. Electrical energy from apparatus such as cables, transformers, switch gear, connections	L3	C4	18
3. Electrical Equipment inspection, testing and tagging to standards	L4	C4	21

5.2.5.3. Explosives

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Explosives – general (Fly rock occurrences, noise and vibrations, neighbour)	L2	C1	2
2. Handling Explosives	L4	C1	7
3. Explosives Storage -including detonators	L5	C1	11

5.2.5.4. Gravitational Energies

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Mine road design and construction	L3	C1	4
2. Fall and dislodgement of earth and rock	L4	C1	7
3. Instability of the excavation and adjoining structure	L4	C1	7
4. Floor	L3	C3	13
5. High wall / pit wall / stockpiles / berms	L3	L3	13
6. Objects / structures falling on people	L4	C3	17
7. Fall of things such as components, tools, structures	L5	C3	20
8. Air blasts / wind	L4	C5	24

5.4.5.5. Mechanical Energies

Equipment such as earth moving machinery (trucks, loaders, dozers, etc.), rail, winders, mining equipment such as drills, shovels, excavator, other

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Road traffic in and out issues	L2	C3	9
2. Inappropriate exposure to moving machinery	L4	C2	12
3. Mechanical failure (including critical systems)	L3	C3	13
4. Loss of control of a vehicle or other machinery at the mine	L4	C3	17
5. Interaction between mobile plant and pedestrians	L4	C3	17
6. Unintentional fire or explosion	L4	C3	17
7. Contact of mobile plant with overhead structures	L5	C3	20

5.2.5.6. Pressure (Fluids/Gases)

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Inrush into/flood intrusion of mine (directly or indirectly)	L2	C2	5
2. Unusual rain event	L3	C3	13
3. Flow failure of pumping system e.g. Outlet blockage	L3	C4	21
4. Road drainage	L4	C5	24

5.2.5.7. Work Environment

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Noise	L4	C2	12
2. Wildlife such as snakes, spiders, insects	L3	C3	13
3. Manual handling hazards	L4	C3	17
4. Biological, such as exposure to work related diseases	L4	C3	17
5. Slip/trip hazards	L4	C4	21
6. Vibration	L4	C4	21
7. Building maintenance / cleaning	L3	C5	22
8. Effects of Ventilation	L5	C4	23
9. Condition of Buildings / Structures	L4	C5	24
10. Sufficient Hygiene Facilities	L4	C5	24

5.2.5.8 Others

HAZARD TYPE	Likelihood Level	Maximum Consequence	Risk Rating
1. Use of PPE	L2	C1	2
2. Spontaneous Heating	L2	C4	12

5.2.6Risk Treatment

- Fly rock can be avoided by maintaining proper burden and spacing and proper arrangement of nonel.
- Hazards due to absence of footpath can be avoided by implementation of traffic rules and display of traffic signal boards

- Accident during movement of pay loader can be avoided by proper supervision and avoid loading and unloading work simultaneously at stock yard.
- Overcrowding can be avoided by making wide roads and one way traffic system.
- Sudden inrush can be avoided by preparation of embankment and its strengthening, proper pumping and continuous checking of vulnerable points.

CHAPTER 6

DISCUSSION AND CONCLUSION

6. DISCUSSION AND CONCLUSION

6.1 DISCUSSION

Mining activity because of the very nature of the operation, complexity of the systems, procedures and methods always involves some amount of hazards. Hazard identification and risk analysis is carried for identification of undesirable events that can leads to a hazard, the analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects.

As the part of the project work, hazard identification and risk analysis was carried out for an iron ore mine and a coal mine and the hazards were identified and risk analysis was carried out. The different activities were divided in to high, medium and low depending upon their consequences and likelihood. These have been presented in chapter 5. The high risks activities have been marked in red colour are un-acceptance and must be reduced. The risks which are marked in yellow colour are tolerable but efforts must be made to reduce risk without expenditure that is grossly disproportionate to the benefit gained. The risks which are marked in green have the risk level so low that it is not required for taking actions to reduce its magnitude any further. The risk rating calculations were carried out by a qualitative method as mentioned in the tables 4.1 and 4.2 respectively.

For the iron ore mine the high risk activities which were recorded were related to face stability (section 5.1.5.3.) and the person blasting the shots (section 5.1.5.2.). It was observed that on a working face of the mine, there were large cracks and unsupported rocks were present, which can lead to a serious hazard and injure workers engaged in loading operation and machineries because of rock falls or slides. This type of condition turn out because improper dressing of the bench and improper supervision.

To avoid the hazards due to fall of rocks the face must be examined, made suitable for working and the remedial measures must be taken to make it safe if there is any doubt that a collapse could take place. Working of the face should be in the direction taking into account the geology of the area such that face and quarry side remain stable.

Another major risk identified in iron ore mine was due to the firing of explosive by an unqualified person (section 5.1.5.2.). In the coal mine there was problem of fly rocks (section 5.2.5.3) and the village is located close to the mine and so it is rated high as it can affect may people. Explosives by nature have the potential for the most serious and catastrophic accident. Planning of round of shots, holes correctly drilled, direction logged, weight of explosive suitable for good fragmentation are the few of the steps necessary to ensure its safe use and if the shots are not properly designed can result in misfires, early ignition and flying rocks. No one would allow any person to use explosives without being properly trained in its handling as specified in section 166 of the coal mine regulations 1957 and section 160 of the metalliferous mine regulations 1961.

In the coal mine a large numbers of heavy vehicles were in operation and the roads were not proper for haulage purpose (section 5.2.5.4.). The haulage roads were not even and were not wide enough for the crossing purpose and hence the chances of hazards are very high. The main hazards arising from the use large earth moving vehicles are incompetent drivers, brake failure, lack of all-around visibility from the driver position, vehicle movements particularly reversing, roll over, and maintenance. Those most at risk are the driver and pedestrians likely to be struck by the vehicle, and drivers of smaller vehicles, which cannot be seen from the cabs of large vehicles. Edge protection is always necessary to prevent inadvertent movement over the edge of roadway or a bench. Seatbelt will protect driver in case of roll. Good maintenance and regular testing are necessary to reduce the possibility of brake failure. Assess to the vehicles should always be restricted to those people necessary for the work in hand.

It was observed in the coal mine that the use of personal protective equipment is not proper (section 5.2.5.8.) and proper arrangements were not there to check if the person is wearing a personal protective equipment or not. The personal protective equipment includes helmet, non-skid safety boots, safety glasses, earmuffs etc. The required personal protective equipment should be provided and used in a manner that protects the individual from injury. Few minor injuries which can be prevented are slip, trip, or fall hazards; hazards due to rock falls and collapse of unstable rocks, atmosphere containing toxic or combustible gases; protects from chemical or hazardous material etc.

The coal mine is situated near the river and in rainy season the water inrushes into the mine causing inundation (section 5.2.5.6.) and creating the problem in workings. It is caused because of breach in embankments of water bodies nearby the mines and inrush of water through openings. In case of inundation, seam wise working layout should be developed and its impact on surface features and structure should be anticipated. If the impact and dangers are excessive then the workings should be planned to bring them to minimum possible level. A disaster management plan should be prepared for taking care of for any disaster.

The risks in the yellow are the tolerable risks buts steps are to be taken to reduce without much expenditure. In an iron ore mines and the coal mine the risks are divided according to the hazard type into categories. In case of hazard due to explosive the tolerable risks are due to handling of explosive, fly rock occurrences, noise vibrations and explosive storage (section 5.1.5.2. and 5.2.5.3.). In gravitational hazard it was related to fall and dislodgement of rock and instability of the excavation and adjoining structure (section 5.1.5.3. and 5.2.5.4.). These were categories in tolerable limits because of the current method used the likelihood of having problem is very low but the consequence are catastrophic hence it is categorised as medium risk.

In mechanical hazards it can be categorised into moving machineries and stationary machineries (section 5.1.5.4.).In case of moving machinery it can be due to inappropriate exposure to the moving machinery and mechanical failure. In stationary machines it can be due to means of prevention, detection and suppression of fire; inappropriate access to moving machinery and mechanical failure. These are in tolerable level because the likelihood of occurrence is low but it leads to lost in time hence it is categorised as medium risk.

Other risk which are included in this category are noise (section 5.1.5.6.), as it occurs and it can lead to permanent disability, and unusual heavy rainfall (section 5.1.5.5.)Which lead to filling of water in mine and create problems for working in the mine and lead to loss of time. It was observed that no dust suppression measures was used (section 5.1.5.7.) to suppress dust generated by blasting also create visibility problem and affect working for the people situated nearby as the dust is allowed to be blown by air current or to be dissipated in the atmosphere. Use of personal protective equipment was proper (section 5.1.5.7) but if it is not used properly it can lead to serious injury or even a fatality hence because of its consequence it should be looked upon and measures must be taken to control the medium risk events.

In coal mine large number of heavy moving machines were appointed and there were lots of problem related to dust, haulage and machines (section 5.2.5.1. and 5.2.5.4.). There were problems related to road traffic in and out issuers; inappropriate exposure of moving machines; mechanical failure and because of large number of moving trucks and dumpers there is large quantity of dust present in roadways which affects the operators and can lead to accidents causing injury. They are in acceptable range because of precautions measures taken but no step is taken it can cause hazard hence steps should be taken to reduce the hazards such as for dust suppression system should be installed.

Other problems similar problems as that of iron ore mine which were noted in coal mines were that of noise and unusual rainfall (section 5.2.5.6. and5.2.5.7.). Different problems which were seen in the coal mine were the problems because of spontaneous heating (section 5.2.5.8) as the incubation period of the coal present is 35 days and there were usually the problems of stack fire which creates difficulty in loading operations in stacks and lots of mosquitoes were present (section 5.2.5.7) in that area as which affect the human health causing malaria, dengue etc. and causing a person to be hospitalised hence it is also noted in medium risk.

6.2 CONCLUSION

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

From the study carried out in the iron ore and coal mine and the risk rating which were made and analysed shows that the number of high risks in the coal mine were more than that of iron ore mine and same goes for the events in medium risk. The high risks which were present in the iron ore mine were due to the loose rock on the face which can be reduced by proper dressing and supervision and due to the blasting done by an unauthorised person on which administration should take action and the person with proper certificates and appropriate experience should be appointed.

The high risk in the coal mine were due to the fly rock on blasting which can be reduced by the following the steps like planning of round of shots, holes correctly drilled, direction logged, weight of explosive suitable for good fragmentation and to ensure its safe use. The problem due to the operation of large number of transport vehicles which cause lots of noise, dust and may even affect people in an accident so the roads must be properly and evenly spread for safe and comfortable movement of machines and proper traffic signals and boards should be installed over certain distance. Improper use of personal protective equipment can be managed by appointing security specially to check if all are wearing personal protective equipment and if not the entry in the working are should be prohibited. The problem of inundation can be solved by making embankments to prevent mine from flooding and if possibility of happening is high then layout of seam wise working should be developed and anticipate its impact on surface features and structures and if the impact and dangers are excessive re-plan to bring them to minimum possible level.

From the distribution of the risk in different risk groups for both the mine and the present arrangement and working methods it can be said that the iron ore mine is comparatively safer than the coal mine and the arrangements for risks reduction that are to be made are more in coal mine than iron ore mine as it has various more problems like spontaneous heating and inundation which are not there in the iron ore mine but on the other hand in iron ore mine the does not take any action to suppress the dust generated after blasting and is allowed to disperse in atmosphere on its on which creates concentration of suspended solids in air and the dust is spread over large area creating problems to the people living near to the mine are.

CHAPTER 7

REFERENCES

7. REFERENCES

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