# 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)

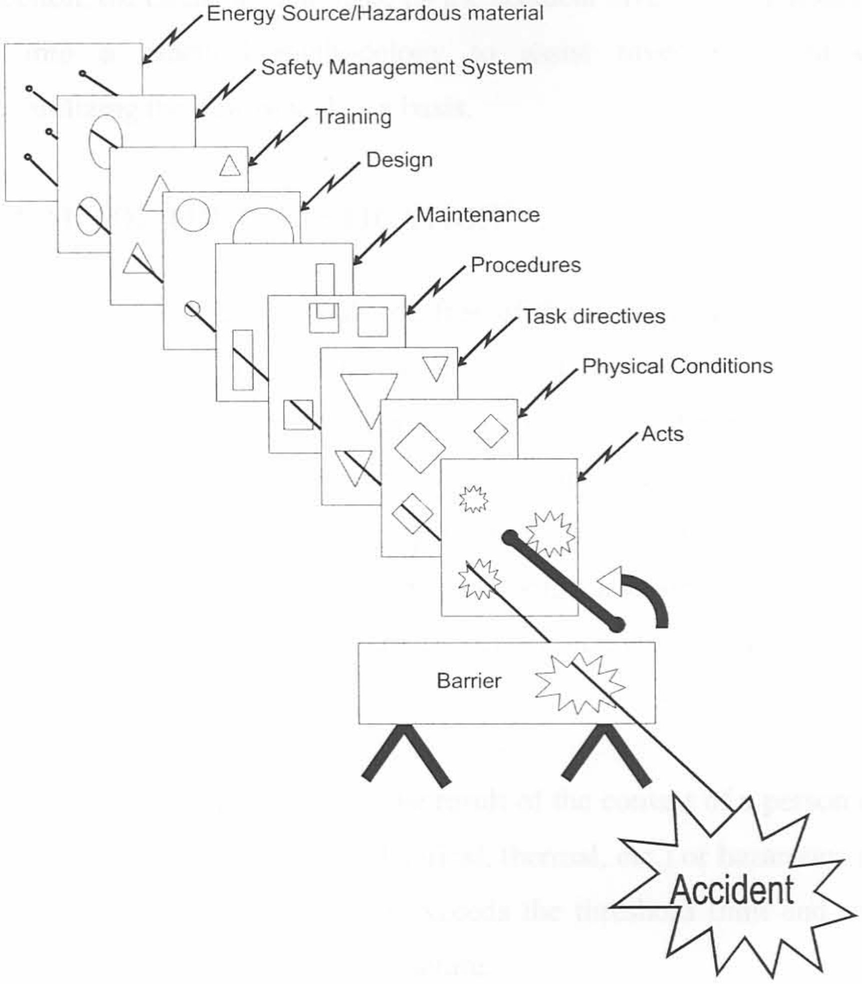


**Figure 5.1: Graphic representation of the fundamental contributing factors associated with accidents (as identified during the empirical investigation)**

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.