An Analytical Accident Investigation Model for the South African Mining Industry

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PRETORIA

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DECLARATION

I declare that this thesis is my own work. It is being submitted on the partial fulfilment of the requirements for the Doctoral Degree in Business Administration to the University of Pretoria. It has not been submitted before for any degree or examination to any other university.

21 April 2003

ABSTRACT

This research set out to develop an analytical accident investigation model for the South African mining industry. Industrial accidents and injuries have notably plagued man since the industrial revolution, when a growing number of workers were exposed to new and dangerous machines in an ever more dangerous work environment.

The main thrust of the thesis is in developing a practical analytical accident investigation model that will provide mines with a managerial tool to establish failure modes by analysing the fundamental contributing factors of accidents. Once a practical analytical accident investigation model is in place, it would contribute to the reduction of the number of accidents on mines.

The research included an in depth literature study of accident investigation techniques used by world-class industrial organisations. Some of the models analysed included various cause and effect models, energy threshold models, probability and risk models, as well as some psychological models.

It was necessary to confirm whether the identified contributing factors, contained in the procedures utilised by multi-national companies and government agencies, should be included in an investigation model. In order to achieve this, the researcher undertook study tours to the USA as well as the United Kingdom.

Confirmation of the academically identified fundamental contributing factors was achieved by means of a questionnaire posted to a sample of middle managers and completed by impartial helpers on behalf of mineworkers during structured personal interviews.

Questions were developed to confirm which of the identified factors should be included in accident investigations. In addition to this, the questionnaire was also

used to determine the importance of relevant accident investigation information to production personnel, in the quest towards safety.

The questionnaire-study confirmed that the established fundamental contributing factors indeed needs to be included in analytical accident investigations. It also established the importance of communicating with managers and workers about accidents and failure modes, in order to prevent accidents and to fulfil their routine obligations.

During the study the traditional accident investigation system as utilised by inspectors of the Department of Minerals and Energy was evaluated.

The elements that comprise the new accident investigation model were transformed into a practical methodology to assist investigators in using the model.

It was established that it would generally not be possible to conduct a detailed investigation into every accident. The decision on the level of detail to pursue should be based on the risk profile associated with the accident or group of accidents. A methodology to objectively make such a decision is presented.

The expected benefits identified in the newly developed accident investigation methodology, were evaluated by practical implementation during a pilot study. The pilot study was also utilised to establish the practical limitations of implementing the model on a scale that may include other industries and more diverse types of accidents.

The results obtained during the pilot study confirmed that it is possible to prevent or reduce occupational accidents and the associated suffering, by implementing appropriate recommendations resulting from the use of this model.

OPSOMMING

Hierdie navorsing het begin met die doel om 'n analitiese ongeluksondersoek-model te ontwikkel vir die Suid Afrikaanse mynbou industrie. Bedryfsongelukke en die gepaardgaande beserings het sedert die Nywerheidsrevolusie deel van die werksomgewing geword. 'n Groeiende aantal werkers is blootgestel aan nuwe en gevaarlike masjiene in 'n selfs meer gevaarlike werksomgewing.

Die fokus van die tesis is om 'n praktiese analitiese ongeluksondersoek-model te ontwikkel wat myne sal voorsien van 'n bruikbare instrument waarmee vasgestel kan word watter fundamentele bydraende faktore sal lei tot ongelukke wanneer dit faal. Sodra 'n praktiese analitiese ongeluksondersoek-model in plek gestel word, sal dit grootliks bydra tot die vermindering van die aantal mynongelukke.

Die navorsing het 'n diepgaande literatuurstudie oor die ongeluksondersoek-tegnieke van wêreldklas ondernemings ingesluit. Sommige van die modelle wat ontleed is, sluit verskeie oorsaak-gevolg modelle, energie-drempel modelle, waarskynlikheids- en risiko-modelle, asook psigologiese modelle in.

Dit was nodig om te bevestig dat die fundamentele bydraende faktore, wat deel vorm van die prosedures van multi-nasionale maatskapye en staatsagentskappe, wel deel behoort te vorm van 'n ondersoek-model. Om dit te bereik, was dit nodig om navorsingsbesoeke na die VSA en Brittanje te onderneem.

Die akademies geïdentifiseerde fundamentele bydraende faktore is bevestig deur middel van vraelyste. Die vraelyste is per pos aan 'n steekproef middel bestuurders versend, terwyl dieselfde vraelyste tydens gestruktureerde onderhoude, deur onpartydige helpers namens mynwerkers voltooi is.

Vrae is ontwikkel om te bevestig watter van die geïdentifiseerde faktore behoort ingesluit te word by ongeluksondersoeke. Die vraelyste is ook aangewend om die belangrikheid van inligting uit ongeluksondersoeke vir bedryfspersoneel te bepaal.

Die empiriese studie, bestaande uit vraelyste, het bevestig dat die fundamentele bydraende faktore gewis deel moet vorm van 'n analitiese ongeluksondersoek. Dit het ook die belangrikheid van kommunikasie aan bestuurders en werkers, met betrekking tot ongelukke en die geïdentifiseerde faktore wat faal, bevestig. Hierdie kommunikasie is noodsaaklik ten einde ongelukke te voorkom en roetine-verpligtinge veilig te voltooi.

Die tradisionele ongeluksondersoek-metodologie wat deur die Departement van Mineraal en Energie gebruik word is gedurende die studie ge-evalueer.

Die elemente waaruit die ongeluksondersoek-model bestaan, is in 'n praktiese metodologie omgeskakel om ondersoekers van hulp te wees tydens die implementering van die model.

Dit is vasgestel dat dit nie normaalweg moontlik is om alle ongelukke tot dieselfde mate van volledigheid te ondersoek nie. Die besluit oor die volledigheid hiervan, behoort op die risiko-profiel van die ongeluk, of groep ongelukke, gebaseer te wees. 'n Metode vir die objektiewe neem van so 'n besluit word voorgestel.

Die geïdentifiseerde voordele wat spruit uit die gebruik van die nuut-ontwikkelde ongeluksondersoek-metodologie is gedurende 'n loodsprojek prakties ge-evalueer. Die loodsprojek is ook gebruik om die praktiese beperkings gedurende die implementering van die model in ander nywerheidsektore en 'n verskeidenheid tipes ongelukke te bepaal.

Die loodsprojek se bevindings het die moontlikheid om ongelukke en verwante lyding te voorkom bevestig, mits toepaslike aanbevelings wat gedurende die gebruik van die model bepaal is, geïmplementeer word.

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This research project would not have been possible without the grace of God, who gave me the necessary wisdom and understanding to complete

this work. I therefore would like to quote the following portion from the Scriptures in recognition to Him.

JOB 28:

1 Men know how to mine silver and refined gold,

2 to dig iron from the earth and melt copper from stone.

3, 4 Men know to put light into darkness so that a mine shaft can be sunk into the earth, and the earth searched and its deep secrets explored. Into the black rock, shadowed by death, men descend on ropes, swinging back and forth.

5 Men know how to obtain food from the surface of the earth, while underneath there is fire.

6 They know how to find sapphires and gold dust-

7 treasures that no bird of prey can see, no eagle's eye observe-

8 for they are deep within the mines. No wild animal has ever walked upon those treasures; no lion has set his paw there.

9 Men know how to tear apart flinty rocks and how to overturn the roots of mountains.

10 They drill tunnels in the rocks and lay bare precious stones.

11 They dam up streams of water and pan the gold.

12 But though men can do all these things, they don't know where to find wisdom and understanding.

THE LIVING BIBLE, 1971, COVERDALE HOUSE PUBLISHERS, ENGLAND

DEDICATION

To Lenél,

Adelein

Ilanie and

Stephan

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An Analytical Accident Investigation Model for the South African Mining Industry

Chapter 1

BACKGROUND AND STATEMENT OF PROBLEM

1.1. INTRODUCTION

Industrial accidents and injuries have notably plagued man since the industrial revolution. Yet the carnage did not attract the attention of managers as a major economic issue until the early 1800s. It was during this time that the industrial revolution exposed a growing number of workers to new and dangerous machines in an ever more dangerous work environment.

In contrast to other sciences, very little concern has been exercised in recording the history of safety practice. According to Guarnieri (1992) accident research only started in the 1900s. The general belief during the 1800s was that alcohol consumption was the primary cause of accidents and this reinforced the deep-rooted Western idea that people were responsible for their own safety and that the injured had to be at least partially blamed for accidents. This 19th century belief appears to be still prevalent in the South African mining industry.

The democratisation of South Africa during 1994 with the election of Nelson Mandela as the President of South Africa was one of the factors resulting in attitudinal changes with industrial accidents and associated injuries becoming more unacceptable to the public, state agencies, public organisations, mining houses as well as the victims and their families.

Following a number of horrific mine accidents involving groups of people at a time, there were again public outcries in South Africa for stricter actions against errant mine managers and owners. Yet prosecution may not prove effective, as this approach may do nothing to eliminate the causes of many accidents. The majority of accidents could be prevented if the basic causes of similar accidents are identified by accident investigation techniques followed by appropriate preventative remedial actions.

In South Africa, as in most other countries, employers are legally responsible, apart from moral concerns, for reducing the risk of accidents and alleviating the suffering of those affected. Already the Mines and Works Act, Act No. 12 of 1911, stated, "the governor-general may make regulations ... in respect of ... the safety and health of persons employed in or about mines..."

The current Mine Health and Safety Act, 1996 (Act No. 29 of 1996) aims to protect the health and safety of persons working at mines and to promote a culture of health and safety in the mining industry.

The continuous upgrading of legislation no doubt had an effect in reducing the number of accidents in South African mines, but according to speakers at the 33rd annual meeting of the United States Risk & Insurance Society during 1995, the best way to alleviate the damage from an industrial accident and to prevent future accidents is to establish a comprehensive accident investigation process.

The South African mining industry is said to be among the most advanced in the world. This statement is valid in many respects, but is not generally true regarding safety and accident investigation.

In an International Labour Organisation (ILO) report (Safety and Health in Mines 1994, no. 51) 19 countries are compared regarding fatal accidents in mining operations, taken on an annual basis between 1989 and 1991. South Africa rated 14th out of the 19 countries, with countries like Turkey, Yugoslavia, Papua New Guinea and Pakistan rated worse.

It is postulated that the relatively inefficient manner in which accident investigations and their results are managed in the South African mining industry, may be one of the major contributing factors to the unacceptably high level of accidents.

1.1.1. THE CURRENT STATE

The accidents reported to the Principal Inspector of Mines in terms of Minerals Act Regulation 25.1.1 in force in terms of Schedule 4 of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996) are recorded in the South African Mines Reportable Accident Statistical System (SAMRASS). This regulation states that *"whenever an accident results in -*

(a) the death of any person;

(b) an injury to any person likely to be fatal

(c) unconsciousness from heatstroke, heat exhaustion, electric shock or the inhalation of fumes or poisonous gas, or any incapacitation normally requiring treatment in a decompression chamber, or

(d) incapacitation from heatstroke, heat exhaustion, electric shock or the inhalation of fumes or poisonous gas which will prevent the affected person from resuming his normal or similar occupation within 48 hours, or

(f) an injury which either incapacitates the injured person from performing his normal or similar occupation for a period totalling 14 days or more, or which causes the injured person to suffer the loss of a joint, or part of a joint, or sustain a permanent disability,

the manager of the mine or the works shall report such accident to the Principal Inspector of Mines."

For the purpose of this research only the accident statistics of coal and gold mines will be utilised to establish the seriousness of the matter under investigation. Reportable injuries in these two sectors represent 89,1% of all reportable injuries while fatalities represent 84,4% of the fatalities in the South African mining industry for 1984 to 1997. As the focus of this investigation is on accident recording, analysis and preventative application of the results, the inclusion of other mining sectors is not regarded as a value-adding exercise.

Bear in mind that in addition to the fatalities and reportable accidents a vast number of other lost time accidents in mines are not reported to the Inspector of Mines under the current regulations. According to studies by Bird and Germain (1996) on 1 753 498 accidents, there were 9,8 reported minor injuries for every major injury that resulted in death, disability, lost time or medical treatment. They did not report the ratio between serious injuries (reportable), as defined by the South African Minerals Act Regulation 25.1.1, and the other lost time or medical treatment accidents. Notwithstanding this, it can be expected that at similar ratio of about 1 to 10 will be found if these definitions are utilised to separate the various accidents by severity.

From the above accident statistics it is clear that the number of accidents in the mining industry is unacceptably high and that a new approach is required to improve the situation.

1.1.2. THE STATUTORY FRAMEWORK

The Leon Commission of Inquiry into safety and health in the mining industry under the chairmanship of Judge Ramon Leon in 1994 identified shortcomings in the Minerals Act, 1991 (Act No. 50 of 1991) which regulated the industry before the promulgation of the Mine Health and Safety Act during 1996.

The Commission concluded that the drastic revision of various Acts in the past that eventually led to the Minerals Act 1991 (Act No 50 of 1991), did not adequately provide for mine health and safety issues. These were confused with the regulation of optimal exploitation of minerals and land rehabilitation issues, although the connection was only tenuous.

As a result of the Leon Commission findings the shortcomings were addressed by embarking upon a new tripartite process to draft the Mine Health and Safety Act, 1996 (Act No. 29 of 1996).

It is notable that the Act distinguishes between investigations and inquiries. Investigations by Inspectors of Mines are provided for under section 60 and inquiries under section 65. In addition, Section 11.5 requires employers to investigate certain accidents at or on the mine and, on completion prepare a report that identifies the causes and underlying causes of the accident of the accident. In addition to this, the employer must also identify any unsafe conditions, acts, or procedures that contributed to the accident, followed by recommendations to prevent similar accidents.

The Mine Health and Safety Act, for the first time in the South African context, recognised that the procedure of investigating accidents could influence the effectiveness of the investigation, hence Section 63(1) that establishes a procedure whereby a certificate of no prosecution may be issued in order to enhance the effectiveness of investigations.

The legislator clearly tried to establish two different approaches, one to identify the causes of an accident and the other to establish responsibility. This research provides a model for investigation only, since establishing responsibility is a legal rather that a managerial pursuit.

1.1.3. COST ASPECTS OF ACCIDENTS

Safety measures always cost money and the employer must foot the bill. A perpetual conflict of interest exists between employer and employee as to the type and magnitude of safety measures that could be considered reasonably practical and reasonable necessary.

The principles of risk assessment as discussed by Marx *et al* (1997), require preventative measures to undergo a cost benefit analysis to establish the required extent to be implemented.

In order to do a reasonable cost benefit analysis it is required to have an idea of the costs per annum associated with accidents in the mining industry.

A study by Marx (1996) using an activity based costing approach to fall of ground accidents indicate that the average cash flow cost to the mine of fatalities caused by falls of ground was R 462 872 while the average cash flow cost of reportable fall of ground accidents was R233 398 in 1994 monetary terms.

Using the above as a basis it would appear that the cash flow cost of accidents to the mining industry in South Africa from 1984 to 1997 amounted to R338,57 billion which gives an average of R 23,04 billion per annum.

The equivalent cost of fatalities and reportable accidents for 1996, using these figures, is calculated to be R1,95 billion. Considering that the total value of minerals sold from South African mines during 1996 amounted to R63,10 billion, according to the 1997 annual publication by the South African Central Statistical Services, the calculated cost of accidents is equivalent to 3.09% of this value.

There is sufficient financial motivation for investigating ways of reducing accidents in the mining industry.

1.2. BACKGROUND

Mining is possibly the world's oldest industry and also one of the most hazardous. Mining differs from almost all other industries in that the work environment continually changes as the work proceeds. Notwithstanding this it is true that the management of mining safety has much in common with safety management in other industries.

One way companies could achieve a competitive advantage is to minimise the cost of industrial accidents by integrating an accident investigation management program into their overall business strategy, according to Powers and Arnstein (1995).

Most modern accident investigation systems aim to determine the causes of accidents in order to prevent them, offer methods of safer design and ensure that risks will be eliminated or minimised by eliminating these causes. The traditional accident investigation approach in the South African mining industry was focused on blame-fixing rather than on these principles. Hermanus and Leger support this view in their submission to the Leon Commission (1993). They found that 65% of the accident investigation reports they examined concluded that the injured or dead person was responsible for the accident.

Preventive measures are seldom identified during accident investigations. In the few cases where preventive measures had been identified during accident investigation, the measures were not implemented in the business strategy of the mine or the industry.

Should this become a matter of course a great number of accidents could be prevented (Hermanus and Leger 1993).

Unreliable accident information is an open invitation to disaster, while good information pertaining to accidents may be used to make a wide range of operational, management and strategic decisions. One of the few practical ways to ensure that accurate accident information is used as a basis for decisions is to undertake in-depth studies of the fundamental contributing factors of accidents.

Accidents mostly result from a combination of factors, which must be present simultaneously or sequentially. An unsafe act or situation does not give rise to an accident until someone is exposed to it and both physical as well as psychological factors, in combination with unsafe work systems, trigger the accident. Combining environmental hazards and human factor hazards multiplies accident potential. The larger the number of hazards, the sooner the accident potential will increase.

1.2.1. Comparison: Gold v. Coal Sector

If one knew what would happen in the future, the outcome of any decision would depend only on how logical and rational the decision was. To manage uncertainty, however, requires a study of the nature of events.

Events may either be dependant or independent. Independent events have no effect on the probability of other related events. A typical example of such independent events is accidents that occur in the gold mining industry versus accidents in the coal mining industry. When a comparison of these two sectors in the mining industry is done that compares the probability of an accident happening in the gold mining sector with the probability of an accident occurring in the coal mining sector the two events are not related and can be viewed in isolation from one another.

Extracts from the statistical summary of accidents (1997) of the Chief Inspector of Mines for these two sectors are reflected in table 2.2 and table 2.3 in Chapter 2 of this thesis.

Significant to this study is the relative performance of the two sectors. A superficial comparison of table 2.2 and table 2.3 indicate that the accident rate in coal mining is significantly lower that that in gold mining.

A number of gold mining managers interviewed during the pre-study believe that this difference can largely be ascribed to the difference in depth of mining in the two sectors. No scientific proof for this claim could be provided.

Depth of mining could influence the number of fall of ground accidents since rock stresses increase with depth. During 1997 however, the injury rate for fall of ground accidents in the gold mining sector was 6,02 compared to the rate of 19,54 for all accidents. This represents a 30,8 % contribution to the total rate.

Coal mining had a fall of ground accident rate of 0.92 during 1997 that represents 18,9 % of the 4.88 total rate. During 1989 this percentage was 27,3 % for coal and 29,2 % for gold mining sector, indicating no significant difference between the contribution of fall of ground accidents in the gold mining sector and the coal-mining sector.

This trend is common for the period from 1984 to 1997 and therefore indicates that depth of mining does not contribute significantly to the total accident rate.

Some other factor or factors must contribute to this difference in accident rates between the two sectors. This researcher is of the opinion that the approach to accident investigations in coal mining is one of the major contributing factors that places managers in that sector in a position to use the results from investigations for accident prevention.

1.3. EXTENT OF RESEARCH

When investigating effective accident investigation and how to manage the results in South African mining it is important to note that the key to successful investigation lies in ascertaining and eliminating the root causes of accidents, rather than in assigning blame to the parties involved. (Woolsey: 1995).

It is envisaged that this may be achieved by replacing traditional approaches of accident investigation in some mining sectors with new methods that focus on fundamental contributing factors rather than apportioning of blame.

This research will focus on investigators and present a model that will provide them with an aid to determine accident causes, and will also ensure that managers and supervisors could utilise the resultant information to prevent similar accidents. The model developed should re-actively identify risks and control measures required to contain risks, as well as to identify pro-active measures by utilising it as a risk assessment tool.

This research will aim to determine how to achieve preventative results from an accident investigation system in the South African mining industry by selecting the best elements from accident investigation techniques in other countries as well as sectors of the local mining industry that are performing well, and then to adapt them to suit the South African mining industry as a whole. These practices and procedures will then be converted into a workable analytical model for conducting accident investigations or pro-active risk assessment procedures.

1.4. FORMULATING THE PROBLEM

1.4.1. FIELD OF RESEARCH

The research in this paper is a subsection of sustainability management. The safety management area of this field will, in particular, be researched.

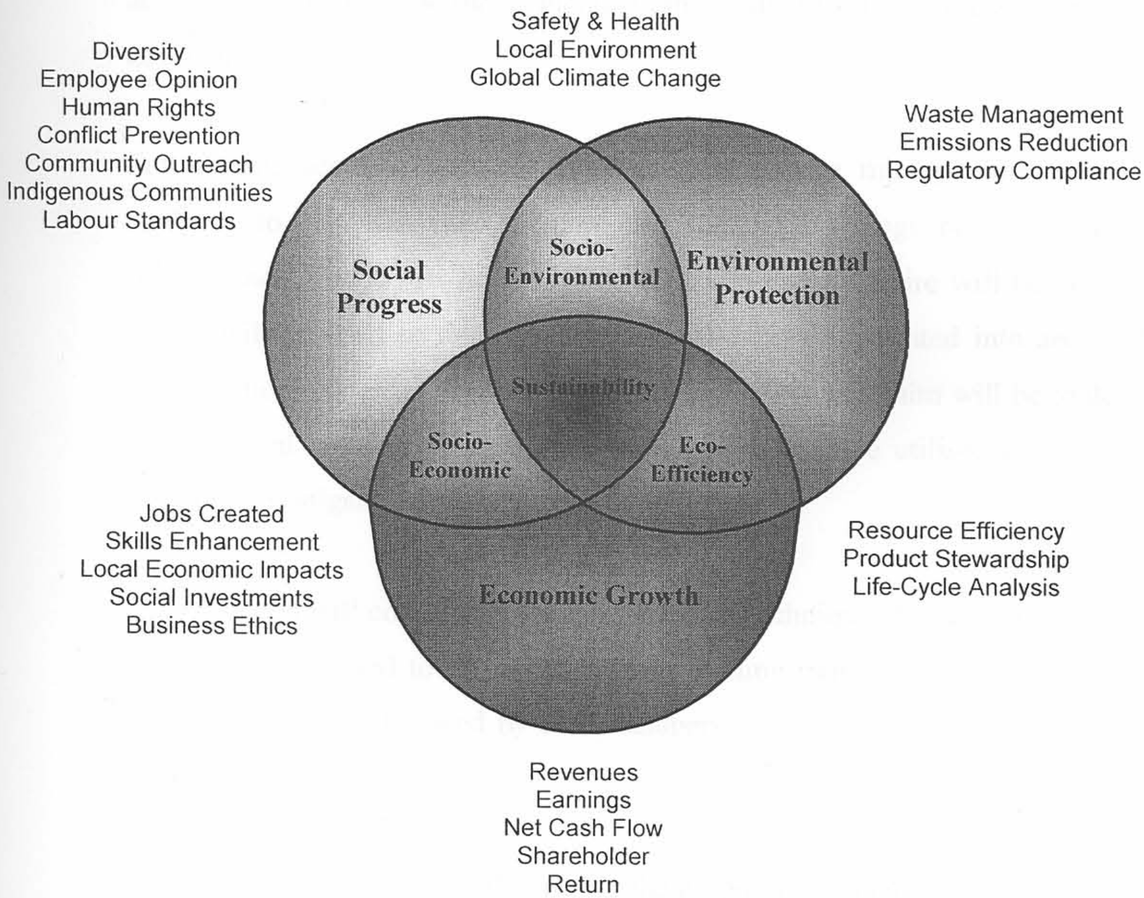


Figure 1.1 - Graphic representation of the main components of sustainability
(Adapted from "Sustainable Reporting Guidelines on Economic, Environmental and Social Performance" by the Global Reporting Initiative Secretariat - June 2000)

With reference to Figure 1.1 depicting the graphic representation of the main components of sustainability, the safety component can be isolated in the sector where environmental protection intersects social progress.

Specific research will be carried out regarding the South African mining industry by adapting world best practice in accident investigation techniques for this industry. To achieve this it is envisaged to establish what is considered nationally and internationally to be the elements of an accident for the purpose of predictive accident investigation.

Further, the accident statistics of the South African mining industry will be analysed to establish two or more comparable groupings based on accident performance. Once this has been established a questionnaire will be developed which will be used to determine what should be incorporated into an accident investigation model for the industry. During the study the aim will be to develop an analytical accident investigation model that could be utilised as a basis for accident investigations.

This research will combine the most successful techniques from around the world in a way best suited to the South African mining industry in a format that will produce results, to be used by line managers and supervisors to prevent similar accidents.

In order to determine ways of applying the proposed accident investigation system, and of applying the results it should generate various existing accident investigation techniques would be identified and evaluated.

Current accident investigation systems will be analysed for effectiveness as well as user friendliness. A selection will be made from the components of the various techniques used and trusted by leading investigators.

To ensure that the complex survey data is correctly interpreted, the results will be evaluated by means of the multivariate analysis technique.

1.4.2. PURPOSE

It is the purpose of this research to develop an analytical accident investigation model for mines in South Africa. This model will then be utilised to develop an accident investigation technique for this industry.

The accident investigation technique so developed will be presented to the Chief Inspector of Mines with the aim or motivating a revision of the current Government Directive (D1) guiding the accident investigation process for Inspectors of Mines. The revision should incorporate the elements of accident investigation identified during this study.

It should be possible to prevent accidents and reduce consequent suffering by implementing the recommendations resulting from the use of the model during accident investigation, into workable solutions.

A proper accident investigation approach would also ensure that a documented, verifiable and repeatable accident prevention programme could be implemented. Current accident investigation systems do not allow this.

During the development phase, the new model will be tested on a number of accidents on different mines, in order to ascertain the practicality of the system. Ideally a pilot programme will be run to verify that the model does achieve the desired results.

1.4.3. RESEARCH METHOD

It is planned to first do an in-depth literature study of accident investigation techniques used by world-class industrial organisations. Elements of the different successful accident investigation techniques will be isolated.

Based on these elements, a questionnaire will be developed, to include all the elements identified in accident investigation techniques.

The results of the questionnaire will then be analysed to establish which of the identified contributing factors should be included in the analytical accident investigation model.

The ideal subject population for the study of an accident investigation system best suited to the South African mining industry would naturally be a group of knowledgeable people. For the purpose of this study the sample will not specifically include mine managers as the author believe that it will prove difficult to get busy managers to spend time on completing lengthy questionnaires, probably resulting in a very low response rate.

The target population from which the sample will be selected will consist of persons accepted as candidates for the Mine Overseer Certificates of Competency as well as the Mine Manager's Certificates of Competency. The reason for selecting this group is that any individual who applies for acceptance as a candidate for a certificate of competency that would limit him/her to work in a specific industry, is committed to that industry.

In addition, the target population is selected from the middle management echelons with at least the following qualifications and experience:

In terms of Minerals Act Regulation 28.18.1 to 28.18.2 a Mine Overseer's Certificate Candidate:

Must have attained the age of 22 years,

Produce evidence of his/her sobriety and general good conduct,

Is the holder of an appropriate permanent blasting certificate and either:

Has at least 4 years practical experience gained in the workings of a mine, or

Holds either a mining engineer's degree, a mechanical or electrical engineer's certificate of competency for mines or any other degree, certificate or diploma acceptable to the Chief Inspector of Mines and has at least 2 years practical experience gained in the workings of a mine.

In terms of Minerals Act Regulation 28.14.2(A) a Mine Manager's Certificate Candidate for the final part of the certificate of competency:

Must have attained the age of 23 years,

Produce evidence of his/her sobriety and general good conduct,

Is the holder of an appropriate permanent blasting certificate and either:

Has at least 5 years practical experience gained in the workings of a mine, or

Holds either a mining engineer's degree, a mechanical or electrical engineer's certificate of competency for mines or any other degree, certificate or diploma acceptable to the Chief Inspector of Mines and has at least 2 years practical experience gained in the workings of a mine.

Although the sampling method will not be perfect, the method used in selecting the group will produce reliable and meaningful results as was found from a similar approach followed by Larrèchè and Montgomery (1997).

According to Caulcutt (1983) the cost of the investigation is normally directly proportional to the sample size while the amount of information obtained from the sample, increase only to the square root of the sample size. It is therefore important to have the optimal sample size that will allow the necessary confidence in the results.

The questionnaires will be sent out under the cover of an official government letter signed by the Chief Inspector of Mines, requesting the selected individuals to submit completed questionnaires. It is anticipated that this approach will increase the response rate substantially.

1.5. STRUCTURE OF THE THESIS

Chapter 1 covers an introduction, a description of the problem as well as an overview of the envisaged research methodology.

An in depth literature study of accident investigation techniques used in world-class companies follows in Chapter 2.

Chapter 3 will consist of a description of the methods used to during the empirical study to verify the information obtained during the literature study. This will be followed by a description of the developing of the questionnaire. A description of the data collection process and the collection plan will complete this chapter.

The interpretation of the results obtained during the empirical investigation will be described in chapter 4.

In Chapter 5 the information obtained during the empirical investigation will be analysed and applied to form an analytical accident investigation model for the South African mining industry. The accident investigation model and a graphical representation of the model are used to explain the interaction of the various components of accident investigations. A detailed description of the steps involved in conducting an accident investigation will also be related.

Chapter 6 describes the results of the pilot study utilising the analytical accident investigation technique based on the model, including the recommendations resulting from it.

Chapter 7 contains the interpretation and evaluation of the results. Conclusions reached during the research process are explained. Recommendations considered necessary conclude the thesis.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

According to the official accident statistics of the past ten years, obtained from the Department of Minerals and Energy, safety performance in the South African mining industry has been static at intolerable levels, if the new risk-based paradigm is utilised as a reference point. While the inevitable year-to-year fluctuations can be distinguished, there has been no discernible downward trend in injury and fatality rates in this decade. This indicates that no real improvement has been achieved in accident prevention by existing approaches. This fact is supported by an analysis of the accident statistics of the South African mining industry. This analysis follows later in this chapter.

Since gold was discovered on the Witwatersrand during 1886 very few major changes have been made to standard mining techniques, according to Futcher, the 1988 President of the Association of Mine Managers of South Africa. The same can be said about the way in which accidents have been investigated during this period.

In this chapter the author will attempt to critically analyse the available literature on accident investigation. To limit misunderstanding, a number of definitions of more important terms will follow. In order to put the research in the correct perspective, a historic overview of accident investigation will be provided. Various recommended accident investigation procedures will be considered and evaluated. A section covering the literature regarding existing accident investigation procedures will follow. Before the elements present in an accident are isolated for further research, the theory of accidents will be reviewed.

This chapter is concluded with a discussion of the perceptions and insights the researcher gained by studying the literature on accident investigations.

2.2 BACKGROUND TO THE RESEARCH

Some of the first recorded organised initiatives to prevent industrial accidents refer to the first factory laws adopted in Great Britain, and shortly after, in the United States of America and other industrialised countries in the 19th century. The first official effort to prevent accidents in South Africa was the promulgation of safety legislation for the mining industry in 1910. The large number of accidents in the industry at that time prompted this legislation, according to Taljaard (1995).

During the past 50 years safety has played an increasingly important role in defining operational standards in industries all over the world. The fact that safety now plays such an important role in legislative and operational standards is a reflection of the demand from society that all activities should be free from risk to the worker or at least kept at tolerable levels of risk according to Makin (1999).

A certain level of risk is inherent in every activity in the workplace. Tolerating some level of risk is necessary, but to protect against unwanted loss such as injury, property damage or production downtime, risks must be eliminated, transferred, controlled or tolerated (ILO convention C 176).

This worldwide trend is emphasised by the fact that the International Labour Organisation (ILO) first accepted a convention (C28) on protection against accidents on 21 June 1929. This convention was aimed at reducing accidents during work performed on shore or on board ships whilst loading or unloading any ship. This convention was revised twice since then, first in 1932 (C32) and again in 1997 (C152). The International Labour Organisation also accepted the following conventions relating to health and safety:

- A convention for safety provisions for buildings (C62) in 1937,
- A convention on the prevention of accidents associated with seafarers (C134) in 1970,

- A convention on occupational health and safety (C155) that applied to all branches of economic activity in 1981,
- A safety and health in construction convention (C167) in 1988,
- A convention on the prevention of major industrial accidents (C174) in 1993,
- A safety and health in mines convention (C176) in 1995.

In addition to these conventions, the International Labour Organisation also accepted a number of conventions dealing with occupational health and occupational medical examinations.

This international emphasis on safety and health is also reflected in the in the South African mining industry new Mine Health and Safety Act, 1996 (Act No. 29 of 1996).

In this Act the emphasis was altered to make it clear that reducing or eliminating risks would improve safety. Design, control or management could be used to reach the desired level of risk reduction for identified hazards. In practice a combination of these approaches is called for.

The decriminalisation of accident investigations was given direction with the inclusion of Section 63 in the Mine Health and Safety Act, 1996 (Act No. 29 of 1996) that attempted to increase the effectiveness of investigations by making it possible for the Chief Inspector of Mines, in consultation with the Attorney General, to issue a certificate of non-prosecution under certain circumstances. Despite the inclusion of this section the inspectors did not make use of it, as there was no formal accident investigation methodology in use in the mining industry that effectively identified the fundamental contributing factors of accidents.

Most industrial accidents result from factors that are constantly present for weeks, months, or even years. It is only a matter of time before the event will occur. This state of affairs urgently needs to be addressed by developing an analytical accident investigation model for the South African mining industry. It is anticipated that knowledge of fundamental contributing factors will influence decision-makers to seek to avoid taking the risk that such events may occur.

In companies where the culture is such that employees are allowed to take risks, it is likely that the attitude towards accidents is that "accidents just happen and there is nothing we can do about it." This type of attitude is not conducive to an effective safety culture. Employers with a healthy attitude towards risk will require the pro active correction of fundamental contributing factors.

To conduct an effective accident investigation, the factors contributing to an accident, as well as ways and means to prevent accidents, must be clearly understood.

2.3 RELEVANCE OF ACCIDENT INVESTIGATIONS TO MINING ACTIVITIES

Safety measures always cost money and the employer must foot the bill. A perpetual conflict of interest exists between employers and employees as to the type and magnitude of safety measures that could be considered reasonably practical and reasonably necessary.

According to Smith (1994:229-234), the long-term future of the South African gold mining industry is largely dependent on the effective extraction, in terms of safety and financial returns, of deep level ore reserves. Should either of these factors not be achieved, the long-term future of the South African gold mining industry may be jeopardised.

It is with the above in mind that a method needs to be developed to establish and isolate the fundamental contributing factors of accidents on mines. Once these factors are known, it would be possible to implement pro-active preventative actions. In addition it would also become possible to focus the risk assessment procedure on the factors identified during accident investigations.

2.4 PREVAILING ACCIDENT INVESTIGATION METHODOLOGY

Mining is probably the world's oldest industry and considered one of the most hazardous. Mining differs from almost all other industries in that the working environment continually changes as the work proceeds. Notwithstanding this, the management of mining safety has much in common with safety management in other industries.

One way mines can achieve a better competitive advantage is to control the cost caused by workplace accidents. This can be achieved by integrating an appropriate accident investigation management program into an overall business strategy, according to Powers and Arnstein (1995).

Most modern accident investigation systems aiming to determine factors contributing to the recurrence of accidents in order to prevent them, offer methods of safer design to ensure that risks will be eliminated or minimised by eliminating contributing factors. The traditional accident investigation approach in the South African mining industry is focused on blame-fixing rather than on these principles. Hermanus and Leger (1993) support this view in their submission to the Leon Commission of Inquiry into safety and health in the mining industry.

South African government mining inspectors investigate all fatal accidents and a large portion of other accidents. The procedure they follow is guided by means of a Chief Inspector of Mine's Directive (D1).

The inspector has to visit the scene of a fatal accident and collect information that would assist during the inquiry. In the majority of the cases the inspector requests the mine's surveyor to measure the area and produce a plan. During this so-called in loco inspection all stakeholders have the right to attend.

From interviews with inspectors and the experience this researcher gained during the investigation of more than one hundred and fifty accidents over nine years, utilising this system, the information that witnesses supply at the scene differ vastly from those given under oath, especially when someone was potentially implicated. The information obtained during informal interviews is not "admissible" during the formal part of the inquiry as the witness is said not to have been under oath.

The formal part of the inquiry is structured in a quasi-legal format where the inspector swears in witnesses and takes down statements from all persons associated with the accident. These statements are taken down in the presence of everybody involved in the accident. Any person present has the opportunity to cross-question the witness. But workers are often not willing to make statements that could implicate their seniors for fear that they may loose their jobs.

Very seldom are preventive measures identified during the accident investigation. In the few cases where preventive measures are identified, no evidence could be found that these measures were implemented in the business strategy of the mine or the industry.

In order to enhance the effectiveness of accident investigations, Section 63 (1) of the Mine Health and Safety Act empowers the Chief Inspector of Mines to decriminalise investigations held in terms of Section 60 of the Act by issuing a certificate of non-prosecution.

In the author's opinion, punishment should never be inflicted as the result of an accident investigation. Such action is shortsighted and counterproductive. Many more productive avenues exist to address shortcomings identified during accident investigations.

During this research some arguments against linking punishment with accident investigations will be presented. This researcher supports the decriminalisation of accident investigation, as this will ensure that the correct information is obtained for analysis.

According to Hermanus and Leger reporting to the Leon Commission (1993), should preventive measures be implemented as a matter of course, a great number of accidents could be prevented.

Unreliable accident information is an open invitation to certain disaster. Information pertaining to accidents may be used to make a wide range of operational, management and strategic decisions. One of the few ways to be sure that the accident information used as a basis for decisions are accurate, is to do an in-depth study of the fundamental contributing factors.

Accidents mostly occur as a result of a combination of factors, which must all be simultaneously or sequentially present. An unsafe act or situation does not give rise to an accident until someone is exposed to it and both physical and psychological factors, in combination with unsafe systems of work, trigger the accidents. Combining environmental hazards and human factor hazards multiplies accident potential. The larger the number of hazards, the more the accident potential will increase.

All the risks that were taken in leading up to an accident have to be evaluated during the investigation. The evaluation should result in identifying the inadequacies in the safety management programme, the standard procedures as well as non-compliance to standards.

2.5 ACCIDENT STATISTICS

The following analysis of accidents in the South African mining industry clearly places the relevance of this type of research in context.

The reportable accidents for all mines in South Africa for the period 1990 to 1997 are summarised in table 2.1, which is an extract from the statistical summary of accidents published annually by the Chief Inspector of Mines (1997). The statistical data is obtained from the South African Mines Reportable Accident Statistics System (SAMRASS).

The accidents statistics for coalmines for the same period is reflected in table 2.2 while the goldmine accident statistics are reflected in table 2.3. The statistics for all other mines such as platinum, diamonds, iron ore etc. combined makes up the difference between the totals, when compared with the totals reflected in the all-mines accident statistics table.

The first of the six columns indicates the year for which the statistics are reported. The columns titled "fatalities" and "injuries" reflect the number of persons fatally injured or reportably injured for each corresponding year. The columns labelled "fatality rate" and "injury rate" indicate the number of fatal injuries per 1 000 employees at work.

The rates are calculated by means of the following formula:

$$\textbf{Injury/fatality Rate} = \frac{\textit{Number of injuries/fatalities X 1000}}{\textit{Employees at work}}$$

The column labelled "Labour" indicates the average number of employees at work for each of the years in the table.

With reference to table 2.1 it can be seen that a total of 4 325 persons lost their lives and that 66 384 persons were reportably injured in the mining industry over this period. During the reporting period the number of persons reported to be at work dropped from a high of 697 658 during 1990 to a low of 483 981 during 1997.

The fatality and injury rates indicate the true change over the years, normalised against the number of employees at risk.

Table 2.1 - REPORTABLE ACCIDENTS: ALL MINES 1990 TO 1997

YEAR	FATALITIES	FATALITY RATE	INJURIES	INJURY RATE	LABOUR
1990	684	0.98	9 830	14.09	697 658
1991	602	0.95	9 058	14.24	636 096
1992	551	0.94	8 795	15.00	586 333
1993	586	1.08	8 524	15.66	544 317
1994	482	0.95	7 934	15.71	505 029
1995	533	1.02	7 717	14.76	522 832
1996	463	0.94	7 426	15.00	495 067
1997	424	0.88	7 100	14.67	483 981
Total	**4 325**		**66 384**		

The number of injuries seem to indicate a constant decline from 1990 (9 830 injuries) to 1997 (7100 injuries), an apparent improvement of 27,8 %, but this would be a complete misinterpretation as the employees at work, and therefore at risk, reduced from 697 658 to 483 981 over this period.

Had the number of employees at work stayed the same from 1990 to 1997 the injuries during 1997 would have been 10 225. The facts represent a deterioration of 4 % in the injury performance for this period.

One should therefore take cognisance of the number of injuries/fatalities in order to evaluate how well an industry is performing in accident prevention, as well as the number of persons exposed to the risk of being injured/killed. The injury/fatality rate is one way of taking cognisance of both these factors.

The discussion of the difference between the specific safety achievements of the gold and coal mining sectors respectively, on page 9 of this thesis, requires further discussion.

The reportable accidents for all mines in South Africa for the period 1990 to 1997 are summarised in table 2.1, which is an extract from the statistical summary of accidents (1997) published annually by the Chief Inspector of Mines. The statistical data is obtained from the South African Mines Reportable Accident Statistics System (SAMRASS).

The accidents statistics for coalmines for the same period are reflected in table 2.2, while the goldmine accident statistics are reflected in table 2.3. The statistics for all other mines such as platinum, diamonds, iron ore etc. combined, make up the difference between the totals of coal and gold and the totals reflected on the All Mines table (table 2.1).

An analysis of the accident trends in the two sectors clearly indicate that the fatality rate in the gold mining sector improved from a rate 1.25 per thousand per annum in 1990 to 0.95 in 1997. (table 2.3) This translates to a 31.57% reduction in the rate. On the other hand, the coal mining fatality rate worsened from 0.53 in 1990 to 0.72 in 1997 (table 2.2) which is a 35.85% regression.

In addition to this, the 1993 rate of 1.57 is worse than the worst of the gold mine performance (1995 – 1.27) in the period under review. This particularly bad performance in 1993 can be ascribed to the Middelbult coal mine disaster that occurred in that year. The injury rates tells a similar story with a regression of 17.31% for coal mining and only 1,72% for gold mining for the same period. Considering that gold mining is a labour intensive industry with very little mechanisation, compared to coal mining where the labour force are much lower and mechanisation much higher, the efforts of the gold mining industry is paying better safety dividends.

Table 2.2 - COAL MINES - ACCIDENT DATA 1990-1997

YEAR	FATALITIES	FATALITY RATE	INJURIES	INJURY RATE	LABOUR
1990	51	0.53	400	4.16	96 154
1991	43	0.48	370	4.09	90 465
1992	46	0.65	358	5.04	71 032
1993	90	1.57	279	4.87	57 290
1994	54	0.96	240	4.26	56 338
1995	31	0.53	235	4.00	58 750
1996	45	0.79	285	4.79	59 499
1997	40	0.72	270	4.88	55 328
Total	**400**		**2437**		

Table 2.3 - GOLD MINES - ACCIDENT DATA 1990-1997

YEAR	FATALITIES	FATALITY RATE	INJURIES	INJURY RATE	LABOUR
1990	531	1.25	8 183	19.21	425 976
1991	461	1.21	7 531	19.80	380 354
1992	407	1.13	7 587	21.04	360 599
1993	426	1.23	7 368	21.34	345 267
1994	371	1.08	6 888	20.00	344 400
1995	415	1.27	6 243	19.13	326 346
1996	319	1.06	5 911	19.57	302 044
1997	279	0.95	5 710	19.54	292 221
Total	**3 209**		**55 421**		

2.6 DISCUSSION OF TERMS

In order to conduct accident investigation properly, some critical terms from the literature and the appropriate laws and regulations should be clarified. In the next section some of the more critical terms will be discussed and explained. It is the aim of the researcher to endeavour not only to supply definitions, but also to explain the terms for the purposes of this research.

The explanations results from interpretations and a combination of explanations from a number of sources listed in the references. The words and phrases may have other meanings in general or scientific use, but for the purpose of this research the meaning of these words will be as explained below.

2.6.1 ACCIDENT v INCIDENT

In publications such as Loss Control Management by Bird and Germain (1996) and National Occupational Safety Association (NOSA) publications, the term incident is used in preference to accident. In order to ensure consistency the following references have been consulted.

The South African Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) defines the term **incident** in Section 24 (1) to include:

> *"Any person who dies, becomes unconscious, suffers the loss of a limb or part of a limb or otherwise becomes ill to such a degree that he is likely to die or suffer a permanent physical defect or likely to be unable for a period of at least 14 days either to work or to continue with activities for which he was employed or is usually employed."*

Despite the definition used by this Act, no other reference could be found of incident having a meaning that includes injury to people.

The following sources all support the use of the term accident whenever injury to people are meant:

The ILO convention concerning the prevention of major industrial accidents adopted on 22 June 1996 (Convention C174:3) states the following:

> *For the purposes of this convention the term major* ***accident*** *means a sudden occurrence such as a major emission, fire or explosion in the course of an activity within a major hazard installation, involving one or more hazardous substances and leading to a serious danger to workers, the public or the environment, whether immediate or delayed.*

Article 5 (2) of the ILO convention concerning safety and health in mines that were adopted on 22 June 1998 (Convention C176:3) requires national laws and regulations to provide for:

> *(c) The procedures for reporting and investigating fatal and serious* ***accidents****, dangerous occurrences and mine disasters, each as defined by national laws or regulations;*
>
> *(d) The compilation and publication of statistics on* ***accidents****, occupational diseases and dangerous occurrences, each as defined by national laws or regulations;*

In Chapter 16 of the Canadian Workplace Safety and Insurance Act, 1997, the use of the term accident for work-related injuries indicate that Canada makes extensive use of the term accident and does not utilise the term incident at all.

The US military standard MIL-STD-882C dealing with system safety program requirements dated 19 January 1993, defines the term mishap or accident to be:

An unplanned event or series of events resulting in death, injury, occupational illness, or damage to or loss of equipment or property, or damage to the environment.

The British Standard with the title "Guide to occupational health and safety management systems" BS 8800:1996 defines the following terms:

Accident:

Unplanned event giving rise to death, ill health, injury, damage or loss.

Incident:

Unplanned event which has the potential to lead to accident

The occupational health and safety assessment series OHSAS 18001:1999 draft 4 dated 18 February 1999 defines the terms as follows:

Accident:

Undesired event giving rise to death, ill health, injury, damage or other loss.

Incident:

Undesired event, which has the potential to lead to accident.

The USA code of federal regulations part 30 (Mineral Resources) defines **accident** extensively in section 50.2 (g). In summary the term is defined to include death and injury to an individual as well as a number of conditions that relate to loss without injuries being associated with the condition. The term incident is not found in this legislation.

The definition of accident, included in the US Federal Government Employees Compensation Act, is interpreted by the appeal commission to encompass both accidental cause and accidental result.

The Queensland Mines Regulation Act of 1964 as in force on 21 March 1997 does not define the term accident, but from Section 39(4) it can be concluded that a reportable accident is an accident that has resulted in loss of working time by any person on or about the mine.

The Victorian (Australian) Accident Compensation Act of 1985 does not define the term accident but from the text it is clear that injuries are compensated by this Act indicating that the term accident is acceptable.

The South African Mine Health and Safety Act, 1996 (Act No. 29 of 1996) does not specifically define the term accident but it is extensively used throughout the Act.

In the light of the above, it is clear that there is overwhelming evidence for the use of the term accident when an event results in the death, ill health or injury to workers. In cases where property damage and/or loss is referred to, most agree that the use of the term incident is acceptable.

For the purpose of this research the term accident will therefore be used and will include the meaning of incident. The motivation for this is that the research will focus primarily on accidents resulting in the death, ill health or injury to workers.

Based on the above definitions obtained from the literature the researcher developed the definitions below.

2.6.2 ACCIDENT

An occupational accident can be described as follows:

The final event in an undesirable, unexpected and unplanned event sequence that interrupts an activity, and directly or indirectly results in immediate or delayed injury or illness to an employee, and may or may not result in property damage or loss in production.

The definition utilises certain words that could have different interpretations and it is therefore necessary to define some of these terms.

2.6.2.1 FINAL EVENT

The final event is the simultaneous, interconnected, cross-linked occurrence that takes place when the last of the fundamental contributing factors interact dynamically with other contributing factors in a four-dimensional space-time continuum.

2.6.2.2 FUNDAMENTAL CONTRIBUTING FACTORS

A fundamental contributing factor is a feature or condition required before and/or during an accident that plays a part during the dynamic interaction of the fundamental contributing factors in such a way that it plays a primary part in the accident sequence.

2.6.3 ACCIDENT INVESTIGATION

An accident investigation is the first step in a fact-finding process aimed at avoiding future accidents. It should determine what, why and how the accident happened. Its purpose should not be to blame someone. A good accident investigation will establish the failure modes of the fundamental contributing factors.

Appropriate accident investigations often confirm that many small, less serious accidents occurred earlier as a result of similar system failures. An accident investigation offers the chance to learn a great deal about the fundamental contributing factors present during an accident and thereby increase the opportunity to intervene in the interest of safety. To be useful, accident investigations must be an honest attempt to establish the facts.

2.7 RISK ASSESSMENT AND ACCIDENT INVESTIGATION IN CONTEXT

Risk Assessment as defined in the South African mining context is the pursuit of managing the future safety of workers. It involves a detailed and systematic examination of any activity, location or operational system to identify risks, understand the likelihood and potential consequences of the risks, and review the current or planned approaches to controlling the risks, resulting in the instituting of additional controls where required.

Successful risk control can include outcomes such as improved safety, health, production, environmental protection or community acceptance.

From this explanation it is clear that essentially there are no differences between the accident prevention risk assessment and accident investigation processes as both aim to prevent unwanted incidents and both have the same components: hazard identification, consequence or impact, controls and failure modes. The consequence or impact stems from hazards being realised. Controls are active management interventions to eliminate or reduce the risks. Failure modes are the primary reasons for controls failing.

Despite the similarities in the two processes some procedural differences do exist. The main distinction is the timing within the management cycle of activation. Risk assessment occurs at the beginning of a management system cycle (pro-active) and accident investigation occurs after accidents (re-active) in the management cycle. However, the information contained in the outcome of accident investigations is fed into the risk assessment process and the cycle is repeated. A graphic representation of the main components of the two processes is given in Figure 2.1.

Accident investigation has a defined re-active outcome (specific information after a once-off activity) as opposed to risk assessment that pro-actively attempts to prevent incidents.

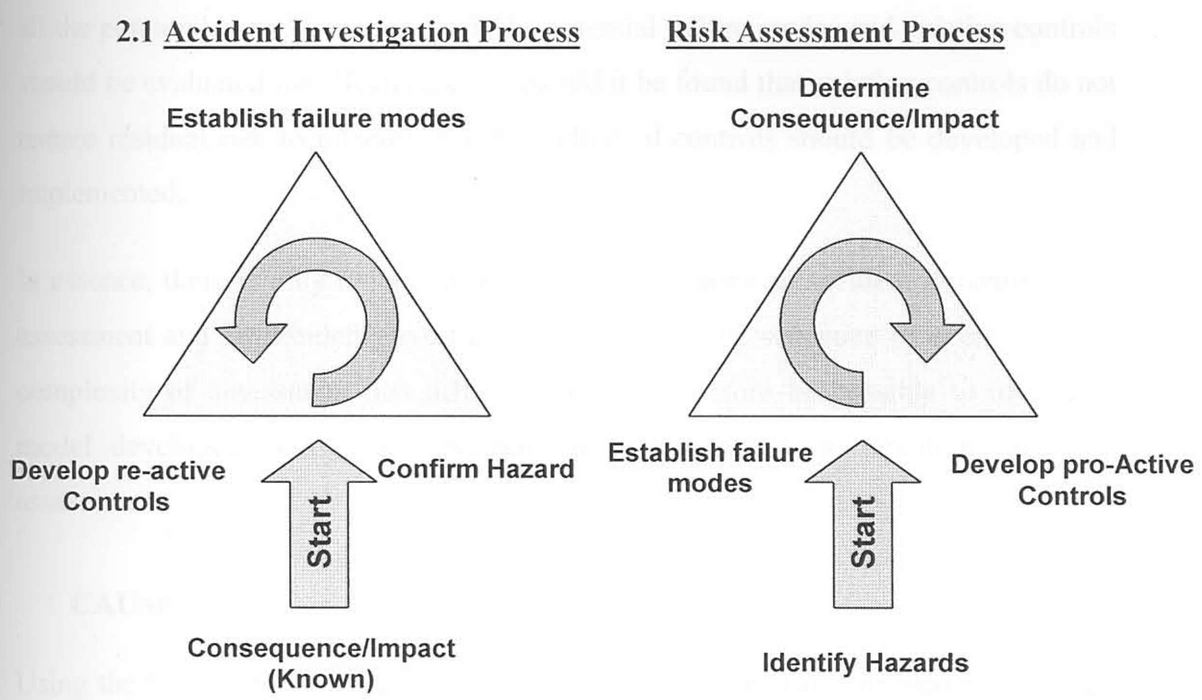


Figure 2.1: Accident investigation and risk assessment processes in context

During the accident investigation process (left triangle in Figure. 2.1) the starting point is after the impact when the consequences are known. The first step is to confirm the hazard responsible for the accident. The next step is to determine the failure modes in order to reactively develop additional controls to prevent a re-occurrence. Since the consequences are known it is reasonably easy to identify the hazards. The challenge is to correctly identify the failure modes and then develop control measures to eliminate, minimise or control the risk at source, as personal protective equipment should only be issued in response to risks remaining after instituting controls.

A risk assessment process (right triangle in figure 2.1) starts before the impact and potential consequences are known. The first step is therefore to identify the risks in each step of the process. The next step is to identify the potential failure modes for all the identified hazards. The aim of this process is to identify and ascertain the consequences pro-actively to develop controls that will prevent the various potential failure modes. It goes without saying that this process is much more complex since all the potential consequences and all the potential failure modes and existing controls should be evaluated for effectiveness. Should it be found that existing controls do not reduce residual risk to tolerable levels, additional controls should be developed and implemented.

In essence, there is only a very small difference between an accident prevention risk assessment and an accident investigation. It is only the sequence of events and the complexity of assessment that differ. It would therefore be possible to utilise the model developed during this research for both accident investigations and risk assessment.

2.8 CAUSE

Using the term cause as an exclusive reason for an accident is criticised by Saunders (1991). They are of the opinion that there are no accidents with a single cause and that the expression should be seen as a general term, including many factors related to the occurrence of an accident.

From the Western Australian Department of Minerals and Energy accident and incident investigation manual (1997) it is clear that they are also of the opinion that accidents mostly occur as a result of a combination of factors which must simultaneously or sequentially be present. They go further to state, "an unsafe situation does not give rise to an accident until someone is exposed to it" and conclude that both physical and psychological factors, in combination with unsafe systems of work, result in accidents.

According to the USA Department of Energy's workbook on conducting accident investigations (1997), during all accidents human consideration or a human-made object, or both, play a significant role. They continue to state that generally any accident can be attributed to a human activity or response. This researcher is of the opinion that this wide definition of "human factors" in accidents will continue to contribute to incorrect approaches during accident investigations that seek to establish blame during accident investigations.

Combining environmental hazards and human factor hazards, would multiply accident potential. The larger the number of hazards, the quicker the accident potential will increase, according to Curtis (1995).

According to the Workers Compensation Board of British Columbia's Worksafe publication, Investigation of Accidents and Diseases: An Overview (1996) the multiple factors associated with accidents include unsafe acts, personal factors, unsafe environmental conditions, unsafe acts by other persons and deficiencies for which others are responsible.

In a work environment several levels of barriers may be used in an effort to prevent accidents. Accidents occur when one or more barriers in a work system, including procedures, standards and requirements intended to control the actions of workers, fail to perform as intended, according to the U S A Department of Energy's workbook on conducting accident investigations (1997). Barriers that protect objects against loss can be physical barriers such as machine guards, administrative barriers such as procedures and policies, and supervisory or management barriers such as work instructions, line management supervision and effective communication strategies.

According to Minerisk Africa (1998) an accident is the result of a combination of parallel and sequential events and conditions, again indicating that accidents are deemed to be the result of multiple factors.

The factors contributing to an accident are equated to the fable about the straw that broke the camel's back, according to Kuhlman (1977). He is of the opinion that each straw contributed as much as the last one. The last substandard act in an accident sequence tells very little by itself. All the risks tolerated in the lead-up to the accident have to be evaluated during the investigation. The evaluation should result in identifying inadequacies in the safety management programme, in standard procedures as well as shortcomings in compliance with standards.

According to Albert Einstein (1961) the world we live in is a four-dimensional space-time continuum and therefore this researcher is of the opinion that it is important that equal significance be allocated to physical and temporal dimensions when isolating factors underlying or contributing to accidents.

From the above it is clear that most leading authors on accident investigation are in agreement that no accident can be attributed to one single factor.

This researcher supports the view that an accident will always be the result of multiple factors interacting, but strongly recommends that the use of the term cause or causes, in so far as it relates to accidents, be replaced by the term contributing factors. This may assist in establishing a caring culture not focussed on apportioning blame.

Where existing literature refers to cause or causes of accidents it is taken to refer to fundamental contributing factors. This researcher will therefore refrain from using the term cause or causes of accidents in the thesis.

2.9 SAFETY MANAGEMENT SYSTEMS

The main objective of any safety management system should be to support better management decision-making that will lead to improved safety outcomes for the workforce, in addition to indirect management benefits that may result. A correctly implemented safety management system can be used to improve the safety performance of any organisation by utilising improved control and accountability mechanisms.

An effective safety management system will include the setting of safety objectives as well as performance review against those objectives. In a safety management system, performance may be measured by using simple and transparent indicators as well as more complex measurement systems. Measurement should however always be from the point of view of the safety of workers and the impact of potential accidents on efficiency, effectiveness, service quality and financial results.

All parts of a safety management system are based on good management principles and it is increasingly seen as an integrated part of daily management activities, rather than isolated from these.

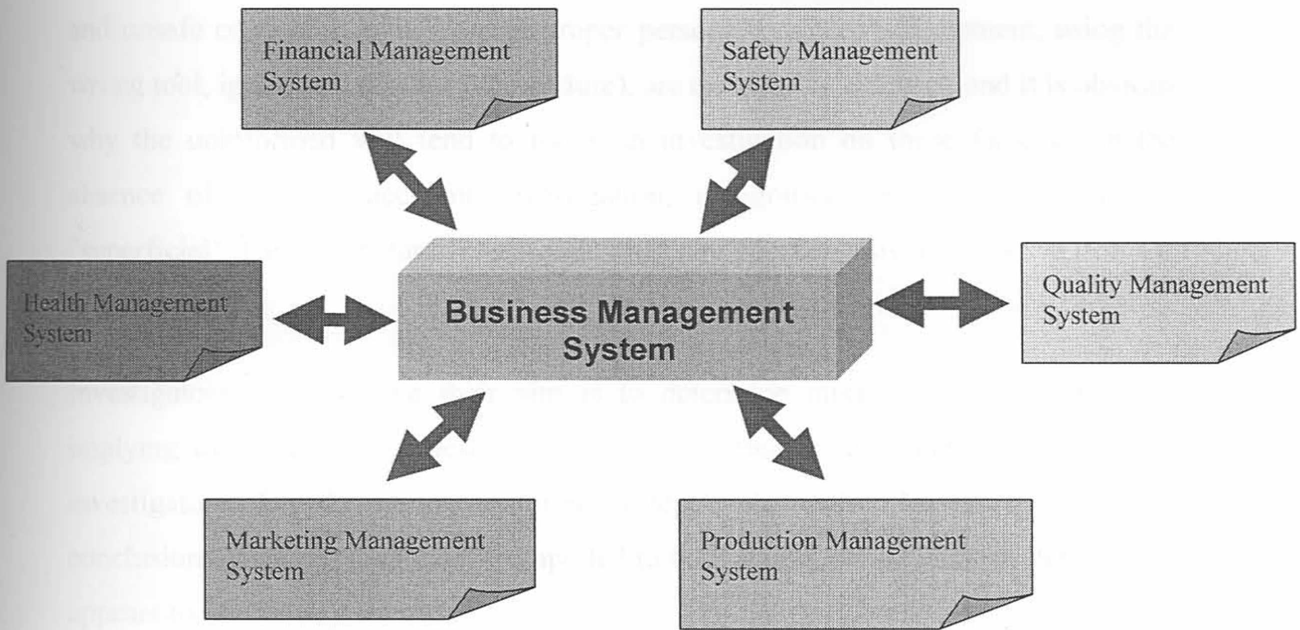


Figure 2.2 – The relationship between a safety management system and other management activities in a business management system. (Adapted from The South African Excellence Model)

2.10 THE EFFECT OF A BLAME-APPORTIONING CULTURE

Accidents are symptoms of problems within an organisation. By addressing only these symptoms, a company may find itself with an accident rate intolerable to all. Accident prevention methodologies focussed only on the symptoms are doomed. Proper accident investigation is the primary tool to establish the information required to effectively reduce accidents on a fundamental level. According to the American Society of Safety Engineers (1999) a punishment-orientated culture ignores this information and is counterproductive to effective accident investigations.

Rather than punishing, management should try to determine what motivates employees to act unsafely, or why workers do not understand what they are supposed to do. Managers often settle for punishment because it is easier than searching for fundamental contributing factors.

The focus of the so-called immediate or proximate causes, often called unsafe acts and unsafe conditions (not wearing proper personal protective equipment, using the wrong tool, ignoring established procedure), are on tangible elements and it is obvious why the uninformed will tend to focus an investigation on these factors. In the absence of in-depth accident investigation, recognition of these symptomatic, "superficial" factors, naturally suggests that the worker was responsible for the accident.

Investigators often believe their aim is to determine unsafe acts and conditions, implying that uncovering these will expose the reasons for accidents. Therefore, investigators often do not pry for more in depth information, leaving them to base conclusions on superficial data. Compelled to take action, punishment of the "guilty" appears to be the only solution.

Another general problem is agitated supervisors who want to complete the accident investigation as soon as possible. Punishment is normally the way of least resistance.

According to Bakker, Chief Inspector of Mines of South Africa, accident investigations should be performed to ascertain the reasons for accidents in order to establish and implement appropriate remedial action(s) to prevent a recurrence (Personal interview, January 1998).

According to Minerisk Australia (1995), accidents frequently occur as a result of deficiencies in the management system and as such they decrease performance and production. This publication informs that accidents should be used as a window through which the existing management system is viewed. The deficiencies revealed and benefits derived should go far beyond rectification of the so-called immediate causes of the accident. The investigation needs to identify the areas where managers or supervisors have unsuccessfully assumed responsibility.

In Practical Loss Control Leadership (1996), Bird and Germain describe Ferdinand Fournie's survey of 4 000 managers, supervisors and company presidents. Thirteen factors were cited for subordinates' failures to follow rules, most of which were not "punishable offences." Clearly, workers who face "obstacles beyond their control, ... think they are performing a task properly" or are "personally unable to do it", do not deserve punishment (Bird and Germain 1996: 423-425).

Management should strive to correct management systems. Inappropriate management systems normally do not anticipate or discover factors before they contribute to accidents. It is believed by some, that with few exceptions, accidents are ultimately the result of management system failures, not employee infractions. This researcher believes that this is too simplistic an approach and that a combination of factors contributes to accidents.

The outcomes of many modern industrial accident investigations do not achieve the desired effect, as the focus is limited to establishing only some of the fundamental contributing factors. Some systems in use maintain a focus on establishing blame.

In many cases, management or the authorities utilises an investigation system that only lends itself to punishing the so-called "guilty party", who may well already have experienced personal injury.

To achieve some sense of justice for a breach of standard or regulation, this type of investigation is still justified by the ill informed.

On many mines the employees involved in causing accidents are still being suspended, demoted, dismissed or otherwise punished for the "crime" of being involved in occupational accidents, according to Speir and Richard (1998).

Invariably companies complain about ineffective or unsatisfactory accident investigation programmes. In the author's opinion, they are doomed to repeat the same investigation for the same transgression again and again, with no hope of resolving the fundamental contributing factors that may lead them to preventing future accidents. The tragedy is that these firms mean well, they are trying to gain control over the factors contributing to accidents, but do not understand enough about accident prevention theory to react properly.

2.11 ACCIDENT INVESTIGATION TECHNIQUES

In this section some of the more typical accident investigation techniques will be discussed individually with a view to evaluating and extracting the best parts from each. The factors so isolated will be combined to develop an analytical accident investigation model for the South African mining industry.

2.11.1 HEINRICH'S TRIANGLE

According to Heinrich, (1980), a well-managed loss control strategy provides an operational strategy that contributes to the improvement of overall management. While Heinrich's triangle is illustrative of the ratio of types of accidents, it implies that the same contributing factors are at work throughout the triangle. Of course, this cannot be the case. Despite being a groundbreaking publication for the era, the basic approach has many flaws and cannot be implemented without major changes.

The triangle clearly indicates that a very specific ratio exists between various levels of severity. This can be very useful when analysing accidents, however, it does not provide any failure modes that may be utilised during pro-active prevention activities.

In Figure 2.3 Heinrich's triangle depicts the ratio between various levels of accident severity. This clearly indicates that every serious or major injury is preceded by ten minor injuries and thirty property damage accidents. Heinrich established no explanation of the reasons for the accidents, and therefore this cannot be viewed as a formal investigation method. The ratios established does however provide invaluable information to investigators regarding accidents that may be unreported.

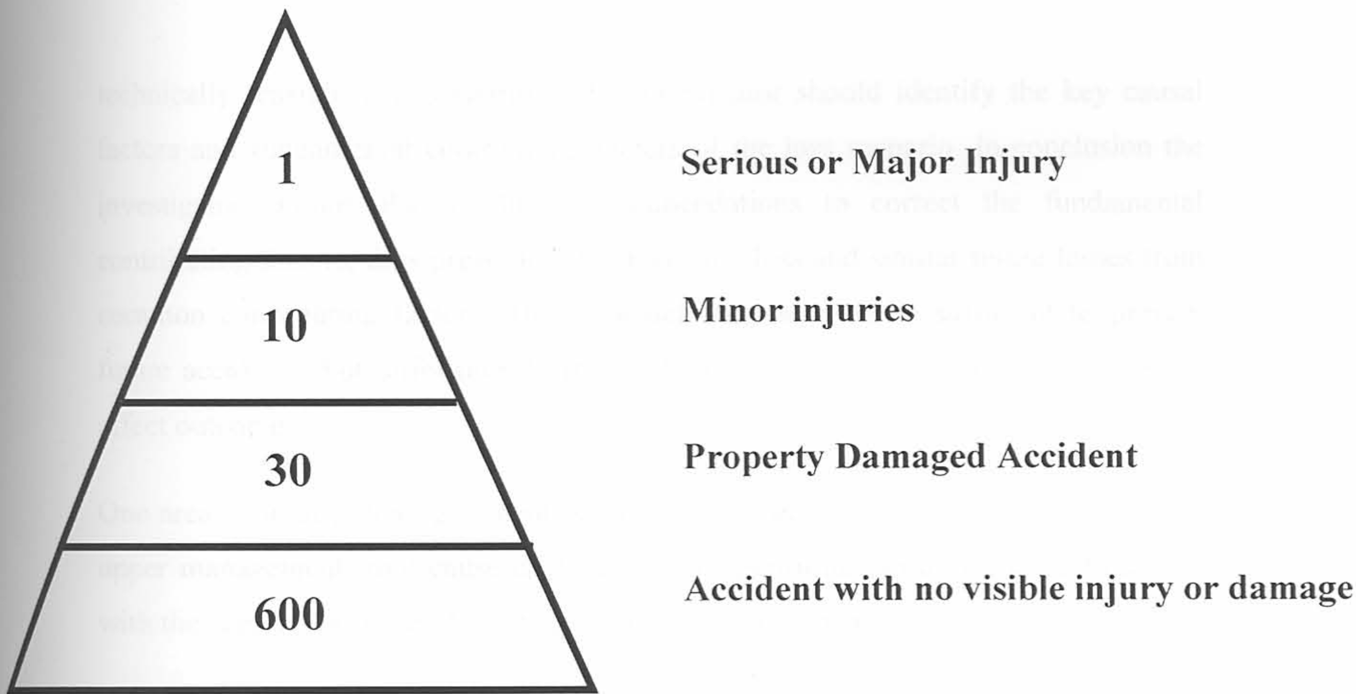


Figure 2.3 - Heinrich's triangle depicting the ratios between the various levels of accident severity.

2.11.2 ROOT CAUSE ANALYSIS

One of the more modern types of accident investigation systems is the root cause analysis, sometimes called the root cause failure analysis. The procedure consists of a set of processes through which the underlying causes of adverse outcomes may be identified. The goal of the investigation is preventing the reoccurrence of such events, according to the United States of America's Joint Commission on Accreditation of Health Care Organizations (JCAHO) (1996).

There are many different processes by which root cause analyses can be performed and the engineering and industrial risk management literature is rife with arguments for and against the different approaches. It is not the purpose of this research to explore those differences.

Root Cause Analysis is designed to systematically evaluate the possible ways that a loss (or series of losses) could have occurred. During the process the investigator collects and arranges factors in such a way as to rule out possibilities and develop a technically feasible loss scenario. The investigator should identify the key causal factors and fundamental contributing factors of the loss scenario. In conclusion the investigator should also produce recommendations to correct the fundamental contributing factors, thus preventing the recurring loss and similar future losses from common contributing factors. This approach may seen to be sufficient to prevent future accidents, but unfortunately the methodology focuses only on a singe cause-effect outcome.

One area of undisputed agreement is the observation that without strong support by upper management, root cause analyses will be performed in a mechanical manner, with the singular purpose of meeting regulatory requirements.

Most real-world events do not follow a simple cause-effect trail. A single factor may have multiple consequences. A combination of factors may bring about a single result, or they may initiate multiple effects. Causes can themselves have causes, and effects can have subsequent downstream effects. The failure mode should also be considered in all of these models.

2.11.3 FAULT TREE ANALYSIS (FTA)

Fault tree analysis is a widely used method in analysing the behaviour of failures in complex systems and is a method used in estimating the probability of occurrence for a particular failure mode. The main purpose of fault tree analysis is to evaluate the probability of a top event using analytical or statistical methods. This approach is most useful when several factors play a role in the occurrence of the failure mode.

Fault tree analysis is a systematic method of analysing contributing events that may lead to accidents. Fault trees can be used to determine the probability of failure of a system (or top event), to compare design alternatives, to identify critical events that will significantly contribute to the occurrence of a top event and to determine the sensitivity of the probability of a top event to the contributions of various fundamental events.

Fault trees describe a sequence of events that lead to system failure. The leaves of the tree can be used to represent the initial causes of the accident (Leplat, 1987). The author would however rather refer to the network of roots of a tree as this more accurately describes the network of events leading to an accident. The logical dependencies at each level of the tree is specified by using so-called AND and OR gates. The AND gate (Indicated by the symbol  in figure 2.4) indicates that the output occurs if only if all of the input events occur. The OR gate (Indicated by the symbol  in figure 2.4) indicates that the output occurs only if at least one of the input events occur. Basic tree nodes can make reference to any dependability model element such as LRU class, hardware configuration, reliability graph, embedded fault tree, or Markov model. Reliability and availability values are calculated for each node and logic gate and are expressed as probability numbers. In figure 2.4 these values are reflected on each of the nodes and logical gates. Vesely *et al* (1981).

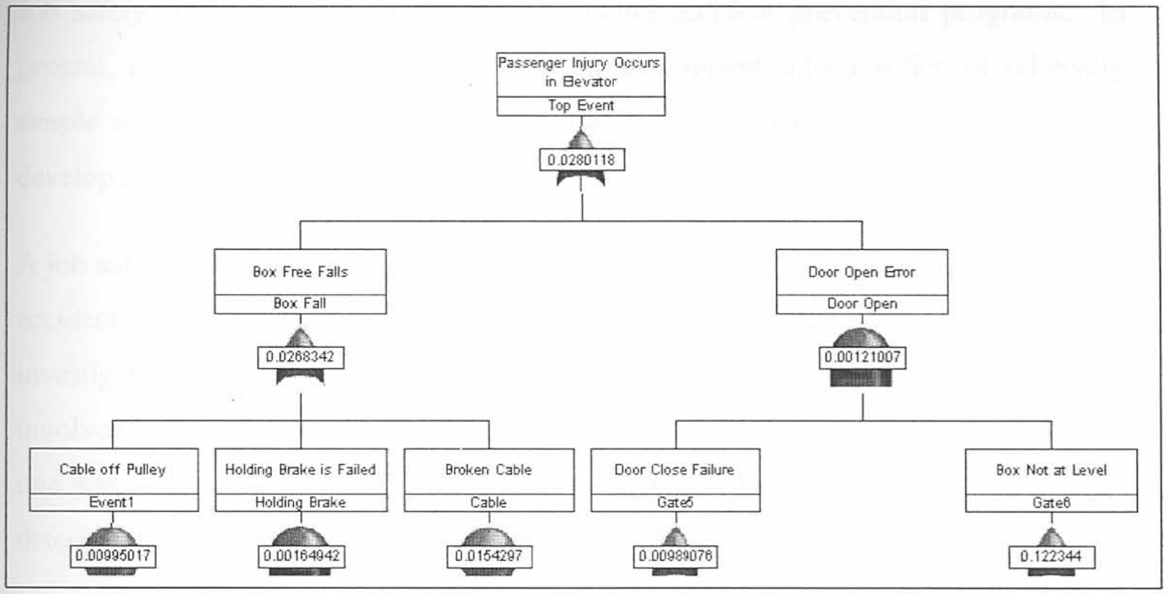


Figure 2.4 – Typical layout of a fault tree with NODES as well as AND & OR gates.

This author is of the opinion that the major disadvantage of fault tree analyses is that it does not recognise fundamental contributing factors as independent contributors to accidents. The fault tree approach is a quantitative system only aimed at establishing the probability of an accident re-occurring rather than establishing failure modes.

2.11.4 CHANGE ANALYSIS

As its name implies, this technique emphasises change. To solve a problem, an investigator must look for deviations from a norm. The investigator must consider all problems that could result from some unanticipated change.

This system requires that an analysis of changes be made to determine the potential consequences, thereby identifying the contributing factors.

Change analysis is an attempt to determine deviations from a pre-determined norm or standard, however, the system fails to provide the investigator a framework on where to expect deviations, according to Bird and Germain (1996).

2.11.5 JOB SAFETY ANALYSIS (JSA)

Job safety analysis forms part of many existing accident prevention programs. In general, it separates a specific job or work assignment into a series of relatively simple steps and then identifies the hazards associated with each step in order to develop solutions to control each hazard.

A job safety analysis consists of a chart listing these steps, hazards and controls. The accident investigation requires the review of the job safety analysis during the investigation, provided that a job safety analysis has been conducted for the tasks involved in an accident. This implies that a job safety analysis should be performed if one was not available. A job safety analysis therefore forms part of an investigation determining the events and conditions that led to the accident.

The main aim of a job safety analysis is to prevent accidents by trying to anticipate and then eliminate the associated hazards. This may be possible in an environment where the jobs and work assignments are well described and reasonably standard, however, in the mining industry the jobs and work assignments are of such a diverse nature that the use of this system will be very difficult to implement (National Safety Council, 1994).

2.11.6 SYSTEMATIC CAUSE ANALYSIS TECHNIQUE (SCAT)

The Systematic Cause Analysis Technique (SCAT) is a method that has been developed by the International Loss Control Institute (ILCI), which can be used to determine the root causes of an incident once a description of the sequence of events has been determined. (International risk control Africa – undated)

The systematic cause analysis technique is based on a five-step fault tree that leads the investigator through a set of pre-determined questions. The yes/no questions are designed so that the investigator is led to a next set of questions. In the first step the investigator is required to collect evidence in five categories, namely people evidence, position evidence, paper evidence, parts evidence and re-enactment of the accident.

Once the evidence has been collected, this step requires the investigator to evaluate the loss potential if the accident is not controlled. This is one of the few accident investigation models that attempt to introduce risk assessment principles into the investigation, however, the loss potential or severity of an accident used here, is only one of the factors considered during a typical risk assessment.

Step two of the investigation requires the investigator to identify the agency from a list of general agencies such as equipment, machinery, electricity or explosive devices, to mention only four of the twenty-five common agencies. If the agency cannot be found here, a further list of sixteen occupational hygiene agencies, that include dust, fumes, noise and radiation, can be consulted. This would appear to be an attempt to identify the energy source, however, some of the general agencies given here cannot be classified as energy sources.

In step three the investigator is required to identify the so-called immediate or direct causes from two lists, one for sub-standard acts and the other for sub-standard conditions. These lists respectively contain twenty-one and sixteen options and include items such as "operate equipment without authority" and "use of unsafe/sub standard equipment" under acts, with "inadequate warning systems" and "sub-standard material" under conditions.

Step four requires the investigator to identify the so-called underlying or basic causes of the accident. In this step the system divides the underlying/basic causes into three categories namely personal factors, job factors and natural factors. The investigator is required to answer a list of two hundred and one questions in thirteen categories.

It is unclear why the system differentiates between the so-called immediate or direct causes and the so-called underlying or basic causes. It would appear that the system attempts to try and isolate more than one contributing factor by differentiating in this way.

During step five the investigator is required to identify control actions needed. The guiding questions take the investigator back to the safety management system elements and require him to make recommendations that will impact on these.

2.11.7 HAZARD AND OPERABILITY STUDY (HAZOP)

The operability study was developed for use in the chemical and petroleum industries. It is based on the theory that most hazards are missed because the system is complex, rather than a lack of knowledge during design. Operability studies identify hazardous or unacceptable situations, according to Knowlton (1985).

Hazard analysis provides a quantitative examination of a serious hazard that has been identified, either by an operability study or by some other hazard identification method. It quantifies the effect of hazards as well as unacceptable situations.

During hazard and operability studies (HAZOP) the two methods are brought together, according to the hazard and operability studies training manual published by International Risk Control Africa under licence of Det Norske Veritas of Sweden.

During hazard and operability studies the plant is examined line-by-line, vessel-by-vessel. The participation of a team of process experts is necessary to evaluate the consequences of hazards that may result from various failures or errors they have identified.

2.11.8 STRUCTURED WHAT IF CHECKLIST (SWIFT)

The Structured What If checklist study technique has been developed as an efficient alternative to the hazard and operability studies for providing effective hazard identification, when it can be demonstrated that conditions do not warrant the rigor of a hazard and operability study.

According to Dougherty (1999) the What If analysis is a structured brainstorming method of determining what could go wrong and judging the likelihood and consequences of those situations occurring. The answers to these questions form the basis for making decisions regarding the tolerability of the risks. This is then used in determining a recommended course of action for the risks judged to be intolerable.

The Structured What If checklist is a comprehensive, methodical, multidisciplinary team orientated analytical technique. It is also a system-orientated technique, which scrutinises complete systems or sub-systems. The Structured What If checklist system relies on a structured brainstorming effort by a team of knowledgeable process experts with complementary questions from a checklist.

When responding to all the questions about reasonable variations from the normal, planned function of a process unit, the team considers the probability of an accident, the possible consequences and the adequacy of safeguards to prevent it. The questions that may be posed by members of the team are structured according to specific categories.

This technique relies a great deal on the experience and insight of the assessment team and if all the appropriate What If questions are not asked, this technique can result in an incomplete conclusion and miss some significant hazards.

2.11.9 FAILURE MODE AND EFFECTS ANALYSIS (FMECA)

The failure mode and effects analysis discipline was developed in the United States military. The military procedure MIL-P-1629, titled "Procedures for performing a failure mode, effects and criticality analysis", dated 09 November 1949 is believed to be the first document describing this process. It was used as a reliability evaluation technique to determine the effect of system and equipment failures. Failures were classified according to their impact on mission success and personnel/equipment safety.

A failure mode and effects analysis is a bottom-up approach utilised to analyse the design of a product or process. The process starts by defining the bottom levels of the system. For each bottom level activity, a list of potential failure modes is generated. Effects of each potential failure mode are then determined.

Unfortunately this system only focuses on system and equipment failure and does not address the potential impact of management failure on the probability of an accident.

2.12 INVESTIGATION PROCEDURE

According to Minerisk Africa (1998), accident investigation procedure requires an impartial investigation team who utilises a systematic, logical and thorough process. They also advocate the use of systems safety analytical techniques to reveal what happened and why.

The International Risk Control Africa hazard and operability studies training manual (1994) requires that hazard and operability studies are embarked upon through the use of formal, systematic and critical examinations of process and engineering intentions of a process design. They also expect that a team with the required technical experience be utilised.

The procedure that Kuhlman (1977) supports is a controlled, methodical process of examination to ascertain how, when, and where an accident took place, aiming to establish why the accident occurred. He identifies four sub-systems to be examined, namely people, equipment, material and the environment.

The University of South Australia (1995) also promotes the use of a team to investigate accidents. Their process involves the inspection of the accident scene, the interviewing of witnesses, the collection of physical evidence and the review of relevant policies, work procedures, workplace inspection reports, maintenance records, etc. In addition to this they also advise on the recording of environmental conditions.

The Western Australian Department of Minerals and Energy's Accident and Incident Investigation manual (1997) states that accident investigation procedures need to be systematic.

They are also of the opinion that the investigation should identify trends, problem areas, basic factors that contributed directly and indirectly to the accident, and deficiencies in the management system. Their procedure allow for teams as well as individuals to investigate accidents. Accidents are categorised by making use of a risk matrix where probability and consequence are used to establish the number of investigators to be involved.

The most important part of any accident investigation is an investigation plan, according to Bird and Germain (1996). In order to ensure effectiveness a pre-developed organisational procedure is encouraged. They further advise that successful investigations will include at least six common activities. These are:

- Go to the accident scene as soon as possible
- Collect pertinent information about the accident
- Analyse all significant contributory factors
- Develop and implement remedial actions
- Review the findings and recommendations on the next level of leadership
- Follow up on the implementation and effect of remedial steps.

The US Department of Energy (1997) prescribes a specific process for conducting accident investigations, including specific tools and techniques that need to be followed under these main sections:

- Appointing the investigation board
- Implementing site readiness
- Managing the accident investigation
- Collecting data
- Analysing data
- Developing conclusions and judgements of need
- Reporting results.

It is clear that there is no consistency in investigation procedures by the different authors, but there is consensus that a systematic procedure should be followed.

A factor neglected by most accident investigation systems in use, is an objective methodology to ensure that resources are allocated appropriately to investigate accidents.

2.13 THE ELEMENTS OF AN ACCIDENT

After careful consideration of the different existing models that try to isolate individual elements of accidents, the researcher came to the conclusion that not one of the existing accident investigation methodologies adequately addresses the issue.

The most appropriate way to conduct an accident investigation will be to isolate fundamental contributing factors based on an analytical accident investigation model for the South African mining industry.

A review of what different authors have to say about fundamental contributing factors will be verified by means of a questionnaire that will be sent out to a broad spectrum of role-players in the mining industry.

A number of the accident investigation systems analysed above do not attempt to isolate fundamental contributing factors, however the study of these systems assist in ensuring that all bases are covered.

Analysing the accident investigation systems that do aim to isolate fundamental contributing factors, the following factors are present in one way or another (mostly hidden), in at least one of the methodologies:

- Who was at fault
- Substandard physical conditions
- Imperfect procedures
- Latent design defects of the equipment or the mine layout
- Breakdown in communication
- Energy source
- Hazardous materials
- Safety management system failure
- Training deficiency
- The policy of the mine
- Inappropriate maintenance
- Unsuitable task directives
- Human factors
- Environmental factors
- Engineering factors
- Unsafe acts
- Barrier failure

The relevant importance of each of these fundamental factors will be confirmed by using a questionnaire. The results obtained are evaluated in Chapter 3 of this research.

2.14 CONCLUSION

Despite the use of highly complex investigation procedures, some investigators still come to the conclusion that the injured are responsible for their own demise.

It is a well-known fact that flawed accident information can prompt the wrong management decisions. If management makes a decision on information they believe to be true, but in reality the information is not a true reflection of the facts, it will most certainly lead to more accidents in the long run.

Unreliable accident information is an open invitation to certain disaster. Information pertaining to accidents may be used to make a wide range of operational, management and strategic decisions. One of the few ways to be sure that the accident information used as a basis for decisions are accurate is to do an in depth study of the fundamental contributing factors of accidents.

Incorrect safety information can place any organisation on a crisis course from which it may never recover. This may lead to problems the organisation can ill afford in today's competitive environment. It may focus line management on the wrong priorities resulting in them solving problems in the incorrect priority.

Enterprises the world over suffer enormous losses as a result of accidents. To survive and develop in a very competitive world market, losses must be prevented as far as possible (NOSA:1995).

Notwithstanding the existence of numerous accident investigation methodologies discussed and described in the literature, not one of these successfully convey what should be done in order to permanently eliminate the fundamental contributing factors, since they fail to instruct the investigator on the importance of these factors.

Accidents are deemed to represent problems primarily associated with management systems, that must be solved through accident investigation. Several formal investigation procedures are recommended to solve problems of varying degrees of complexity. These systems will only have the desired effect if they identify the fundamental contributing factors correctly in order to recommend appropriate remedial action.

Sadly most accident investigations fail to uncover the fundamental contributing factors as the investigation is terminated once the investigator believes that a "cause" was determined.

In the next chapter the methodology followed during the empirical investigation will be discussed.

Chapter 3

THE EMPIRICAL INVESTIGATION - METHODOLOGY

3.1. BACKGROUND

There are three major differences between scientific and non-scientific research identified by Boyd et al. (1989:23-37). They are of the opinion that the objectivity of the investigator, the accuracy of the measurement and the degree to which all pertinent facts are considered, distinguishes scientific from non-scientific research. Objectivity is the extent to which the researcher bases judgements on facts and not on preconceived sentiments or intuition. Accuracy of measurement differs widely, depending on the field of research. It is also important to keep in mind that business research is typically less exhaustive than research in science.

The researcher complied with the requirements set out by Barzun and Graff (1985:56-59) that include a love of order, accuracy, a logical approach, honesty, self-awareness and creativity to ensure objectivity.

The validity and reliability of an empirical investigation are authenticated by the scientific accountability of the researcher. Validity is said to be an attribute of research methods that measure what they claim to measure. Reliability, on the other hand, is an attribute of research methodology that allows any researcher to repeat the procedure with the same or very similar results (Gregory and Ward 1974).

3.2. THE DATA LIFE CYCLE

According to Lehtonen and Pahkinen (1995), their data life cycle model, depicted in figure 3.1, consists of three steps, namely planning, implementation and assessment. This data life cycle model was utilised as the basis of the empirical investigation part of this research.

Lehtonen and Pahkinen (1995) explain that during the planning phase a systematic planning procedure should be used to define quantitative and qualitative criteria for determining when, where, and how many samples (measurements) should be collected to a desired level of confidence.

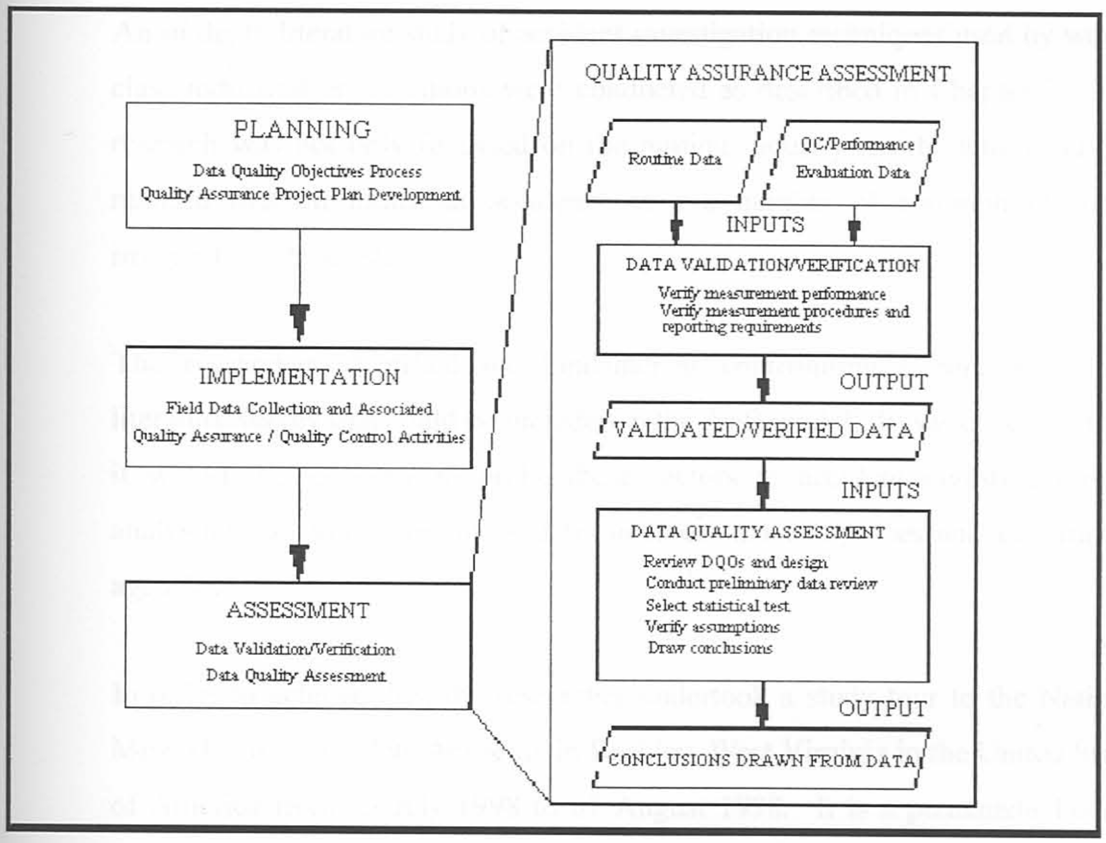


Figure 3.1 - Data life cycle (from LEHTONEN and PAHKINEN 1995)

This information, along with the sampling methods, analytical procedures, and appropriate quality assurance and quality control procedures, must be documented in a Quality Assurance Project Plan. Data is then collected following the Quality Assurance Project Plan specifications. Carrying out the assessment needed to determine if the planning objectives were achieved completes the data life cycle process.

During the assessment phase, the data is validated and verified to ensure that the sampling and analysis protocols specified in the Quality Assurance Project Plan were followed, and the measurement performed in accordance with the criteria specified in the Quality Assurance Project Plan. The researcher then proceeds using the validated data set to determine if the quality of the data is satisfactory.

3.3. CONFIRMING THE DRAFT MODEL

An in depth literature study of accident investigation techniques used by world-class industrial organisations were conducted as described in Chapter 2. This research was not only focussed on the mining industry, as the author quickly realised that all industrial accidents have a number of common elements, irrespective of industry.

The researcher identified the fundamental contributing factors during the literature survey that could be included in the draft model. It was concluded that it would be necessary to probe these factors in accident investigations by analysing the procedures utilised by international companies and government agencies.

In order to achieve this, the researcher undertook a study tour to the National Mine Health and Safety Academy in Beckley, West Virginia in the United States of America from 13 July 1998 to 07 August 1998. It is a permanent Federal academy responsible for training the mine safety and health inspectors and technical support personnel of the Mine Safety and Health Administration.

During this visit the researcher interviewed the accident investigation lecturers at the academy as well as specialist accident investigators from the Washington DC Federal Inspectorate. The researcher was also requested to present a lecture on the conclusions of his literature survey to advanced accident investigation students.

The legal system utilised in the United States of America for regulating occupational health and safety, is based on the principle of specific compliance. This implies that the owner of the mine has to specifically comply with each and every specification contained in the Act. By utilising this type of legislation the legislator prescribes, in detail, to the owner how safety and health should be achieved.

In contrast to this, the South African Mine Health and Safety Act is based on the principle of placing a duty of care on the owner. This type of legislation is outcomes-based and prescribes what should be achieved while leaving the method/s up to individual mines.

Despite the fact that the basic legal systems differ, the elements present in accidents are the same, irrespective of the country where the accident occurred.

The system utilised by the United States Department of Mines to conduct investigations into accidents has a two-tiered approach. During this process two independent investigations are conducted in parallel. The one investigation aims to determine the elements contributing to the accident in order to prevent future accidents, while the other, called a special investigation, aims to determine culpability under the Act. In practice, to two investigations are totally isolated from one another and are conducted by different government agencies to ensure that the different goals can be achieved.

Interviews with members of the agency responsible for special investigations contributed very little to this research, as the aim of this research is to develop an accident investigation system that will focus on establishing fundamental contributing factors. The interviews however, confirmed that this aim would not be achieved in an investigation environment where prosecutions are a possible outcome.

The interviews with the other accident investigators confirmed without a shadow of a doubt that the elements identified from the literature should indeed be included in accident investigations.

In addition to the study tour to the USA, the researcher interviewed and discussed fundamental contributing factors with the Chief Inspector of Mines from the United Kingdom Health and Safety Executive, Mr Brain Langdon, during a study tour of the United Kingdom.

The legal system in use by the United Kingdom for regulating occupational health and safety is based on the principle of the duty of care placed on the manager of the mine. In the South African mining industry the duty of care is statutorily placed on the owner of the mine.

During the same study tour of the United Kingdom, from 27 January to 12 February 1999 the theory was also discussed with Mr HC Evans and Mr RJ Cole, both Principal Inspectors of the Health and Safety Executive and Mr G Goodlad, a Principal Inspector of Engineering of the Health and Safety Executive. All confirmed the usefulness of the inclusion of the said fundamental contributing factors in accident investigations.

The theory was also discussed with Mr David Brown, Health and Safety Director British Petroleum, and other members of the Health and Safety division in London who also supported the inclusion of these fundamental contributing factors in accident investigations.

The above study tours confirmed that the fundamental contributing factors isolated during the literature study should be included in the questionnaire developed for the research.

3.4. DEVELOPING OF THE QUESTIONNAIRE

Most modern investigation systems require the investigation of unsafe acts and unsafe conditions. In general these techniques only broadly describe what is meant. A number of the more modern models identify that the energy source is of importance during investigations. Most systems analysed during the research are based on a time line approach. This approach was found to be extremely limiting during investigations utilising any of the recognised accident investigation systems. This led the researcher to conclude that a different methodology would be required to remove some of the more serious stumbling blocks created when utilising a time line approach.

Some of the more important models analysed include:

Various cause effect models,

Energy threshold models,

Probability and risk models, and some

Psychological models.

All the models analysed were found to be true to the claims made by their authors. The author believes, however, that none of them truly identify the fundamental contributing factors of accidents and that a different approach would be required to achieve this.

It was established that all accident investigation systems focus on trying to determine the cause or causes of accidents. This approach has a basic conceptual problem in that, if causes of accidents are to be determined, it implies that accidents are not unplanned events but brought about events.

An accident is generally defined as an unexpected, unplanned and undesirable event that results in harm to people, damage to property or breakdown of production systems or something very similar (MIL-STD-882C, BS 8800:1996 and OHSAS 18001:1999).

The definition of an accident as developed by this researcher (chapter 2 page 31) is:

> *The final event in an undesirable, unexpected and unplanned event sequence that interrupts an activity, and directly or indirectly results in immediate or delayed injury or illness to an employee, and may or may not result in property damage or loss in production.*

The definition use terms that may need further explanation:

FINAL EVENT

The final event is the simultaneous, interconnected, cross-linked *occurrence that takes place when the last of the fundamental contributing factors interact dynamically with other contributing factors in a four-dimensional space-time continuum.*

FUNDAMENTAL CONTRIBUTING FACTORS

A fundamental contributing factor is a feature or condition required before and/or during an accident, that plays a part during the dynamic interaction of the fundamental contributing factors in such a way that an accident results.

This definition conforms to the basic principles contained in most definitions given to accidents. It excludes "causes" and therefore it is concluded that any "accident" that was "caused" can no longer be called an accident.

The Concise Oxford Dictionary of Current English (1995:208) gives the following meaning for the word cause.

> ***Cause*** *n. & v.* • *n.* ***1 a*** *that which produces an effect, or gives rise to an action, phenomenon, or condition* ***b*** *a person or thing that occasions something* ***c*** *a reason or motive; a ground that may be held to justify something (no cause for complaint).* ***2*** *a reason adjudged adequate (show cause).* ***3*** *a principle, belief, or purpose which is advocated or supported (faithful to the cause).* ***4 a*** *matter to be settled at law* ***b*** *an individual's case offered at law (plead a cause).* ***5*** *the side taken by any party in a dispute.* • *v.tr.* ***1*** *be the cause of, produce, make happen (caused a commotion)* ***2*** *(foll. By to + infin.) induce (caused me to smile; cased it to be done).* □ ***cause and effect 1*** *a cause and the effect it produces; the doctrine of causation.* ***2*** *the operation or relation of a cause and its effect* ***in the cause of*** *to maintain, defend, or support (in the cause of justice).*

Not any of the explanations in this section align with the notion that an event sequence was interrupted, resulting in loss, further supporting the notion that an accident investigator should not be focussing on trying to determine the "cause" or "causes" of accidents.

As the focus of the research is on accidents and not on some other entity that results in harm to people, damage to property or breakdown of production systems, it was determined that a new paradigm is required when trying to analyse accidents with the aim to prevent them.

For this reason it is considered more appropriate to focus on the identification of the fundamental contributing factors of accidents. Once this paradigm shift is made, it is quite easy to conduct an analysis of the existing models and extract the appropriate fundamental contributing factors utilised by each of the systems analysed, while eliminating the search for causes.

Based on the in-depth literature study of accident investigation techniques and having confirmed the draft model as used by world class mining and industrial organisations and government agencies, a questionnaire was developed to confirm the importance of the identified fundamental contributing factors to conduct effective accident investigations.

The questionnaire, which is included as annexure "A", consisted of three sections.

Section 1 consists of 13 questions developed to establish which issues of importance should be established during accident investigations. These questions were developed to confirm which of the factors should be included in accident investigations. Question 14 was included in order to establish the ranked importance of each of the factors and the open-ended question 15 allowed any other factors deemed necessary for inclusion in the accident investigation process to be reported on by the respondents.

Section 2 consisted of ten questions designed to determine how effective information regarding accident investigations are utilised by production personnel to improve safety and one open ended question to determine any other important issues.

Section 3 of the questionnaire consisted of seven demographic questions designed to establish the demographic profile of the respondent in order to effectively subdivide the respondents into the various subgroups included in the study.

In sections one and two the 5-point Lickert scale was selected for the respondents to record their view by indicating their choice with an X in the appropriate box. In addition to the 5 choices a 6th choice namely "No opinion" was provided as an option to prevent respondents to leave out any response. It was also included in an effort to reduce the central tendency normally associated with a 5-point scale. It was expected that the inclusion of this option would improve the useable returned questionnaires.

3.5. THE SAMPLE

According to Smit (1993:16-19) research is a method to obtain insight and knowledge, to describe observed phenomena, to arrange it in an understandable way and to explain it. In order to ensure that the research findings are sustainable he states that the sample should be representative and of sufficient size to truly represent the population.

According to Caulcutt (1983:53), the cost of conducting research is normally directly proportional to the sample size while the amount of information obtained from the sample, only increase to the square root of the sample size. It is therefore important to use the smallest possible sample size that will allow confidence in the results obtained.

The size and magnitude of the questionnaire was taken into account when the physical design was made as the questionnaire was posted to 858 management representatives and 388 mine workers were interviewed giving a total of 1 246 persons potentially participating in the study.

To be representative the sample had to contain respondents from the management echelons as well as from workers, spread across the three main commodity types being mined in South Africa. To this end six sub-groupings were identified as follows: coalmine management, goldmine management, platinum mine management, coalmine workers, goldmine workers, platinum mine workers.

3.6. THE DATA COLLECTION PROCESS

It was anticipated that during this research process, the researcher would encounter a combination of quantitative and qualitative data derived from the same research instrument. The relationship between the type of research method used and the type of data that was obtained during the process was carefully separated to ensure accuracy of interpretation.

The data collection process was conducted in a two-phased approach. The first phase consisted of postal questionnaires sent to persons from the middle management echelons of the mining industry. The second phase of the study had the intention to capture the views of the mineworkers. Conducting structured interviews with mine workers were utilised to complete the questionnaires on their behalf.

This phased approach was decided upon, as it was necessary to get the views of a vertical slice of employees in the mining. As a large part of the lower level workers is functionally illiterate it was necessary to provide assistance in the completion of the questionnaires. Personal experience of the researcher in the mining industry guided him to decide that structured interviews will be best suited for this purpose, while postal questionnaires would be best suited for the management component of the sample.

3.7. THE COLLECTION PLAN

In order to ensure that the collection of data could be completed in a reasonable time it was decided to create a formal collection plan. The following is a brief description of the process followed during the collection of the data.

The first step was to finalise the questionnaire before it was sent out via the post to the identified sample. This implied that the editorial and layout of the questionnaire needed to be done in order to ensure that it was going to fit into the envelopes without making it appear cramped or having the font size to small. Once the researcher was satisfied a few samples were printed and colleagues not being part of the sample were requested to complete it. This was done to correct any practical problems that may have been present in the design.

The questionnaire was field tested by distributing copies to 50 fourth year mining students from the University of the Witwatersrand. The comments and replies were evaluated and included where appropriate prior to finalising the questionnaire.

3.7.1. PHASE 1

For phase 1 the mailed questionnaire was selected for the collection of the research data from the management and supervisory section of the sample. In this survey the respondents was required to complete the questionnaire without any intervention from the researcher.

This part of the sample consisted of all the applicants for the Mine Overseers and Mine Managers certificates of competency form January 1996 to December 1997. A total of 1 246 persons were registered as applicants for these two certificates on the database of the Chief Inspector of Mines for this period. The inclusion of these individuals in the sample ensured that the participants had a certain minimum experience as well as some previous training relevant to the research.

The selected method provides greater privacy for the respondent than other instruments. As no intervention from the researcher took place during the collection of information during phase 1, it was imperative that the questionnaire was designed to reduce misunderstanding to the utmost minimum. In addition to this the design had to ensure the minimum incomplete responses possible.

In order to ensure that the maximum possible response would be achieved the covering letter was drafted under the signature of the Chief Inspector of Mines Mr D Bakker as well as Prof N Alberts of the University of Pretoria, a copy of which is included as annexure "B".

Before the questionnaires could be posted the names and addresses of the sample was entered into a database and the database converted to a mail merge file. The covering letter was also converted into a mail merge letter and the letters printed with the correct addresses by merging the mail merge file and the converted letter.

The printing of the questionnaires was conducted and the addressed covering letters attached to them.

The postal questionnaires were posted while keeping a record of each addressed questionnaire posted. After a 4-week period follow up notices were sent out to all the original recipients. A second reminder followed this a further 4 weeks later.

As the completed questionnaires were received back the questionnaires were carefully filed after receiving a unique reference number, to ensure that no returned response was lost.

3.7.2. PHASE 2

An attempt was made to ensure that the responses received from the management component in each commodity constituted a similar relative size to the responses from the workers from that commodity. As a result of the unpredictability of the number of replies received from a postal questionnaire replies from the interviews only represent approximate similar relative sizes. The relative sizes are deemed to be sufficiently similar to draw statistically meaningful results.

Phase 2 consisted of interviews with workers selected randomly as they were clocking out at the end of the shift. This type of selection was deemed to be sufficiently random to ensure that the sample will be representative. The mines selected to obtain the worker views through interviews were selected to provide a similar commodity distribution as achieved with the postal questionnaires.

The clocking out process at the mines selected has a duration of between 2 and 4 hours. During this period workers are hoisted to surface with the aid of large cages that can hoist between 20 and 150 workers at a time. The hoisting plan normally starts at the upper levels end progressively moves down to finish up at the lower working level. The mines selected for the survey are designed to clear all workers from underground in about two hours. A structured interview conducted to complete one questionnaire was timed to take about ten minutes on average. Each interviewer therefore conducted about twelve interviews per mine.

The respondents were invited to the interview rooms based on the time they arrived on surface. There is normally a continuous stream of workers flowing through the clocking out point at the end of the shift. The interviewers invited the next person who clocked, to the interview room as they completed each questionnaire.

This ensured that the sample did not only contain workers from a specific area or type of work.

The persons selected to conduct the interviews were well versed in mining terminology and were trained to conduct interviews correctly, on the content of the questionnaire as well as the methodology necessary to ensure that the interviewee gives an objective answer to each question. They could also speak the language of the respondents. They were instructed to establish a rapport with each mineworker to be interviewed prior to providing them with the instructions for the interview. In addition, the interviewers were instructed on an approach to follow when asking the questions and on the methodology for recording responses. The answers were recorded on questionnaires by the interviewers on behalf of the interviewees.

3.8. ANALYTICAL APPROACH

The original questionnaire was utilised to develop a codebook to interpret the responses. This was simply a completion of the questionnaire with values entered into each of the possible choices.

Utilising the codebook, the raw data of each returned questionnaire was entered into an Excel spreadsheet. This was necessary in order to ensure that the data supplied to the statistical section of the University of Pretoria was user-friendly. This implied that questionnaires not being fully completed and others with multiple answers for the same question had to be removed.

The spreadsheets together with the original questionnaires were provided to the statistical section of the University of Pretoria who further cleaned the data and then utilised a statistical analysis package to make recommendations to the researcher in respect of the responses received from the respondents.

The study consists of 591 useable replies from the two phases. Each phase contained replies from three distinct groupings, namely the commodity being mined coal, gold and platinum.

3.8.1. INTERPRETATION OF RESPONSES AND GRAPHS OF RESPONDENTS

The interpretation of the results of the individual questions contained in the questionnaire will be discussed in chapter 4. At the conclusion of each section an overall conclusion of that section will be given.

The graphs constructed using the responses on questions are reflected in column charts with corresponding titles. On these graphs the responses of the six different groupings are individually displayed as a percentage of the group. This was done to assist with comparison across groups.

Chapter 4

THE EMPIRICAL INVESTIGATION - INTERPRETATION

4.1. INTERPRETING THE RESULTS

In this chapter the results obtained with the aids of the questionnaires developed and distributed as explained in Chapter 3 will be analysed and interpreted.

4.2. THE RESULTS

The research results are based on the responses of 591 usable questionnaires representing the views of a population of 268 751 workers in the South African mining industry, with a confidence level of 95 % and a margin of 5%. This was achieved by sending out 858 questionnaires through the post as well as interviewing 388 mineworkers.

A total of 171 questionnaires were posted to coalmine management of which 67 (39,2%) replied with usable questionnaires, goldmine management received 598 questionnaire and returned 151 (25,3%) usable questionnaires while platinum mine management received 89 questionnaires and the researcher received 24 (27,0%) usable replies from this sector. The replies the coalmine workers (82), goldmine workers (235) and platinum mine workers (32) were obtained after the postal questionnaires were received back and it was decided to keep the sectors replies similar in size. This resulted in coalmine management to represent 11,34% of the total sample while the coalmine workers represented 13,87%. The goldmine management represented 25,55% while the goldmine workers represented 39,76% and Platinum mine management 4,06% Platinum mine workers 5,41%

The 591 useable questionnaires represent 47.4% of the total number of questionnaires issued.

Both phases contained replies from three distinct commodity groupings namely coal, gold and platinum. An attempt was made to ensure that the responses received from the management component in each commodity, constituted a similar relative size to the responses from the workers in that commodity. As a result of the unpredictability of the number of replies received from a postal questionnaire, replies from the interviews represent approximately similar relative sizes.

4.2.1. SECTION 1

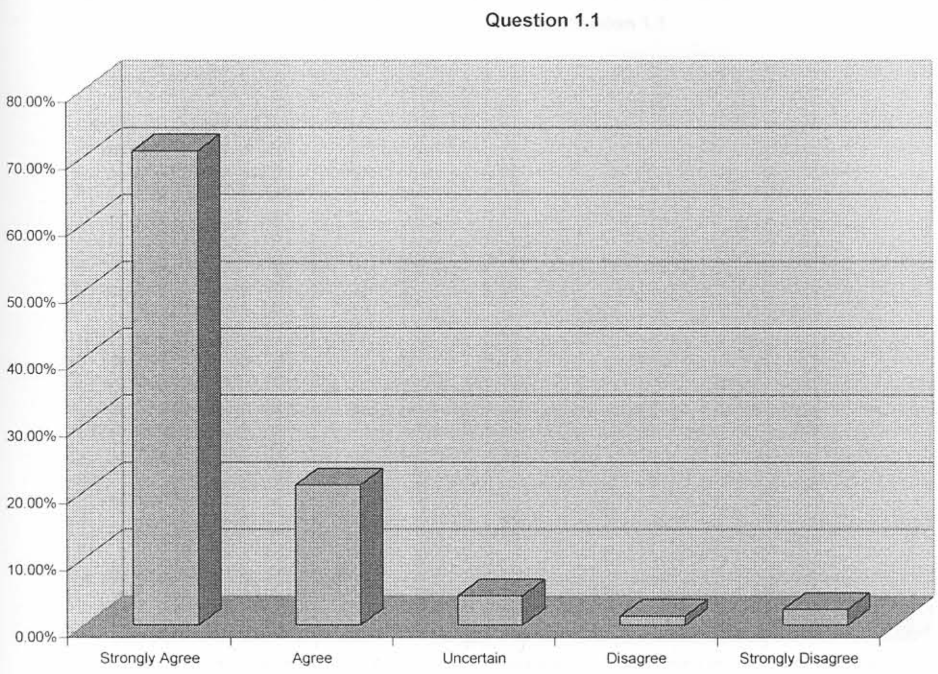
The aim of Section One was to establish whether the fundamental contributing factors isolated from the various accident investigation techniques, do indeed represented the factors that are believed to require confirmation during accident investigations.

4.2.1.1. QUESTION 1.1

The questionnaire started with a general question on the effect of properly conducted accident investigations in the South African mining industry. Question 1.1 wanted to establish whether the respondents were of the opinion that proper accident investigations could prevent future accidents.

Of the 591 respondents, 419 indicated that they strongly agreed and a further 124 recorded that they agreed with the statement. This means that a total of 91.88% of the respondents support this view. A total of 26 (4.40%) were uncertain while 8 (1.35%) disagreed and 14 (2.37%) strongly disagreed.

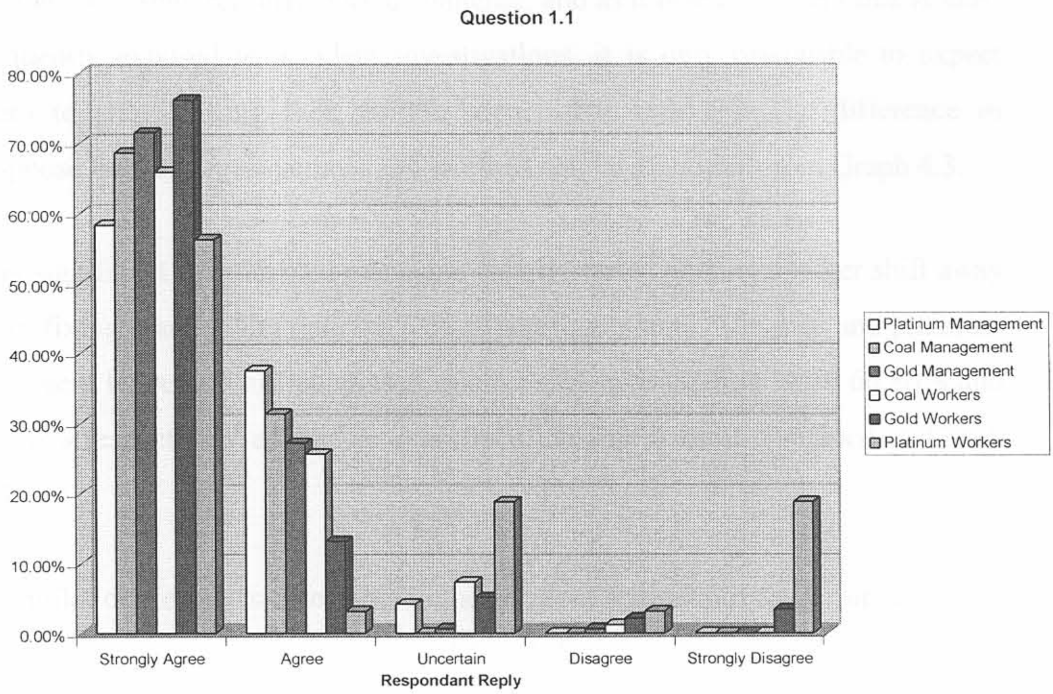
The overwhelming response was that they strongly agree that proper accident investigations will prevent future accidents as can clearly be seen from Graph 4.1.



Graph 4.1 - Replies to Question 1.1

The question was also utilised to establish any disparity between the six identified groups.

From Graph 4.2, constructed using the sub-group responses on question 1.1, it is clear that, with the exception of some of the platinum workers, the overwhelming majority of the sample agreed that, in order to reduce accidents, proper accident investigations was essential.



Graph 4.2 - Sub-group responses to Question 1.1

The difference in response from some platinum workers could possibly be ascribed to the relatively small number of respondents from this group that will cause a large percentage difference for a small numerical difference.

4.2.1.2. QUESTION 1.2

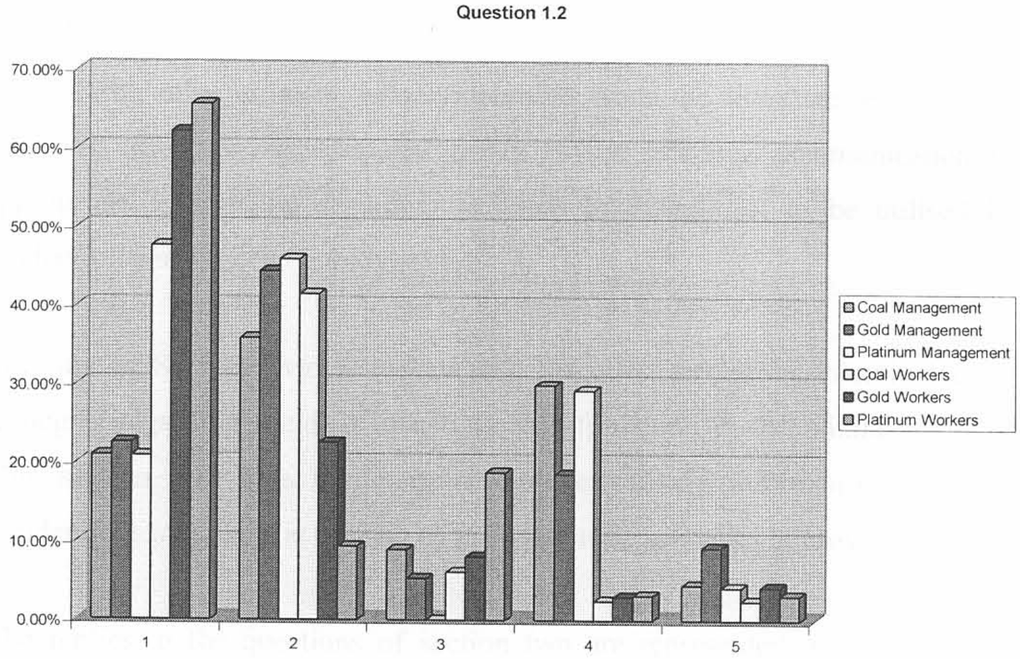
Question 1.2 aimed to establish the respondent's opinion on the importance of establishing the person responsible for the accident. This question stated that it is important to establish who was at fault during accident investigations. The inclusion of this question was to establish the belief of the different groupings and sub-groupings in relation to blame-fixing. The literature is unanimous that blame-fixing will achieve nothing to reduce the occurrence of accidents.

From the replies it is clear that the South African mining industry is still very much focussed on fixing blame. Of the 591 respondents, 259 (43.82%) replied that they strongly agreed that it was important, while 192 (32.49%) agreed that it was important. A total of 44 (7.45%) was uncertain. It was encouraging to note that 96 (16.25%) of the respondents disagreed.

As the focus only recently started changing, and as it is management that is most frequently exposed to accident investigations, it is only reasonable to expect them to start shifting their beliefs sooner than workers. The difference in response between management and workers can be identified from Graph 4.3.

It is significant that the coal managers clearly started making a larger shift away from fixing blame, with only 56.72% supporting blame. The gold and platinum managers however, still supported this type of investigation, with 66.86% and 66.66% respectively as can be seen from the information contained in Graph 4.3.

A similar difference is detectable in the accident statistics of the groupings.



Graph 4.3 - Sub-group responses to Question 1.2

It is meaningful to note that all worker groupings were of the overwhelming opinion of the importance of establishing who the person at fault was. These responses confirm the influence that the current accident investigation system in use in the mining industry, has on workers.

4.2.1.3. QUESTION 1.3 TO 1.13

Question 1.3 to 1.13 aimed to establish whether the respondents agreed that the ten elements isolated from the literature were indeed important to establish during accident investigations, in order to prevent similar accidents.

Only a very small percentage of respondents disagreed (0.51% to 5.25%) with the inclusion of the ten fundamental contributing factors in an accident investigation designed to prevent future accidents.

These graphs can be viewed for detail in annexure "C".

4.2.2. SECTION 2

One of the other primary issues identified from the literature as having a profound effect on occupational safety is the effective communication of appropriate information regarding accident investigations, to be utilised by production personnel to improve safety.

The aim of Section Two is to establish the effect of current communication strategies regarding accident investigation information in the mining industry. This section also tries to determine how effectively information regarding accident investigations is utilised by production personnel to improve safety.

The replies to the questions of section two are represented in a table. The information is grouped as follows:

The first column is utilised to separate the respondents into different categories. The first three groups are the management respondents from respectively coal, gold and platinum mining. The next three groups are worker respondents from these sectors. The main body of the table gives the number of respondents replying to each of the options (Strongly Agree; Agree; Uncertain; Disagree and Strongly Disagree). The percentages reflect the proportion of respondents in each category that selected a specific response. In the last row the total replies for each response type is added together to give the total picture irrespective of the category of the respondent.

4.2.2.1. QUESTION 2.1 TO 2.3

The questions in this section deal with the frequency of official communication of the occurrence of accidents of various severities to the respondents.

Question 2.1 required the respondent to state, "How often are you officially informed that a fatal accident occurred on the mine that you work on?"

Table 4.1 gives the replies received from the 591 respondents in respect of this question. It is clear that the official communication of information regarding fatal accidents is conducted effectively. A total of 84.94% of respondents either replied that they are always or regularly informed of this type of accident. The difference between the replies from management and workers are negligible. A worrying factor is that 3,38% of the respondents replied that they are never officially informed about the occurrence of a fatal accident while a further 2,2% responded that they are seldom informed. As a result of the severity of this type of accident one would have expected that these replies would not occur.

Table 4.1 - Responses in respect of Question 2.1

Category	Always	Regular	Sometime	Seldom	Never	Total
Coal Management	58	4	3	1	1	67
	86.57%	5.97%	4.48%	1.49%	1.49%	100.00%
Gold Management	130	12	6	2	1	151
	86.09%	7.95%	3.97%	1.32%	0.66%	100.00%
Platinum Management	20	2	1	1	0	24
	83.33%	8.33%	4.17%	4.17%	0.00%	100.00%
Coal Workers	47	14	13	4	4	82
	57.32%	17.07%	15.85%	4.88%	4.88%	100.00%
Gold Workers	176	13	32	5	9	235
	74.89%	5.53%	13.62%	2.13%	3.83%	100.00%
Platinum Workers	26	0	1	0	5	32
	81.25%	0.00%	3.13%	0.00%	15.63%	100.00%
Total	457	45	56	13	20	591
	77.33%	7.61%	9.48%	2.20%	3.38%	100.00%

Question 2.2 was included to determine how often respondents are officially informed that a **Reportable** accident occurred on the mine that they work on. Table 4.2 gives the responses in respect of this question.

Table 4.2 - Responses in respect of Question 2.2

Category	Always	Regular	Sometime	Seldom	Never	Total
Coal Management	43	12	9	3	0	67
	64.18%	17.91%	13.43%	4.48%	0.00%	100.00%
Gold Management	79	46	16	10	0	151
	52.32%	30.46%	10.60%	6.62%	0.00%	100.00%
Platinum Management	10	9	4	1	0	24
	41.67%	37.50%	16.67%	4.17%	0.00%	100.00%
Coal Workers	39	20	11	2	10	82
	47.56%	24.39%	13.41%	2.44%	12.20%	100.00%
Gold Workers	141	19	45	11	19	235
	60.00%	8.09%	19.15%	4.68%	8.09%	100.00%
Platinum Workers	18	5	4	0	5	32
	56.25%	15.63%	12.50%	0.00%	15.63%	100.00%
Total	330	111	89	27	34	591
	55.84%	18.78%	15.06%	4.57%	5.75%	100.00%

A total of 74.62% replied that they are either always or regularly informed about a reportable accident on the mine that they work on. There are no, or very little distinction between the responses of the workers and management.

This regression of effectiveness of communication can only be attributed to the perception of the communicators that a reportable accident is less severe than a fatal accident and therefore requires less communication effort.

Question 2.3 required the respondents to indicate how often they are officially informed about a **Lost Time** accident on the mine that they work on. Their responses are reflected in table 4.3.

Table 4.3 - Responses in respect of Question 2.3

Category	Always	Regular	Sometime	Seldom	Never	Total
Coal Management	33	14	14	4	2	67
	49.25%	20.90%	20.90%	5.96%	2.99%	100.00%
Gold Management	64	37	25	19	6	151
	42.38%	24.51%	16.56%	12.58%	3.97%	100.00%
Platinum Management	5	10	6	3	0	24
	20.83%	41.67%	25.00%	12.50%	0.00%	100.00%
Coal Workers	32	17	12	1	20	82
	39.02%	20.74%	14.63%	1.22%	24.39%	100.00%
Gold Workers	133	27	27	9	39	235
	56.60%	11.48%	11.49%	3.83%	16.60%	100.00%
Platinum Workers	17	4	5	0	6	32
	53.13%	12.50%	15.62%	0.00%	18.75%	100.00%
Total	284	109	89	36	73	591
	48.05%	18.45%	15.06%	6.09%	12.35%	100.00%

A total of 66.50% of respondents replied that they are either always or regularly informed. The difference between the replies from management and workers are negligible.

From the responses to the three questions it is clear that the less severe the accident the lower frequency of communication. It is also significant that management are not better communicated to than workers.

The information obtained from these questions is very important in that it highlights the focus that mines are placing on the severity of accidents. At first it appears that this approach is correct, however, the severity of an accident is only one indication of the risk. According to Marx (2000) health and safety risk is the combination of the severity of the consequences, the frequency of occurrence and the level of exposure of the workforce to the hazard.

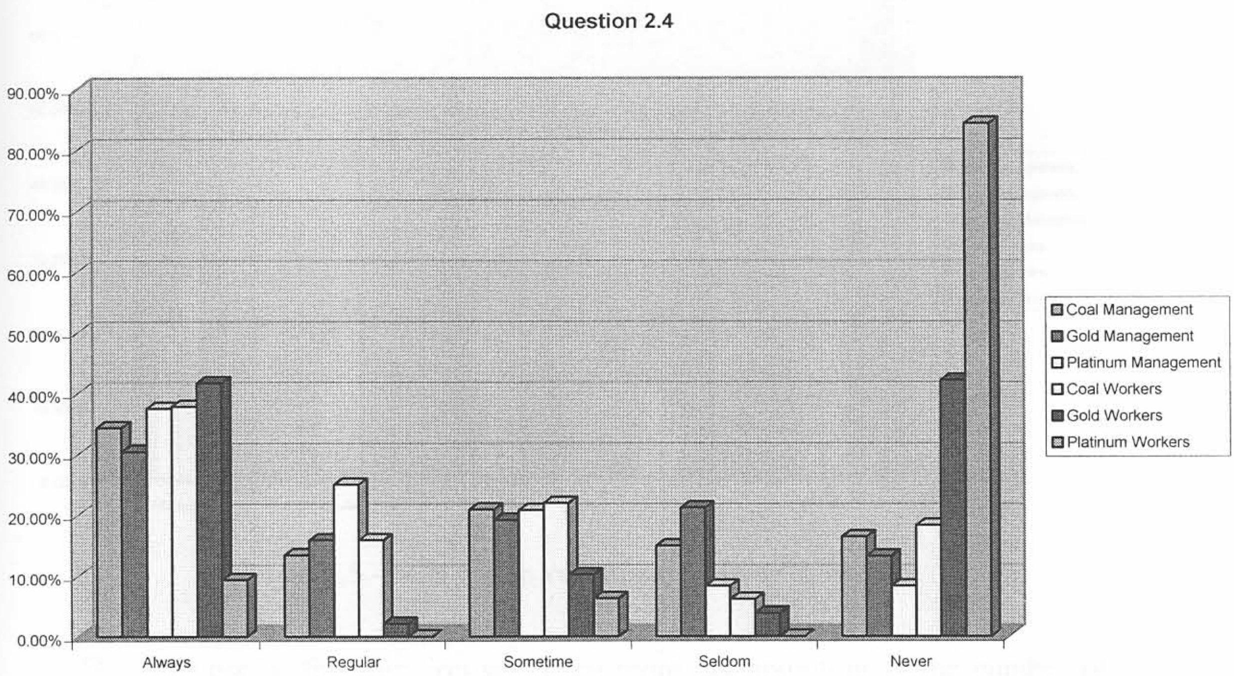
The replies indicate that South African mines do not necessarily follow this approach when deciding on a health and safety communication strategy.

4.2.2.2. QUESTION 2.4 TO 2.6

The next three questions dealt with the frequency of official communication regarding the outcomes of accident investigations on the mine where the respondents are employed.

Question 2.4 required the respondents to reply to the question: "How often are you officially informed about the **outcome** of **fatal accident investigations** held on the mine that you work on?"

The reply to this question was very disappointing as the replies clearly indicate that, once the investigation is completed, the emphasis is off the accident. Yet the first step to prevention is to ensure that all role-players are informed about the appropriate corrective action.

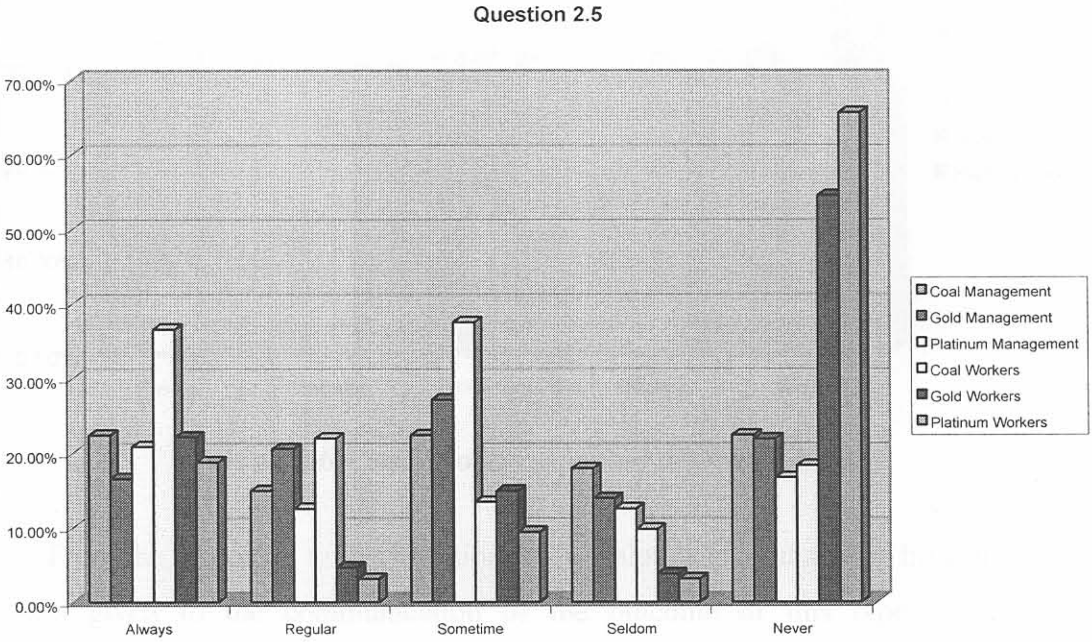


Graph 4.4 - Sub-group responses to Question 2.4

Should the outcome of a fatal accident that happened on the mine where the respondents work not be communicated it can be expected that very little action would follow to rectify any deviations identified.

The data shows that only 45,18% of respondents was always or regularly officially informed about the outcome of fatal accident investigations held on the mine that they work on.

Question 2.5 required the respondents to reply to the question: "How often are you officially informed about the outcome of **reportable accident investigations** held on the mine that you work on?"

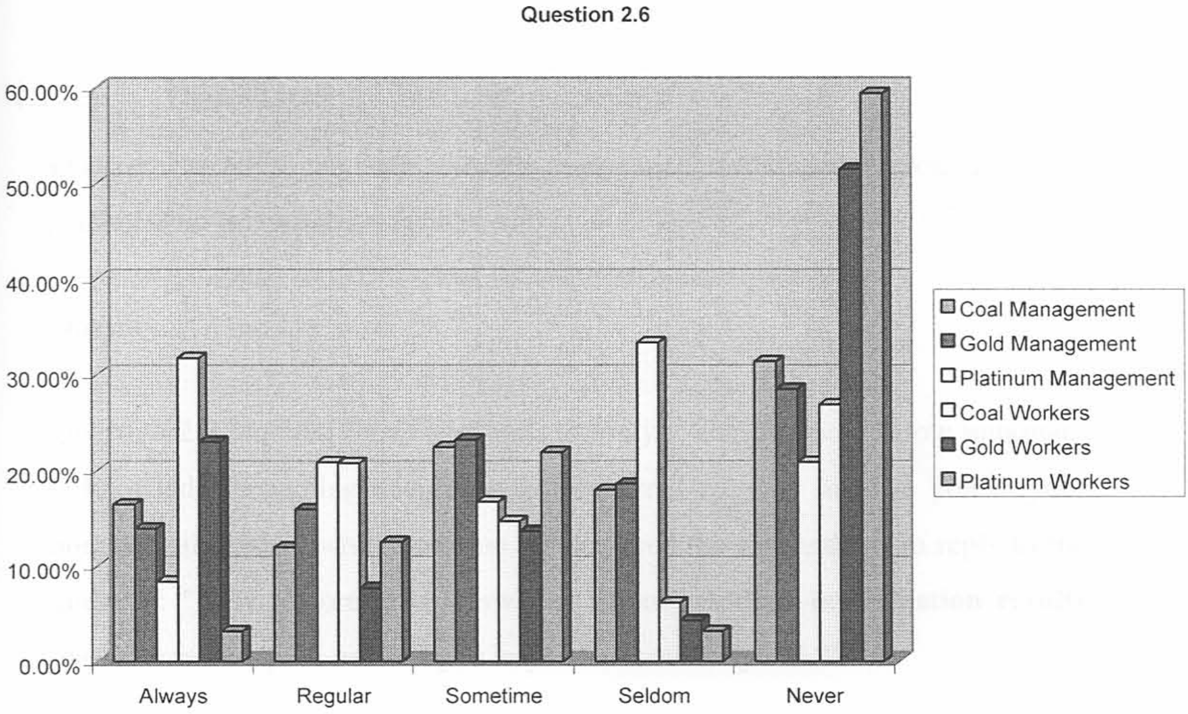


Graph 4.5 - Sub-group responses to Question 2.5

The response to this question was even more disappointing as the number of reportable accidents exceed the number of fatalities by a factor of about 5, as can be seen from table 2.1 in Chapter 2. With the higher incidence of reportable accidents the multiplying effect is clear. The data indicate that 64,97% of the responses was that the respondents were sometimes, seldom or never informed about the outcome of this type of investigation.

Question 2.6

Question 2.6 required the respondents to reply to the question: "How often are you officially informed about the outcome of **lost time accident investigations** held on the mine that you work on?"



Graph 4.6 - Sub-group responses to Question 2.6

From the responses to this question it is absolutely clear that very little attention is given to the communication of the outcome of this type of accident investigation. The data indicate that 32.32% of the total sample, management as well as workers, are only informed about the outcome "regular " or " always". The equivalent responses from the worker respondents is even lower at only 20,30%.

Conclusion

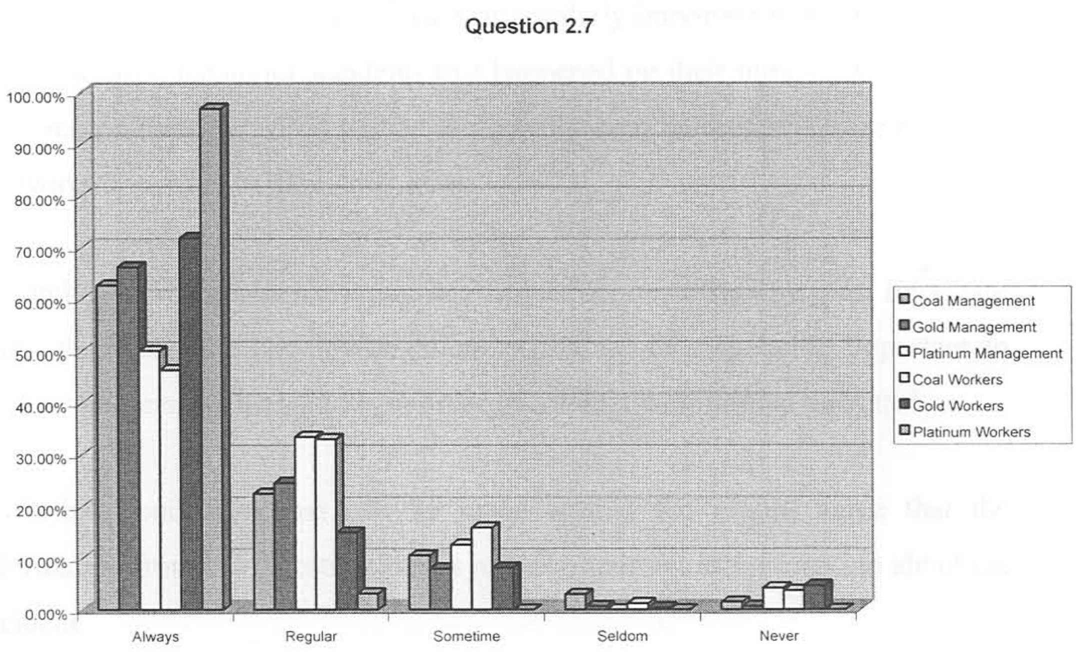
The poor communication of accident investigations results to persons not directly associated with the investigation, together with the fact that the importance of communication is associated with the severity of the consequences of the accident prevention information obtained during accident investigations are one of the primary conclusions that can be drawn from this portion of the empirical investigation. One possible reason for this may be that the existing investigation methodologies are not producing practical preventative measures, as they are primarily focussed on finding a party to blame.

4.2.2.3. QUESTION 2.7 TO 2.10

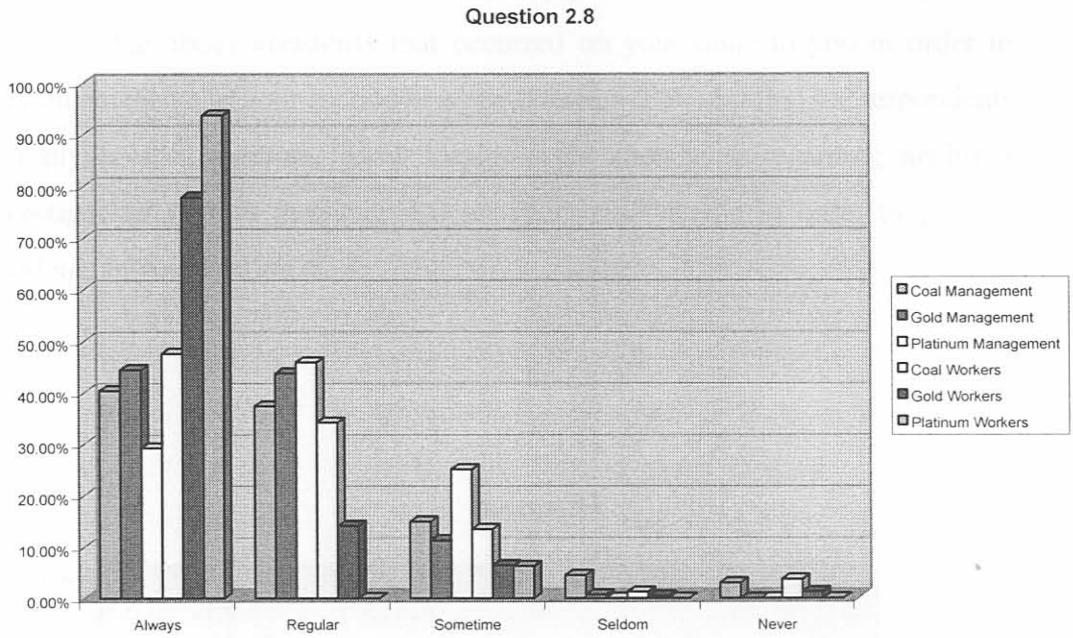
Questions seven to ten deals with the importance of knowledge about accidents and accident investigation results.

Question 2.7 and Question 2.8

Question 2.7 required the respondents to reply to the question: "How important is knowledge regarding **accidents** that occurred on your mine to you in your normal daily task?" while question 2.8 required the respondents to reply to the question: "How important is knowledge about **accident investigation results** that occurred on your mine to you in your normal daily task?"



Graph 4.7 - Sub-group responses to Question 2.7



Graph 4.8 - Sub-group responses to Question 2.8

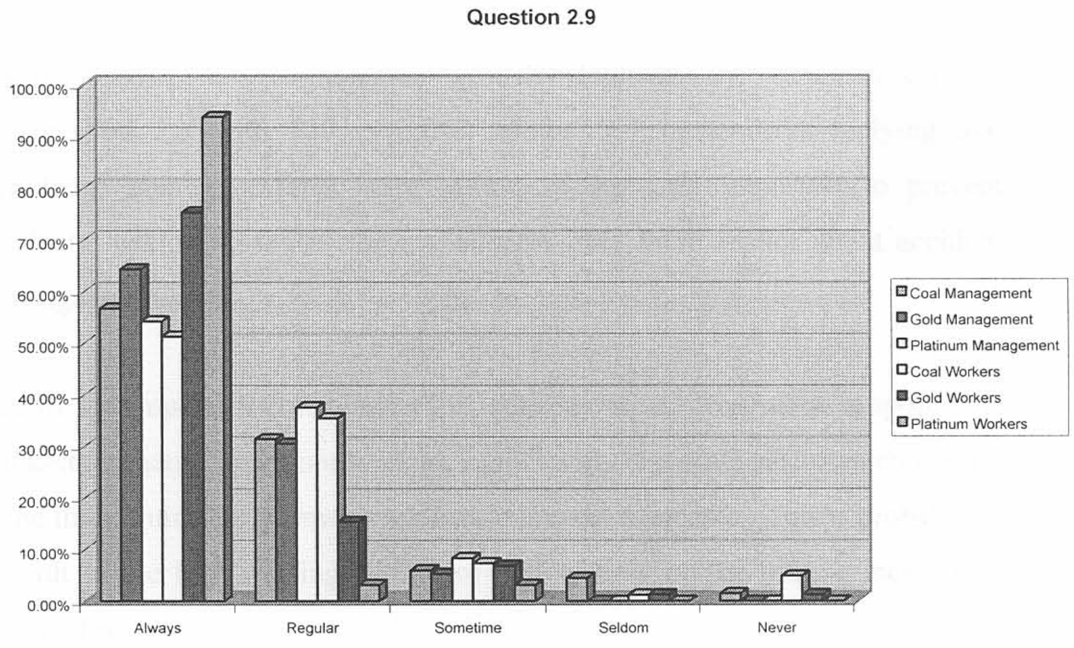
It is significant that a shift is noticeable when the respondents had to evaluate the importance of accident investigation. Responses indicated that 87,14% of the respondents felt that it was always or regularly important to their daily tasks to have knowledge about accidents that happened on their mines. With slightly more respondents (87,31%) replied that results from investigations are regularly or always important to their daily tasks.

A number of conclusions are possible from these results. The most important being that accidents and investigation results are overwhelming important to workers and management alike, in order to conduct their normal daily tasks.

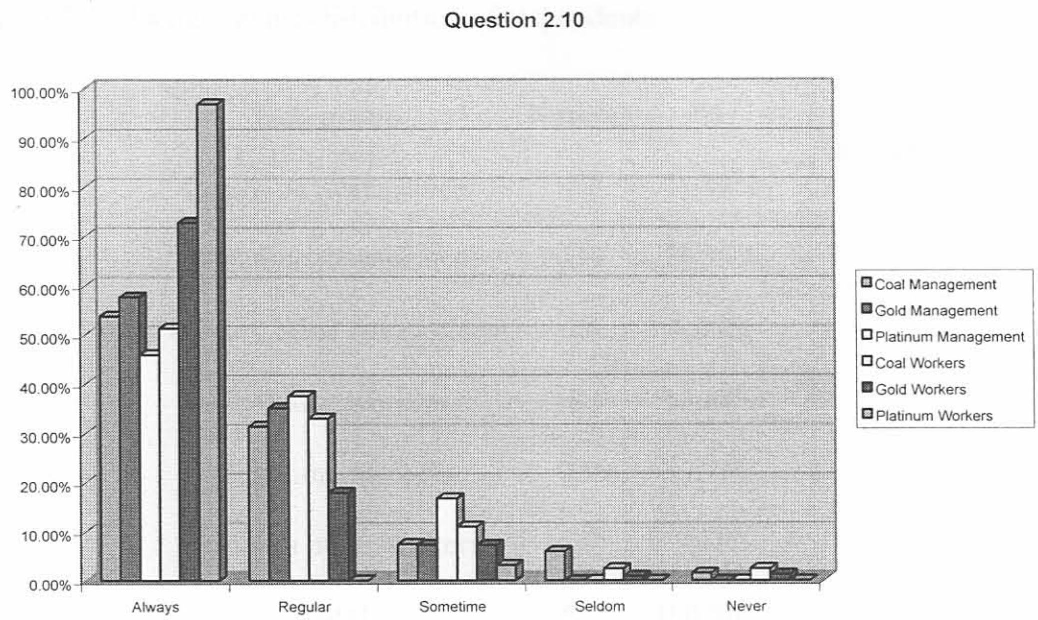
A further conclusion that can be made is that the groups agree that the information from the investigations is just as important as information about the accident

Question 2.9 and Question 2.10

Question 2.9 required the respondents to reply to the question: "How important is knowledge about **accidents** that occurred on your mine to you in order to prevent accidents in your section?" while question 2.10 required the respondents to reply to the question: "How important is knowledge regarding **accident investigation results** that occurred on your mine to you in order to prevent accidents in your section?"



Graph 4.9 - Sub-group responses to Question 2.9



Graph 4.10 - Sub-group responses to Question 2.10

The responses of the two questions virtually duplicates the responses received for question 2.7 with 539 (91,20%) of the 591 respondents replying that knowledge about accidents were always or regularly important to prevent accidents, while 89,68% of the respondents gave these replies about accident investigation results.

One of the important conclusions that can be derived from these responses is that neither management nor workers significantly distinguishes between the use of the information for normal work and to prevent accidents. This is probably as a result of the longstanding culture of "safety first" in the mining industry in South Africa.

4.2.3. SECTION 3

In section 3 questions to establish the demographics of the sample were asked. This was necessary in order to establish whether there were any major differences between the responses of the various subgroups.

Table 4.4 – Demographic distribution of respondents:

Sub-group	Number	%
Coalmine management	67	11,34%
Goldmine management	151	25,55%
Platinum mine management	24	4,06%
Coalmine workers	82	13,87%
Goldmine workers	235	39,76%
Platinum mine workers	32	5,41%
Total	**591**	**100,00%**

No further discussion about this is necessary.

4.3. CONCLUSION

It is concluded beyond any reasonable doubt that it would be justifiable to include the following fundamental contributing factors in accident investigations designed to prevent future accidents of a similar nature:

- Energy sources out of control,
- Management system failure,
- Training deficiency,
- Latent design defects,
- Inappropriate maintenance,
- Imperfect procedures,
- Unsuitable task directives,
- Substandard physical conditions,
- Unsafe acts,
- Barrier failures.

The conclusion is supported by the outcome of Section 1 that dealt with the specific fundamental contributing factors, as well as all the sections dealing with communication and the usefulness of information.

The identified fundamental contributing factors will, in chapter 5, be utilised to develop the new analytical investigation model.

The research also confirmed that communication to managers and workers about accidents and failure modes is necessary in order to prevent accidents as well as to conduct their daily tasks.

In the next chapter the information confirmed in the empirical investigation above will be utilised as building blocks to develop an analytical model that can be utilised as the basis for accident investigation methodologies.

CHAPTER 5
DEVELOPING THE MODEL

5.1. INTRODUCTION

In this chapter the information obtained during the empirical investigation will be united to form an analytical accident investigation model for the South African mining industry.

In order to put the model in a realistic context, traditional accident inquiries conducted by government inspectors will be used as a reference. This is important, as most mines will follow the methodology utilized by these inspectors.

The next section of this chapter will summarise the new approach required in terms of the South African Mine Health and Safety Act (1996). Finally the model will be described against the background of an actual accident example where the different elements are individually explained and a graphical representation of the model is presented. A detailed description of the steps involved in conducting an accident investigation will conclude the chapter.

5.2.TRADITIONAL INQUIRIES

The accident inquiries conducted by the South African government inspectors of mines under the Mines and Works Act, 1956 (Act no 27 of 1956) and later the Minerals Act, 1991 (Act no 50 of 1991) were focused on establishing legal accountability. In most instances the accident inquiries concluded that the deceased person was responsible for his own demise (Hermanus & Leger 1993).

An analysis of the traditional inquiry system makes it clear that the authors of the Mine Health and Safety Act (1996) intended investigators to go way beyond the levels possible with the traditional methodology. This research provides the framework to establish a model that will allow investigators to do just that.

A Chief Inspector of Mine's Directive (D1) guides the traditional procedure. What it amounts to is that an inspector must visit the scene of a fatal accident and at the scene collect information that would assist during the inquiry. In the majority of cases the inspector requests the mine's surveyor to measure the area and to produce a plan of the accident scene for the inclusion in the accident investigation record. During this so-called "in loco inspection" all stakeholders have the right to attend. Strangely, information that witnesses would supply at the scene is not "admissible" during the formal part of the inquiry as the witness are said to be not under oath at the accident scene. In the majority of the investigations that the author conducted over the years (in excess of 150) the informal statements of witnesses differed vastly from those given under oath, especially when someone thought that a colleague could potentially be prosecuted.

The formal part of the inquiry is structured in a quasi-legal format where the inspector swears in witnesses and takes down statements from persons associated with the accident. These statements are taken down in the presence of all persons associated with the accident, witnesses and managers alike. Any person present has the opportunity to cross-question any of the witnesses. This leads to workers not being willing to give statements that could implicate their seniors for fear that they may loose their jobs.

In the few cases where it was possible to establish legal accountability and where these cases were presented to the Attorney General, the witnesses were mostly not available by the time the case could be heard in court.

The following factors that contribute to unsuccessful prosecutions were also identified:

1. The judicial system in South Africa, as in a number of other countries, is congested with criminal and civil cases. The additional burden of occupational health and safety cases could have been justified if it resulted in an acceptable rate of successful prosecutions. But this has never been the case and the already strained resources of the Department of Justice are being

tested to the limit by (sometimes) unnecessary cases being taken to court. This results in inexperienced public prosecutors having to prosecute in highly technical cases.

2. The migratory labour system in use in the South African mining industry is not conducive to an effective judicial system. In many cases the witnesses are not available for court appearances as their contracts came to an end or some other factor caused them to be at home hundreds or thousands of kilometres away on the court date.

In addition to the above problems the hours spent to take down verbatim statements are wasted. Statements taken during the inquiry may be presented as evidence in court, but public prosecutors normally call witnesses again. In only a very small percentage of the investigations conducted in this way would it be possible to establish the fundamental factors contributing to an accident. This is supported by the fact that no significant reduction in accident rates has been achieved following this procedure (SAMRASS 1990-1999).

During 1999, 64 fatal accidents occurred in the North West Region as defined by the Minerals Act. Formal traditional inquiries were conducted as a result of all 64 of these accidents. In only 16 the reasons of the accident were identified by the investigators as being contraventions of the Mine Health and Safety Act and were referred to the Attorney General for his consideration. Of those referred to the Attorney General only 4 resulted in prosecution. The 6.25% prosecution rate does not instil confidence that the courts will be in a position to reduce the number of accidents.

Inspectors, when requested by the researcher to identify areas where this type of investigation can be improved, have also identified the following disadvantages of the traditional accident inquiry methodology:

- The motive of employee and employer representatives in a formal accident inquiry is to get their clients "of the hook" and not to establish the fundamental contributing factors of the accident.

- Witnesses in formal accident inquiries are reluctant to present the relevant facts. The reasons could be fear of prosecution; intimidation by the employer or advice from their union representative or legal advisors.

- Formal accident inquiries are time consuming and not cost effective. Formal accident inquiries can take anything from 2 days to several weeks to complete. Legal representation is normally very costly. In many cases lower category workers cannot afford legal representation.

- The judicial process is time consuming and years may pass before a case, which has been referred to the Attorney General, is finalised. Statements, which are recorded during the inspectors' formal inquiry, are required to be given again by witnesses during trail.

- In the case of non-fatal, reportable accident investigations, the single statement traditionally taken down from the injured is totally inadequate to determine any fundamental contributing factors.

5.3. A NEW APPROACH

The Mine Health and Safety Council arranged a tripartite summit during November 1998 to review the state of health and safety at mines. As a result of this summit a number of recommendations were made.

One of the recommendations was that a committee should be tasked with establishing guidelines for the appropriate use of Sections 63 and 71 of the Mine Health and Safety Act.

These sections were included in the Act with the aim to enhance the effectiveness of accident investigations and reads as follows:

63.(1) For the purpose of enhancing the effectiveness of an investigation in terms of section 60, the Chief Inspector of Mines, in consultation with the appropriate Attorney-General, may issue a certificate that no prosecution may be instituted in respect of any contravention of, or failure to comply with, a provision of this Act related to the event being investigated. If a certificate is issued, no fine in terms of section 55D, or disciplinary action related to the event investigated may thereafter be imposed on or taken against any person.

63. (2) The Chief Inspector of Mines must communicate in writing the protection afforded under subsection 63. (1) to all persons questioned during the investigation.

63.(3) Persons questioned during the investigation who are afforded protection under this section must answer every question to the best of their ability and may not refuse to answer any question on the grounds that the answer may be self-incriminating.

71. (1) Subject to subsection 71. (2), every person giving evidence at an inquiry must answer any relevant question.

71. (2) The law regarding a witness's privilege in a court of law applies equally to any person being questioned at an inquiry.

71. (3) The person presiding at an inquiry may direct that evidence given by a person during an inquiry may not be used for the purposes of sections 55A. to 55D, or any appeal relating to those sections, or in any criminal or disciplinary proceedings against that person except in criminal proceedings on a charge of perjury against that person.

71.(4) When a directive has been issued under subsection 71.(3), the person involved is not entitled to refuse to answer any relevant question only on the grounds that the answer could expose that person to a criminal charge, disciplinary proceedings or a recommendation under section 55A.

71. (5) A person instructed in terms of section 70. (c) must comply with that instruction unless the person has sufficient cause for not doing so.

The Mine Health and Safety Council Convenors agreed on 1 October 1999 that a task group should be established to consider methods to enhance the effectiveness of accident investigations conducted in terms of section 60 and section 11(5) of the Mine Health and Safety Act.

It is clear that by the inclusion of Section 63(1) in the Mine Health and Safety Act the spirit of the Act already envisaged that conditions might exist where a certificate of no prosecution may be issued. This certificate would then prevent prosecution instituted in respect of any contravention of, or failure to comply with, a provision of the Act related to the event being investigated.

It is obvious that, despite its good intentions, the provisions of this section of the Act are not effective, as no such certificate has been issued since the promulgation of the Act in January 1996.

In order to develop an accident investigation model, the information obtained and verified during the empirical investigation needs to be incorporated in a model that takes cognisance of these factors and also of the basic issues identified during the literature review.

While a number of approaches are possible, building the model around different failure modes would add most value and ensure that the model could be used by accident investigators. These failure modes are graphically represented in figure 5.1.

5.4. FUNDAMENTAL CONTRIBUTING FACTORS

In Chapter 4 the fundamental contributing factors that should be included in an accident investigation was confirmed through the empirical investigation. These factors will now be utilised to develop the analytical investigation model.

The role that different fundamental contributing factors play in any given accident is explained at the hand of an actual accident. The accident involved more than could be explained in this chapter but the relevant information is supplied to substantiate the presence of fundamental contributing factors and associated failure modes. The relevant accident information is supplied next:

A worker was fatally injured and two others seriously injured when whey were struck by a locomotive in a straight part of the main tramming haulage of a deep gold mine. The accident happened as the worker, who was part of a team of eight, walked the 2.4 km from the workplace to the station at the end of the nightshift.

The overhead trolley locomotive involved had been tramming reef for the full duration of the shift preceding the accident. The accident happened on a Wednesday morning at about 04:50. The workers had come on shift the night before at about 21:00. There were no novices involved. The locomotive driver had been a driver on the same mine in the same workplace for eight months preceding the accident. He had been employed as a locomotive driver on the same mine for about five years preceding the accident without being involved in an accident.

The accident happened on a large gold mine that employs a certificated engineer to take responsibility for the mechanical and electrical equipment on the mine. The mine also has an in-house training centre where locomotive drivers are trained. The driver of the overhead trolley locomotive did undergo the prescribed training at this training centre.

The accident will now be systematically analysed by establishing the presence of the individual fundamental contributing factors at the time of the accident.

5.4.1. ENERGY SOURCE / HAZARDOUS MATERIALS

According to Haddon (1967) damage is caused to the body of a living being when the amount of energy applied to the body is in excess of the corresponding injury threshold of the body. This implies that when the energy of the impact is greater than the capacity of the body to absorb it, injuries will result. The more the threshold is exceeded the more serious the injury will be.

A number of commonly occurring energy sources have been identified in the literature. For the purposes of the mining industry the following can be utilized as a guideline:

- Mechanical energy
- Electrical energy
- Thermal energy
- Chemical and Bio-chemical energy
- Electromagnetic energy
- Potential (gravitational) energy
- Kinetic energy
- Acoustic energy

Various elements present prior to an accident may trigger the release of large amounts of energy or hazardous materials. During the investigation it is important to establish the energy source or hazardous materials causing the injury threshold of the injured person's body to be exceeded.

In the example it was quite clear that the kinetic energy of the locomotive that struck the now deceased and injured exceeded the injury threshold limit of a normal human being substantially and can safely be identified as the energy source of this accident. It regularly happens that more than one energy source is associated with an accident. In some cases it is the combination of more than one energy source that causes the injury threshold to be exceeded. The accident investigator should be vigilant about the combined effect of energy sources.

5.4.2. SAFETY MANAGEMENT SYSTEM FAILURE

The role of safety management system failure should be critically reviewed during the accident investigation. The main objective of safety management systems is to effectively manage the identified significant risks by ensuring that control measures for these risks are constantly in place.

During the investigation of the accident described above, it soon became evident that the same driver had been involved in a number of minor accidents with the same locomotive. The safety management system of the mine made provision for these minor accidents to be reported despite the fact that no person was injured. Records were found of the reports by the driver, that his supervisor had passed it on to the mine overseer. The safety management system required the records to be forwarded to the mine's safety department that had to analyse them and make recommendations in terms of trends and similarities. The implementation of this part of the system was not done correctly and these records were found filed without the necessary analysis having been done. Apart from other inefficiencies found in the safety management system, the failure to appropriately implement this section of the system was identified as being a failure mode in a fundamental contributing factor.

5.4.3. TRAINING DEFICIENCY

A lack of appropriate training has been identified by Leon (1993) as a major contributor to the unacceptably high accident rate in the mining industry in South Africa. To address this problem the South African mining industry agreed to the inclusion of Section 10 in the Mine Health and Safety Act that requires employers to ensure that every employee is properly trained as follows:

Section 10

10. (1) A far as reasonably practicable, every employer must –

(a) provide employees with any information, instruction, training or supervision that is necessary to enable them to perform their work safely and without risk to health; and
(b) ensure that every employee becomes familiar with work-related hazards and risks and the measures that must be taken to eliminate, control and minimise those hazards and risks.

(2) As far as reasonably practicable, every employer must ensure that every employee is properly trained –

(a) to deal with every risk to the employee's health or safety that –
  (i) is associated with any work that the employee has to perform; and
  (ii) has been recorded in terms of section 11;
(b) in the measures necessary to eliminate, control and minimise those risks to health and safety;

(c) in the procedures to be followed to perform that employee's work; and
(d) in relevant emergency procedures.

(3) In respect of every employee, the provisions of subsection (2) must be complied with –
(a) before that employee first starts work;
(b) at intervals determined by the employer after consulting the health and safety committee;
(c) before significant changes are introduced to procedures, mining and ventilation layouts, mining methods, plant or equipment and material; and
(d) before significant changes are made to the nature of that employee's occupation or work

During the investigation of the case under review it was found that the locomotive driver had been trained in the mine's training centre in the operation of overhead trolley locomotives. Initially no irregularity could be found with the content or methodology utilised in the training process.

Once the training centre was inspected it was established that the overhead trolley locomotive utilised for training was totally different from the ones in general use underground. The controller on the training unit was in a different location in the cab and the direction that the control lever needs to be moved to bring the unit to a stop was exactly opposite to the one involved in the accident. The normal operation of the locomotive was not affected by this training deficiency, however, under the emergency situation that occurred at the time of the accident, the training of the driver on a different locomotive layout proved to be a critical failure mode. This explained why the driver accelerated instead of slowing down when the pedestrians on the track, just prior to the accident, surprised him.

This training deficiency clearly constituted a fundamental contributing factor.

5.4.4. LATENT DESIGN DEFECTS

Most existing accident investigation models imply that, in any given situation, latent design defects will affect the possibility that an accident may occur. Some models call it ergonomics and others construction failure, structural defects or assembly faults. Irrespective of what it is called, most authors agree that latent design defects play an important part in any accident.

During the investigation of the locomotive accident as described above the search for latent design defects was as difficult as one would expect. Initially the investigation focussed on the locomotive, the combination of hoppers and the locomotive, as well as the communication mechanism from the driver to the guard. The normal problems that exist in all underground trains were found, but nothing that could be classified as a failure mode of a fundamental contributing factor could be isolated. It was only once the investigation team started looking at the layout of the track system that it was realised that this presented a fundamental contributing factor.

The Mine Health and Safety Act require that the tunnel be designed with a 500-millimetre walkway on the one side. During the developing of this specific tunnel, this requirement was conformed to. At the point where the accident occurred the tunnel deteriorated as a result of a pillar that was left in the reef horizon. To correct the situation, steel set supports were installed in the area. As a result of this, the travelling way was separated from the rails, which seemed to be an improvement. Interviews with the workers that regularly travel on foot in this tunnel confirmed that the narrower travelling way made it almost impossible to travel behind the steel set legs while carrying hand tools and therefore most workers did not use it.

It would appear that the group of workers misjudged the speed of the oncoming train and was caught in the narrow portion when the train struck them.

This latent design defect clearly constituted a fundamental contributing factor in this accident.

5.4.5. INAPPROPRIATE MAINTENANCE

Most modern accident investigation models have underplayed the contribution of inappropriate maintenance to accidents. Vincoli (1993) identifies maintenance as a factor in accidents but focuses on the contribution that maintenance personnel can make in identifying potential hazards and risk.

In the accident analysed in the example, an inappropriate maintenance factor that contributed fundamentally to the accident was identified since the locomotive's headlamp was replaced with an inferior quality lamp when a replacement was needed two weeks prior to the accident.

During tests performed on the locomotive after the accident it was found that the illumination of the locomotive lights produced only 6.8 lux average in the direction of travel at a distance of 20 metres. This constituted a contravention of Minerals Act Regulation 15.3.1 requiring an illumination of ?? lux at 20 meters. It was clear that it also constituted a fundamental contributing factor.

The correct lamp would have improved the view of the driver and therefore the time he would have had to react as well as prevented the group of workers from misjudging the distance of the oncoming train.

5.4.6. IMPERFECT PROCEDURES

According to Vincoli (1993) procedures should be developed to assist personnel to safely operate hazardous systems. He continues that procedures may include the use of personal protective equipment in hazardous conditions. Section 11(2) (d) (i) of the Mine Health and Safety Act also identifies the use of personal protective equipment as a means of minimising the risk to workers under certain circumstances.

During the investigation of the locomotive accident under review the investigators initially did not find any imperfect procedures that constituted fundamental contributing factors.

After careful analysis of the facts it was established that the selection procedures for locomotive drivers had a serious flaw. All the locomotive drivers on the mine had to undergo a stringent medical screening that included an eye test. The driver of the ill-fated train also underwent the eye test and passed with 6/6 vision. Careful analysis of the test indicated that tests for night vision did not form part of the screening procedure, despite the fact that the underground environment mimics constant nighttime conditions. Once tested it was established that the driver involved in the accident had serious night vision problems that clearly contributed to the accident.

5.4.7. UNSUITABLE TASK DIRECTIVES

A task directive is a detailed explanation of the steps to be followed to enable a worker to safely conduct the tasks making up a job. In the absence of a task directive the complexities of a task is left to the discretion of the worker. This often, results in tasks being conducted without the impact of the specific order being considered. For this reason all high-risk tasks should be supported with a suitable task directive.

During the development of task directives it is important to involve a vertical slice of the workforce.

Task directives do not always describe every task. This should not prevent the accident investigator from analysing tasks to establish the need for task directives. In some cases task directives may exist, but may not effectively be communicated to the relevant workers.

The investigation of the locomotive accident example indicated that a number of task directives existed for the tramming of rock by means of locomotives and hoppers. A detailed analysis of the nature and content of these task directives indicated a number of deficiencies. The task directive dealing with the action of the driver when approaching pedestrians did not include slowing down as it was argued that sufficient travelling ways should be provided. This was a fundamental contributing factor to the accident.

5.4.8. SUBSTANDARD PHYSICAL CONDITIONS

The physical environment, and especially sudden changes to that environment, should be identified. The situation at the time of the accident is important, not the "usual" conditions, according to A Guide to Accident Investigation by the Canadian Centre for Occupational Health & Safety. Investigators may want to establish, for example, how the conditions at the time of the accident differed from the so-called normal conditions at the scene.

It is important that investigators understand that task directives, procedures and maintenance programmes are based on standard conditions. Should the physical conditions vary from the expected, the task directives, procedures and maintenance programmes may become inappropriate to prevent accidents.

During the investigation of the locomotive accident being analysed, a number of changes in the physical conditions contributed to the accident. The most obvious was ground conditions that required the installation of steel set support units that in turn required the establishment of an unusual travelling way between the set legs and the sidewall, clearly a fundamental contributing factor.

5.4.9. UNSAFE ACTS

This contributing factor is the one that most authors use to explain the reason for accidents, but it is also the most controversial and misunderstood factor. Acts or omissions are often utilised to apportion blame and prosecute individuals. It is normally focused on the acts of the injured or persons in the immediate vicinity of the accident, and in so doing moves the focus away from more remote but equally important unsafe acts.

During the investigation of the accident described above a number of unsafe acts were identified, none of them being more important than the other as each contributed in its own way as a factor to the accident. Acts are normally associated with the existence of other failure modes. These acts include:

- Allowing energy sources to exceed tolerable levels, for example by over-speeding the locomotive.
- Ignoring requirements of the management system by not forwarding the reports of the minor accidents to the safety department for trend analysis..

- Allowing inappropriate training programmes to be presented by training the driver on a locomotive not equipped with the same type of control as the one in use underground (at the time of the accident).
- Ignoring or allowing latent design defects to continue when the travelling way was moved to be behind the steel set support legs.
- Conducting or allowing inappropriate maintenance in that the light of the locomotive was not appropriately repaired, resulting in an inferior light shining in the direction of travel.
- The drafting of imperfect procedures in this instance included the lack of the eye testing procedure to test for night blindness for all underground locomotive drivers.
- The issuing of unsuitable task directives in this case included an omission to include an instruction requiring the locomotive to slow down when approaching pedestrians.
- Allowing substandard physical conditions to form or continue. In this case the changing ground conditions resulted in unusual physical conditions, resulting in the rerouting of the travelling way.

5.4.10. BARRIER FAILURE

Barriers are basically of two types, physical or time barriers. The purpose of physical barriers is to physically prevent the energy source to come into contact with persons in the event of other failures. When assessing the effectiveness of physical barriers it is important to establish the capability of the barrier to arrest the energy source in such a way that the energy will be dissipated so that the threshold limit of the person potentially in contact with the energy would not be exceeded. A time barrier aims to ensure the absence of persons during a final event.

In the example the use of time barriers was attempted. A rule was made that no pedestrians were allowed during the main tramming shift. The accident investigation revealed that there was no clarity as to whether the accident occurred during the main tramming shift or not. Conflicting evidence as to the exact time of the end of the main tramming shift was obtained. Some witnesses were of the opinion that the main tramming shift ended at 04:30 and others stated that it ended at 05:00.

This time barrier clearly failed as persons were travelling on foot while tramming was taking place.

5.5. GRAPHIC REPRESENTATION

In order to clarify the interaction of the various failure modes identified during this research, a graphic representation was developed and is represented in figure 5.1. The fundamental contributing factors are represented as individual solid plates rotating at individual, varying speeds on a common axis. Each plate in the model represents a fundamental contributing factor associated with a potential accident. The solid parts of the plates represent a perfect condition in each of the elements. The randomly positioned holes in the plates represent failure modes of the fundamental contributing factors:

- Energy sources out of control,
- Management system failure,
- Training deficiency,
- Latent design defects,
- Inappropriate maintenance,
- Imperfect procedures,
- Unsuitable task directives,
- Substandard physical conditions,
- Unsafe acts,
- Barrier failures.

(Figure on next page)

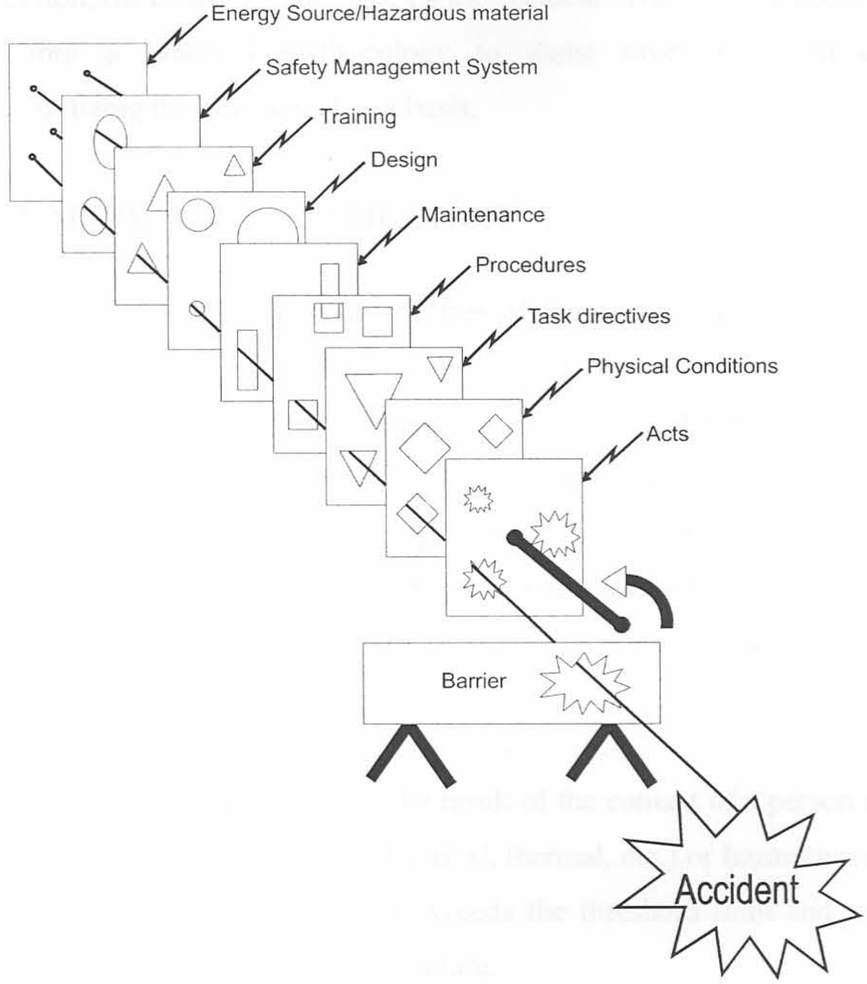


Figure 5.1: Graphic representation of the fundamental contributing factors associated with accidents (as identified during the empirical investigation)

If at any time all the theoretical holes are aligned, or arranged so that a line of sight passes through all the plates, an accident will result. In practice this means that an unsafe act or any of the other factors alone cannot cause an accident. The unsafe act forms part of a system of interactive failures where all the fundamental contributing factors have a defect lined up in the four-dimensional space-time continuum. This may explain why defects in any of the fundamental contributing factor areas may exist for a long time without an accident resulting.

5.6. CONDUCTING AN ACCIDENT INVESTIGATION

In the next section, the elements that make up the accident investigation model will be transformed into a practical methodology to assist investigators to conduct investigations utilizing the new model as a basis.

5.6.1. GOALS OF THE INVESTIGATION

Where possible, the investigator should be free of the operational influence of the employees concerned, in order that the investigation may be objective. The investigation should be a thorough attempt to identify fundamental contributing factors. The tendency to blame an accident on any employee's "carelessness" should be avoided because the term is too vague and usually hides all the other problems that could be corrected, if identified. More often than not, it is easier to rectify problems in other areas, in the short term, and to address behavioural changes in workers over a longer period.

It has been established that accidents are the result of the contact of a person or piece of equipment with energy (mechanical, electrical, thermal, etc.) or hazardous material (carbon monoxide, dust, water, etc.) that exceeds the threshold limit and results in injury, property damage and/or equipment failure.

During an investigation the investigator should determine the fundamental contributing factors to the accident by first establishing what happened, why it happened and how the contributing factors of the accident each contributed. The outcome of a good investigation should include the assignment of persons to implementing preventative actions based on the outcome of the investigation.

In order to investigate accidents successfully it is required to understand the elements involved in an accident. Usually, an accident is the result of multiple elements acting together. Based on this research, the investigation model described in the next section is considered to be best suited for South African mining industry conditions.

5.6.2. DECISION TO INVESTIGATE

It will generally not be possible to conduct a detailed investigation into every accident. The decision on the level of detail of an investigation should be based on the risk profile associated with the accident or group of accidents.

Marx et al (1996) identify four general levels of ranking risk as follows:

- High risk
- Moderately high risk
- Moderately low risk
- Low risk

Taking into account the consequence potential, the frequency of occurrence and the exposure of the workforce to the hazard that resulted in the accident, the risk category should be determine.

A number of alternative approaches for the measurement of risk are available. The most commonly used method is a risk matrix approach. In using this approach the investigator should categorise the consequences of the hazard and its frequency separately and then combine these in a matrix to determine the risk ranking.

Table 5.1: Risk Matrix (Frequency/Exposure Index) (after Marx et al 1996)

		FREQUENCY OF OCCURRENCE			
		Weekly	**Monthly**	**Annually**	**1 in 10 years**
CONSEQUENCE	**Fatality**	1	2	3	4
	Permanent disability	2	3	4	5
	Hospitalise	3	4	5	6
	Lost time	4	5	6	7

This two-dimensional risk ranking can then be translated into a three-dimensional ranking by making use of a second matrix where the consequence/frequency index, determined in the first table, (Table 5.1) is combined in a second matrix with the exposure of the workforce to the specific risk.

Table 5.2: Risk Matrix (Ranking)

		EXPOSURE OF WOKFORCE			
		100%	**75%**	**50%**	**25%**
CONSEQUENCE/FREQUENCY INDEX	**1**	1	2	3	4
	2	2	3	4	5
	3	3	4	5	6
	4	4	5	6	7
	5	5	6	7	8
	6	6	7	8	9
	7	7	8	9	10

An example of how to utilise multiple matrices is shown in Tables 5.1 and 5.2. In this example a severity, frequency, exposure risk ranking of 1 will indicate the highest category. Should an accident result in a risk ranking of 10, no immediate action may be required.

The investigator should take the risk category into account when deciding on the level of the investigation to be arranged, as well as the size and composition of the investigation team, in respect of any accident.

When utilising multiple risk matrices, the intersection between the consequences and frequency axes are determined, as can be seen in table 5.1, where a consequence of "Hospitalise" and a frequency of "Annual" results in a consequence/frequency index of 5. This index is then transferred to the risk-ranking matrix as depicted in table 5.2 on the vertical axis (consequence/frequency index). Where "Exposure" and "Consequence/frequency index" intersects the investigator will find the risk ranking.

It is normal practice for each mine to develop a tolerability index. This implies that only accidents with a risk ranking higher than the tolerability level for that mine will be investigated.

According to the International Labour Organisation the determination that the risk of an accident is at a tolerable level should be made in the light of an adequate assessment of the probability of occurrence and an understanding of the severity of the outcome as well as the exposure levels anticipated. In addition, the Inspector of Mines' expectations and the public's perception typically should serve to reduce the tolerance for risk on any individual mine.

Tolerable in this instance does not mean acceptable, it only refers to the willingness to live with a risk so as to secure certain benefits in the confidence that the risk is being properly controlled.

The decision whether to investigate or not should also take cognisance of accident trends on a particular mine, as well as recent accidents which invoked exceptional public interest.

5.6.3. RECEIVING NOTICE OF AN ACCIDENT

On receipt of a report that an accident occurred, it is important to record as much information as possible for the following purposes:

- To allow the investigator to determine the urgency of the accident investigation.

- To provide a convenient means of communicating the essential details of an accident to all interested and affected parties. The details may be used to prepare briefing minutes to stakeholders, if the circumstances require. It is therefore essential that the information is correct and as detailed as possible.

The person receiving the report should try and obtain the following information from the person reporting the accident:

5.6.3.1. PERSON REPORTING THE ACCIDENT

The name of the person reporting the accident.

This is important, as it may be necessary to question this person again at a later stage, when further details of the accident may be required. Initial accident reports are often made before even the most rudimentary of preliminary investigations have taken place and details given are often based on hearsay and very sketchy information.

The reporting person's position within the organisation.

It may be necessary to question the person making the report to determine whether the manager/employer is aware that an accident has taken place and, if so, what instructions he has issued on the matter.

Full contact details

This should be obtained so that further information can be readily obtained if necessary. The location of the telephone contact should be ascertained (home, work or control room, extension or switchboard) and some idea of whether that contact number will be continuously manned, should be obtained. A telephone number is of no use if it cannot be used to regain contact.

5.6.3.2. PERSONS INVOLVED IN THE ACCIDENT

This information is important from the point of view of determining what immediate action that would be required.

The condition of any injured persons must be established and their specific conditions recorded.

5.6.3.3. BRIEF DETAILS OF ACCIDENT

In obtaining the details of the accident, the following information should be ascertained:

- What was the injured person(s) DOING immediately prior to the accident?
- What was the specific OCCURRENCE, which resulted in the injury?
- Was there any OTHER FACTORS, which contributed to the accident?

The description should be as brief and concise as possible while giving all the relevant facts as reported. In most cases, precise information on the exact contributing factors of the accident will not be available yet. The report should therefore make clear where reasonable inferences have been drawn. Just stating the type of accident is not sufficient.

I.e. if a mechanical fitter was injured while driving a loader the details of the accident might commence thus,

"While a mechanical fitter was test driving a loader following mechanical repairs...."

5.6.3.4. DATE AND TIME

The date and time of the accident should be recorded while it is still fresh in the memory of the person making the report.

5.6.3.5. RESPONSIBLE PERSONS

It is important to obtain the contact information of the employer representative as well as the statutory appointed manager. This is important to ensure that the investigator will be able to contact the appropriate persons to initiate an investigation.

5.6.3.6. PERMISSION GRANTED TO RESUME WORK

The immediate instructions regarding the treatment of the accident scene should be recorded. If the accident is to be investigated, the person making the report should be reminded to advise the manager that the scene of the accident is not to be disturbed or interfered with in any way other than with a view to rescue persons.

5.6.4. PREPARATIONS

Where appropriate and depending on circumstances and the type of accident the investigator must decide on the composition of the investigation team.

All the activities that were taking place prior to the accident have to be evaluated during the accident investigation to determine the risks the injured persons were exposed to. The evaluation should result in identifying the inadequacies, defects and unsafe elements as discussed above.

The in loco inspection is a very important part of any accident investigation. The following is a suggested sequence of events when an in loco inspection is planned:

- Ensure that the relevant supervisors, safety representatives and witnesses are available to attend the in loco inspection.
- Prepare for the in loco inspection.

- Perform the in loco inspection.

In preparation for the investigation the following steps should be followed:

- The investigator should arrange an appropriate date and time for the in loco inspection. Remember that the sooner you get to the scene of the accident the more accurate the information obtained will be. It is essential that the inspection in loco should be carried out as soon as possible after the occurrence of the accident. The inspection must, as far as reasonable practicable be conducted under the same circumstances as those that prevailed at the time of the accident (the same shift is preferable in most cases).
- The investigator should obtain all relevant documentation pertaining to the accident and became familiar with the relevant portions of all the documents. This could include:
  - ✓ Codes of practice
  - ✓ Standards and designs
  - ✓ Minutes of meetings
  - ✓ Special instructions
  - ✓ Layout plans and maps
  - ✓ Procedures
  - ✓ Statutory inspection reports.
  - ✓ Maintenance procedures.
  - ✓ Appropriate lesson plans and Unit Standards.
  - ✓ Task Directives.
  - ✓ Safety Management documentation.
  - ✓ Specialist documentation.
  - ✓ Planned job observations.
- The investigator should arrange for specialised equipment that may be required at the accident scene, depending on the circumstances, such as:
  - ✓ Light meters
  - ✓ Sound meters
  - ✓ Flow meters

- ✓ Thermometers (wet and dry bulb)
- ✓ Stop watches
- ✓ Cameras
- ✓ Dust level meters
- ✓ Tape measures or distomats
- ✓ Radiation level meters etc.

- The investigator should arrange for the appropriate personal protective equipment (PPE), notebook and other personal items required to successfully conduct the in loco inspection.

5.6.5. IN LOCO INSPECTION

The following actions should result during the in loco inspection:

- Ensure that all the persons concerned with the accident (potential witnesses) are available for interviews and to give explanations of what may have happened.
- On arrival at the site, the accident scene must be secured to prevent important physical evidence to be disturbed or destroyed.
- The investigator must lead the in loco inspection.
- Once the area is secured, the necessary sketches and photographs should be prepared. Notes should be made of any evidence found on the scene of the accident that may shed light on events before, during and after the accident.
- Each piece of physical evidence should be carefully labelled and accurate records should be kept of the time, place and person from whom the evidence was received.
- Should any item be removed from the mine, the investigator must issue a receipt for that item to the responsible person on site.

- It is recommended to encourage all stakeholders to attend such inspection in loco. Prior to entering the accident site the manager must assess the safety of the party. Special care should be taken not to expose the investigating team and other members assisting them to unacceptable risks.

Despite the above, the investigator should inspect the scene for any hazards that could result in another accident and keep everyone away from the immediate area so that the scene remains undisturbed until all the facts are collected, use barrier tape, or other appropriate material.

Before allowing anybody to visit the scene, the following must be ensured:

- Ascertain what dangerous conditions prevail at the scene,
- Inform the persons who will accompany the investigator regarding any hazardous conditions at the scene,
- Ensure that the presence of such persons, because of their conduct or number, does not hinder the proper investigation.

The investigator should personally interview everyone involved, i.e. the injured person(s), nearby employees, and other personnel who may provide clues to the fundamental contributing factors of the accident. Investigators must emphasise that their investigation is a fact-finding exercise, not a faultfinding mission, otherwise the workers and supervisors who have the information may conceal the information to protect themselves and their fellow employees.

The more information obtained, as soon as possible after the accident, the more accurate the investigation results will be. With this in mind all victims and potential witnesses should be identified and interviewed as soon as possible. Also conduct interview with those who were present prior to the accident and those who arrived at the accident scene shortly after the accident to establish the conditions prevailing at these times.

The investigator should not try and remember what every witness had to say or try and record everything that every witness says. Notes should be made of the salient points mentioned by each witness and ensure that they know what was said, and by whom, should it become necessary to clear up any uncertainty.

A reconstruction/re-enactment of the accident should only be permitted if it can be 100% sure that the accident will not be repeated.

During the inspection in loco the investigating officer/team should refrain from making improper remarks that could lead to a perception of prejudice. Only the person in charge of the investigation may act as a spokesperson.

5.6.6. PREPARING FOR THE INTERVIEWS

Before the interviews of relevant person's starts a number of arrangements must be made to ensure the successful completion of the investigation. These arrangements will include at least the following if not done during the in loco inspection:

- Determine the appropriate sequence of witnesses.
- Confirm the date and venue for the interviews with all the interested and affected parties.
- Study the appropriate laws, regulations, codes of practice, special instructions and national codes.
- Compare company specific standards with industry standards and guidelines with the aim of establishing reasons for deviations.
- Evaluate previous similar accidents and proposed remedial actions.
- Prepare specific questions for each witness.
- Arrange for specialist witnesses as appropriate e.g.
  - ✓ Medical experts
  - ✓ Rope experts
  - ✓ Explosives experts
  - ✓ Rock engineering experts
  - ✓ Chemical experts etc.
- Arrange for an interpreter if required
- Review the preparations.

Where a team does the investigation the team leader of the accident investigation team must define the scope of the investigation, if somebody else has not already done this. The lead investigator must assign specific tasks to each member of the team as appropriate. In the event of the team consisting of one person only, the investigator must ensure that s/he keeps track of requests made for information.

The team should always keep in mind that the purpose of an accident investigation is the determination of the fundamental contributing factors of the accident and not to try and determine who was responsible for the accident.

Accidents represent problems that must be solved. To solve a problem the investigation procedure requires an impartial investigation team who utilises a systematic, logical and thorough process. They need to remember that where hazards are combined the accident potential will multiply. The larger the number of hazards, the quicker the accident potential will increase.

5.6.7. THE INTERVIEW

The investigating team must compile a list of all persons present at the investigation signed by such persons whether the investigation is carried out in a group or as individual interviews.

The interview could take the form of a discussion with all effected parties around the table or witnesses could be called in one by one and interviewed. The particular circumstances associated with the specific accident will dictate which method to be followed.

It is strongly recommended that in the event of an accident that could result in punitive action, the witnesses be interviewed one at a time to prevent persons from being influenced on the interpretation of the way they understood the situation at the time of the accident.

An interview, arranged for the purpose of an investigation, could be arranged with the person required to be interviewed alone. Despite the fact that the Mine Health and

Safety Act do not prescribe that a representative is present, it is advisable to allow this if such a request is received to assist persons questioned during an investigation.

It is normally most appropriate to interview persons directly related to the accident first. They could be persons performing tasks directly related to the accident, key supervisors, technical experts or eyewitnesses.

The investigator should start the interview by asking the witnesses to describe in their own words, what they know about the accident. This should include what they saw, heard, smelt or felt as the case may be.

After witnesses have outlined their experiences the investigator should ask predetermined questions to prompt for more detail or in depth information. When obtaining conflicting reports from witnesses the investigator should not assume that one party is not telling the truth, as even observations of the same incident from different angles may result in differing conclusions. In addition to this, different individuals may not perceive the same information to be relevant, may have overlooked some information or due to the trauma of the event may have subconsciously suppressed it.

A detailed investigation into any accident must at least start with answers to the questions as listed in annexure "D".

During interviews it would be important to keep these questions in mind in order to enable the investigator to answer the questions when writing the accident investigation report. It is also important not to focus on the victim only but to apply the questions to all the persons associated with the accident.

The investigator should explain to witnesses that the purpose of any note taking during the interview would only be utilised as a memory tool for the use of the investigator only.

It is not envisaged that verbatim statements are recorded, but no investigator should rely entirely on memory for information obtained from witnesses. Personal notes should be kept.

Note taking should be informal so as not to distract the train of thought of the witness. The notes should include comments on the tone, repetitiveness, expressions and body language of witnesses that can later be helpful in analysing the evidence.

5.6.8. ANALYSING THE DATA

Once all the data pertaining to the accident has been collected it should be analysed in a structured way. If the information gathered during the interviews were reviewed the most obvious contributing factors would normally be identified quite easily. These will normally be from the areas of unsafe conditions, unsafe acts and barriers that failed. The accident data needs to be evaluated in much more depth to establish the fundamental contributing factors, as these failures can be seen as symptoms thereof.

After the investigating team has compiled all of the data, the team should select what is significant and eliminate the irrelevant. Drawing balanced conclusions from the evidence naturally presents a challenge.

This task can best be undertaken by means of a four-phased approach as follows:

- Considering the Evidence
- Analysing the Evidence
- Maintaining Perspective
- Adjusting the Recommendations to the Circumstances

5.6.8.1. CONSIDERING THE EVIDENCE

Experienced investigators develop the skill and the ability to ascertain the characteristic of the evidence gathered. Further skills required are the capability to examine, correct and continually be impartial and to ensure that the origin of data is unbiased and equitable. The evidence (verbal or documentary) should not be accepted as the truth unless it has been verified and substantiated by the investigator. This may require further confirmation of facts than just verbal evidence.

5.6.8.2. ANALYSING THE EVIDENCE

Each portion of the evidence, which offer a conclusion should be further analysed in order to establish if it is entirely supported by facts or logic, or both. The system of logic required to be followed here is a matter of common sense. Inconsistencies in the reasoning of others are normally easy to identify but individuals are ordinarily unable or unwilling to exercise self-criticism of their own analysis. Self-criticism will not only assist analysis, but will also allow the investigator to predict the valid objections to the findings, and to change, qualify or better explain such findings.

To ensure objectivity the identification of any section of the safety management system that failed should be noted. The lack in training, latent design defects and ineffective part of the maintenance programme identified. All unsafe portions of the procedures and task directives must be isolated. This all must be brought into context with the dangerous physical conditions and unsafe acts associated with the accident. In the event of physical or time barriers having failed their appropriateness should be analysed.

5.6.8.3. MAINTAIN PERSPECTIVE

Maintaining perspective during an investigation is critical to provide a focussed solution. The investigators should not become so interested in specific detail that they forget the real purpose of the investigation. This can be achieved by utilising a systematic approach.

The system utilised will have to ensure that no part is skipped, by only focussing on the obvious. An easy way of overcoming this problem is to take ten pages, one for each plate, and place the title of each plate on the top of a clean page.

By following the sequence of events, from a time before the accident happened until a time after the accident, whilst focussing on one plate at a time and recording the significance of the events on the specific plate, the fundamental contributing factors will easily be identified for later inclusion in the report.

Often, the events before the accident are more important than the instant of the accident. In order to establish all the relevant factors, each investigation team should determine how far back into history the investigation should start.

5.6.8.4. ADJUSTING RECOMMENDATIONS TO CIRCUMSTANCES

The investigator may find more than one answer to each question, but in reality there is usually only one appropriate conclusion. A conclusion on a particular set of facts should be reached based on the particular circumstances. The reasoning behind the conclusion MUST be given and recommendations made should be based on the evidence obtained during the interviews as well as observations made during the in loco inspection, and any other physical evidence collected.

If the investigation had been thoroughly completed, the conclusions reached will probably suggest themselves to the investigator. Should the investigator be surprised as to the outcome and conclusions reached this may be the result of an inappropriate investigation.

With the above information available it should be possible for the investigating officer/ team to determine **WHAT** happened, **WHY** the accident occurred and **HOW** the release of energy could have been controlled.

5.6.9. THE REPORT

The main purpose of an accident investigation report is to communicate the specific facts of an accident to interested and affected parties. The accuracy of these facts cannot be over-emphasised, as various different actions will result, based on the content of the report.

The report should contain at least the following information:

Introduction

The introduction must contain a short factual description of the accident.

Findings

The report must include:

- The sequence of events preceding, during and subsequent to the accident.
- A short description based on factual evidence produced at the investigation regarding each failure mode.
- Where appropriate a short description of what should have been done.

These must be brought into context with the actual conditions found during the in loco investigation.

Recommendations

In order to prevent a similar accident from occurring, recommendations must be made to the employer/manager to develop a preventative plan based on the identified failure modes.

The investigator(s) should only make specific preventative action recommendations in cases where these suggestions are justified by the weight of the evidence. Recommendations should be limited to the rectification of the failures identified during the investigation, rather than to how results should be accomplished. It remains the responsibility of the employer to ensure that the mine is operated in safe and healthy manner.

Conclusion

The conclusion of the report should be a fully developed statement of fundamental contributing factor(s) of the accident. This is not the same as the cause of the injury. Careful consideration should be given to this section to avoid the common mistake of confusing the cause of injury with the fundamental contributing factors of the accident.

5.6.10. POST-INVESTIGATION BRIEFING

At the conclusion of an accident investigation report, a formal post investigation briefing should be held to inform the management team and members of the safety committee of the outcome of the investigation.

During this briefing it is important to ensure that the focus of presentation is on the fundamental contributing factors of the accident. The manager should also be reminded of the statutory instruction to submit action plans with milestone dates and responsibilities to institute preventative actions.

5.7. CONCLUSION

This chapter considered the new approach required in terms of the Mine Health and Safety Act (1996) and also outlined the model with the aid of an actual accident example where the different elements are individually explained and a graphical representation of the model is given. The chapter was concluded by giving a detailed description of the steps involved in conducting an accident investigation utilising the developed model as a basis.

In the next chapter the theoretical benefits identified in utilising the newly developed methodology will be evaluated by considering the result of a pilot study.

CHAPTER 6

PILOT STUDY

6.1. INTRODUCTION

Once the questionnaire study confirmed that the ten identified fundamental contributing factors should indeed be included in accident investigations, an analytical accident investigation model was developed based on the research. A draft accident investigation guideline was drawn up. This guideline is fully described in Chapter 4 of this thesis.

To confirm that the theoretical benefits of utilising the newly developed methodology could be realized in practice it was decided that conducting an actual field trail pilot study should test the investigation process. The pilot study was also utilised to establish the practical limitations of implementing the model on a scale that may include other industries and types of accidents.

The chapter will commence by giving the background to the pilot study, some of the consequences of the study as well as the advantages of the proposed accident methodology as identified by the field staff conducting the trails. The chapter will then continue with a summary of recommendations and a concise description the process that was followed to effect changes to the legislative framework to accommodate the results of this research.

THE PILOT STUDY

The purpose of the pilot study was to ensure that all the practical problems that may be encountered with the implementation of the system in all the mining regions in South Africa could be identified and rectified. In addition to this it was necessary to verify the impact of the new system on the accident statistics.

It is a requirement of Section 60(2) of the Mine Health and Safety Act that inspector's of mines may investigate any accident or occurrence at a mine that resulted in the serious injury or serious illness of any person. As these inspectors have a legal right to investigate accidents, the Chief Inspector of Mines was approached and gave permission for the draft investigation protocol to be tested in one of the regions of the Republic of South Africa.

In terms of Section 47(2) of the Mine Health and Safety Act, the Minister established nine mining regions for the administering of the Act. One of these regions cover the Gold mines in the Klerksdorp area as well as the Platinum Mines in the Rustenburg area. This mining region was selected, as it is the only such region that contains gold as well platinum mines. From the accident statistics discussed in Chapter 2 of this thesis it was clear that the highest accident rates persist on these types of mines.

In order to ensure that the inspectors utilising the new system were fully aware of the implications, they were trained in the use of the system prior to implementation. In addition, the researcher also formed a task team to evaluate and amend, where necessary, the draft accident investigation guidelines.

A Department of Minerals and Energy task group was formed, consisting of 4 experienced officers of the Department of Minerals and Energy.

This team comprised of the following members:

Mr C Marx, Project leader (Researcher)

Mr RS McLoughlin, Principal Inspector of Mines

Mr L Naude, Principal Inspector of Mines

Mr W Prinsloo, Senior Inspector of Mines

This task team evaluated the proposed accident investigation system, based on the accident model described in Chapter 4. The brief of this task team was to confirm that the use of this model will in fact enhance the effectiveness of accident investigations. Some minor adjustments were made and the team recommended to the Chief Inspector of Mines to proceed with the pilot study.

As a result of the statutory requirements as contained in Section 65 of the Mine Health and Safety Act pertaining to the conducting of inquiries into the death of any person, the Chief Inspector of Mines gave permission to allow the pilot study to continue with the requirement that only non-fatal accidents be investigated utilising the proposed accident investigation system.

Traditional inquiries (taking down statements under oath), were still conducted in the event of all fatal accidents to comply with current statutory requirements.

The pilot study was conducted between 01 January 1999 and the end of May 2000. A total of 1143 accidents have been investigated by means of the procedure prescribed in Chapter 5, by the inspectors in the selected region.

During the period of the pilot study, a number of changes have been recommended and affected to the original draft proposal, to ensure that the system is user friendly and effective. For the duration of the pilot study, the task team conducted regular interactive sessions with the field staff to establish whether any changes were necessary. Once a potential change was identified, the task team considered the practical and legal consequences before accepting any such changes to the investigation protocol.

The participating inspectors were requested to identify the advantages and disadvantages of the system. This was requested to enable the researcher to ensure that the advantages are not lost in future implementations while attention can be paid to reduce the impact of any disadvantages identified. At the conclusion of the pilot study, and based on their collective experience accident investigations the following list of advantages was drafted by these inspectors.

6.2.1. ADVANTAGES OF THE PROPOSED INVESTIGATION METHOD

The inspectors involved in conducting the pilot study identified the following advantages of the newly developed accident investigation method:

- The fundamental contributing factors of accidents are effectively identified if the investigation focus on the failure modes as was the case during the pilot study.

- Accident investigations were less time consuming than formal inquiries, more cost effective and there were no need for expensive legal representation, as union representatives with little or no legal background could sufficiently represent their members.

- Employers and employees both recognised the investigation methodology as a tool that could assist them in determining the fundamental contributing factors of accidents and not as a punitive measure of apportioning blame.

- It was established that persons involved in the accident investigations took active part in the investigation and expressed their opinions freely. This resulted in more information becoming available that could be utilised during the establishment of the fundamental contributing factors of the accident to prevent future similar accidents.

- Inspectors were not required to take down useless verbatim statements, allowing the inspector to concentrate on establishing the fundamental contributing factors of the accidents investigated. Only information that positively contributed needed to be recorded.

- All parties were participating in decisions regarding the development of remedial actions, resulting in an improved ownership of the solutions and therefore resulting in more effective implementation.

- Remedial action implemented had a distinct positive affect on the accident statistics as the reportable injury frequency rate declined from 13.51 in January 1999 (the start of the trail) to 12.08 in December 1999. The downward trend is indicated on figure 6.1. The persons participating in the pilot study unanimously agreed that this significant downward trend in reportable accidents could primarily be attributable to the accident investigation methodology utilised and the associated remedial actions developed during the study.

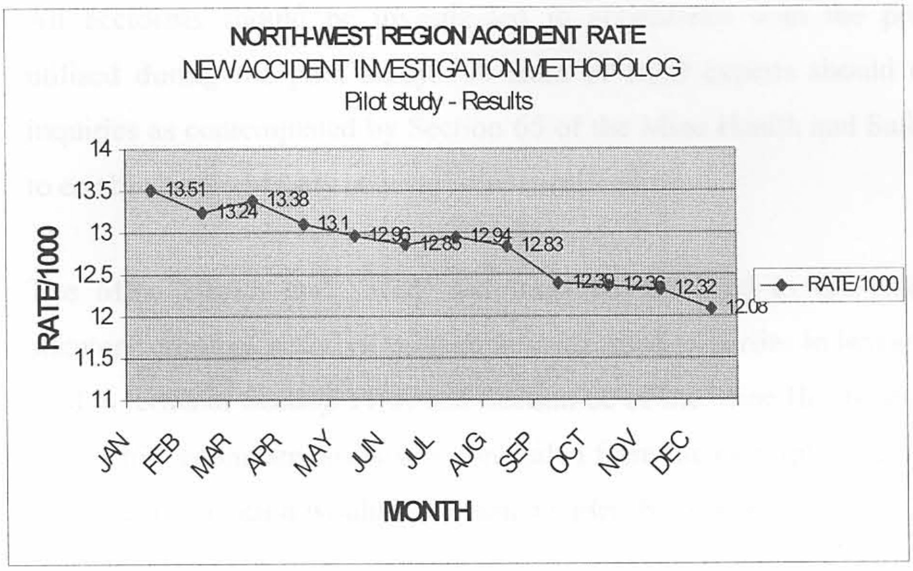


Figure 6.1: Significant downward trend of the accident rate resulting from the implementation of the newly developed accident investigation methodology

From figure 6.1 it is clear that the impact of this methodology was slow in the initial stages of the study but increased as more and more accidents were investigated. According to the field staff, this trend can primarily be attributed to two factors. Firstly, the impact of the corrective actions agreed to during the first few accident investigations were insignificant as the number of major failure modes identified still unattended to, were overwhelming. Secondly, and more significantly, the inspectors reported a great deal of mistrust from the stakeholders, in the initial stages of the study, as the Inspectorate is not known for this type of preventative approach during accident investigations. This mistrust was replaced by increasing openness as the participants in accident investigations realized that the investigators did not collect the information to use it in future prosecutions.

6.2.2. PILOT STUDY RECOMMENDATIONS

As a result of the positive results obtained during the pilot project, the following recommendations were made to the Mine Health and Safety Council:

- All accidents should be investigated in accordance with the procedure utilised during the pilot study. A team of legal experts should conduct inquiries as contemplated by Section 65 of the Mine Health and Safety Act, to establish whether any statutes were contravened.

- The Mine Health and Safety Act must be amended to the extent that statutory criminal and civil protection is afforded to parties in investigations held in terms of Section 11(5) and Section 60 of the Mine Health and Safety Act. This recommendation was concluded from the principle that more and accurate information would be obtained under these conditions.

6.3. CHANGING THE LEGISLATIVE FRAMEWORK

The Mine Health and Safety Act was fully developed and promulgated on a tripartite basis. The Act introduced a number of novel concepts in a South African context. The Act envisaged that conditions might exist where prosecution may not be the focus of investigations, by allowing for a process whereby the Chief Inspector of Mines, in consultation with the appropriate Attorney-General, may issue a certificate of no prosecution in respect of any contravention of, or failure to comply with, a provision of the Act, related to the event being investigated.

It is clear from the inclusion of Section 63(1) in the Mine Health and Safety Act, that the spirit of the Act was aimed at establishing the reasons for accidents in order to prevent future accidents, rather than wanting to establish statutory accountability.

It is obvious that, despite good intentions the provisions of this section of the Act is not effective, as no such certificate has been issued since the promulgation of the Act.

After having been presented with the facts, the Mine Health and Safety Council agreed that a tripartite task group be established that consists of a tripartite legal drafting team, who will be supported by one technical expert from each of the three stakeholders. This researcher was appointed as the State technical expert to convene the task group.

The task group consisted of the following members:

Mr C Marx, State technical expert (Researcher)

Me S Meso, State legal advisor

Mr JR McEndoo, Employer technical expert

Mr A van Achterbergh, Employer legal advisor

Me M Llala, Employee legal advisor

It was agreed that the mandate of the task group be as follows:

- To clearly define the objectives of investigation and inquiries respectively, as envisaged by sections 60, 11(5) and 65 of the Mine Health and Safety Act and consider methods of incorporating it into the Act.
- To establish a statutory framework whereby the objectives as defined, can best be achieved.
- To recommend amendments to the Mine Health and Safety Act that will enhance the effectiveness of accident investigations, as anticipated by Section 63(1) in the Mine Health and Safety Act, that will give meaningful effect to the notion of enhancing the effectiveness of accident investigations.
- To develop a proposal on possible ways to determine the impact of de-linking of accident investigations from the legislative process on the social responsibility of the stakeholders, to uphold law and order in an industrial environment and develop contingency plans to ensure that no negative impact is caused.

The task group confirmed that there should be a clear distinction between investigations and inquiries, particularly regarding their objectives.

The objectives of investigations were defined as follows:

- Establish all the direct and indirect contributing factors to an accident/occurrence (without establishing statutory responsibilities or breaches) – in order to ensure, as far as possible, that similar accidents/occurrences, are prevented.

- Investigate (proactively or otherwise) any occurrence, practice or condition concerning health or safety of persons at one or more mines.

The objectives of inquiries were defined as follows:

- Establish whether there has been a breach of any health or safety provision associated with an accident/occurrence, in order to:

(a) Recommend prosecution of person/s alleged to be guilty of an offence; and

(b) Identify what needs to be done to prevent similar breaches in future.

Having regard to various factors, the task group concluded that there is probably no need for inquiries in the Mine Health and Safety Act, for the following reasons:

- There are numerous ways of obtaining evidence in order to substantiate criminal prosecutions (or administrative fines) where they are warranted;
- There are certain state organs that are specifically geared to institute criminal proceedings and these should be used to initiate criminal proceedings – with the assistance of the Inspectorate where necessary;
- Inquiries tend to be long, drawn out legal proceedings that achieve little positive outcomes;
- Inquiries into deaths can be dealt with in terms of the Inquests Act. Amendments can be suggested to the Inquests Act to ensure the involvement of inspectors.

The objectives of section 11(5) investigations should remain unchanged.

6.4. CONCLUSION

The results obtained during the pilot study confirmed that it is possible to prevent occupational accidents and reduce resultant suffering by implementing appropriate recommendations resulting from the use of the new model during accident investigation into workable solutions.

The use of the new accident investigation model also allowed a documented, verifiable and repeatable accident prevention programme to be implemented without any superfluous record keeping.

In the next chapter a summary of the research will be given and some final conclusions drawn.

CHAPTER 7

SUMMARY, RECOMMENDATIONS AND FINAL CONCLUSIONS

7.1. INTRODUCTION

The primary purpose of this research was to develop an analytical accident investigation model for the South African mining industry. Adapting world best practice accident investigation techniques to a workable new model formed part of the research.

The research combined the most successful techniques from around the world in a way best suited to the South African mining industry. It was combined in a format proven to produce a reduced accident rate.

An in depth literature study of accident investigation techniques used by world-class industrial organizations was conducted with a view to isolating common fundamental contributing factors present in most of these techniques.

Based on the identified factors, a questionnaire was developed that included these factors. The results of the questionnaire was analysed to establish which of the identified contributing factors should be included in the analytical accident investigation model. These results were utilised to develop the accident investigation model. The model was converted into a practical investigation methodology that was tested for effectiveness during a pilot study.

During the pilot study it was proven that line managers and supervisors can use the model developed to prevent similar accidents. The reportable injury frequency rate in the area where the pilot study was undertaken declined from 13,51 persons injured per thousand at the start of the trial to 12,08, twelve months later, at the conclusion of the study. A total of 1 143 accidents were investigated by means of the new procedure during this time.

The use of the analytical accident investigation model as a basis for accident investigation also ensured that a documented, verifiable and repeatable accident prevention programme could be implemented without any unnecessary recording of information.

7.2. THE ANALYTICAL MODEL

The analytical accident investigation model developed as a result of this research comprises of a system that identifies the fundamental contributing factors to an accident, and then associating the relevant failure modes with the occurrence of the accident.

The failure modes were identified by combining the identified failure modes in techniques used by world-class industrial organizations and governmental originations into a single model.

In order to clarify the interaction of the various failure modes, the graphic representation in figure 7.1 is used where the fundamental contributing factors are represented as individual solid plates rotating at individual, varying speeds on a common axis. Each plate in the model represents a fundamental contributing factor associated with a specific potential accident. The solid parts of the plates represent perfect conditions in each of the elements. The randomly positioned holes in the plates represent failure modes of the fundamental contributing factors:

- Energy sources out of control,
- Management system failure,
- Training deficiency,
- Latent design defects,
- Inappropriate maintenance,
- Imperfect procedures,
- Unsuitable task directives,
- Substandard physical conditions,
- Unsafe acts,
- Barrier failures.

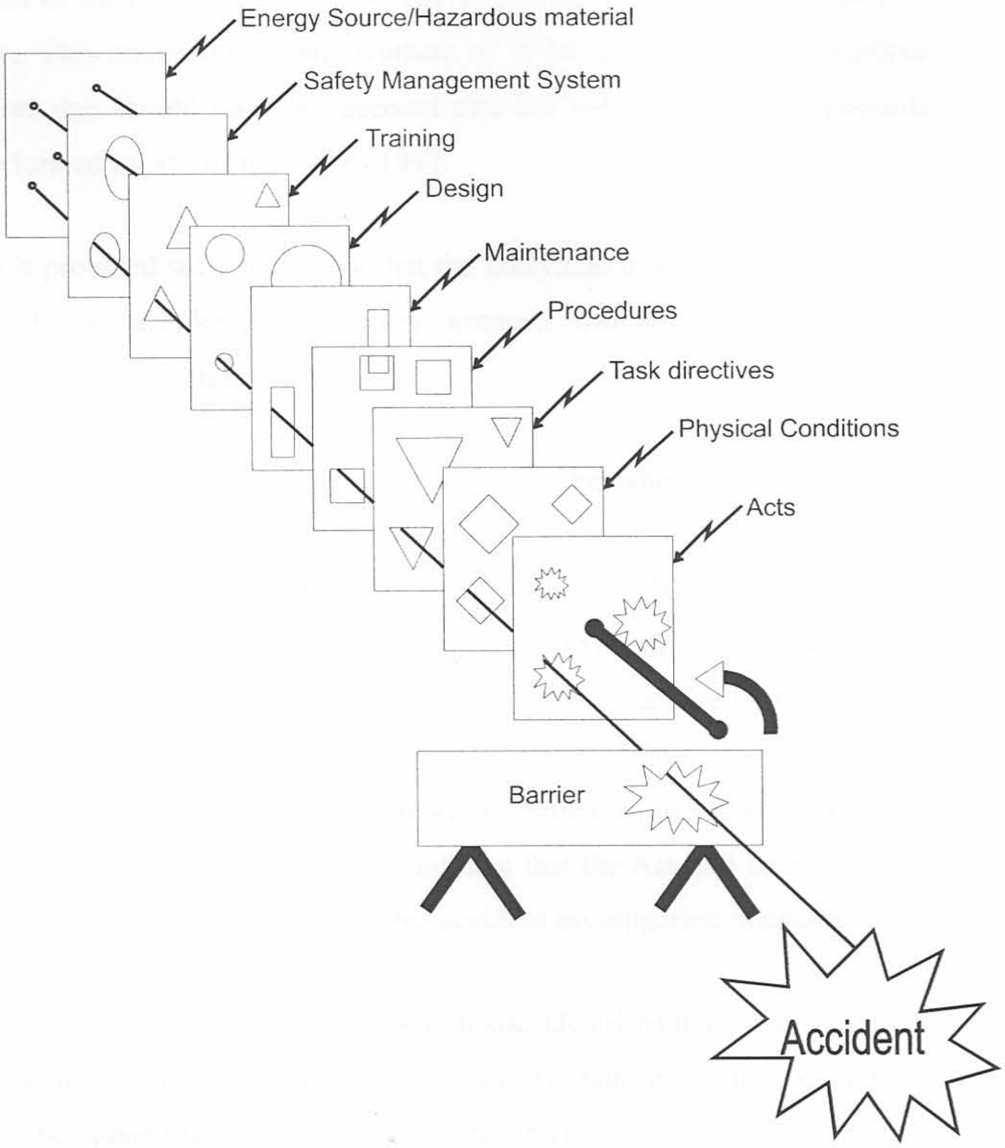


Figure 7.1 – Accident model as developed in Chapter 4

7.3. ACHIEVING THE ORIGINAL GOALS

The researcher set out to develop an analytical accident investigation model to be utilized as a tool to investigate accidents in such a manner that similar accidents could be prevented. The developed model was successfully field tested as reported in Chapter 6 of this thesis. It can safety be said that the pilot study proved the effectiveness of the model since the reportable accident rate in the geographical area where the study was undertaken was reduced from 13,51 at the start of the pilot study to 12,08, twelve months later at the conclusion of the study. This represents an improvement of 10,58%. To bring this in proper perspective one should take into account that the industry average reportable rate deteriorated by 4% from 1990 to 1997.

This result provided sufficient proof that the analytical model, when utilized as the basis for an accident investigation protocol, will result in a significant reduction in accident rates.

The developing of the analytical model also set the wheels of legislation in motion to make changes to legislation to accommodate this value adding approach to accident investigation in legislation. At the conclusion of the research a technical task group, appointed to evaluate the possibility of amending the Mine Health and Safety Act to take advantage of the research results, already submitted their report to the statutory Mine Health and Safety Council, responsible to advise the Minister of Minerals and Energy on health and safety matters. The researcher is confident that the Act will be amended in due course to allow for the recommended accident investigation methodology.

In addition to the original goals, the research also identified that the model could be successfully utilized to pro-actively identify failure modes, should the principles be applied to a qualitative risk assessment. This resulted in a totally new approach in the mining industry in respect of its approach to combining accident investigation and risk assessment methodologies.

7.4. RECOMMENDATIONS FOR FURTHER RESEARCH

While this research was only focused on the mining industry, the author suggests further investigations to assess the applicability of the model in industries and even for the investigation road accidents.

Needs for further research includes how to incorporate the behaviour based aspects of accidents in the methodology of isolating and identifying appropriate failure modes, without reverting back to a blame fixing culture.

The author is of the opinion that additional research in respect of the ratio relationship of incidents as explained by Heindrich, and the identified hazards, risks and failure modes identified during a qualitative risk assessment will further enhance the potential to manage positive performance indicators for safety in the workplace.

Research in this area should clarify the ratios and relationships between incidents and pro-active positive performance indicators as well. The author believes that the triangle could be expanded as indicated in figure 7.2.

This research identified the failure modes or fundamental contributing factors resulting in accidents. This researcher is confident that the identified factors are comprehensive. It is however clear that the level of control required to bring the risks of the individual fundamental contributing factors down to tolerable levels would vary among the individual factors. The methodology to determine these levels of intervention could possibly be found by utilising existing fuzzy logic methodologies.

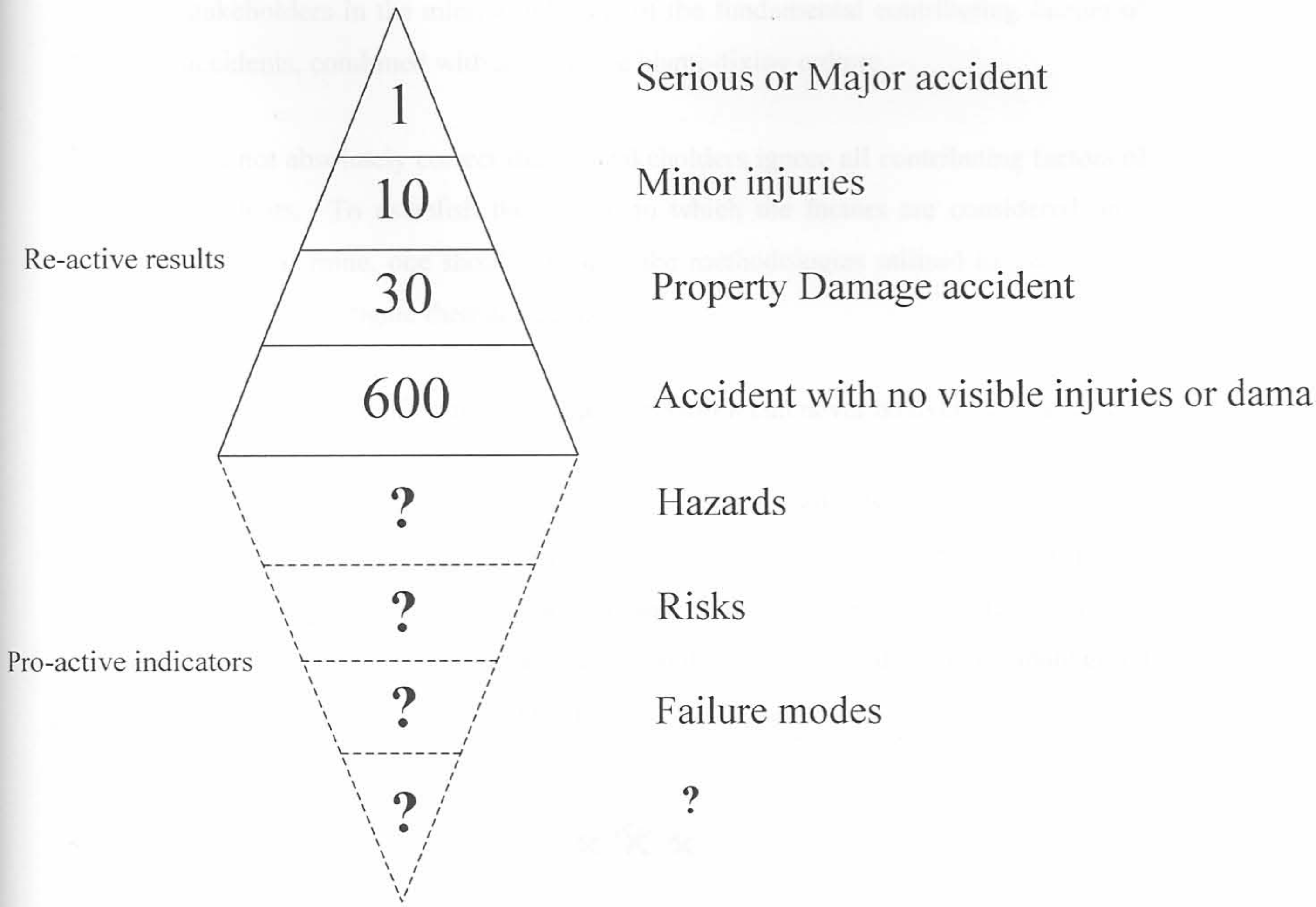


Figure 7.2 Areas identified for further research on Heindrich's triangle

7.5. PUBLICATIONS

During the course of the research a number of articles and technical papers were published in a wide variety of technical publications. The publication of the papers were utilised to ensure that the research outcomes were peer reviewed, by the scrutiny of targeted audiences, at the conclusion of each phase of the research. A list of the publications is contained in annexure "E".

7.6. FINAL CONCLUSIONS

The distinct possibility of a safer mining environment will never be realised as long as the cultural balance is tilted towards compliance rather than prevention.

The primary reason for this state of affairs is the lack of awareness among most stakeholders in the mining industry, of the fundamental contributing factors of accidents, combined with a pervasive blame-fixing culture.

It is not absolutely correct that all stakeholders ignore all contributing factors of accidents. To establish the degree to which the factors are considered on a particular mine, one should evaluate the methodologies utilised to assess their risk and investigate their accidents.

The importance of ensuring accident reduction can never be over-emphasized.

The dream of a safer mining environment could be realized if all the stakeholders focus on fundamental contributing factors as identified during this research and apply their findings and results to prevent similar accidents. Preventative accident management should be integrated into the managerial cultures of mining and all industries.

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Annexure A: Questionnaire

SOUTH AFRICAN MINING INDUSTRY ACCIDENT PREVENTION QUESTIONNAIRE

Instructions

Please answer all the questions, as this will contribute to the validity and reliability of the research results

Researchers have found that the best results are obtained if you record the first answer that comes to mind as that reduces any ambiguity that may be read into the questions.

There are NO CORRECT ANSWERS to the questions in this questionnaire. The aim of the research to establish the opinion of the members of the industry.

The content of questionnaires will be kept anonymous. Please do not write your name or any other form of identification anywhere on this questionnaire.

The questionnaire is divided into different sections as follows:

Section 1 - ***Deals with the opinion of the respondent regarding accident investigations.***
Section 2 - ***Deals with the use of accident and accident investigation information***
Section 3 - ***Deals with the experience and training of the respondent***

The type of answer you are required to record is indicated in brackets after each question.

Please send the completed questionnaire to the following address:

The Deputy Director: Management Support & Internal Control
Accident Investigation Research Project
Department of Minerals and Energy
Private Bag X 59
Pretoria
0001

Fax: ***012 317 9152***

e-mail: ***smimar@mepta.pwv.gov.za***

Section 1

The aim of this section is to establish which issues of importance should be established during accident investigations to reduce the occurrence of similar types of accidents. You should give your own opinion based on you experience with accident investigations. Remember there are NO CORRECT answers to these questions. Please only use the "No Opinion" options if you truly do not know what to answer.

1. 1. Proper accident investigations can reduce accidents.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 2. During accident investigations it is important to determine who was at fault.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 3. Establishing whether the physical conditions prevailing at the time of the accident, is an important feature of an accident investigation method.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 4. During accident investigations it is important to determine whether the procedure prescribed by the mine could have been the underlying cause of the accident.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 5. During accident investigations it is important to determine whether the design of the equipment or the mine layout could have caused the accident.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 6. During accident investigations it is important to determine whether inappropriate task directives could have been the underlying cause of the accident.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 7. During accident investigations it is important to determine whether any person carried out an unsafe act that could have been the underlying cause of the accident.

(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 8. Establishing whether a lack of correct training caused the accident is an important feature of an accident investigation method.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 9. During accident investigations it is important to determine what energy sources and/or hazardous materials were responsible for the accident.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 10. During accident investigations it is important to determine whether the accident was caused by any part of the safety management system that failed.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 11. During accident investigations it is important to determine whether any human factor caused the accident.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 12. During accident investigations it is important to determine whether any barriers failed that caused the accident.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 13. Establishing whether non-compliance with the maintenance programme of the mine caused the accident is an important feature of an accident investigation method.
(*Indicate you opinion with an* X)

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree	No Opinion

1. 14. Rank in order of importance. During correct accident investigations, I am of the opinion that the issues that should be focused on, are:
(*Rank from 1= most important to 11= least important)*

To determine **who was at fault**..	
The **physical conditions** prevailing at the time of the accident.........	
The mine **procedures**..	
The **design** of the equipment or the layout of the mine......................	
Compliance with the **maintenance programme** of the mine..........	
Incorrect **task directives**...	
Incorrect **training**...	
To determine the **energy sources** involved in the accident................	
To determine what **systems failure** caused the accident....................	
To determine whether an **unsafe act** caused the accident..................	
To determine which **barriers failed**...	

1. 15. List any other issues of importance not mentioned in the above questions that you feel are important to establish during accident investigations in order to prevent similar accidents in the future.

____

____

____

____

____

Section 2

The aim of this section is to determine how effective information regarding accident investigations can be utilised by production personnel to improve safety. Please only use the "No Opinion" options if you truly do not know what to answer.

2. 1. How often are you officially informed that a **fatal** accident occurred on the mine that you work on?
(*Indicate you opinion with an* X)

Always	Regularly	Sometimes	Seldom	Never	No Opinion

2. 2. How often are you officially informed that a **reportable** accident occurred on the mine that you work on?
(*Indicate you opinion with an* X)

Always	Regularly	Sometimes	Seldom	Never	No Opinion

2. 3. How often are you officially informed that a **lost time** accident occurred on the mine that you work on?
(*Indicate you opinion with an* X)

Always	Regularly	Sometimes	Seldom	Never	No Opinion

2. 4. How often are you officially informed about the outcome of **fatal accident investigations** held on the mine that you work on?
(*Indicate you opinion with an* X)

Always	Regularly	Sometimes	Seldom	Never	No Opinion

2. 5. How often are you officially informed about the outcome of **reportable accident investigations** held on the mine that you work on?
(*Indicate you opinion with an* X)

Always	Regularly	Sometimes	Seldom	Never	No Opinion

2. 6. How often are you officially informed about the outcome of **lost time accident investigations** held on the mine that you work on?
(*Indicate you opinion with an* X)

Always	Regularly	Sometimes	Seldom	Never	No Opinion

2. 7. How important is knowledge regarding **accidents** that occurred on your mine to you in your normal daily task?
(*Indicate you opinion with an* X)

Extremely Important	Very Important	Important	Seldom Important	Not Important	No Opinion

2. 8. How important is knowledge about **accident investigation results** that occurred on your mine to you in your normal daily task?
(*Indicate you opinion with an* X)

Extremely Important	Very Important	Important	Seldom Important	Not Important	No Opinion

2. 9. How important is knowledge about **accidents** that occurred on your mine to you in order to prevent accidents in your section?
(*Indicate you opinion with an* X)

Extremely Important	Very Important	Important	Seldom Important	Not Important	No Opinion

2. 10. How important is knowledge regarding **accident investigation results** that occurred on your mine to you in order to prevent accidents in your section?
(*Indicate you opinion with an* X)

Extremely Important	Very Important	Important	Seldom Important	Not Important	No Opinion

2. 11. List any other important issues you feel will improve the effective use of information resulting from accident investigations in order to improve safety.

___

___

___

___

___

Section 3

This section should reflect your total experience and training in the mining industry.

3. 1. I am **currently** employed as a (*indicate with a* X)

Section/Underground Manager....................................... ☐
Inspector of Mines.. ☐
Mine Overseer... ☐
Shift Boss.. ☐
Miner/Mineworker.. ☐
Other *(Please specify type)*_____________________................ ☐

3. 2. I have the following **total** experience in the mining industry (*Number of full years in each sector*)

Gold Mines.. ☐
Platinum Mines.. ☐
Coal Mines.. ☐
Other Mines *(Please specify type)*_________________.............. ☐

3. 3. I have the following **mining related** qualifications (*indicate with a* X)

3-Year Diploma Metalliferous Mines.............................. ☐
4-Year Diploma Metalliferous Mines.............................. ☐
3-Year Diploma Coal Mines... ☐
4-Year Diploma Coal Mines... ☐
South African Mining Degree... ☐
Other Mining Degree.. ☐
Mine Overseer Certificate of Competency..................... ☐
Mine Managers Certificate of Competency..................... ☐
None.. ☐
Other *(Please specify type)*_________________.......................... ☐

3. 4. I have personally been involved in the following number of accident investigations done by the **Mine's Safety Department** over the last 12 months.(*number*)

☐

3. 5. I have personally been involved in the following number of accident investigations done by the **Inspector of Mines** over the last 12 months.(*number*)

☐

3. 6. I have personally been involved in the following number of accident investigations done by my **Direct Supervisor** over the last 12 months.(*number*)

3. 7. I have **personally** carried out the following number of accident investigations over the last 12 months.(*number*)

Thank you for taking the time to complete this questionnaire. It is only with efforts like this that we can make our mining industry a safer place.

Annexure B: Covering letter for questionnaires

MD460
DEPARTEMENT MINERALE EN ENERGIE
DEPARTMENT OF MINERALS AND ENERGY
DEPARTEMENTE YA TsA DIMINERALI LE ENEJI
IDIPHATIMENTI YESAMINERALI NEZE-ENEJI
PRIVAATSAK
PRIVATE BAG X 59
PRETORIA
0001

Republiek van Suid Afrika — Republiek of South Africa

Mr. «Initial» «Name»
«Addres1»
«Addres2»
«Addres3»
«Code»

☎ 317-9000 Faks . Fax 320-0357
Navrae
Enquiries C. Marx Uitbreiding
Extention 152

Datum
Date 2 August, 2003

ACCIDENT PREVENTION RESEARCH PROJECT : SOUTH AFRICAN MINING INDUSTRY

The Department Minerals and Energy is embarking on a process of developing a better accident investigation system for the industry.

You have been randomly selected to participate in the research project that aims to establish the most important issues in accident investigations. The attached questionnaire should not take you longer than 15 min. to complete.

Individual information contained in the questionnaire will be treated in the strictest of confidence. To ensure that all scientific research principals are being adhered to, please do not record your name or any other form of identification anywhere on the questionnaire.

In order to ensure the validity and reliability of the research results it is important that you return the questionnaire to the above address immediately after completion.

PLEASE DO NOT IGNORE THIS QUESTIONNAIRE AS YOUR OWN SAFETY MAY ONE DAY DEPEND ON THE OUTCOME OF THIS RESEARCH.

It is important to answer all the questions. Researchers have found that the best results are obtained if you record the first answer that comes to your mind as that reduces any ambiguity that may be read into the questions.

REMEMBER there are no right or wrong answers, the truth is that your opinion is important as you represent in your own way your colleges and the rest of the mining industry's views on occident investigations.

Your co-operation is highly appreciated and therefor it has been decided to inform you of the outcome of this research personally, once all the data has been analysed and interpreted

Yours faithfully

Chief Inspector of Mines
Department Minerals and Energy

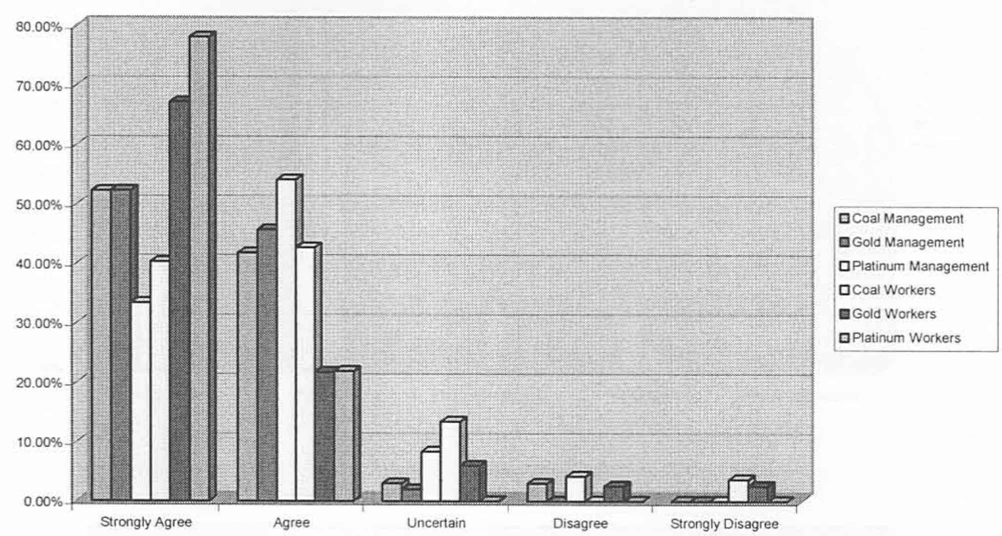
Graduate School of Management
University of Pretoria

Annexure C: Graphs for questions 1.3 – 1.13

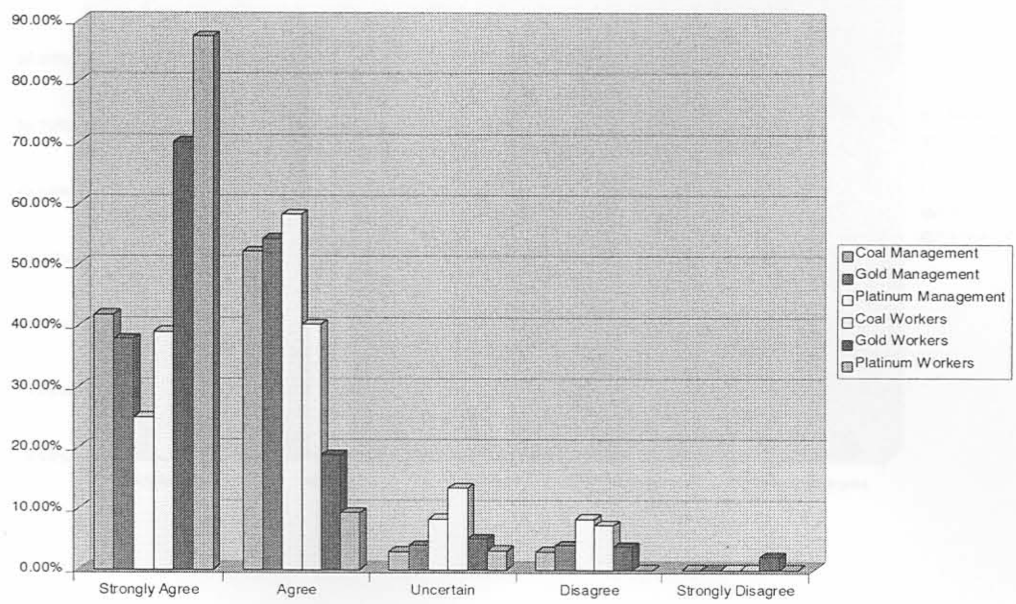
GRAPHICAL RESPONSES TO QUESTIONS 1.3 TO 1.13

The following graphs represent the responses obtained for Questions 1.3 to 1.13. These questions aimed to establish whether the identified fundamental contributing factors should be included in accident investigations.

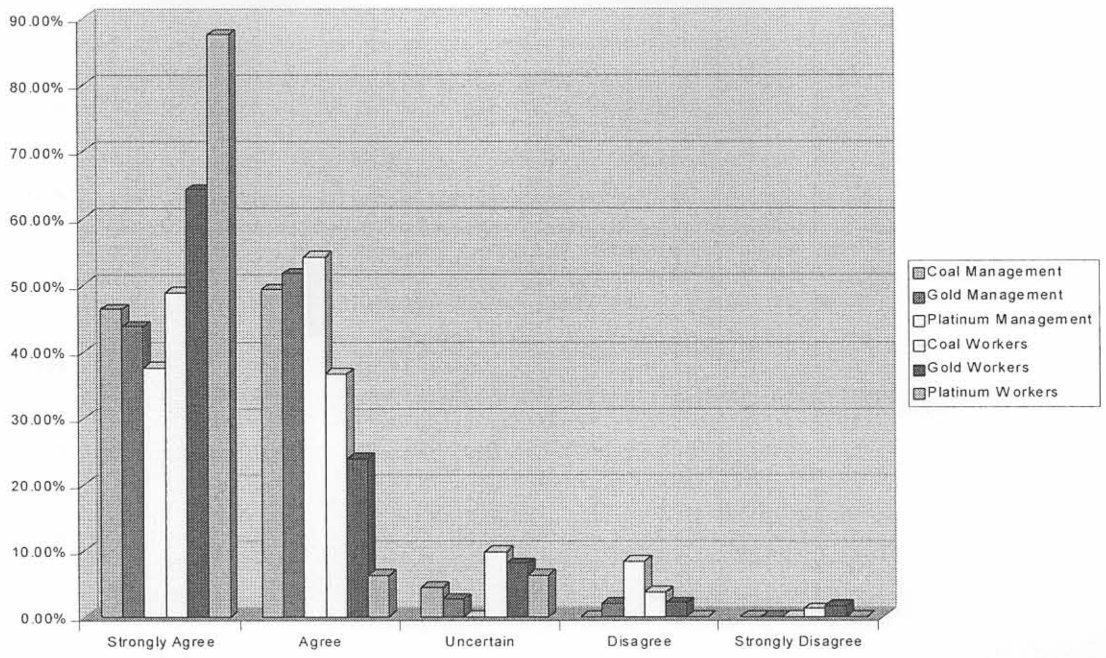
Question 1.3



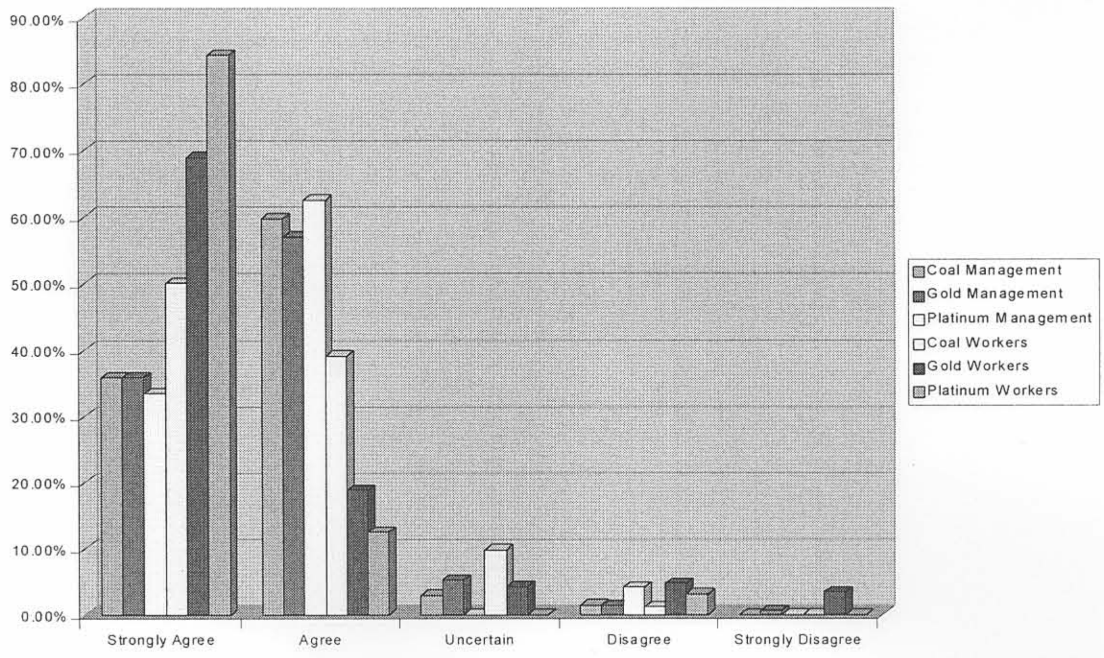
Question 1.4

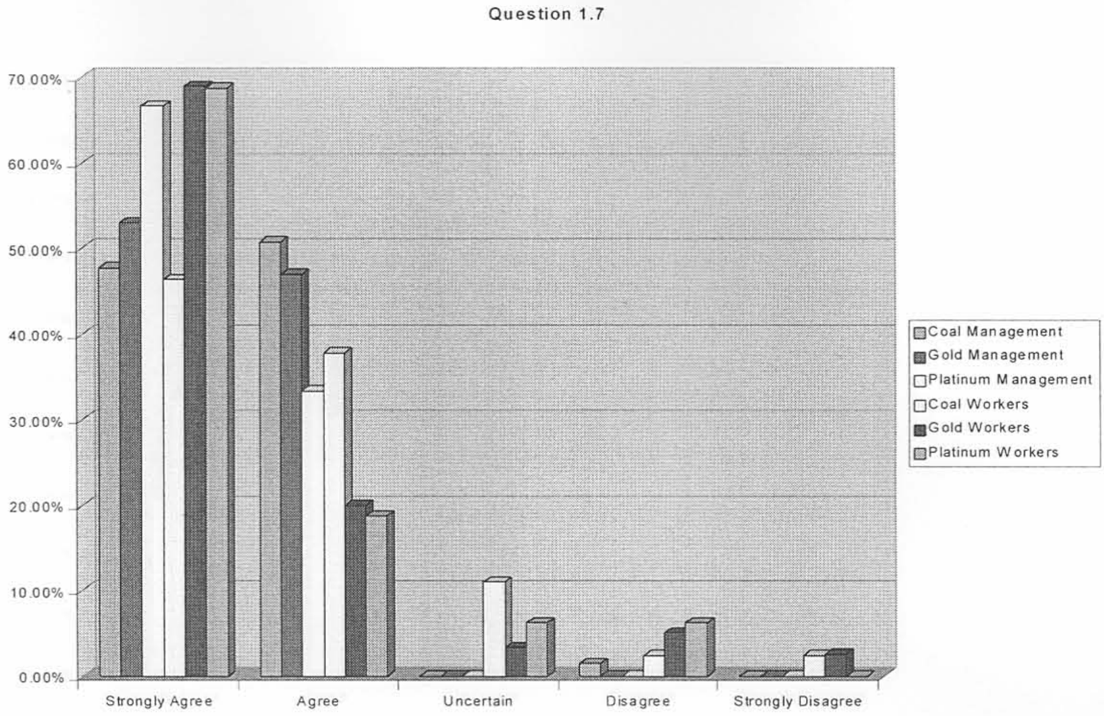


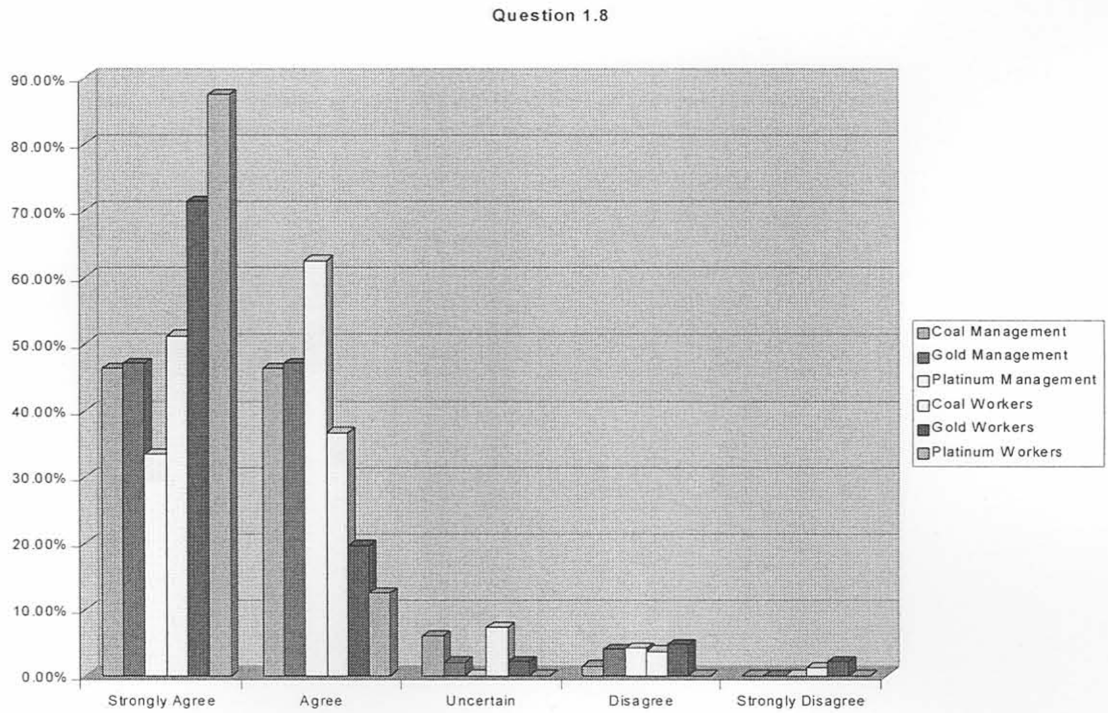
Question 1.5

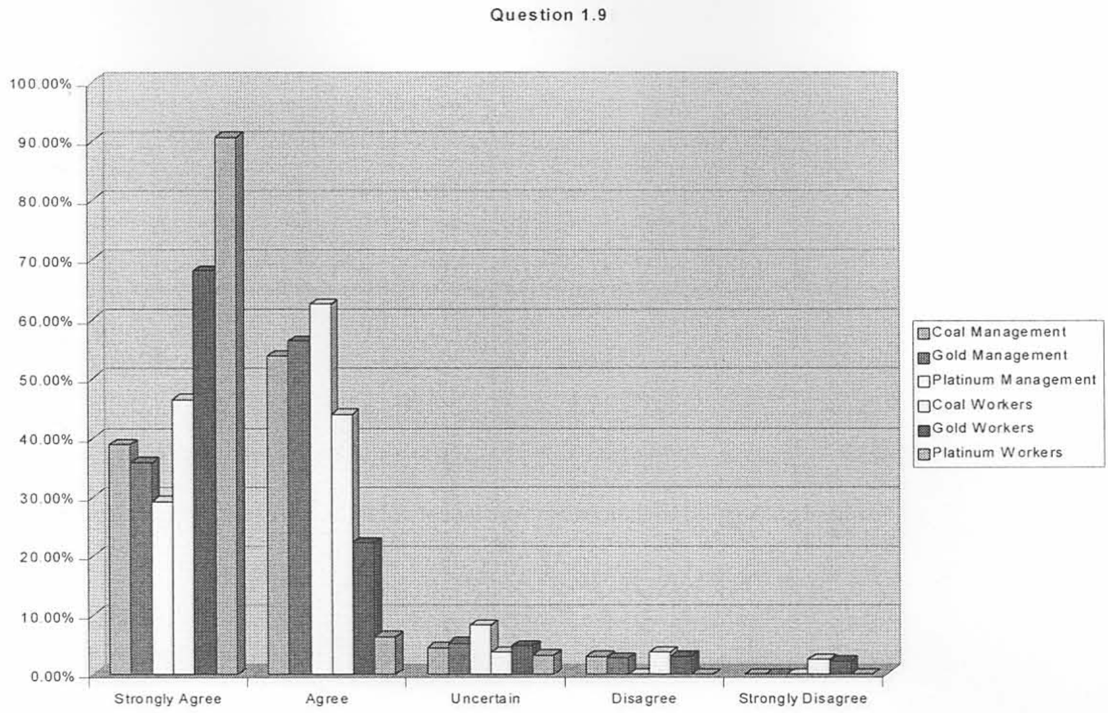


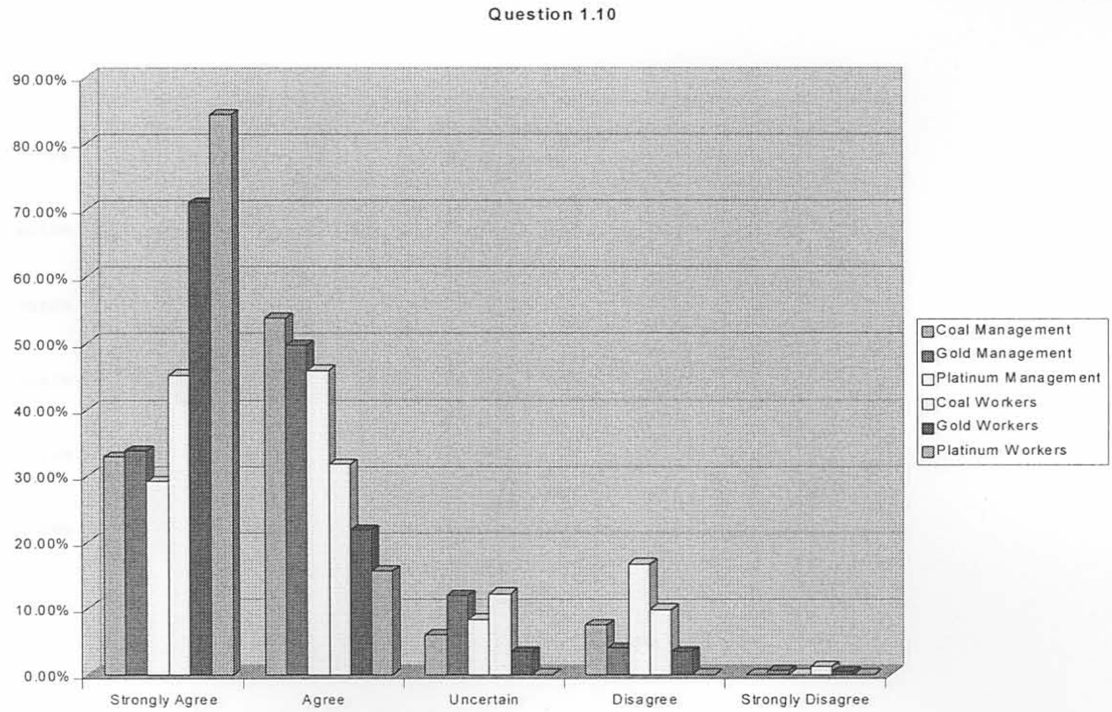
Question 1.6



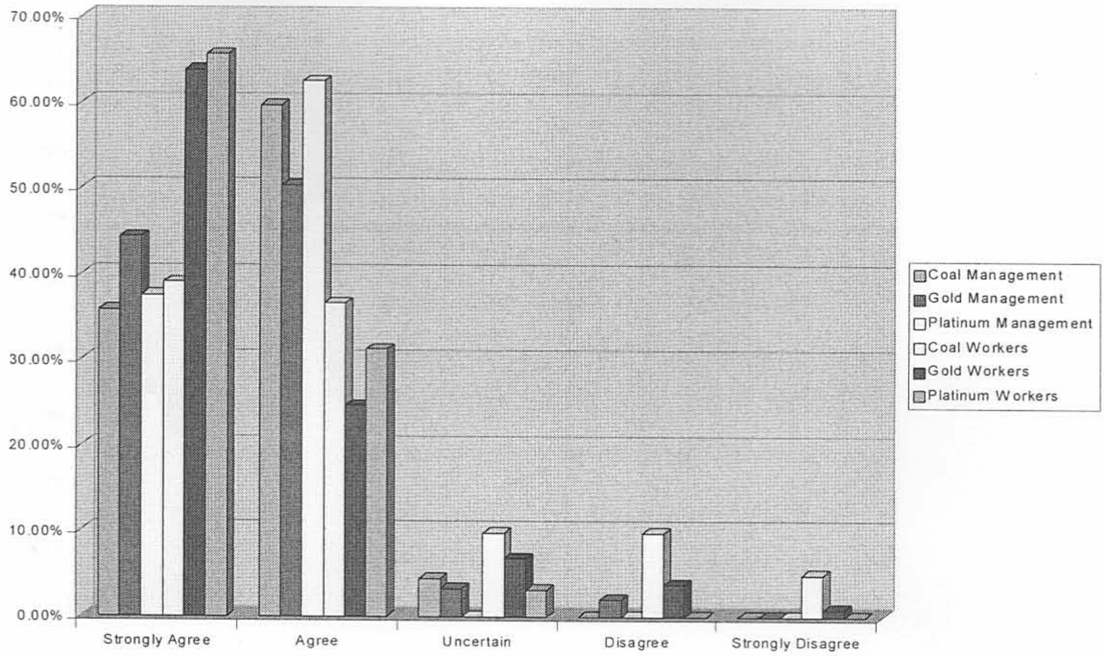

Question 1.7
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Strongly Agree
Agree
Uncertain
Disagree
Strongly Disagree
Coal Management
Gold Management
Platinum Management
Coal Workers
Gold Workers
Platinum Workers


Question 1.8
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Strongly Agree
Agree
Uncertain
Disagree
Strongly Disagree
Coal Management
Gold Management
Platinum Management
Coal Workers
Gold Workers
Platinum Workers

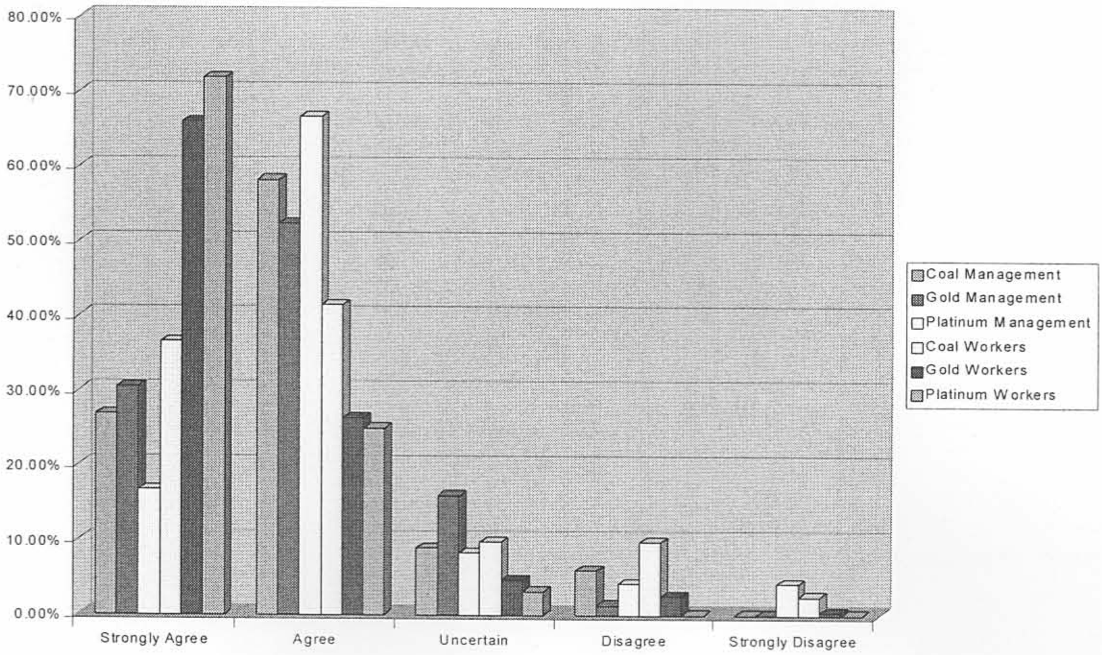

Question 1.9
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Strongly Agree
Agree
Uncertain
Disagree
Strongly Disagree
Coal Management
Gold Management
Platinum Management
Coal Workers
Gold Workers
Platinum Workers


Question 1.10
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Strongly Agree
Agree
Uncertain
Disagree
Strongly Disagree
Coal Management
Gold Management
Platinum Management
Coal Workers
Gold Workers
Platinum Workers

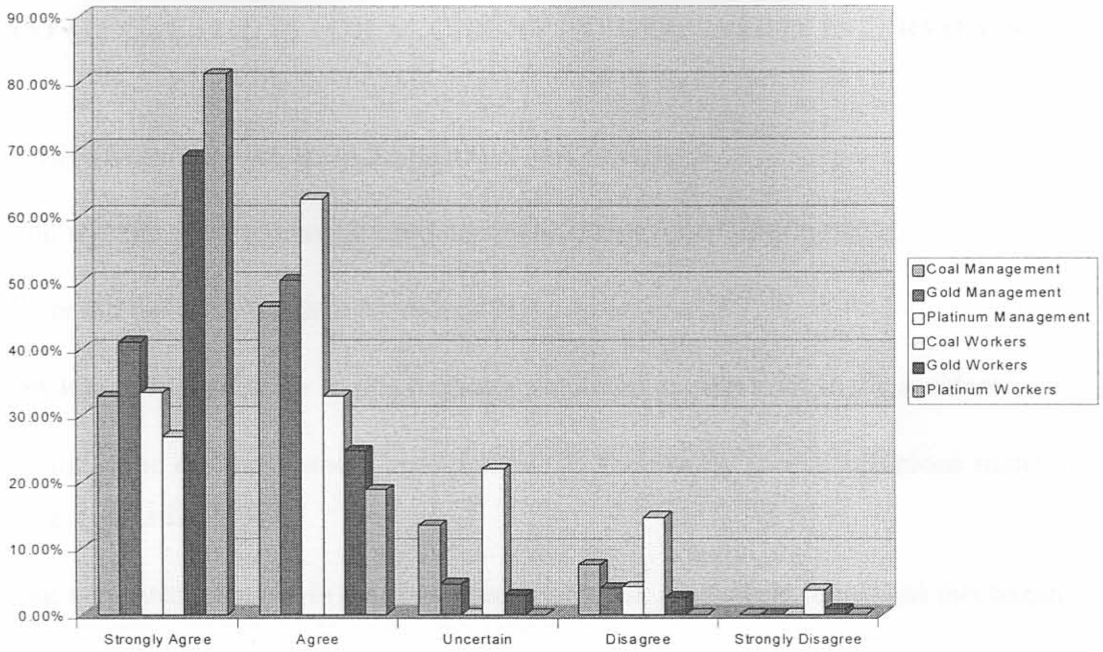
Question 1.11



Question 1.12



Question 1.13



Annexure D: Questions for Interviews

LIST OF QUESTIONS FOR ACCIDENT INVESTIGATION INTERVIEWS

1. ENERGY SOURCE/HAZARDOUS MATERIALS

What was the energy source/hazardous material that contributed to the accident?

Where did the energy source/hazardous material originate?

How long was the energy source/hazardous material present prior to the accident?

Did the mine risk assessment process identify the energy source/hazardous material as being a hazard?

What measures were put in place as a result of a risk assessment to address this hazard?

What resulted in the measures to be ineffective?

What is the potential exposure of the workforce to the energy source/hazardous material?

Could the energy source/hazardous material be eliminated, controlled at source or the effect minimised?

2. SAFETY MANAGEMENT SYSTEM

Does the mine have an adequate safety management system in place?

Does the safety management system procedure form an integral part of the daily management at all levels?

Which section/sections of the safety management system failed that resulted in the accident to occur?

Was the section of the Safety management system that failed identified during the mine risk assessment process?

What measures were put in place as a result of the risk assessment to address this hazard?

What contributed to the measures to be ineffective?

3. TRAINING

Are all the persons associated with the accident correctly trained to do their individual jobs?

Does the training material utilised during training include sections on safety and health issues relevant to the specific task?

Where does training take place - on the job or in a training centre?

Is the equipment on which training took place the same that featured in the accident?

When last was the training material updated to include input from risk assessments done on the mine?

What was the lack in training that contributed to the accident? (i.e. HIRA)

4. DESIGN

Was the equipment/section of the mine that was involved in the accident designed according to acceptable design parameters?

Was there any interaction between two pieces of equipment/different mining areas that contributed to the original design to be less effective?

Does the mine have an effective system in place to identify when deviations from the design parameters occur?

What was the identified latent design defect that contributed to the accident?

Was the latent design defect that contributed to the accident identified during the mine risk assessment process?

What measures were put in place as a result of the risk assessment to address this hazard?

What contributed to the measures to be ineffective?

5. MAINTENANCE

Does the mine have an appropriate maintenance programme on the equipment involved in the accident and/or do they have a system in place to ensure the system designs are maintained correctly?

Were the maintenance/systems design maintenance programme followed?

What part of the maintenance/systems design maintenance programme was not followed that contributed to the accident?

Was a potential failure in the maintenance/systems design maintenance programme identified during the mine risk assessment process?

What measures were put in place as a result of the risk assessment to address this hazard?

What contributed to the measures to be ineffective?

6. PROCEDURES

Does the mine have an appropriate procedure for the tasks that were carried out during the accident? (Permit to work etc.)

Does the procedure make provision for the specific circumstances prevailing during the time of the accident?

Was the procedure based on the outcomes of risk assessments done on the mine?

When was last update made to the procedure(s)?

Was the procedure properly communicated to the appropriate personnel?

What part of the procedure was lacking that contributed to the accident to happen?

7. TASK DIRECTIVES

Does the mine have pre-use inspection checklists for all the appropriate equipment associated with the accident?

Was the checklists developed and periodically updated as a result of risk assessments done on the mine?

Which task directive was not followed that contributed to the accident?

8. CONDITIONS

Is there a statutory Code of Practice requirement that caters for the conditions pertaining at the time of the accident? (I.e. Support COP)

Does the mine have standards or codes of practice defining the minimum standard for physical conditions pertaining to the accident?

Do the physical conditions conform to the standards or codes of practice defining the minimum standard?

What dangerous condition existed that contributed to the accident?

9. ACTS

Did any supervisor perform any unsafe act that contributed to the accident?

Did any worker perform any unsafe act that contributed to the accident?

Which unsafe act/s contributed to the accident?

10. BARRIERS

Were any physical barriers supposed to be in place to prevent contact with the energy source?

Were any time barriers supposed to be in place to prevent contact with the energy source?

Which barriers were ineffective that contributed to the accident?

11. THE ACCIDENT

Can the accident be re-constructed safely to confirm the evidence accumulated?

Do you need to secure any physical evidence for further testing and evaluation?

Do you need to secure any documentation for further analysis and scrutiny?

Annexure E: Publications

PUBLICATIONS RESULTING FROM RESEARCH

The following is a list of the articles and papers that resulted from this research:

1. A practical guide on risk assessment in the South African mining industry (1996) *SIMRAC research publication.*
2. Aide-Memoire for the compilation of Regulation in the Department of Minerals and Energy (1997) *Industry wide publication*
3. Taking the risk out of Africa (1998) *Paper presented at International conference, Sandton, South Africa.*
4. Drafting Mine Health and Safety Act subordinate legislation : A Tripartite Approach (1999) *Paper presented at Minesafe International Conference, Sun City, South Africa.*
5. An Introduction to Safety Management for Engineers, Technologists and Scientists (2000) *Chapter in textbook.*
6. Developing a Decriminalised Accident Investigation Methodology (2000) *Paper presented at Minesafe International Conference, Perth, Western Australia.*
7. The South African experience in Mine Safety (2001) *Journal of Mines, Metals and Fuels, India.*
8. Effective Workplace Risk Assessments: A Saving Grace or a Fallacy (2001) *De Beers Diamonds, Annual Safety Conference, Hunters Rest South Africa*
9. Risk for sale (2001) *Safety Management, magazine article*
10. Risk Assessment And Incident Investigation In Context (2002) *World Coal, magazine article.*
11. Effective Risk Management: The mystery exposed : A workplace risk assessment approach (2002) *Paper presented at NOSCON International Conference, Sun City, South Africa.*
12. Accident investigation and Risk Assessment : The Links (2002) *Paper presented at the CLP Guohua Power International Risk Management Seminar, Beijing, China.*

13. Effective Worker Representative Involvement In Coal Mining (2002) *Paper presented at the China International Conference on Coal Processing, Utilization and Environmental Protection, Beijing China.*

14. Reducing Blasting accidents by reducing the risks (2002) *Paper presented at Marcus Evans International seminar, Sandton, South Africa.*