

**Safety in Mines Research Advisory Committee**

**Final Report**

**Investigate the causes of transport and  
tramming accidents on coal mines**

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# Executive Summary

Transport and tramming accidents on coal mines in South Africa are a major component in the overall pattern of colliery accidents. Furthermore, there is now a widespread acceptance that human error is a common cause of failure in accident patterns. The objective of this project is to create a better understanding of the design, organisational, management and human factors contributing to transport and tramming accidents, together with suggestions for solutions to both specific and generic potential accident causes.

The report covers an investigation of the causes of transport and tramming accidents on coal mines using IMC's behavioural safety system, **BeSafe**. The investigations have provided a detailed and systematic knowledge of the factors likely to predispose transport and tramming accidents across the full range of mining operations.

*Investigations focused on **identifying the potential** for human error within **existing operations**, since the reduction of error potential [or accident risk] has hitherto received relatively little systematic attention as an approach to accident prevention. Adopting such an approach had the advantage of releasing investigations from the constraint of using past accident records as a basis.*

Studies were undertaken at four coal mines, and addressed both underground and surface operations. Operations were studied at both small and large mines. A total of over 250 "accident likely" situations i.e. *Potential Active Failures* were identified together with the factors which were likely to predispose such accident likely situations. In effect a *cause/effect analysis* is carried out. These predisposing factors were used to identify *Latent Failures* [factors within the organisation that increase the likelihood of active failures] in the areas of:

- *equipment design* [for example, operational difficulties due to limitations in the original design and subsequent modifications of transport equipment.]
- *rules and procedures* [for example, potentially serious problems concerning the way in which rules and procedures are formulated, reviewed and maintained, their content and coverage, and in the way that new rules and procedures are communicated to the workforce]

- *safety management/safety assurance* [for example, failure to ensure that the safety systems which had been set in place were sufficiently robust and were reliably applied and enforced]
- *organisation and working methods* [for example, failure to ensure that tasks and activities are organised and planned in the safest practical way and failure to provide adequate resources to enable operations to be undertaken safely]
- *safety education and training* [for example risk perception and hazard awareness issues were rarely included in formal training and were left almost entirely to supervisory management to address on an informal basis]
- *attitudes to safety* [for example, failure to take appropriate action in situations where potentially unsafe conditions/behaviour was known to exist]
- *maintenance* [for example, failure to control the influence of poorly maintained plant and equipment on the safety of transport and tramming operations]
- *management of contractors* [for example, failure by the mines to exercise the same level of monitoring and control over contractor activities as was applied to operations undertaken by their own permanent workforce].

Recommendations are made which suggest actions to reduce accident potential in relation to both the *Potential Active Failures* and *Latent Failures* identified. The recommendations are presented as suggestions for action at Mining House, individual mine and Department of Minerals and Energy [DME] level and by the industry's equipment suppliers.

Generic recommendations to address accident potential resulting from the identified Latent Failures are:-

1. Ergonomic information and guidance must be provided on the critical factors to be considered during the design, manufacture and modification of equipment.
2. The ergonomic guidance must be specifically tailored for use by original equipment manufacturers, mine engineers and training providers.
3. Original equipment manufacturers must provide risk assessments that address the hazards and risks arising from ergonomic limitations.

4. Risk assessments must identify the limitations and shortcomings within existing rules and procedures.
5. Rules, procedures and codes of practice must clearly indicate the risks and hazards they are designed to address.
6. The competence of supervisory staff must be upgraded to improve the effectiveness of “on-the-job” training in terms of occupational health and safety issues.
7. All driver and operator training must contain integrated occupational health and safety hazard awareness components.
8. Training effectiveness, and its impact on worker hazard awareness, must be assessed using risk perception and hazard awareness based techniques.
9. All mines should adopt an integrated occupational health and safety management system.
10. Pre-emptive measures such as safety culture indicators, in addition to accident and incident reports, should be used to assess management system effectiveness.

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# 1. Introduction

## 1.1 Background

Coal mining has always been an intrinsically hazardous industry where safe working has been under constant threat from the very nature of the operation. Traditionally, the major hazards have included falls of ground, fires, explosions etc. However, accident patterns in most of the developed coal mining communities also show transport and tramming as a major accident category.

Philips (1996), in an analysis of South African mining accident records, ranked accidents associated with transport and the use of heavy plant and machinery as a close second to accidents resulting from falls of ground. Similarly, Oberholzer and Thorpe (1995) in their report on SIMRAC Project COL 203 "*Quantify the nature and magnitude of the contribution of human and engineering factors to the risk of injury or fatality caused by underground machinery or transport and delineate the essential causes*" quoted accident statistics which showed that transport and machinery related accidents had the highest significance in terms of the number of accidents and the number of injuries. One of the recommendations produced by this project was that increased research effort should be applied to the study of transport and machinery related accidents.

Similar accident patterns have also been reported in the UK by Rushworth, Mason and Simpson (1995), in Australia by Davis (1993) and in the USA in several reports by the US Bureau of Mines e.g. Randolph (1993).

In the late 1980's the importance of human behaviour as a significant contributory factor in the aetiology of mining accidents became widely recognised. Sims *et al* (1986) showed, for example, that 55% of the haulage and transport accidents reported in the UK Chief Inspector of Mines Annual Report were directly attributable to "human failings". At about the same time, in a review of human error and accidents, the US Bureau of Mines concluded that up to 85% of mining accidents may be due to human error. More recently, Peake and Ritchie (1993) in their report on SIMRAC Project OTH 003 "*Establish the primary causes of accidents on mines other than gold, coal and platinum*", concluded that, while failures of a mechanical or environmental nature are major contributors to an accident, the human factor, which is the least understood and the least predictable, has an influence on the greatest number of accidents.

The emphasis on human error in the above sources introduces a wider perspective to accident investigation. It goes beyond the traditional narrow concept which has tended to be restricted to simply operator error being exemplified simply by phrases such as “pilot error” and “driver error”. This wider concept includes all those aspects associated with an operation or system - from design, through education and training, installation, management and supervision to maintenance and operating staff.

Although it is widely recognised that human error is implicated in the vast majority of mining accidents, the reduction of error potential [or risk] has received relatively little systematic attention as an approach to accident prevention. To this end SIMRAC Project OTH 202 “*Investigation of the causes of transport and tramming accidents on mines other than coal, gold or platinum*” was undertaken in 1996 (Simpson *et al*, 1996). Over 200 “accident likely” situations were identified, together with the design, organisational, training and management factors which increased the probability of such errors. Project OTH 202 was regarded as being one of the most in-depth studies of transport and tramming accidents undertaken in South African mines at that time. The investigation and analysis techniques used were part of the IMC behavioural safety system known as 'BeSafe' and proved to be highly successful in generating recommendations and suggested actions for reducing accident potential.

Traditionally, safety assurance has been largely reactive, with the primary aim of accident investigations focused on apportioning blame and avoiding repeat events. In part, this focus arose from the adoption of an over-simplistic approach when establishing the causes of accidents. The approach was based on the concept of identifying a single primary cause - either an unsafe act or an unsafe condition. In the former case, responsibility was clear and blame could be apportioned. In the latter case, a technical solution could be sought. In part this approach to accident investigation also arose from the fact that a reactive approach, based on identifying a single primary cause, was an easy one to handle.

This narrow, blame oriented, perception of accident causation has, however, often missed three important, and inter-related, issues:

1. The idea that accidents happen as a result of a single primary cause is a gross simplification of what is often a highly complex event having several contributing causes. In addition, the term “unsafe act” embraces a wide range of human errors, equating, even at the most basic level, both deliberate and unintentional errors and

assuming that “blame” is the best means of understanding and dealing with such errors.

2. The consideration of unsafe acts and unsafe conditions as independent causes of accidents does not allow for the fact that an unsafe act can create an unsafe condition, nor for the fact that an unsafe condition can predispose an unsafe act.
3. Attention to unsafe acts has focused almost exclusively on errors made by the people who had the accidents, or those close to hand when the accident occurs. Those managers, designers, engineers, etc., whose action [or inaction] may have created the circumstances whereby “operator” error became more likely, have often escaped attention. Such an analysis leaves out the all-important question of what caused the operator to err. Often the cause can be attributed to faulty equipment design, inadequate or improper instruction and training or unsafe management policies.

Taking a reactive “blame” approach to human error in accidents has limited value in terms of future accident prevention. Unfortunately this is a reasonably accurate description of the approach to reducing human error accidents that has been adopted in most industrial organisations, including mining, for many years.

If accidents are to be prevented in the future, there is little value in simply blaming people for their mistakes unless a detailed understanding of what caused the mistakes can be initially established. Only by understanding all the issues which caused, or could cause, an accident, is it possible to effectively prevent future accidents. In this regard, the primary objective of this project was to create a better understanding of the wide-ranging factors that are likely to contribute to transport and tramming accidents. The BeSafe System provides a major shift in emphasis away from the tendency to equate human error with operator error and thence with blame. It is designed to provide a greater understanding of human error potential and, in particular, the elements within an organisation which are likely to predispose error.

## **1.2 Objectives and scope of project**

The objectives of the current project were to provide a detailed understanding of factors, such as, design, organisational, management and human, contributing to transport and tramming accidents in coal mines, together with suggestions for solutions to both specific and generic potential accident causes. The current project was based on use of the

same techniques employed by OTH 202 and can therefore be regarded as a follow-on project. In addition to generating recommendations and suggested actions for reducing transport and tramming accidents in coal mines, it was considered that by replicating the success of the earlier project, the value and applicability of the technique in all South African mining contexts would be effectively demonstrated.

Potential Human Error audits were undertaken at four mines. The mines were selected in consultation with the SIMCOL committee and included two large mines and two smaller mines. One of the large mines was an underground mine and the other a surface mine. The two small mines conducted both surface and underground mining operations. The range of transport and tramming operations investigated across these four mines included the following:

◆ Surface Operations

- ◇ Loading and tipping activities involving shovels, dozers, loaders and haultrucks.
- ◇ The transport of run-of-mine coal and discard material.
- ◇ The transfer of coal to tips using haultrucks.
- ◇ Transport operations associated with rehabilitation work.
- ◇ Transport and tramming operations associated with other support/service vehicles.
- ◇ Operations in an open cast area operated by private contractors.
- ◇ Operation of a railway system between a marshalling area and a processing plant.
- ◇ Loading and tipping operations in processing plants involving loaders, tractors and trailers, haultrucks and railtrucks.
- ◇ Transport operations associated with loading, tipping and rehabilitation work in an open cast re-processing area.
- ◇ The impact of maintenance activities on the safety of surface transport and tramming operations.

◆ Underground Operations

- ◇ Transport and tramming operations in production areas.

- ◇ The transport of vehicles and workmen in a lift, and activities in shaft station areas.
- ◇ Transport and tramming operations on inclined shafts and ramps.
- ◇ Transport and tramming operations on main travelling roads.
- ◇ Transport of workmen to production areas.
- ◇ The impact of maintenance activities on the safety of underground transport and tramming operations.

### 1.3 Methodology

The IMC BeSafe System was originally developed within the framework of the European Coal and Steel Communities [ECSC] Ergonomics Action Programme and was produced in response to reports from the UK Health and Safety Executive identifying that over 90% of accidents involve an element of human error.

In order to bring some structure into such a diverse field, it is necessary to have an effective means of classifying human error potential. The IMC BeSafe System incorporates a module referred to as the Potential Human Error Audit, which is based on an effective classification of error as outlined below.

The Potential Human Error audit uses two error classifications, the first distinguishing between *Active* and *Latent Failures* and the second providing an analysis of the *Active Failures*.

*Active Failures* are typified by operator errors, and *Latent failures* are typified by those errors committed by other parts of an organisation.

***Active Failures:*** These are errors made by operators and maintenance staff i.e. those with hands-on control of the system/equipment. They occur immediately prior to the accident event and are often seen as the “immediate cause”. *Active Failures* can be extremely varied and occur for a wide range of reasons. It is necessary to have some means of grouping them in order to determine solution possibilities without having to consider each error as unique.

Distinction is made in the classification of Active Failures between *Unintentional Errors* [i.e. *Slips/Lapses* and *Mistakes*] and *Intentional Errors* [i.e. *Violations*].

**Slips/Lapse Errors:** These occur in well known tasks with operators who know the process well and are experienced in the work. They are 'action errors', which occur while the task is being carried out. They often involve missing a step out of the sequence, or getting steps in the wrong order, and frequently arise through a lapse of attention.

**Mistake Errors:** *Mistakes* occur when the elements of a task are being "planned". They are decisions which are subsequently found to be wrong, although at the time the operator does not consider them to be incorrect. A *Mistake* is therefore an inadvertent error.

**Violations:** Violations occur when the plan of action is decided upon in full knowledge that it is in breach of the rules or codes of safe working practice. Taking short cuts or failing to take the prescribed precautions in order to enhance performance, are typical *Violations*.

While it is a considerable step forward in terms of accident prevention to have identified potential *Active Failures*, unless the underlying factors, i.e. the *Latent Failures*, which increase the likelihood of an *Active Failure* occurring are identified, the problem has only been partially addressed.

**Latent Failures:** These are the factors or circumstances that reside within an organisation which increase the likelihood of *Active Failures*. They are the broader issues with the potential to influence a wide range of *Active Failures*. Typical *Latent Failures* include, inadequate training, poor equipment design, work organisational problems, limitations in safety rules and procedures, etc.

A single Latent Failure has the potential to influence a wide range of potential errors and thereby accidents. It follows therefore that removing a *Latent Failure* is an extremely powerful and cost-effective accident prevention measure.

The importance of the type classification of errors is that the classifications can be used as an indication of the best route to a solution. A more comprehensive description of the methodology is included in Appendix 1 [page 76].

While the process provides the means of identifying solutions to *Active Failures*, it also provides the first step in identifying the *Latent Failures* associated with a given error. Consideration of the following error description provides a straightforward example of how *Latent Failures* can be identified.

*The visibility from the driver's position on LHDs was very limited in all four quadrants. On many occasions these restrictions were sufficient to restrict the operator's ability to identify pedestrians in time to take corrective action. Furthermore, operators were often seen leaning out of the machine profile to enhance their view.*

The *Active Failures* which increase the probability of accidents are (a) the failure to see pedestrians and (b) leaning out of the cab. (a) and (b) describe **what** happened. In identifying the potential route to solution, it is evident that the problem arose from the initial design of the machine where little consideration appeared to have been given to driver vision. This is **why** it happened, and is therefore an indication of a *potential Latent Failure*. In this context, therefore, equipment design is a *potential Latent Failure* which predisposes the two *Active Failures*, which in turn increase the probability of transport accidents.

A total of 250 *Potential Active* failures, or potential accident likely situations, were identified across the four mines studied and these were used to identify the *Latent Failures* underlying transport and tramming operations on coal mines. A summary of the best routes to solution for generic potential active failures is included in Appendix 2 [page 89].

## **2. Underlying causes of transport and tramming accidents on coal mines**

Figure 2.1 shows that the relative occurrence of transport and tramming accidents, expressed as a percentage of the total number of accidents, has not decreased over the ten year period 1988 to 1997. Over this period the total number of accidents in coal mines decreased significantly [from about 600 to about 350]. At an average of 25 % of the total, transport and tramming accidents make up a significant proportion of all accidents on coal mines. It is thus important that the causes of these accidents are understood.

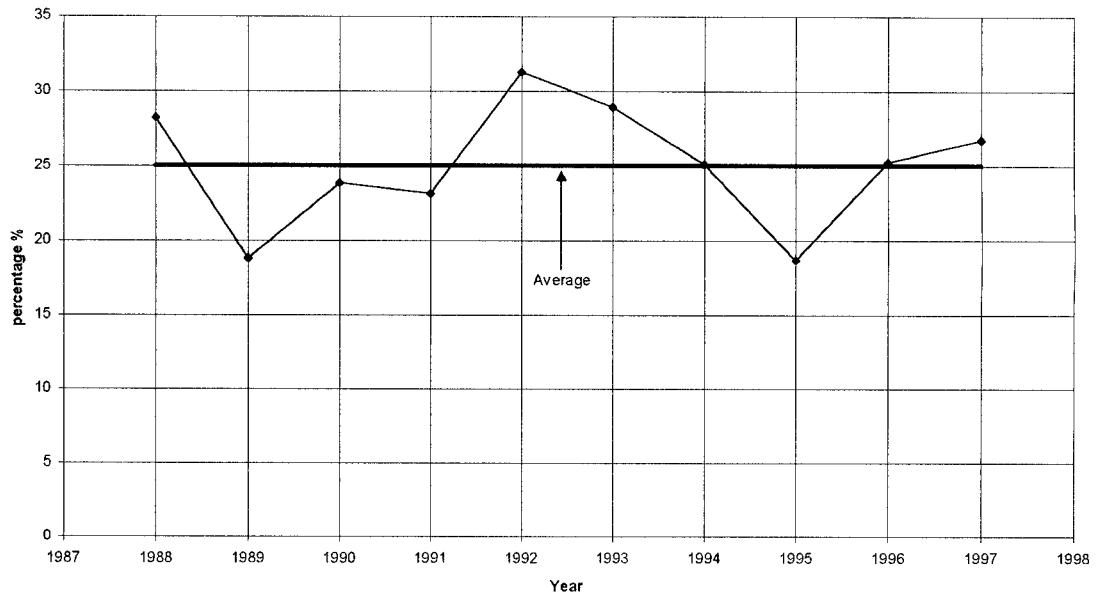
Although the Besafe methodology specifically does not concentrate on the past accident history of an operation but rather concentrates on the accident potential in the current operation, the SAMRASS accident data base was examined for any possible input to the present project.

Figure 2.2 shows the number of transport and tramming accidents recorded for the years 1994 to 1997 plotted against the cause of the accident as specified by the official conducting the enquiry. The information stored in the SAMRASS system does not allow for the detailed causes of accidents to be captured. There are 17 'basic' causal factors, many of which are in fact the immediate cause of the accident. From the Figure it is clear that the most significant cause of transport and tramming accidents is cause 2 - 'Failure to comply with recognised good practice/standards/procedures'. Because of the limitations on specifying accident causes, it is not possible to analyse the SAMRASS information any further. However, the BeSafe system used in this project would identify the underlying causes of the accidents and would thus allow for the factors within the organisation which increase the accident risk potential to be addressed.

In the context of the current project it is not possible to identify from the SAMRASS data any relationship with the latent failures identified during the visits to individual mines and therefor no further reference is made to the SAMRASS data. The data captured for the SAMRASS data base should be expanded. This could be done in conjunction with developing a guideline to implement the BeSafe system more generally so that when an accident investigation is carried out, the latent failure underlying the accident can also be identified.

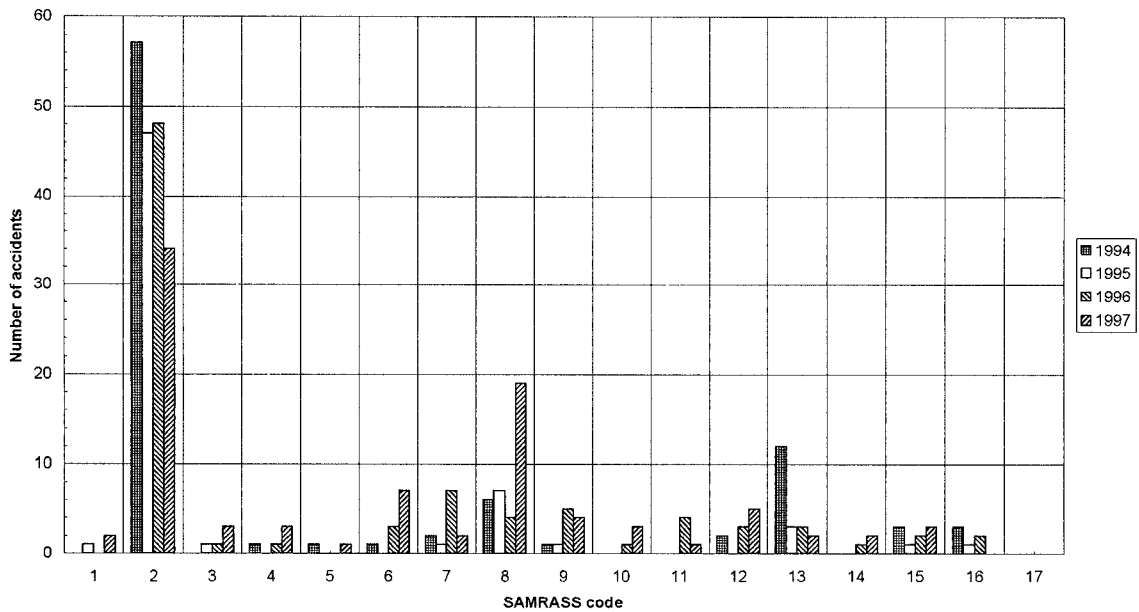


Transport and tramming accidents a proportion of total number of accidents



**Figure 2.1** Transport and tramming accidents shown as a proportion of total number of accidents on coal mines

Analysis of accidents according to SAMRASS codes



**Figure 2.2** Analysis of accidents according to SAMRASS

- Code 2 Basic cause: 'Failure to comply with recognised good practice/standards/procedure'
- Code 8 Basic cause: 'Lack of caution/alertness'
- Code 13 Basic cause: 'Inadequate examination/inspection/test'

## 2.1 Latent failures

Examination of the factors influencing the potential Active Failures identified by the individual mine studies during this project, indicated underlying causes, i.e. Latent failures, in the following eight major areas:

1. Equipment Design
2. Maintenance
3. Organisation and Working Methods
4. Rules and Procedures
5. Management of Contractors
6. Attitudes to Safety
7. Education and training in occupational health and safety issues
8. Safety Assurance Systems

It should be appreciated that most of the Active Failures identified were influenced by several Latent Failures. For example, an Active Failure concerning the failure to lock-out parked machines, was influenced by seven Latent Failures as follows:

- The failure to design and locate lock-out devices where they could be reliably operated was a Design issue
- The failure to address the above design limitations was a Maintenance issue.
- The failure to provide padlocks that were compatible with the associated lock-out mechanisms provided on the machines was influenced by Poor Organisation and Working Methods i.e. the failure to provide adequate safety equipment.
- The failure to identify and initiate remedial action was influenced by a failure in one of the mine's Safety Assurance Systems i.e. a failure to identify and deal with the problem through safety inspections
- The failure by drivers and supervisors to report the problem was influenced by Poor Attitudes to Safety.

- The failure to incorporate lock-outs as an item requiring inspection on the driver's/operator's pre-use checklist was influenced by a failure in another aspect of the mine's Safety Assurance System.
- The general behaviour of the drivers/operators was influenced by a Lack of Training in Risk Perception and Hazard Awareness.

In this particular example, this Active Failure was influenced by all but two of the Latent Failures identified by the project. Details of the Active Failure are given in Appendix 2 [page 89].

## 2.2 Components of latent failures

Each of the Latent Failures identified encompasses a number of individual components. A complete list of the Latent Failures identified and their primary components is given below:

### 2.2.1 Equipment Design

- ◆ Operational difficulties due to limitations in the original design of transport equipment. (These are the ergonomic limitations that are likely to “force” [or encourage] operator error. Examples include restricted sightlines, lack of operator protection, unsafe access conditions, restricted workspace provision).
- ◆ Similar ergonomic limitations in the design of plant, furnishings and infrastructure provided by the mine that relate to transport and tramping operations.
- ◆ Limitations in modifications implemented by the mines to original equipment.
- ◆ Limitations in the fundamental design of transport systems introduced on the mine.

### 2.2.2 Maintenance

- ◆ Failure to control the influence of poorly maintained plant and equipment on the safety of transport and tramping operations.
- ◆ Failure to control the influence of poorly maintained environmental effects on the safety of transport and tramping operations.

### 2.2.3 Organisation and Working Methods

- ◆ Failure to organise and plan tasks and operations in the safest practical way.

- ◆ Failure to provide adequate resources in terms of manpower, and/or appropriate plant and equipment.
- ◆ Failure to provide adequate safety equipment.

#### **2.2.4 Codes, Rules and Procedures**

- ◆ Failures in the formulation of new codes, rules and procedures.
- ◆ Failure to review and update existing codes, rules and procedures.
- ◆ Critical situations and activities that are not adequately covered by codes, rules and procedures or because the rules lack vital information [i.e. "Omissions"].
- ◆ Situations and activities covered by sets of safety rules that are in conflict with one another [i.e. "Conflicts"].
- ◆ Insufficient information provided to enable the requirements of a rule to be fully understood and reliably complied with [i.e. "Vagueness"].
- ◆ Situations in which the rules do not accurately reflect and address the hazards and practical difficulties associated with the tasks for which they were formulated [i.e. "Impractical"].
- ◆ Failures in the reliable communication of new rules and procedures to the workforce.

#### **2.2.5 Management of Contractors**

- ◆ Failure to adequately vet the safety management systems of contractors prior to their appointment.
- ◆ Failure to effectively monitor contractor activities.
- ◆ Failure to control the condition of plant/equipment used by contractors.

#### **2.2.6 Attitudes to Safety**

- ◆ Failure by management to take appropriate action in situations where unsafe conditions and methods of work are known to exist.
- ◆ Managers and supervisors fail to obey the rules and consequently adopt unsafe working practices in front of the workforce [i.e. setting a poor example].
- ◆ Workers appear to be encouraged to break rules and work unsafely by managers and supervisors [i.e. in the interest of production].
- ◆ Inadequate monitoring and disciplining of unsafe behaviour by supervisors.

- ◆ Poor attitudes to safety by the workforce arising primarily from poor hazard awareness and/or risk perception.
- ◆ Poor understanding and application of written procedures, etc.

### **2.2.7 Education and Training in occupational health and safety issues**

- ◆ Inadequate outcomes based education and training that emphasises competence and an understanding of occupational health and safety issues.
- ◆ Inadequate refresher education and training.
- ◆ Deficiencies in the content of training modules/course material [for example, lack of training on awareness of hazards and risks].
- ◆ Failure to adequately identify training needs.
- ◆ Failure to upgrade the competence of trainers, particularly supervisors who play a significant role in providing on-the-job training on written procedures, etc.
- ◆ Failure to evaluate competence i.e. failure to systematically evaluate the effectiveness of training provided.

### **2.2.8 Safety Assurance Systems**

- ◆ Failure to recognise the need for essential safety systems
- ◆ Failure to set appropriate safety systems in place in situations where the requirement for such systems were recognised.
- ◆ Failure to ensure that existing safety systems were robust and reliably operated.
- ◆ Failure to consistently monitor the application and effectiveness of the safety systems.

Each of the above Latent Failures is discussed below. In the discussions, appropriate potential Active Failures identified by the project have been used as examples to verify the existence of problems raised.

## **2.3 Equipment Design**

Limitations in the design of mobile machinery and the associated plant and furnishings provided on the mines was a common latent failure in the studies undertaken at all the mines visited. The problems identified were regarded as being likely to have a significant influence on the occupational health and safety of the workforce involved in both

underground and surface operations. Significant among the issues which had the potential to predispose human error and thereby increase accident risk, were limitations in the standard of ergonomics applied to the design of the equipment or plant concerned. The problems can be considered in relation to limitations in the design of machines and equipment acquired from external sources as well as limitations in design initiatives undertaken by the mines themselves. While it is usual to associate design limitations with unintentional errors i.e. slips and mistakes, a number of poor design features were identified which were considered likely to create a strong motivation for operators to violate safe working procedures.

### **2.3.1 Limitations in the original design of transport equipment**

While the use of modern mobile machines has revolutionised many areas of mine transport and has eliminated many of the dangers associated with other more traditional methods of mining and transporting materials and equipment, they have also introduced new hazards. Many of the accidents associated with this equipment can be attributed to a failure on the part of the designers and manufacturers to adequately consider the requirements of the operators and other members of the transport teams in the original design of the equipment used.

An example of this involved the design of a commonly used roofbolting machine which was observed at two of the three underground mines studied. The machine was operated from a control station located mid-way along one side. This required the operators to walk alongside the machine to control tramming operations, which created the following potential hazards:

- Operators driving the machine over their feet.
- Operators stumbling, losing control of the machine and trapping themselves against the ribside.
- The machine colliding with cable handlers and other workmen, machines and obstructions resulting from the operator's line of sight restrictions.

In a further example, the haultrucks used at one of the mines had the following limitations:

- Inconsistencies in the layout of the controls provided on different makes of haultruck had the potential to create confusion, and therefore operational errors, by drivers who were required to drive both types of truck.
- Access and egress to the cab was a problem with constraints such as variability between steps, insufficient step widths, lack of handrails at crucial balance/weight transfer points, excessive distances between the ground and the first steps, and very flexible lower section supports for the bottom steps, all significantly contributing to accident potential.

Error and accident potential resulting from the following ergonomic limitations was identified consistently across the range of vehicles and machines studied:

- Inadequate upper body protection for the drivers of underground machines, particularly tractors, loaders and LHDs.
- Limitations in the design and provision of lights, audible warning systems and lockout arrangements.
- Limitations in the design of cabs on production machines, particularly with regard to line of sight provision, access and seating arrangements, headroom layout, design of controls and the provision of labels and warning instructions.
- Lack of emergency stop controls on underground production machines placed spotters, cable handlers and other people working close to the machines at unnecessary risk.
- Limitations in the design of braking and steering systems.

Ergonomic limitations were also identified as having a potential impact on the safety of maintenance activities. An example of this involved the design of a commonly used grading machine. Due to the lack of any working platforms, workmen had to stand on the tyres to refuel the vehicle and carry out routine servicing.

A further example concerned the design of the thermal switches used on some LHDs to protect the engines from overheating and minimise the risk of fires in the scrubber boxes. Three different switches were used, each operating at a different temperature. All three switches were identical in size, appearance and method of fitting - the only means of distinguishing between them being a part number and the temperature stamped in very

small letters. Furthermore, the IN and OUT ends of the probes were not marked. The ease of confusing these components created various potential errors, viz.:

- The issuing of incorrect devices by the stores.
- Workshop staff fitting incorrect devices.
- Fitting the probes incorrectly.

### **2.3.2 Limitations associated with in-house design**

The study established that design problems were not confined to equipment purchased from external suppliers. Problems were also identified in relation to design initiatives undertaken by the mines. These initiatives included vehicle modifications, the design of roadways and the ancillary equipment and furnishings associated with transport and tramming operations, and wider, more fundamental, aspects of mine infrastructure design. Each of these three areas is discussed separately below.

### **2.3.3 Vehicle modifications**

These problems resulted mainly from workshop modifications involving new arrangements that introduced operational inconsistencies, problems of compatibility and generally exacerbated the ergonomic limitations. The problems identified were associated predominantly with underground machines.

One example involved modifications carried out at one of the mines to the cab of a loader. The following ergonomic limitations were introduced:

- Reduced headroom beneath the canopy required operators to work with their heads inclined to one side, which created visual limitations and considerable discomfort.
- Reduced legroom created the situation where the tramming controls were often inadvertently activated by the operator's knees.
- The modified tramming controls did not produce the expected directional response from the machine when activated, with the result that the operators sometimes set the machine off in the wrong direction.



- Removal of the screening between the cab and the conveyor resulted in the cab filling up with coal when loading out.

### **2.3.4 Roadways and ancillary equipment**

A number of cases were identified where it was evident that insufficient thought had been given to the safety requirements of the transport activities in the design of roadways and the ancillary equipment associated with transport and tramping operations.

A typical example of this involved the design of a very steeply inclined road leading to the entrance to an underground mine. In addition to the ground being uneven, pot-holed and covered in loose shale and rocks, there were substantial cross gradients and at some points the road was too narrow for vehicles to pass one another. In places the ground at the sides fell away sharply and there were no barriers or bermwalls. In dry weather the incline was difficult to negotiate safely. In wet weather driving was, reportedly, almost impossible with drivers regularly losing control of their vehicles.

Other problems identified included the failure to provide adequate:

- plant lighting at critical places;
- demarcation of travel roads;
- barriers and drop gates to prevent runaways entering working areas out of control;
- ventilation/dust extraction systems at tips;
- clearance between items suspended from the roof and mobile machines operating in underground sections

### **2.3.5 Transport system design**

A fundamental and potentially more far-reaching problem may have arisen from limitations in the design of mine infrastructures and the impact of these limitations on the provision of safe transport and tramping operations. For example, limitations in the layout and design of a processing plant made it virtually impossible to effectively organise the safe marshalling and transportation of railtrucks, the movement of mine and privately owned vehicles, and the activities of workmen on foot in the area. As a result

there was a high risk of collisions between vehicles, between vehicles and railtrucks, and with plant structures and workmen.

### **2.3.6 Design factors influencing the potential for violations**

Experience shows that employees can be easily tempted to violate safe working procedures if it makes their job easier. Central to this notion is the adequacy of the design of the equipment that is provided for them to use. There is a wide range of poor design features which can contribute to the difficulties in operating a machine. While these poor design features are usually linked with slips and mistakes, they can also be predicted to act as a strong motive for operators to violate some safety rules. The studies identified a number of such cases. For example:

- LHD operators were seen standing and leaning out of the cab to overcome line of sight restrictions.
- Shuttlecar operators tied the panic bars on their machines in the off position where they could not be used. They had apparently taken this action because the controls were vulnerable to accidental operation and were regarded as a nuisance factor.
- Some haultruck drivers refused to wear seat belts because interactions between the belts and the seat caused discomfort.
- The drivers of some haultrucks refused to use wheel chocks when parking because they claimed that they were too heavy to handle.

## **2.4 Maintenance**

Throughout the mining industries of the world, it has been demonstrated that maintenance can be a very costly and time-consuming activity. Maintenance is also important in the context of occupational health and safety since previous studies have shown that poor maintenance activities are associated with excessive accident rates. The issue has particular relevance to transport and tramming operations since there is a history of serious accidents that result from mobile machinery and plant being used in a neglected condition.

An appreciable number of maintenance-related active failures were identified at all four mines studied providing clear evidence that maintenance was a significant latent failure.

The problems were identified underground and on the surface in virtually equal measures, and can be considered in relation to limitations in the maintenance of plant and equipment, and limitations in the maintenance of environmental conditions such as ground and roadway conditions, lighting, etc.

### 2.4.1 Poor maintenance of plant and equipment

Throughout the studies, poorly maintained mobile machines and equipment were regularly seen in use. To provide an example of the widespread nature of the problem, the table lists the defects identified on three tractors which were seen operating at the three underground mines. Any one of the defects could have had a potentially serious impact on the safety of transport and tramming operations.

Defects	Mine		
	A	B	C
Worn out front tyre	√	√	
Severe tyre damage all round			√
No covers over exposed fanbelt and pulleys	√		
No seat - driver sat on cardboard taped to baseplate	√		
Damaged seat squab and back rest			√
Defective seat adjuster			√
No safety chain on trailer coupling	√	√	√
Defective reverse hooter	√	√	
No seatbelt	√		
Defective seatbelt anchorage		√	
No useable lockout device	√	√	
Knobs missing from all control levers			√
Fire extinguisher out of order			√
Defective headlight			√

In a further example at one of the surface mines, the following defects were identified across a range of vehicles:

- Several vehicles were seen being driven with badly worn tyres. In one case, extensive areas of outer rubber had completely worn away and the inner fabric was showing.
- The audible reversing alarms on several vehicles were defective.
- Several vehicles were seen being operated with defective lights. In only a short period of study at one mine the following examples were seen:
  - ◇ The brake lights and tail lights were defective on a haultruck.
  - ◇ On another haultruck the reversing lights operated continuously and the orange warning flasher was defective.
  - ◇ The orange flasher on a rubber tyred dozer was defective.
  - ◇ The tail lights on a mobile crane and an LDV were defective.

The active failures clearly established that the following factors were likely to be influential in the failure to maintain plant and equipment in a safe condition:

1. Failure to reliably undertake pre-use inspections.
2. Failure to initiate appropriate remedial action following pre-use inspections.
3. Lack of commitment by both maintenance and production staff towards the efficient operation of planned maintenance systems.
4. Failure by management and supervision to take vehicles that are known to have critical defects out of service.
5. Limitations in the ordering and delivery of replacement components.
6. Failure to maintain adequate stocks of critical [safety] components.
7. Lack of training among operators and maintenance staff on the risks associated with operating poorly maintained equipment.
8. Lack of resources to deal with unexpected demands
9. Use of machines that are not 'maintenance friendly' creates a temptation among some maintenance staff to improvise, take short cuts, or neglect some tasks.

## **2.4.2 Poor maintenance of environmental conditions**

The failure to adequately maintain environmental conditions was also established as the underlying cause of many potential active failures. A specific example of this involved the extremely poor state of some of the inbye travelling roads at one of the mines, which made safe and efficient driving extremely difficult. Deep rutting was seen on several occasions to almost wrest control from the drivers, to slew vehicles and to tilt them to potentially dangerous angles. Large areas of deep water concealing potholes and obstructions also had to be negotiated. The risks were also further increased by the presence of pedestrians at various points along the road and by glare from the lights of on-coming vehicles.

In one open pit production area the ground was flooded to a depth in excess of 1.0m. The pumping system was apparently defective and had been for some weeks. However, operations continued with the coal haulers 'feeling' their way through the water as they travelled the approximately 400 metres between the bottom of the ramp and the loading shovel. The ground under the water was uneven and a number of large potholes and submerged boulders created significant accident and damage potential. No markers were placed to aid the drivers, and to avoid the obstructions they had to take a winding route which they followed from memory. On two occasions LDVs were seen traversing the area with the water level more than half way up the doors. This active failure was influenced by a number of latent failures. However, the failure to maintain the area in a safe working condition was the primary cause of the problem.

The studies identified a number of other such cases. For example:

- Effective track inspections could not be undertaken through the failure to clear accumulations of spillage from the rails and sleepers.
- Safe locomotive operations were compromised by the failure to repair defective plant lighting.
- Safe haultruck operations were compromised due to the failure to reduce dust levels or restore defective lighting at tips.

In several cases, error potential predisposed initially by design limitations, was increased by the environment within which vehicles were used. It follows therefore that the effectiveness of any retrofit changes will be limited unless the influence of these environmental factors is also more effectively controlled. Specific examples of this

interaction involved the influence of high dust levels and poor standards of mine illumination at night on haultrucks, and loco drivers whose sightlines to important visual attention areas were already obstructed by design limitations in the equipment and/or workplace layout during loading operations and when propelling railtrucks.

## **2.5 Organisation and Working Methods**

Organisation and working methods refers to a failure to ensure that tasks and activities were organised and planned in the safest practical way. It also includes situations where there were failures to provide adequate resources to enable operations to be undertaken safely.

### **2.5.1 Poor organisation and planning**

Effective planning and organisational structures are required to ensure that tasks and activities are routinely planned and organised in the safest practical way. An example of poor organisation and planning at system level was reflected in the risks associated with the intensive activities involving the movement of haultrucks, dozers, loaders, utility/support vehicles, and spotters/attendants on foot at a coal tip. The apparent failure to co-ordinate and control the individual movements and interactions between the vehicles created significant collision potential. For instance:

- Vehicles approached from different directions and did not line up at the tip in formal queues.
- They drove onto the tipping point as and when they chose, rather than at the command of the tip attendant.
- While coalhaulers operated by the mine could be driven forward onto the tip, the rear dumpers operated by contractors had to be turned round and reversed onto the tip.
- The tip attendant had to 'spot' for the reversing rear dumpers and release the tailgates. During this activity they had to walk across the tip and station themselves where they were at risk from being struck by the coalhaulers entering the tip.
- No methods of communication or signalling were employed between dozers and the haultrucks, with the result that some haultrucks attempted to drive onto the tipping points while the dozers were still operating.

- Plant lighting was ineffective at night and tip attendants were not provided with high visibility clothing.
- To facilitate simultaneous tipping by two haultrucks, the tip was provided with two separate grilles. However, when only one truck was tipping, thick clouds of black dust were emitted into the air from the grille not being used.

All of these factors had potentially serious safety implications and were the product of a failure to properly plan and organise the operation.

An example of failure to plan and organise operations in underground mining, was reflected by the seemingly unrestricted use of vehicles on an inclined shaft. The main areas of concern arose from failures to provide the following:

- facilities and procedures to effectively test the brakes of vehicles before descending the shaft,
- control over the number of vehicles operating on the shaft at any given instant,
- control over concurrent machine and pedestrian activity in the shaft,
- sidewalls or crash barriers to prevent machines from running over the edge of the ramp or careering into belt attendants and plant at the bottom of the incline,
- transport vehicles that were suitable for use on inclined shafts,

In high activity areas [e.g. near shaft stations, in production sections, at major cross-roads, in processing plants, at loading points and tips, etc.] there was a widespread failure to effectively co-ordinate and control the movement and activities of both mine owned vehicles and vehicles operated by private contractors. The difficulties were often further exacerbated by the failure to provide effective plant lighting, spotters, traffic signs and effective roadside markers.

Poor organisation and planning at a more detailed task level is illustrated by an example taken from one of the underground studies where an electrician was seen perched near the top of a free standing ladder while repairing a light fitting in the centre of a travel road. Roof height was approximately three metres, no fall-arrest equipment was used and no-one was charged with the task of steadying the ladder while work was in progress. Furthermore, vehicles were seen being driven by on either side of the ladder

while the man was working at the top. Clearances between the vehicles and the ladder were less than one metre. Since the light fitting under repair was defective, the area was relatively dark and no supplementary lighting had been provided. Furthermore, the electrician did not wear any form of high visibility clothing, the ladder was dark coloured and therefore did not contrast sharply with the ground, and no signs were placed prohibiting vehicle movement or warning that work was in progress.

A further example involves the transportation of abnormally large loads without gaining appropriate authorisation and setting in place suitable safeguards e.g. providing warnings, limiting the movement of other traffic, scheduling the operation for periods of general inactivity, and providing drivers with additional visual aids and lines of communication to compensate for restricted vision.

The ultimate end point stemming from a lack of organisation and planning is that improvisation takes over and standards of safety begin to deteriorate.

## **2.5.2 Failure to provide adequate resources**

The failure to provide adequate resources results in improvisation and the failure to take the appropriate precautionary measures. In this context, increased error and, therefore, accident potential, can be identified by inadequacies in the provision of for, example, essential safety information, manpower, safety devices and appropriate plant and equipment. Examples of the failings identified by the project are outlined below.

### **Safety information**

Problems were identified in terms of the standard and reliability with which important safety information was communicated. Information was generally communicated directly by word of mouth through organised meetings, or by notices and signs displayed at strategic places.

With regard to meetings, there seemed to be no standard process by which the information was passed downstream. For instance, two of the mines studied were committed to five minute safety talks at the start of, or during, each shift. One mine provided similar five minute safety talks for underground workmen but nothing for surface workers, and the other mine provided a twenty minute safety meeting every Wednesday afternoon. Limitations in the composition of written instructions, in the selection/type of information and in the standard of communicating this information are dealt with under



Section 2.6 'Codes, Rules and Procedures' [page 27] and Section 2.9 'Education and Training on Occupational Health and Safety Issues' [page 42]. However, interviews with a number of vehicle drivers/operators indicated that some important safety information relating to changes in their methods of work were not reliably passed on to them as a result of planning and organisational limitations. For instance, the weekly safety meetings omitted to take account of the shift system operating on the mine, with the result that workmen were only able to attend one in four of the meetings. Similarly, with regard to the five minute safety talks given every shift, some workmen had important duties to perform at the time of these meetings and no alternative mechanisms had been set in place to provide them with the information.

With regard to displayed information, codes, rules and procedures were often not available for workmen and supervisory staff to consult. There was also a general failure across all the mines to signpost warnings of high noise zones, road junctions, obstructions ahead, adverse and abrupt changes in road conditions and other potential hazards. In some cases the signs provided were positioned where they were difficult to see and/or presented in such a way that they failed to gain the attention of the drivers/operators.

### **Manpower**

The failure to provide sufficient manpower often results in workmen being over-burdened and required to do tasks with which they are not familiar, or not adequately trained to undertake. The failure to supply sufficient manpower was identified at two of the mines studied. In both cases, to compensate for operators who were absent, workmen were 'pressed' into operating machines that they had not been trained and licensed to use. While these events represented a clear breach of recognised safe working practices, they also reflected a basic failure to maintain an adequate supply of skilled personnel, as well as a poor attitude to safety by management and supervision [discussed in this context under Section 2.8 'Attitudes to Safety' [page 35].

### **Safety equipment**

It is generally accepted that certain items of safety equipment are essential to the safety of transport and tramming operations. Written procedures and regulations normally specify such items of equipment and how they should be used. Such items include wheel blocks and padlocks to enable vehicles to be parked safely and a range of

personal protective equipment [PPE]. Although the studies identified a wide spread failure to ensure that such equipment was routinely and easily available, the problem was considerably more pronounced at some mines than at others. The following table lists some of the more common items of safety equipment and PPE which some mines regularly omitted to provide:

<b>PPE</b>	<b>Equipment</b>
Eye protection	Coupling chains
Hearing protection	Lockout devices
Dust masks	Seat belts
Gloves	Hazard warning triangles/signs
High visibility clothing	Buggy whips
	Fire extinguishers
	Portable flashing lights
	Reversing alarms

### **Plant and equipment**

Several potential active failures describe problems that result from the use of inappropriate equipment for particular activities or operations due to a failure to acquire and provide the right equipment for the job. The net result of such an omission is the temptation for workmen to improvise and to 'make do', with the inevitable result that safety standards are eroded. A summary of a sample of the active failures identified in this regard are given below:

- Machines in an underground production section were too large for the headings in which they were used, which created a high risk of collision damage whenever they were moved.
- Machines having a wide range of ergonomic limitations had been acquired and deployed within the mines without any regard for the potential hazards associated with the use of such vehicles.
- Equipment provided for the transportation of loads was often inadequate and created a series of potential hazards. For example:

- ◇ Long pipes were seen being transported by an LDV, which extended beyond the front and back of the vehicle by at least two meters. In the absence of any restraining straps, workmen were seen sitting on them to hold them down.
- ◇ A wide flat load, which extended an appreciable amount over each side of the vehicle, was seen being carried on an LDV.
- ◇ A large pump pontoon unit was seen being transported while suspended by an improvised arrangement of chains from the bucket of a loading machine. At one stage the loader was left for an appreciable period of time with the load suspended off the ground. During this period people were seen working crouched under the load and at the side of the unit.
- ◇ An ad hoc arrangement of chains was used to suspend materials such as large concrete blocks to the bucket of an LHD for transportation. The materials could not be readily scooped up in the buckets.

The majority of the above examples reflected a failure by management to plan and organise the tasks in the safest practical way and set in place special precautions or safeguards to ensure that the operations were carried out safely. It is recognised that smaller mines may not always possess ideal vehicles and plant to handle abnormal and irregularly shaped loads and that a degree of improvisation is needed. However, safe procedures incorporating the appropriate essential safeguards should be established and followed at all times.

## **2.6 Codes, Rules and Procedures**

Most of the safety information at the mines was produced in the form of written procedures [Standard Instructions, Managers Instructions, Mine Standards, Codes of Practise, etc.]. They were usually written by senior management and/or engineering staff and issued under the signature of the mine manager. This information was therefore seen as providing the framework upon which safety assurance was built.

In addition to the problems associated with “compliance”, which are dealt with in Section 2.8.7 'Attitudes to codes, rules and procedures' [page 39], there were other potentially serious problems concerning the way in which they had been formulated, reviewed and maintained, their content and coverage, and in the way that new codes, rules and procedures were communicated to the workforce. Significantly, a substantial proportion

of the potential active failures identified were classified as “Mistakes”. This suggests in part that the underlying causal factors were often associated with uncertainties and a lack of clarity concerning the various task requirements. This indicates a lack of clear direction/safe procedure, which is, in theory, precisely what the procedures are intended to provide.

### **2.6.1 Formulation**

The formulation of written procedures appeared to be, in some cases, a reactive response to accidents and incidents rather than the product of a successful pro-active safety policy.

Procedures generated in response to a specific accident/incident can be self defeating. They often take the intention to avoid a similar event to such an extreme, or are so general or vague, that the instructions generated are ineffective, impractical or in conflict with others. Not surprisingly, such written procedures tend to become discredited. This was highlighted in a problem concerning the requirement to use buggy whips at one of the mines. Following an accident, a written procedure was produced which required all vehicles under 7 tonnes to be fitted with buggy whips of sufficient length to enable them to be more ‘easily seen’. However, the use of vehicle weight, rather than height, as the criterion on which to base the requirement, was questionable. Some of the vehicles on the mine were dimensionally quite small and, if parked next to a haultruck would be difficult to see, but exceeded the 7 tonne limit. As a result several of the mine’s low profile heavy vehicles were allowed to operate without buggy whips.

A further example concerned the requirements at one mine for shunting railtrucks. In response to a series of accidents it was decided that railtrucks should not be shunted singly. It was recognised that by shunting them in multiples the probability of further accidents would be reduced. However, considerable confusion existed as to how many railtrucks should be coupled together, since individual written instructions produced after each accident stipulated two trucks, two to five trucks and four trucks respectively. In the resulting confusion single railtrucks were regularly seen being shunted, which defeated the purpose of the instruction.

Limitations in the role and responsibilities of the Safety Department and inadequacies in near-miss accident reporting systems, were seen as an important factor in this problem area. Safety Departments were rarely involved in the formulation of new written

procedures and, due to limited resources, safety inspections often enabled only cursory workplace assessments and the necessary investigations of accidents. Very little opportunity therefore existed for the safety function to look ahead for potential accident situations and initiate preventive measures through appropriate written procedures. Near-miss reports can provide valuable information on the conditions that predispose accidents. By failing to systematically acquire and incorporate this information in the procedures, a potentially very effective means of pre-empting repeat occurrences was being neglected.

### **2.6.2 Review and maintenance**

In addition to the above failings in the basic standard of written procedures, management's perception of their importance was often reflected in the frequency with which they were reviewed and maintained. To reflect changing circumstances, each should have been reviewed and re-dated on a regular basis. However, the majority of those examined had not apparently been reviewed for some years. Some had clearly not been reviewed since their inception in the 1980's. Some referred to sections of the mine and methods of operation that ceased to exist several years ago.

### **2.6.3 Conflicts**

If written procedures which are in conflict exist at a mine, there is a high probability that the easiest or most advantageous to work with will be the one complied with. Alternatively, the conflict can often be taken as an excuse not to work to either. The example outlined above involving the shunting of railtrucks was a particular case in point. Whatever the reason, in the event of an accident, the mine will be identified as being in breach of its own procedures and therefore culpable. Problems of a conflicting nature were identified in varying degrees at all the mines studied. For example, at one mine there were several operational areas. Each area was governed by different sets of written procedures. While the operations were basically the same, essential details in the procedures were, for no apparent reason, different. This reportedly caused confusion among vehicle drivers who were required to travel through the different areas. Conflicts were also identified within given sets of written procedures. For example, at one colliery, instructions given to drivers during their induction training stipulated that a 40 km/h speed limit existed throughout the mine, however, written procedures stipulated that the speed limit was 20 km/h. The confusion was compounded by the failure to post

speed limit signs at appropriate places in the mine. In their confusion, and in order to optimise production, drivers were encouraged by supervisory management to work to the higher limit.

#### **2.6.4 Vagueness**

In contrast to the above conflicts, some of the written procedures were vague, imprecise and open to miss-interpretation. For example, confusion existed at one mine regarding the correct way of securing vehicles in a lift. The written procedure stated that *“stop blocks must be placed at the wheels”* but did not state how many blocks should be used or where they should be placed. Again differences of opinion were expressed by different members of the mine staff. For instance, a safety officer stated that each vehicle should be diagonally chocked with two chocks per wheel i.e. using a total of four chocks. However, a senior training instructor held the view that vehicles should be chocked on either end i.e. using only two chocks. Regardless of this confusion however, there were only four chocks carried in the lift. Therefore, given the number of vehicles transported on some runs, they could not have been made secure by any sensible interpretation of the procedure. Interpretation of such procedures is left to the discretion of the supervisors or operators and is perceived by some as the means by which managers “cover their backs” in the event of an accident.

#### **2.6.5 Coverage and Omissions**

As far as transport and tramming operations were concerned, the dependence on written procedures varied considerably across the mines studied. At one extreme, procedures had been produced in detail to cover most activities. At the other extreme, it was not possible to identify a single written procedure relating to transport and tramming operations during the period spent on the mine. This lack of instruction was regarded to have been influential in terms of the accident /incident profile at the mine and the large number and type of potential active failures identified during the study.

At the detailed level, a range of omissions was identified across the mines. In the situation referred to above, for example, where conflicting procedures had been produced for different operational areas, one set of procedures charged management and supervisory staff with the responsibility of clearing loose material away from the edges of highwalls. However, the edges of the highwalls in other areas of the mine, which were not covered by such a procedure, were littered with rocks and small

boulders. These conditions increased the risk of haultrucks operating close to the bases of the highwalls being struck by any material inadvertently pushed over the edge. The problem was compounded by a lack of information [vagueness] in the written procedure relating to parking next to highwalls. While stipulating that vehicles should not be parked next to the highwalls, there was no indication given as to what was considered by the mine to be a safe distance.

A study at a different mine, which used both steam powered and diesel powered locomotives to transport railtrucks, provided a further example of an omission which had potentially serious safety implications. While a comprehensive set of written procedures had been produced to cover operations undertaken by the steam locos, no procedures had been produced for diesel loco operations. The diesel loco was in fact used in preference to the steam locos and, in the absence of any written instruction, the different work teams had developed their own methods of work which were based on their individual perceptions of hazard and risk.

### **2.6.6 Impracticalities**

In some instances, written procedures were seen to lack credibility because they did not accurately reflect the hazards and practical difficulties associated with the tasks for which they were formulated. In part, this was due to a failure to review and update them to reflect changing circumstances. It was, however, also due to the failure to consult [during the formulation process] people who were directly involved in, or who had knowledge of the difficulties involved, in the operations concerned. A procedure which was considered to be impractical placed a responsibility on attendants working on the bank of an inclined shaft to prevent vehicles from using the shaft while men were working or travelling in the shaft. The procedure was regarded as being impractical because:

1. The attendant had several other tasks to perform on the bank and was not always available to perform the checks.
2. To perform the checks reliably, the attendant had to walk half way down the shaft to visibly check for the presence of any workmen for each vehicle entering the mine.
3. There was no attendant at the bottom of the shaft to make similar checks before vehicles left the mine via the inclined shaft.

Impractical procedures tend, by definition, to be ignored. In the above example, discussions with several representatives from the workforce indicated that it was not unusual for vehicles to enter the mine without any of the required checks being made. This situation has the effect of not only discrediting a particular procedure, but also creating a lack of concern about the significance of other procedures. This is a well established tendency in the understanding of violation errors. In addition, tending to ignore impractical procedures also creates the possibility that, in the event of an accident, the mine would be identified as basing safety standards on impossible requirements and would therefore be culpable. Specifying a range of speed limits for vehicles without speedometers is a classic example which was identified at all of the mines studied by the project.

### **2.6.7 Communication**

With regard to communication, problems were identified in terms of inconsistencies in the methods used to communicate this information, and interpretation problems stemming from the variety of languages and literacy problems on a typical South African coal mine.

New written procedures were usually issued, on agreement with the Mine Manager, through the management structure, to local shift foremen/supervisors who were responsible for ensuring that the employees under their supervision were made aware of the relevant information. However, there seemed to be no specified process or procedure by which the information was reliably passed downstream. It appeared to be the decision of the individuals involved as to who needed to know the information, how and when the information was presented and by whom. Interviews with a number of drivers and operators indicated that some important information was not reliably communicated to them. Some claimed that they were not informed of new codes, rules and procedures that were relevant to their work and others that they were not informed of important changes to existing procedures. Problems associated with the organisation and planning of safety meetings are discussed in Section 2.5 'Organisation and Working Methods' [page 22].

With regard to language difficulties, the transmission down the management structure of the crucial aspects of a written procedure often involved a translation into different languages e.g. from English to Afrikaans to Fanakalo, and finally, by safety representatives, into one of the tribal languages. The information loss resulting from such a process was potentially considerable and appeared to be reflected in safety



performance. For example, on all the mines, management regularly felt that the majority of accidents could be ascribed to a failure to follow written procedures.

In summary, both the documents themselves and the process by which they were communicated had serious limitations in their contribution towards effective safety assurance.

## **2.7 Management of Contractors**

Work in several of the open cast mining areas studied was undertaken by teams of contractors. Contractors were also employed in other haulage and transport operations on the surface. These contractors were not on the payroll of the mines, however, since they performed work for and on behalf of the mines, the mines had a duty to implement effective systems and controls for managing their safety. It became evident, when analysing the results of the studies, that the incidence of active failures was often greater in the areas where work was undertaken by contractors and it was therefore concluded that the failure by the mines to effectively manage these activities constituted a significant latent failure. It was quite evident that latent failures similar to those identified at the mines, existed within the organisations contracted by the mines. However, the problem can also be regarded as a failure by the mines to exercise the same level of monitoring and control over contractor activities than was applied to operations undertaken by their own permanent workforce. The following two specific examples involving contractor activities were typical of the problems identified.

In the first example, a ramp had been over-watered with the result that it was extremely slippery. Drivers of all types of vehicles experienced difficulties maintaining control when ascending and descending. When attempting to climb the ramp, an LDV was almost in collision with an articulated haultruck travelling down the ramp. The driver of the truck could see that the LDV was in difficulties but was unable to stop or attempt to steer a wide path around the LDV due the risk of jack-knifing. Accident potential was further increased by the failure to set in place any control system to regulate the movement of vehicles, provide any hazard warning signs or provide bermwalls that complied with written procedures. The unexplained absence from the working area by the supervisor and the failure to place someone else temporarily in charge who could have effectively controlled watering operations or suspended activities until appropriate safeguards had been introduced, was also regarded as being influential as the situation developed.

The second example involved the employment of a private bus company to transport mineworkers to and from the more remote parts of the mine at shift changes. The following issues were identified that could have had a potential impact on passenger safety:

- While all vehicles and mobile machines used on the mine had to be subjected to a pre-use safety check, the bus company did not operate such a system.
- While all vehicles used on the mine were required to carry fire extinguishers, no form of fire fighting equipment was provided on any of the buses.
- Bus drivers did not wear seatbelts, although written procedures required all vehicle drivers on the mine to wear such protection.
- Bus drivers routinely allowed school children and other non-mine employees to travel in the buses, which was in breach of the mine's written procedures.

A brief summary of the problems experienced with contractors is given below:

- There was wide-spread failure to comply with regulations in terms of the provision of adequate illumination at night in working areas, the implementation of correct driver licensing procedures, use of the required personal protective equipment, and the provision of lights and audible warnings on vehicles.
- There was a similar failure to comply with written procedures produced by the mines in terms of the design and maintenance of safe roads, the adoption of safe methods of working and the implementation of appropriate safeguards at working areas.
- In the context of design, many of the limitations outlined under Equipment Design existed. An additional problem concerned conflicts between contractor and mine owned vehicles in terms of the colour and arrangement of head light, tail light, and indicating lights.
- Driving standards were poor as evidenced by the high prevalence of speeding, the failure to comply with road signs, the failure to safely lock-out vehicles and place warnings where hazardous conditions existed.
- Pre-use vehicle checks were not reliably carried out and there was a failure to maintain vehicles in a safe condition.

- Drivers were encouraged to break rules and work unsafely by their supervisors who demonstrated a lack of commitment to safety by adopting unsafe practices themselves.
- None of the drivers interviewed in the studies had received training on the written procedures [produced by the respective mines] covering transport and tramming operations.

## **2.8 Attitudes to Safety**

Attitudes to Safety was the most influential of the eight latent failures identified in terms of its impact on the active failures identified. Across the four mines studied, problems were identified in relation to the safety commitment of management and supervisory staff and, to a lesser extent, the workforce. Problems were also identified in relation to the degree of compliance with accepted safety and work standards.

### **2.8.1 Management attitudes to safety**

The tenor of the safety culture of an organisation is established essentially by the attitudes to safety shown by management and, in turn, by the supervisory staff. No amount of hard work and careful preparation in the establishment of codes, rules and procedures, in the development of training, etc. will have any lasting effect if those “safe working practices” are not routinely supported by high standards of managerial and supervisory commitment to both encourage and monitor compliance.

A management that is consistently, clearly and overtly committed to safety, and which demonstrably takes action on a day-to-day basis to ensure and reinforce safe working, will engender a similarly high safety commitment among their staff. Unfortunately, this was rarely the case at the mines studied.

While many of the supervisors and management teams appeared, during discussions, to fully appreciate the importance of their role in promoting safety, a high proportion of the potential active failures and the responses to the questionnaires and “formal” interviews at the mines indicated that there was a considerable lack of visible safety commitment.

## **2.8.2 Failure to take appropriate action**

The failure by management to take appropriate action in situations where potentially unsafe conditions/behaviour was known to exist, appeared to be a common practice. The problem was evidenced by a widespread failure to provide workmen with essential personal protective equipment such as eye, hearing and respiratory protection, self rescuers, helmets, overalls and high visibility overalls, despite the fact that in most instances adequate stocks of this equipment were held in the stores. A range of other examples was identified across the mines. For instance, the main underground travelling roads at two of the mines had been allowed to deteriorate to the point where they were almost undriveable. At another mine, management were fully aware that some drivers had developed the habit of visiting a squatter camp, and of the accident risk posed by the unrestricted access and movement of non-mine personnel in working areas. However, little obvious remedial action had been taken. Similarly, machines were allowed to be driven in an unsafe condition, and unsafe methods of transporting large loads were tolerated.

The failure by management to constructively address specific problems, clearly had the effect of dispelling any incentive among the workforce to report other safety related concerns. This was clearly demonstrated at one of the mines where management consistently failed to address a wide range of commonly adopted unsafe driving practices. In response, there was a notable failure by the drivers to report potential roadway hazards in order that appropriate warnings or safeguards could be set in place. Other examples in a similar vein were reported at the other mines. This was considered to be a possible cause for the poor response shown generally by the workforce to the introduction of near-miss incident reporting procedures which had been introduced at some mines.

As part of the overall safety assurance system at some mines, management staff were required to routinely observe critical tasks associated with the various jobs which were under their control. These were the particular elements of the jobs that were considered to have a potentially high risk, unless certain precautions and safe working practices were adopted. Evidence collected by the study indicated that these checks were often not reliable either in terms of frequency or content.

By the form of inaction outlined above, management were perceived as accepting poor safety standards.

### **2.8.3 Failure to pay regard to rules**

The failure by managers and supervisors to obey the rules, and consequently adopt unsafe working practices in front of the workforce, was also seen frequently. The failure to use appropriate safety equipment was commonplace at some of the mines, and appeared to be ignored by supervisors, representatives from safety departments and senior management alike. Managers and supervisors were regularly seen in the mines without wearing the appropriate personal protective equipment. Operators and other workers cannot be relied upon to wear this equipment if they perceive that management does not feel it is important to do so. Other instances in which management and supervisory staff were seen to set a poor example included driving defective vehicles, exceeding speed limits, failing to stop at stop signs, failing to over-inspect pre-use checks, and failing to hold agreed safety meetings.

### **2.8.4 Failure to control unsafe behaviour**

Inadequate monitoring and disciplining of unsafe behaviour by supervisors was identified as a significant failure across the mines studied. More than half of the potential active failures involved a failure to comply with safety related codes, rules and procedures and implicated inadequate standards of supervision in their causality. While the failure to comply was most evident at operator level, supervisors should have played a more active role in enforcing a higher degree of compliance. This lack of involvement in ensuring compliance was evident throughout the audits in that on many occasions where violations were seen, both supervisory staff and management were present at the work place. A specific example of this inaction was reflected in the unsafe condition of both surface and underground vehicles. Whilst it was the responsibility of the drivers to routinely check the condition of the vehicles before each shift, it was the overall responsibility of management to ensure that these checks were in fact correctly carried out and to implement the appropriate remedial action. The state of the vehicles clearly represented a failure by operators to check, and supervisors/managers to monitor and take action.

Staff perception at the mines indicated that between 60% and 80% of all accidents resulted, at least in part, from a failure to follow codes, rules and procedures. Unsafe driving practices and the failure to lock-out vehicles safely at shift change periods, were recognised as well known breaches of written procedures that were, effectively, accepted. By their inaction, supervisors were at least implicitly accepting the breaches.

### **2.8.5 Encouragement to break rules**

In addition to their failure to adequately monitor and discipline unsafe behaviour, evidence also implicated supervisory management in problems associated with real or perceived pressures to break codes, rules and procedures. For example, in the absence of the regular operator, a workman at one of the mines was seen to be delegated to operate a coal cutting machine that he had not been trained to operate nor held a license for. The supervisor was aware that the workman was not authorised to operate the machine, but ignored the man's protests and pressured him into operating the machine throughout the shift. In another case, workmen were pressed into working without self rescuers. The following cases were also reported to the project team:

- Two operators at one colliery were pressed into operating machines that they did not hold licenses to operate.
- Loading operations involving shovels, dozers, loaders and haultrucks were required to continue within the swing radius of a drag-line.
- LHDs used to load out material blasted from a face were required to operate under unsupported roof.
- Drivers were pressed into operating vehicles that were unsafe to use.

Whilst it is recognised that supervisory staff have potentially conflicting responsibilities for safety and production, their attitude, insofar as safety is concerned, is very influential on the safety of the workforce. Evidence from the studies clearly suggests that management and supervisory staff were aware of their responsibilities for safety, and appeared genuinely to believe in the importance of this role. All too frequently, however, they "condoned" unsafe operations by default. These circumstances were seen to downgrade the perceived importance of safety among the workforce.

### **2.8.6 Workforce attitudes to safety**

At the workforce level, there were indications that a lack of clarity existed regarding the individual's perception of their corporate and personal responsibility for safety. When asked who they thought was primarily responsible for safety in their workplace, some immediately answered 'themselves', while others considered that it was someone else, e.g. the foreman, miner, shift boss, management, etc. This suggests that a proportion of

the workforce did not recognise their responsibility for their own personal safety or the safety of their workmates. In either case, there were numerous examples where it was clear that practice failed to live up to theory. For example:

- Workmen shunting railtrucks regularly walked in front of moving trucks despite the fact that there had recently been a serious accident at the mine in almost identical circumstances.
- An LDV was almost struck by an on-coming haultruck, which had swerved to avoid an area of ground subsidence. While an accident was avoided, no remedial action was taken by either driver to prevent a repetition of the incident.
- Vehicles were left unattended with the keys in, and sometimes with the engines running.
- Spotters operating at tips at night failed to wear high visibility clothing.

A common element in each of these circumstances, and in other similar examples identified, was a lack of hazard awareness and/or an inadequate perception of risk, not only in terms of the workforce, but also including, as outlined above, both supervisors and management staff. This clearly represents a limitation in existing training provision as well as a problem in relation to attitudes to safety.

The fact that safety commitment was found to be an issue at both management/supervisory and workforce levels suggests that the problem was inter-related. Each level appeared to have been influenced by and had an influencing effect on other levels. On the one hand, management were clearly exasperated by the poor attitude of some of the workforce and this appeared to have led to an erosion of their own commitment. On the other hand, the poor management/supervisory commitment appeared to have created a workforce reaction along the lines of "if they are not bothered, why should we bother?" Both positions appeared to have reinforced each other in that expectations were lowered, standards had drifted, and each level was able to justify its position by perceived limitations at other levels.

### **2.8.7 Attitudes to codes, rules and procedures**

The study provided a strong indication that, in addition to the formulation, composition and communication problems detailed in Section 2.6 'Codes, Rules and Procedures' [page 27], there were problems associated with real or perceived pressures to break

codes, rules and procedures. This was reflected in a number of potential active failures identified, and was alluded to on a number of occasions in the latent failures discussed above. A specific study undertaken at the three mines which had sets of written procedures covering transport and tramming operations, confirmed that attitudes to rules and procedures was indeed a problem.

The study was based on techniques developed in previous SIMRAC project GEN 213 "Improve the safety of workers by investigating the reasons why accepted safety and work standards are not complied with on mines" (Talbot *et al*, 1996). It involved the presentation of a short questionnaire on attitudes to codes, rules and procedures to staff whose work involved transport and tramming operations.

The questionnaire enabled an examination of the following thirteen factors which had the potential to influence the standards of compliance with the codes, rules and procedures.

Rules: Aims and objectives	Supervision: Style
Rules: Application	Plant and Equipment Design/Modification
Training: Rules and Procedures	Job Design
Training: Hazards and Risks	Working Conditions
Safety Commitment: Workforce	Logistic Support
Safety Commitment: Management	Organisation
Supervision: Monitoring and Detection	

For the purposes of analysis, the total pool of people answering the questionnaire were divided into the following three groups.

1. **Management:** including Mining Managers, Mine Captains/Overseers, Section Engineers, Shift Bosses and staff associated with Safety and Training Departments.
2. **Drivers/Operators:** including LHD, haultruck, shuttlecar, tractor, LDV and general utility vehicle drivers.
3. **Artisans:** including both mechanics and electricians.



Of the factors that were seen as being most likely to reduce the ease of compliance, the following were the most significant and should be regarded as the major areas of concern:

### **Rules: Aims and Objectives**

This category identified where people perceived a lack of clarity in terms of the actual aims and objectives of written procedures. This was perceived to be a problem by all three subject groups.

### **Training: Codes, Rules and Procedures**

The management group saw training in codes, rules and procedures to be a problem. An indication of this perception was also gained in structured interviews with individuals from within this group who believed that a high proportion of incidents resulted from a failure by the workforce to follow written procedures.

A probable reason why the workforce did not recognise this as a problem, is because they are often provided with 'on-the-job' training rather than formal training, and in many cases are unlikely to be aware of the existence of written codes, rules and procedures.

### **Training: Hazards and Risks**

This category reflected a lack of appreciation of the actual hazards and risks to which the codes, rules and procedures related. It was again only the management group who saw training in hazard and risk awareness as being a problem. However, it was considered significant that within this group, Safety and Training departments did not see this issue as being pertinent. If these departments are to fulfil their primary function of providing proactive safety, the identification and amelioration of potential hazards and risks is crucial.

### **Safety Commitment: Management**

The vital point is that it is not sufficient for a manager to be personally committed to safety if this commitment is not actually continually demonstrated to the workforce by the day-to-day implications of his decisions/actions. Questionnaires completed by the drivers and artisans suggested that some management were seen as being less committed to safety than was expected by the managers themselves, for example,

management were seen in the mines not wearing the required personal protective equipment, and the provision of essential safety equipment were sometimes ignored.

### **Supervision: Monitoring and Detection**

A strong disincentive to rule violation is a high probability of detection and possibly disciplinary action. This factor, therefore, reflected the view that, regardless of how well written procedures were advocated, their credibility was eroded by the lack of consistent monitoring.

All three subject groups recognised this factor as a significant issue.

### **2.8.8 Plant and Equipment Design/Modification**

This issue indicated that limitations in the design of plant and equipment was seen as making compliance with written procedures difficult, or even impossible on some occasions. In short, it reflected instances where the equipment was not “user friendly” i.e. where it failed to comply with sound ergonomic standards.

The groups who saw this as being especially significant were the drivers and artisans.

### **2.8.9 Working Conditions**

Working conditions, particularly the physical/environmental conditions, were also seen as making compliance with written procedures difficult, or impossible, on some occasions. Poor working conditions were also seen as the cause of intentional violations.

Not surprisingly the group which saw this as being influential on compliance were drivers and operators.

The questionnaire result is discussed in more detail in Appendix A3 [page 105].

## **2.9 Education and Training on Occupational Health and Safety Issues**

At the time of the study, outcomes based education and training [OBE], as envisaged in terms of the South African Qualifications Authority [SAQA] Act: 1995, had not been implemented on the mines visited. This process is being overseen by the Mine Qualifications Authority [MQA, as proposed by the Leon commission, 1994] and relevant

unit standards are currently being developed. Many of the shortcomings outlined in the sections below will be addressed when OBE systems are fully implemented throughout the mining industry.

It was not possible within the time scales of the project to examine the standard of general induction training at the mines in detail. However, the provision of formal basic and refresher training for drivers, operators and members of haulage and transport teams were examined. Also examined, was the way in which informal training on risks and hazards was given to the workforce by supervisory management, the training process associated with the introduction of new written procedures, methods used to assess the effectiveness of training given, and the means to address new training needs.

More than half of the potential active failures identified by the project could be related, at least in part, to a lack of competence i.e. the need for additional training or re-training. These ranged from the need for relatively simple “reminders”, such as the importance of wearing stipulated personal protective equipment, to more formal training programmes to overcome, for example, the proliferation of unsafe driving/operating practices. In all of these training programmes emphasis must be placed on understanding why such driving practices are unsafe.

The scope, type and standard of safety training provision varied considerably both across and within the four mines studied. At one extreme, one of the mines had no training function or training material. Basic training was carried out by an instructor, who, being based at another mine, had little knowledge of the conditions and methods of work that existed. Furthermore, the training course material was inappropriate and did not address many of the hazards and risks associated with the work, no practical aspects of training or testing was administered, there was no mechanism for identifying and addressing specific training needs or evaluating the effectiveness of the training, and the training was not consistently applied across the various working groups involved in transport operations. In addition, no training records were kept. At the opposite extreme, well structured skills based training was given which attempted to foster risk perception and hazard awareness issues. However, even at this mine, training staff acknowledged that some limitations still existed and that there was room for further improvement.

The following common limitations were identified within the standards of training provided at the four mines.

## 2.9.1 Training course content

Limitations were identified in the standard of training course material both across and within the mines. One of the mines had no written material of its own on which to base their training. To overcome this problem they had borrowed material from a neighbouring mine. Training at another mine was based on commercially available video tapes. At both of these mines the material was inappropriate in that it did not cover the types of equipment used or the methods of work adopted, nor did it address the specific hazards and risks associated with the methods of work employed.

The other two mines possessed a considerable amount of training material. However, limitations were identified in terms of important omissions and inaccuracies within the material, and conflicts between the training material and the working practices stipulated in the mine's written procedures. There was also a tendency by these mines to rely very heavily on general guidance provided in manuals produced by equipment manufacturers rather than in developing their own mine specific training material.

A central issue identified by the potential active failures regarding both basic training and re-training for drivers and operators, concerned the practical elements of their training. While the theoretical training was administered by training departments, training instructors were rarely involved in the practical aspects of training. This role was usually taken by line management and supervisory staff who, in some circumstances, were not licensed to drive the vehicles themselves and had never received any instruction or training in how to train and test effectively. In some cases no practical training or testing was given at all.

With specific regard to re-training, as part of the licensing requirements, all drivers should attend regular review training and this training should include a theoretical component followed by practical training for every vehicle that the person is licensed to operate. On many occasions, the practical training was ignored, and when such training was given, it was usually only on the vehicles on which the drivers were currently employed. There appeared to be no limit to the number of licenses that any one person could hold and practical re-training on some of the vehicles which they were licensed to drive was often ignored. This problem was particularly apparent with respect to operators of underground mobile equipment.

The process being undertaken by the MQA in ensuring the implementation of outcomes based competency education and training will address the above shortcomings. In this

system, training providers will base training course content on the unit standards currently being developed. The emphasis of training will be on ensuring competence and the ability 'to know and to do'.

## **2.9.2 Education and training on hazards and risks**

From a safety and accident reduction perspective, the adoption of training methods and approaches that ensure competence in risk perception and hazard awareness in trainees is of paramount importance. However, within the current training programmes seen at the mines, this is unlikely to happen. Risk perception and hazard awareness issues were rarely included in formal training and were left almost entirely to supervisory management to address on an informal basis.

A great deal of reliance was placed on the use of five minute safety talks to communicate codes, rules and procedures to the workforce. Limitations in the composition and process used to communicate this information has been dealt with under section 2.6 'Codes, Rules and Procedures' [page 27]. However, in the context of training in risks and hazards, an additional limitation was identified. Many of the written procedures examined only laid down the rules or statements in the sequence and manner in which specific tasks had to be done. From this information alone, the trainees gained little insight into why the jobs had to be done that way, and what the possible consequences were if they failed to comply with the instructions. To gain an insight into the hazards associated with their work they had to rely on supervisors passing on this information to them informally.

The high number of violation errors identified reflected a failure by the workforce to fully understand the risks and hazards associated with their work. This, in turn, was considered to stem largely from inadequate training.

Behaviour is unquestionably influenced by the degree to which a person is aware of hazards in the workplace. With no, or little, awareness more people will be willing to, or inadvertently, deviate from the rules and procedures in place. In fact, written procedures are likely to be perceived more as working restrictions rather than good and safe working practices.

In the case of intentional violations, the decision to commit a violation is often derived from a conscious assessment, which balances the perceived risks against the perceived

benefits. An incorrect balance of risks and benefits will clearly result in increased accident potential.

Good quality and carefully targeted training in hazards and risks has therefore a vital role to play in reducing accident potential. It has particular relevance in reducing violations. In this regard, understanding is of particular importance since it is unrealistic to expect people to slavishly follow rules simply because they have been told to do so. Competency based education and training, as being implemented by the MQA, will address these shortcomings.

### **2.9.3 Identification of training needs**

The above discussions concern limitations in the standard of training given to workmen and supervisors directly involved in transport and tramming operations. Given that training implications were associated with so many potential active failures, the safety training needs of the mines were clearly not being adequately analysed and/or addressed. There appeared to be no systematic, on-going commitment to identify safety training needs. Moreover, training needs were clearly not limited to the workforce. The inspection and reporting procedures adopted at the mines, the standards of planning, organisation and design, and the general attitudes to safety shown by managers and supervisors, certainly in so far as transport and tramming was concerned, were all heavily implicated in potential active failures.

Of particular concern in this regard was the general failure across the mines to identify the need for improved training on hazards and risks. Given the high percentage of active failures involving rule violations, a clear need was identified for the introduction of mechanisms to establish the degree to which hazards were understood by the workforce, and their perceptions of the risks to which they would be exposed if they failed to take the appropriate precautionary measures. Only through the introduction of such measures would it be possible to more accurately focus future training initiatives.

The Leon Commission in 1994 proposed the establishment of the MQA to review the need for particular certificates required in the mining industry and to review course content [amongst other issues]. The MQA is currently managing the process of drawing up unit standards and assessing qualification requirements. In terms of the Mine Health and Safety Act, it is the responsibility of employers to ensure that an employee is competent to carry out a task. It is also the responsibility of the employee, once he has

been deemed competent, to assess risks in his workplace and to take action to minimise these risks. The process of complying with these requirements will identify occupational health and safety training needs.

#### **2.9.4 Upgrading the competence of supervisors in terms of occupational health and safety training**

At all four mines studied, supervisory staff played an important, albeit informal, role in the overall safety training provision. This was indicated by the role of supervisors in informing/training workers on rules and procedures in, for example, five minute safety talks. Despite this crucial role, supervisors were shown by the study to be less than competent in many potentially safety-critical areas and to have potentially conflicting responsibilities for both safety and production. The supervisor is in many ways critical to safety standards and in the development of a sound safety culture, yet the study has shown that they receive very little systematic safety training themselves. They often possess few training skills and receive only minimal support in their safety role.

There is evidence from both Active and Latent Failures that there are limitations at various levels of management in terms of either their safety knowledge, or their commitment to routinely follow safe practice. This is not surprising, for in many respects, the training of management in terms of safety is little different from that of the workforce. A particular area of concern regarding management training, is that staff in safety and training departments were often transferred from jobs with production responsibilities with little or no specific safety training or experience. The provisions of the Mine Health and Safety Act require recognised competence for Occupational Hygiene staff and for Occupational Medical staff, but no such specification is made for safety and training staff on mines.

#### **2.9.5 Training evaluation**

In many respects training is a formal requirement for those employed in the mining industry, and for this reason it is often falsely assumed that training standards are always high. In this regard, the study established two common problems:

1. A belief that training addressed all relevant safety issues,
2. A belief that since training was effective initially, it continued to be effective.

A central factor around both problem areas was the lack of measurement of the competence of trainees at the end of their training [i.e. a measure of the training effectiveness], both immediately after the training and at subsequent intervals, to determine any need for refresher training. Like many organisations, both elsewhere in mining and in other industries, the mines studied appeared to have little or no systematic process to evaluate the effectiveness of safety training. There appeared to be no formal feedback channels to the safety and/or training functions on either the good or bad points of safety training. Perhaps the nearest “system” which commonly existed which could have provided such feedback was “critical task analysis”, but this was not used for this purpose and questions were raised on how systematically and reliably critical task analysis was conducted.

The combination of the tendency to place a large element of safety assurance on written procedures, combined with the unique difficulties of coping with a multiplicity of languages and a low level of literacy, makes it essential that quality information is obtained on training effectiveness. Without such information the inevitable result will be a false sense of security and a considerable waste of finance and effort.

## **2.10 Safety Assurance Systems**

Accident potential must be actively and systematically controlled if reliable and improving safety standards are to be achieved. In order to achieve the required level of control, it is essential that mines have in place a wide range of effective safety assurance systems. This is particularly true in relation to transport and tramming operations where the potential for accidents is high. However, in this regard, the active failures clearly indicated that limitations associated with the safety assurance systems at the mines constituted a significant latent failure.

In some cases the problems stemmed from a basic failure by the mines to have appropriate systems in place. There had been a failure to either recognise the need for the systems, or to successfully set the systems in place. A specific example concerned the failure to have systems in place to prevent unauthorised access onto mine property by individuals who were not employed by the mines, and who had no legitimate business with the mines. Throughout the period of the studies, non-colliery personnel were seen walking, cycling or driving through the mines. These people included men looking for work or taking short cuts through the mines, women who were clearly trying to catch the attention of drivers, people from squatter camps and hostels, children travelling to and



from school, etc. In some cases mine management did not appreciate the extent of the problem and therefore did not perceive the need for action. However, in other instances management were fully aware of the problem but had made little effort to implement effective control systems.

Further examples of where mines had omitted to introduce safety assurance systems included the failure to:

- Produce any written codes, rules and procedures covering transport and tramming operations.
- Appoint any safety personnel and implement safety inspections.
- Conduct planned task observations.
- Issue and ensure the use of personal protective equipment.
- Monitor and control the activities of contractors.

A more widespread, and potentially more serious, issue stemmed from a failure to ensure that the safety systems which had been set in place were sufficiently robust, and were reliably operated. The active failures identified problems relating to a range of current systems across the mines. Some of the more significant issues are discussed below:

### **2.10.1 Safety inspections**

Safety departments play an important part in monitoring and engendering safety commitment at the mines, and have a primary role in the safety inspection and monitoring system. However, inspection was seen by some production staff to be largely reactive rather than proactive, of policing rather than promoting and, to a degree, marginal to the day-to-day safety assurance of the mines. This view was supported by the results of the study since, within a very limited period, a whole range of issues having potentially serious safety implications were identified. Many of these issues were not only in breach of written procedures, but also contravened widely recognised safe mining practices. The failure to provide adequate safety devices, lock-out mechanisms, safe road and track conditions and the required personal protective clothing, are all specific, but typical, cases in point. The question of why these issues are not more effectively addressed through the safety inspection and reporting system clearly needs to be

considered. Apart from failing to constructively address specific problems, this general failure was perceived by the project team as dispelling any incentive within drivers and operators to report other safety related concerns. One of the active failures, for example, described how a Kombi was almost struck by a coalhauler which had to swerve to avoid a deep depression in the road. The subsidence had been in evidence for several days, but had not been reported by the drivers despite the high accident potential which existed.

It became evident when analysing the results of the studies, that the incidence of active failures was often greater in areas where work was undertaken by contractors, and at night. Further investigations established a need for:

- Contractors to more effectively monitor and inspect their own activities.
- Mines to increase their level of control over contractor activities through the monitoring and inspection process.
- An increase by both parties in the frequency and level of inspection at night time.

### **2.10.2 Pre-use checks**

Pre-use checking is the primary system used by the mines to prevent mobile equipment from being used in an unsafe condition. However, throughout all four mine studies, machines and vehicles were seen being operated with a range of potentially serious defects such as defective lights, brakes, tyres, hooters, reverse warnings, seat belts, lock-out mechanisms, etc. Further examples are given in the latent failure on Maintenance in Section 2.4 'Maintenance' [page 18]. Several active failures were identified as a result of the following shortcomings in the current systems:-

- Some drivers, including supervisory staff, continued to use equipment even when defects of a potentially critical nature had been recorded.
- Some supervisory staff regularly failed to over-inspect the checks, and consequently failed to initiate appropriate remedial action when required.
- There were limitations in the design and issue of the checklists in that: none existed for some classes of vehicle; some were written only in English and did not include translations or pictograms; in some cases important safety critical items were not included; some did not highlight particular defects that required equipment to be

immediately removed from service; and some were designed to cover only a five day working week when operations often continued over a six or seven day week.

- Completed checklists were not always collected, and reported defects were sometimes ignored by the maintenance departments.
- Checks were not always conducted before shifts commenced, with the result that work often started with drivers having little knowledge of the state of their vehicles.
- There was often no communication of problems between drivers during shift changes.
- There was often no monitoring to check that reported problems had been dealt with.

### **2.10.3 Security of mine entry and exit systems**

The failure to have systems in place to prevent unauthorised access onto mine property is outlined above. Most of the mines did have security systems in place, but active failures identified flaws in relation to the designs of the systems and/or the efficiency with which they were operated. For example:

- Checks by security guards on the condition of vehicles owned by coal merchants and transport contractors prior to entering the mines were not always reliably undertaken. This resulted in vehicles entering the mines with bald tyres, doors without catches, defective lights and hooters and without seatbelts.
- Similarly, there was a failure to check that individuals entering mines were aware of the safe working procedures that they were required to comply with and that they possessed the essential PPE.
- Security booms at secondary entrances to the mines were sometimes left unattended, creating the potential for accidents as a result of trespassers entering the mines, and collisions between slow moving heavily laden haultrucks crossing or joining provincial roads and fast moving road traffic.
- Warning systems provided at the entrances to the mines were sometimes defective, creating the potential for collisions between mine vehicles and vehicles using the provincial roads
- Lack of control over non-employees entering the mine:

- ◇ People were seen jumping into the back of moving vehicles, riding in the back of flat-bed vehicles and entering the plant without safety boots, helmets, gloves and other appropriate PPE.
- ◇ People entering the mine included women and children who clearly had no appreciation of the potential hazards that could exist.
- ◇ People were seen entering the plant for the first time without receiving any form of safety induction/instruction.
- ◇ Drivers were allowed into the plant without signing the required form to verify that they had been instructed on the prescribed safety issues.

#### **2.10.4 Planned task observations**

As part of the overall safety inspection/monitoring process at the mines, line management were required to institute a process to routinely observe critical tasks associated with the various jobs which were under their control. These were the particular elements of the jobs that were considered to be associated with a particularly high potential hazard/risk unless certain precautions and safe practices were adopted. The purpose of the inspections, which were intended to be given without warning, was to check that the necessary precautions were taken. Evidence collected by the audit team indicated that this process was highly variable in terms of quality, and rarely conducted systematically. As a result, in some cases, the precautions and safeguards that should have been implemented were neglected. This failure in the system demonstrated a management attitude that could, in turn, clearly predispose a lack of commitment to safety from the workforce.

#### **2.10.5 Feedback from incident and accident reports**

Apart from the statutory requirements to report accidents, most mines have in place a system for reporting incidents and near-miss events. The purpose of the system is to reduce accident potential by identifying and instituting effective control measures to prevent any re-occurrence of the incident. The use of near-miss information is particularly useful in this regard, in that those involved in such an event are often more willing to reveal the underlying causal factors than those involved in an accident where people are injured. Evidence collected by the audit team again indicated a lack of

commitment to operate the system reliably. As a result, in some cases, the precautions and safeguards that should have been implemented to reduce the risk of a repeat event were neglected.

### 3. Recommendations

Two sets of recommendations arise from the project:

1. Recommendations dealing with individual Active Failures
2. Recommendations dealing with Latent Failures.

A summary of the generic potential Active Failures is identified on the four mines studied is outlined in Appendix 2 [page 89].

Recommended routes to solution for each of the generic potential active failures are also contained in Appendix 2 [page 89] for consideration by other mines.

The recommendations dealing with Latent Failures are detailed below. Since the Latent Failures were generally consistent across the mines, the recommendations have generic applicability. Furthermore, as Latent Failures cover wider issues such as overall training provision, design standards, etc., many of them have relevance beyond the action level of an individual mine. Suggestions have therefore been made for possible action at industry or mining house level, as well as actions that can be undertaken at an individual mine. The recommendations have therefore been condensed slightly from the eight Latent Failure entries considered in Section 2 in order to focus on the specific areas of “responsibility for possible action” as defined above. The recommendations are presented under the following four headings:

- Design
- Codes, Rules and Procedures
- Training
- Safety Management

#### 3.1 Design

The majority of the problems in relation to error and accident potential stemming from inadequacies in equipment design arose from a failure, on the part of the original designers and manufacturers of the equipment, to adequately consider the ergonomics implications of their designs. In some cases, the error implications were so considerable that the machines could be regarded as having been purchased with built-in error

potential. The most effective solutions to such problems involve initiating improvements in ergonomics at the design stage. The foundation for this route to solution was laid by Section 21 of the Mine Health and Safety Act, 1996 and amendment 1997 (hereafter referred to as 'the Act') which places a clear onus of responsibility on the industry's machinery and equipment suppliers.

A second important problem arises from the fact that it will take a considerable time for new designs to be produced and even when such designs become available, it is unreasonable to expect a mine to replace a whole fleet of vehicles or equipment immediately. There is, therefore, a need to consider what can be done in relation to improving the ergonomics of existing machines by a *controlled* process of retrofit modification. Ideally these modifications should be in accordance with specifications agreed to by all parties involved in the design and use of the equipment, that is, the mine, manufacturers and suppliers, all of whom have legal responsibility to ensure that the 'article is safe and without risk to health and safety when used properly' in terms of Section 21.(1) and (2) of the Act.

In addition to the error potential arising from original manufacturer's designs, a number of potential errors arising as a result of machine modifications made on mines were identified. Furthermore, limitations were also identified in relation to the design of roadways, lighting, mine infrastructure, plant layout and ancillary equipment, which were also likely to have a significant impact on the provision of safe transport and tramming operations.

The responsibilities for identifying and reducing error potential arising from poor design lie, therefore, with both the original manufacturers/suppliers and the employers [mines] themselves.

### **3.1.1 Manufacturers responsibilities**

Section 21 of the Act places an unequivocal responsibility on manufacturers and suppliers to consider ergonomics in the following terms.

21.(1) Any person who -

(c) designs, manufactures, erects or installs any article for use at a mine must ensure, as far as *reasonably practicable*, that

ergonomic principles are considered and implemented during design, manufacture, erection or installation.

Currently, no guidance on the ergonomic principles that should be considered and implemented is provided. Furthermore, the standards considered to be “reasonably practicable” are not easily determined without an indication of the implications of failing to meet ergonomic criteria. Traditional textbooks and other sources of ergonomics information are of little value in resolving these questions for the following reasons:

- Only a small percentage of the information provided can be used in the mining context generally, and even less in the specific context of South African coal mining.
- Very little information is contained that is applicable to the types of machines that are used in mining, and the conditions in which they operate.
- Information is rarely presented in a form that is appropriate for direct use by designers.
- Information is rarely presented in a form that enables designers to make optimised solutions where conflicting requirements exist.

It is evident from the above that there is a need to increase the appreciation of mining equipment ergonomics among the suppliers to the South African coal mining industry, and to provide clear guidance in terms of what is expected from them in complying with the Act.

Manufacturers also have a duty to inform their customers of potential hazards and risks that may arise from the use of their equipment. Many mines are now insisting that all new equipment supplied be accompanied by a risk assessment conducted by the manufacturer or supplier.

### **3.1.2 Employer's responsibilities**

In terms of the Act, specific responsibilities are assigned to the employer to ensure the health and safety of employees at the mine.

Specifically, attention is drawn to the following sections of the Act which assign responsibility in terms of design and ergonomic issues:



- Section 2.(1) (a), (b) i.e. mine design
- Section 5 (2) (a), (b) i.e. identification of hazards
- Section 11 (1), (2), (3), (4) i.e. assessment of risks
- Section 21 (1), (2) i.e. equipment design issues

The above sections of the Act assign responsibility to employers to identify and assess risks arising from both new and existing machines as well as mine layout/design.

- In the case of new machines, they need to conduct pre-emptive or “issue-based” risk assessments, which should include a consideration of the potential impact of any ergonomic limitations.
- In the case of existing equipment, they need to conduct “routine” risk assessments. For routine risk assessments to be regarded as being *suitable and sufficient*, they again need to identify any significant risks that may arise from ergonomic limitations.

In carrying out such risk assessments on new and existing machines, employers [or personnel on mines to whom this responsibility has been delegated] face similar problems to those experienced by the original equipment manufacturers in that their appreciation of mining ergonomics is limited and, in this regard, there is a lack of clarity in terms of what is expected from them in order to comply with the Act.

With particular regard to existing equipment, employers should consider setting up risk assessment teams consisting of operators and engineers to systematically identify the ergonomic limitations/safety problems and practical cost-justifiable retrofit improvements. However, given the current level of awareness of mining equipment ergonomics, it is probable that initially the teams would benefit from training in the factors that should be addressed, and the practical standards that can and should be achieved. Additional benefits could be obtained by networking the results of their efforts across mines, thereby ensuring that all have the opportunity to capitalise on any successful ideas identified. Similarly, any retrofit improvements which proved successful should be routinely passed on to the suppliers to ensure that they can be incorporated as standard on future equipment.

Although the extent of improvement by retrofit is inevitably more limited than that which can be achieved on a new design, there is often a considerable amount that can be achieved at relatively little cost.

Implicit within the Act, is the responsibility for employers to identify the hazards and assess the risks associated with the design of the 'environments' within which mobile equipment operates. There is a need to focus such assessments on the wider 'external' factors that are likely to influence the safe use of mobile equipment such as:

- Design and layout of processing plants and aspects of mine infrastructure.
- Design and layout of underground and surface travel roads.
- Areas of potential interaction between the different operational elements within transport systems, and between the transport systems and other mine operations.
- The impact of environmental conditions such as climate and the visual environment.

To address these issues, risk assessment teams should again be set up to carry out pre-emptive assessments on planned new developments or installations, and routine assessments on existing operations.

Past SIMRAC research also provides potentially valuable guidance on hazards associated with design limitations and the means of controlling such hazards. Important SIMRAC research in this area includes:

COL 203 Engineering and human factors in machinery and transport accidents

COL 341 Guidelines for the development of safer mobile machines

COL 416 The influence of ergonomics of trackless machines on safety and health

COL 451 Assessment of illumination and visibility standards in coal mines

GEN 501 Investigation of safety and health benefits of stand-off controls

GEN 503 The measurement of vibration characteristics of mining equipment

A number of potential improvements are identified in Appendix 2 [page 89].

### 3.1.3 Summary of design recommendations

- The industry should consider the provision of guidance on the critical ergonomic factors that should be addressed during the design, manufacture and modification of mining machines in support of Section 21 of the Act.
- The ergonomic guidance should be tailored to the needs of three primary user groups, namely:
  - ◇ Original equipment manufacturers and suppliers.
  - ◇ Mine engineers and mine risk assessment team members.
  - ◇ Training providers.
- The ergonomic guidance should:
  - ◇ Identify the important factors that need to be addressed.
  - ◇ Provide explanations on why they should be addressed in terms of their potential impact on hazards and risks.
  - ◇ Indicate the practical standards that can and should be achieved.
- The industry should consider the introduction of specific ergonomic guidelines for the design of individual types, or “families”, of machine.
- Original equipment manufacturers should be required to provide risk assessments that address the hazards and risks arising from ergonomic limitations. These assessments should demonstrate that the industry guidance has been incorporated in the design, or identify alternative control measures to mitigate operational risk.
- Individual mining houses and mines [i.e. employers] should consider setting up risk assessment teams whose members are trained in the principles of ergonomics to enable them to:
  - ◇ Identify the ergonomic limitations and the resulting potential hazards.
  - ◇ Develop practical, cost-justifiable retrofit improvements.
- A network of retrofit ideas should be considered both within and across the Mining Houses and between the Mining Houses and equipment manufacturers.

## **3.2 Codes, Rules and Procedures**

Written codes, rules and procedures are currently regarded as the main pillar of the approach to safety assurance on South African coal mines. It is clear, however, from the results of the project, that serious flaws exist in the current provision of codes, rules and procedures. Evidence has been presented to show that there are important omissions, and that some rules and procedures are impractical, incomplete, too complex, irrelevant or contradictory. Furthermore, in some cases there are too many of them to be remembered reliably and complied with routinely. All of these problems are exacerbated by the training limitations referred to in Section 3.3 [page 61].

In the context of controlling risks and hazards, there is a further important limitation. Many of the written procedures examined set out the instructions or statements in a manner which prescribe only the way in which tasks have to be done. From this information alone, workmen and supervisors gain little insight into why jobs have to be done that way, and the potential consequences, in accident terms, which may result from the failure to comply.

A combination of the above problems leads to an acceptance across the workforce that, under certain circumstances, rules can be broken. This situation has the effect of not only discrediting a particular procedure, but also creating a lack of concern about the importance of other procedures. In turn, this leads to an increase in unsafe behaviour and improvisation, both of which are likely to have a direct impact on accident potential.

There is a clear need to re-examine the existing sets of written codes, rules and procedures to ensure practicality, ease of understanding, and to minimise contradictions and conflicts. If this is to be accomplished successfully, it is essential that the workforce and supervisory staff are directly involved, for it is they who have to “live” with the rules on a day-to-day basis and who understand, at first hand, the relevant practicalities and limitations.

Similarly, the workforce and supervisory staff should be involved in the development of new codes, rules and procedures if future standards are to be improved. This will simultaneously reduce impracticalities, reduce complexity and increase the sense of “ownership”, all of which will increase compliance.

The tendency to produce new codes, rules and procedures reactively in response to an accident or incident should be replaced by writing them pro-actively on the basis of risk

assessment. This will have the additional benefit of reducing the number and rationalising the overall rule set on the basis of specific hazards and risks. It will also ease the training burden by tailoring the rules to specific jobs and/or work areas.

### **3.2.1 Summary of recommendations on codes, rules and procedures**

- Risk assessments should be undertaken by the mines to identify limitations and shortcomings in the existing written codes, rules and procedures.
- In future, new codes, rules and procedures should be created pro-actively through the process of risk assessment.
- The workforce should be involved in the process of reviewing existing codes, rules and procedures and in the creation of new ones.
- Codes, rules, and procedures should clearly indicate the hazards they are designed to address and should form a foundation for the development of effective safety training material.
- Codes, rules, and procedures need to be communicated effectively to all concerned through effective systematic training programmes.
- If supervisors are to continue to play a major role in the communication of codes, rules and procedures, they should be more actively supported by the mines both in the development of their training skills and in the provision of better quality training aids and material.

## **3.3 Safety Education and Training**

Training poses special problems in the South African coal mining industry as a result of the multiplicity of first languages and often low levels of literacy. Given the scale of these problems and the intrinsic hazards associated with coal mining operations, it is not surprising that safety education and training was identified as a prominent Latent Failure. On the basis of the study, it would appear that the scope, type and standard of safety education and training provision vary considerably across the industry. At one extreme, mines appear to be attempting to deliver well structured skills based training programmes which incorporate a consideration of risk perception and hazard awareness issues. However, at the other extreme, safety education and training is virtually neglected at

some mines. It is important that emphasis be placed on development of specific occupational health and safety competence. Competence is a product of outcomes based education and training, i.e. a system in which the trainee learns and understands why things have to be done in specific ways and then is able to do them safely. Within this variation, four fundamental issues arise from the project which merit serious consideration:

1. The need to develop improved competence to identify hazards and to react to these hazards.
2. The need for a much more systematic approach to safety training needs analysis in order to identify shortcomings/deficiencies in specific occupational health and safety competencies.
3. More consideration needs to be given to upgrading the training competency of supervisory staff since they are an integral part of the training process on the mines.
4. There is an urgent need to systematically improve the competency of safety training providers i.e. in terms of occupational health and safety issues.

### **3.3.1 Hazard awareness and risk assessment**

A fundamental aspect of any safety training is the need to assess trainees' perception of risk and their awareness of hazards. Without an adequate awareness of hazards there can be no sound basis for safe behaviour, and without an adequate perception of risk, any judgements on safety issues are likely to be flawed.

The requirements for risk assessment introduced by the Act provide an ideal opportunity to improve training provision in this area for, by definition, the output of an effective risk assessment must identify the potential hazards and risks within particular operations. This information can therefore be used systematically to target both basic and refresher training requirements effectively.

### **3.3.2 Training needs analysis**

The introduction of risk assessment can provide a structured and well-focused basis on which to identify safety training needs. In addition, the output from risk assessment can

provide the basis for the development of training course content, for it will focus attention on the relevant hazards, their potential consequences, and the factors in the job which could increase the risk of an accident.

### **3.3.3 Upgrading occupational safety and health training competence of supervisory staff**

At all the mines studied, supervisory management played an important, albeit informal, role in the overall occupational health and safety training provision - principally through their involvement in informing/instructing staff on codes, rules and procedures - and in safety talks. Despite this pivotal role, they have been shown incompetent in several safety critical areas and have potentially conflicting responsibilities for both safety and production. While the role of supervisors is critical to the promotion of high safety standards, they receive little systematic training themselves and often possess only limited training skills. There is a clear need, therefore, for occupational health and safety training for supervisors.

### **3.3.4 Evaluation of training effectiveness**

The project found little evidence of any systematic evaluation of safety training, even at the mines which had invested heavily in training. There was a lack of measurement and/or evaluation, both immediately after training and at subsequent intervals, to determine any need for refresher training. Given the specific difficulties in South African coal mining mentioned above, it is particularly important to gain a measure of the effectiveness of any training given.

It is almost impossible to relate safety training to actual reductions in accident level, for there are too many intervening variables. However, using the risk assessment and training needs analysis to focus on hazard and risk during training, could provide the basis for before and after questionnaires on hazard awareness and risk assessment. As these are both fundamental to occupational safety, any failure on the part of an individual to respond more positively after a course will indicate the need for further training. Similarly, if trainees do not appear to have shifted in their assessments, then this provides an indication of shortcomings in a course.

The systematic use of feedback from incident and near-miss reports, safety inspections and supervisory staff would provide an important, albeit less formal, means of assessing training effectiveness.

### **3.3.5 Summary of recommendations on training**

- All driver and operator training should contain integrated occupational health and safety hazard awareness components. A primary objective of such training should be to impart an understanding, within the trainees, of the reasons for following prescribed safety codes, rules and procedures, and the subsequent hazards that are likely to arise if they do not comply. Drivers/operators need to be able to assess risks in any situation and be able to appropriately react to the risks.
- Training needs analysis should be used to identify the required content of training courses/programmes. Training needs analysis should be based on:
  - ◇ The results of risk assessments  
[Ideally it should become routine practice for the outcome of risk assessment to include a training needs analysis which covers the training needs of all relevant staff up to, and including, management.]
  - ◇ Written procedures and instructions
  - ◇ Codes of practice
- Consideration should be given to the introduction of specific occupational health and safety training courses to upgrade the competence of supervisory staff if they are to continue in their training role.
- There is an urgent need to develop standard approaches to the measurement of safety training effectiveness. Training effectiveness, and its impact on worker hazard awareness, should be routinely assessed using risk perception and hazard awareness assessment techniques.

## **3.4 Safety Management**

Latent failures were identified which, when considered collectively, clearly reflect limitations in the overall safety management (assurance) systems employed by the mines. For example;



- The failure by some mines to recognise the need for and/or successfully set in place and operate appropriate safety systems.
- Problems were identified across the mines in relation to the commitment and attitudes to safety by management, supervisory staff and the workforce.
- Tasks and activities were often not adequately planned and organised in the safest possible way, and limitations were identified in relation to the provision of adequate resources to enable operations to be completed safely.
- Problems were recognised in relation to the management of maintenance and contractor activities.

There is a clear need for management at Mining House level as well as individual mines to recognise that they should attach the same importance to the achievement of high standards of health and safety management as they do to other key aspects of their business activities. The need for effective safety management is particularly important in relation to the new goal setting environment introduced by the Act. This demands the adoption of a structured approach to the identification of hazards and evaluation and control of work related risks. However, risk assessment is only of value if it is an integral part of an effective safety management system.

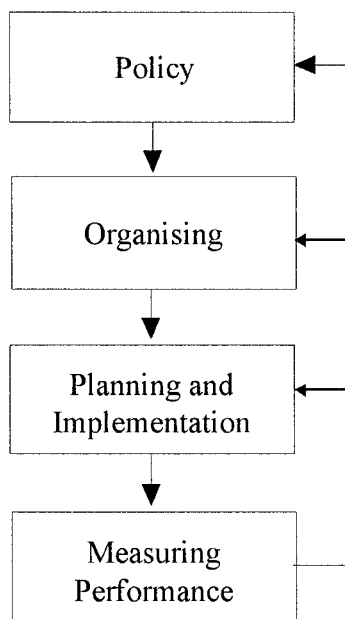
There are a number of internationally recognised frameworks and guidance that could equally well be adopted or tailored to fulfil the spirit and letter of the Act and thereby meet the needs of the South African coal mining industry. For example,

- ISO14001, the environmental management systems standard.
- BS 8800, the British Standard guide to occupational health and safety management systems.

These guidelines are based on the general principles of good management, and are designed to enable the integration of occupational health and safety management within an overall management system in order to:

- minimise risk to employees and others;
- improve business performance; and
- assist organisations to establish a responsible image within the market.

Many of the features of effective safety management are indistinguishable from the sound management practices advocated by proponents of quality and business excellence. In this regard, the four key elements of successful safety management are set out briefly below, and the relationship between them is shown in Figure 3.4.1. In a review of existing arrangements, an examination of these four elements will provide a detailed independent appraisal of the quality and performance of whatever management system is in place.



**Figure 3.4.1. Fundamental Management System Elements**

### **3.4.1 Management policy and strategy**

Management leadership, commitment and accountability are key factors in any management policy. Mine management should therefore define, document and implement its management system in a strategic plan and/or health and safety policy that outlines its commitment. All employees should be made aware of the policy, understand it and be involved in making it work.

### **3.4.2 Staff organisation**

As well as giving a verbal commitment to the policy and strategy, management need to set in place effective organisational structures and commit sufficient resources to both support the policy and strategic plan and implement the safety management system effectively. This includes the allocation of roles and responsibilities to individuals to

manage the system on a day-to-day basis, and the development of a process to train and encourage the widespread involvement and participation of all employees in the risk assessment process.

### **3.4.3 Planning and implementation**

This element involves the planning and implementation of occupational health and safety programmes, for example, those programmes required to conduct routine and pre-emptive risk assessments and the remedial actions arising from such assessments.

### **3.4.4 Measuring performance**

Performance measurement is required to provide information on the effectiveness of the safety management system, by monitoring the extent to which the overall policy and risk assessment objectives are being met. This includes the use of quality assurance principles to ensure the maintenance of standards and consistency within and across mines.

The ultimate measure of occupational health and safety performance is accident and incident rates. However, such measures are reactive rather than pro-active. They can be misleading if only fatal or high-severity low-frequency incidents are reliably recorded. One of the primary objectives of an occupational health and safety management system is to create and develop, through a process of continual improvement, a positive safety culture among all members of the workforce. Using safety culture indicators similar to the ones developed by the previously completed SIMRAC Project GEN 312 (Talbot *et al*, 1996), it is possible to monitor progress in the development of such a culture, and to identify areas where additional improvements are needed. Such approaches are particularly valuable as they provide a pro-active indication of system performance.

### **3.4.5 Summary of recommendations on safety management**

An effective occupational health and safety management system would have minimised many of the potential hazards identified by the project. Hence it is recommended that:

- All mines should adopt an integrated Occupational Health and Safety Management System. The system should be designed to create and encourage the development of a positive safety culture.

- Safety Culture “indicators” could be used to monitor effectiveness and progress [see for example Project GEN 312]
- The DME should provide guidance on the minimum requirements of an effective occupational health and safety management system, and use this guidance to form the basis for mine audits/inspections.

## **3.5 Technology Transfer**

### **3.5.1 Exploitation of Results**

This project has provided a detailed insight into the design, organisational, management and human factors which are likely to increase error potential [or accident risk] and increase the risk of accidents in transport and tramming operations. Effective exploitation of results is perceived to be a key element of this project, and special emphasis has been placed in presenting the results of the research in a straight-forward, easily understood user-friendly manner.

Particular attention has been given to the presentation of recommendations and potential routes to solution to problems that are considered likely to exist across all mines, rather than at the individual mines studied. This information gives an indication of the potential generic action areas for safety improvements that may be applicable and hence worthy of consideration by all mines.

For the industry to capitalise fully from the potential benefits of the studies, it is recommended that the results of the project should be made available to all the mines. Details of the Active Failures identified at the individual mines have been documented and these could be made available if required.

### **3.5.2 Future Research**

This project, together with the previously completed SIMRAC project OTH 202, has demonstrated that the IMC BeSafe System is widely applicable across the whole of the South African mining industry, and is a potentially valuable tool for reducing human error potential. It is therefore strongly recommended that the system should be used to examine other areas in mining where high accident potential exists.

Further work should be undertaken to convert the existing system into a process that can be used widely by the South African mining industry. The key objective of this work would be to widen access to the procedures used and ensure that technology transfer is successful to a wide range of mine staff. The current system, whilst very effective, requires skilled input from human factors specialists. The proposed intention is to modify the suite of tools so they can be used by mine staff with occupational health and safety responsibilities.

The mechanism of technology transfer would be based on the development of simple and effective procedures, working aids and training provisions. The value of such provisions should be evaluated and confirmed via a number of mine site-evaluations.

## 4. Summary

The project has provided a detailed understanding of the design, organisational, management and human factors that contribute to transport and tramming accidents. A whole series of issues have been identified where the reduction in accident potential requires a change of emphasis away from the allocation of blame, to a greater understanding of the factors which create error potential.

Although the project was not designed to provide an indication of the relative differences in occupational health and safety risk between large and small mines, potentially high risk active and latent failures tended to be more prevalent at the smaller mines studied. This would indicate that limitations in manpower and equipment experienced at smaller mines tend to exacerbate limitations in occupational health and safety provisions. To compensate for such limitations, there is a greater need to ensure effective management and supervisory vigilance at smaller mines. However, it should also be noted that there was little or no difference between large and smaller mines in terms of the areas of concern and the potential routes to solution recommended by the project.

Recommendations dealing with generic potential Active Failures are given in Appendix 2 [page 89].

Generic recommendations produced to address accident potential resulting from Latent Failures established the following requirements:-

1. Ergonomic information and guidance must be provided on the critical factors to be considered during the design, manufacture and modification of equipment.
2. The ergonomic guidance must be specifically tailored for use by original equipment manufacturers, mine engineers and training providers.
3. Original equipment manufacturers must provide risk assessments that address the occupational hazards and risks arising from ergonomic limitations.
4. Risk assessments must identify the limitations and shortcomings within existing codes, rules and procedures.
5. Codes, rules, and procedures must clearly indicate the risks and hazards they are designed to address.

6. Supervisory staff must be provided with training and support material to improve the effectiveness of “on-the-job” training.
7. All driver and operator training must contain integrated occupational health and safety hazard awareness components.
8. Training effectiveness, and its impact on worker hazard awareness, must be assessed using risk perception and hazard awareness based techniques.
9. All mines should adopt an integrated occupational health and safety management system.
10. Pre-emptive measures such as safety culture indicators, in addition to accident and incident reports, should be used to assess management system effectiveness.

This project, together with the previously completed SIMRAC project OTH 202, has demonstrated that the IMC BeSafe System is widely applicable across the whole of the South African mining industry, and is clearly a valuable tool for reducing error potential. It is therefore strongly recommended that:

- The system should be used to examine other areas in mining where high accident potential exists.
- Further work should be undertaken to convert the existing system into a process that can be used widely by the South African mining industry.
- The information entered into the SAMRASS system should be examined so that latent failures within the organisation at which the accident occurred can be identified. This can be done in conjunction with the BeSafe system.

## **5. Acknowledgements**

The input and assistance of the following is clearly acknowledged:

- The mines that invited the project team to carry out observations of their operations.
- Participants in a project workshop at which the objectives and main recommendations of the project were discussed. Participants also subsequently commented on the summary of best routes to solution for the active failures identified on the mines visited.



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# **SUMMARY OF APPENDICES**

## **A.1 Methodology**

The methodology used, together with definitions of the terminology are described in more detail in the appendices.

## **A.2 Potential Active failures and best routes to solution**

The 250 potential active failures which were identified across the four mines studied are generically grouped in this section. For each group, there is a list of best routes to solution to address and/or reduce the likelihood of an accident.

Management could relate to similar conditions or activities at their mine and consider the proposed routes to solution to address the specific potential problem.

## **A.3 Questionnaire technique to gauge attitudes to rules and procedures**

The methodology, as well as an analysis of the response from the questionnaires is reflected in this section.

## **A.4 Copy of project scope of work**

# APPENDIX 1

## A1. Methodology

The IMC BeSafe System was originally developed within the framework of the European Coal and Steel Communities Ergonomics Action Programme and was produced in response to reports from the UK Health and Safety Executive identifying that over 90% of accidents involve an element of human error. The system has been designed and further developed to identify the potential for human error within existing operations thereby:

- Releasing the investigation from working exclusively on past accident records; and
- Establishing the factors that are likely to increase error potential which are beyond the responsibility of the individuals concerned.

Given the now widespread acceptance that human error is a common cause failure in accident patterns, it is clearly a logical step to try and understand such errors within a framework that provides an effective route to error and, therefore, accident reduction. However, the phrase “human error” covers an extremely wide range of circumstances, causes and potential consequences. In order to bring some structure into such a diverse field it is necessary to have an effective means of classifying human error potential.

### A1.1. Classification of human error potential

It is particularly important in such a classification that the types of error identified must have common elements, in terms of the best way of avoiding or reducing error probability. There must be a common basis for the reduction of all errors that fall within a particular type category. Without such a classification, it is impossible to develop a practical proactive approach to address human error potential and the behavioural aspects of safety effectively. The IMC BeSafe System incorporates a module referred to as the Potential Human Error Audit which is based on an effective classification of error as outlined below.

The Potential Human Error audit uses two error classifications, the first distinguishing between *Active* and *Latent Failures* and the second providing an analysis of the *Active Failures*.

*Active Failures* are typified by operator errors and *Latent failures* are typified by those errors committed by other parts of an organisation.

***Active Failures:*** These are errors made by operators and maintenance staff i.e. those with hands-on control of the system/equipment. They occur immediately prior to the accident event and are often seen as the “immediate cause”. *Active Failures* are those errors which traditionally have been described as human error - driver error and pilot error being typical examples.

***Latent Failures:*** These are the factors or circumstances that reside within an organisation which increase the likelihood of *Active Failures*. They are the broader issues with the potential to influence a wide range of *Active Failures*. Typical *Latent Failures* include, inadequate training provision, poor equipment design [particularly in terms of ergonomics], poor attitudes to safety [at any or all levels, e.g. workforce, supervisors, management], work organisational problems, limitations in occupational safety, codes, rules and procedures, etc.

The distinction between *Active* and *Latent Failures* is important for several reasons:

1. If consideration is focused only on *Active Failures*, then the natural tendency is to focus on blame, which has little value in accident prevention terms.
2. If the *Latent Failures* are not recognised, then repeat or similar accidents are inevitable. For example, consider an operator who makes a mistake which leads directly to an accident. If the investigation focuses only on the *Active Failure*, it overlooks the fact that the training he received was inadequate. In this case training is the Latent failure and is the true cause of both the error and the accident. Failure to recognise the training inadequacies perpetuates the likelihood that other operators will make the same mistake.
3. A Latent Failure has the potential to influence a wide range of errors and thereby accidents. Poor ergonomics considerations in the design of equipment influence both a wide range of errors and, potentially, a wide variety of accidents. For example, restricted driver vision on LHDs increases the risk of collisions and of drivers being injured as a result of leaning out of the cab and adopting other unauthorised practices to overcome visual limitations. It follows logically that

removing a *Latent Failure* is an extremely powerful and cost-effective accident prevention measure.

While establishing **what** happened, or could happen, is usually sufficient to isolate *Active Failures*, it is essential to establish **why** it happened, or could happen, if the *Latent Failures* are to be exposed.

The second classification in the Potential Human Error Audit provides a break-down of *Active failures*. *Active Failures* can be extremely varied and occur for a wide range of reasons. It is necessary to have some means of grouping them in order to determine solution possibilities without having to consider each error as unique.

The distinction made in this classification is between *Unintentional Errors* i.e. *Slips/Lapses* and *Mistakes* and *Intentional Errors* i.e. *Violations*.

***Slips/Lapse Errors:*** These occur in well known tasks with operators who know the process well, and are experienced in the work. They are action errors which occur while the task is being carried out. They often involve missing a step out of the sequence or getting steps in the wrong order, and frequently arise through a lapse of attention. An every-day example would be if you go to make a cup of coffee and suddenly realise that you have put a tea-bag in the cup. Operating the wrong control through a lapse in attention or accidentally selecting the wrong gear are good examples of *Slips/Lapses* in the mining context.

***Mistake Errors:*** *Mistakes* occur when the elements of a task are being “planned”. They are decisions which are subsequently found to be wrong, although at the time the operator does not consider them to be incorrect. A *Mistake* is therefore an inadvertent error. The driver of a vehicle who decides to set off in second gear and later realises that he should have set off in first has made a *Mistake*. Similarly, a driver when considering that he is travelling at a safe speed to negotiate a bend in the road and then realises that he is going too fast, has made a mistake.

***Violations:*** *Violations* occur when the plan of action is decided upon in full knowledge that it is in breach of the rules or codes of safe working practice. *Violations* usually involve some form of perceived personal gain for the individual. Taking short cuts, or failing to take the prescribed precautions in order to enhance performance, are typical *Violations*. There are often “good” reasons why *Violations* occur, for example, a rule may

be impractical, or all the necessary equipment to follow a rule may not be available. A poorly designed vehicle cab may predispose the adoption of such unsafe operating practices as standing and leaning out of the cab to overcome sightline restrictions.

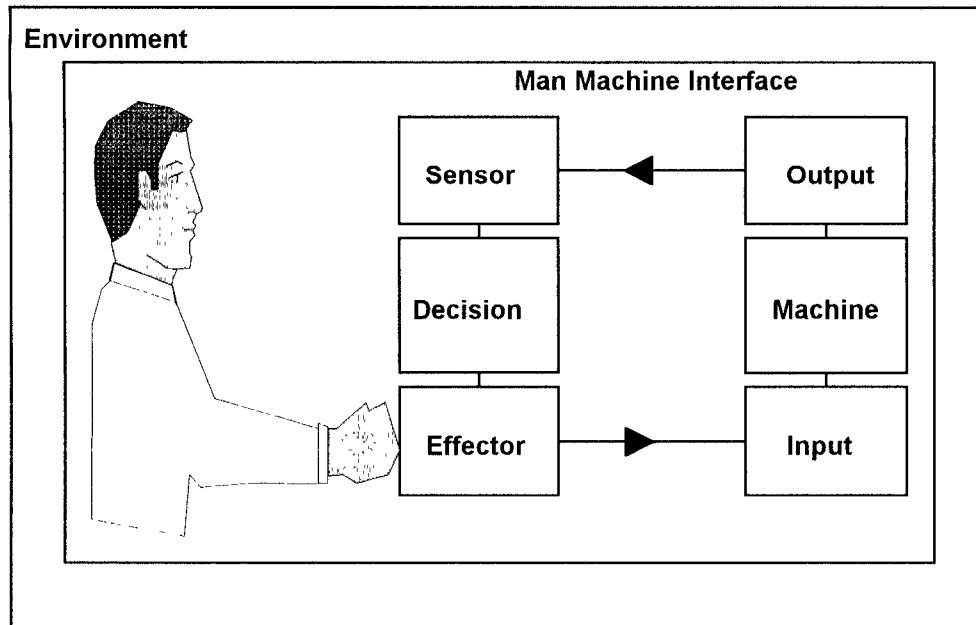
The importance of type classification of errors is that the classifications can be used as an indication of the best route to a solution. Even from the brief descriptions given above, it can be appreciated that they relate to different types of error and that they require different routes to solution. For example, improved training in the importance of a rule, to ensure an understanding of the potential consequences of non-compliance, may be of particular value in relation to reducing *Violations*. However, no amount of training will eliminate the likelihood of an operator confusing two identical controls positioned adjacent to each other i.e. a *Slip* error. In this case the most appropriate route to solution is likely to be through design improvements.

The primary routes to error reduction identified by the IMC BeSafe classification system include:

- Design changes to equipment and the local environment.
- Changes to codes and rules, safe work procedures, etc.
- Improved training/education.
- Improvements in the effectiveness and commitment of management.
- Improvements in the effectiveness and commitment of supervisory staff.
- Changes to work organisation.

## **A1.2. Identification of human error potential**

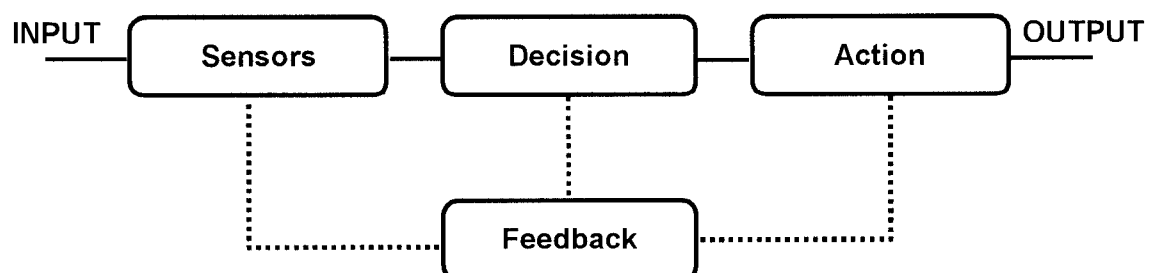
The definition of *Active Failures* given above indicates that they occur at the interface of the man and his equipment, machine, system, etc. Therefore, the traditional ergonomic man-machine system, as shown in Figure A1.1, represents an ideal starting point for the identification of *Active Failures*.



**Figure A1.1 Man-Machine System**

In this diagram it is evident that the operator receives information from the machine about the state of the operation, for example, whether the machine is doing what he wants it to, whether it is in the correct position, etc. He uses this information in order to make a decision as to whether he needs to change the operation of the machine in any way, and if so, to take the appropriate control action. The system works therefore as two superimposed feedback loops, the man providing the feedback to the machine and the machine to the man. If the system is to work safely and efficiently these two loops must be working effectively.

If the above man-machine system is re-drawn to concentrate on the man's role it is possible to create a simple representation of the human operator control function, as shown below in Figure A1.2.



**Figure A1.2 Human Operator Control Function**



Figure A1.2 shows that, in the context of human error potential, there are four basic elements which can denigrate the safety and efficiency of an operation:

### **Information input**

The information input to the sensors i.e. vision, hearing, touch, may be insufficient. The information source may be obscured, the correct information may not be available when the operator needs it, it may not be presented accurately enough, or too accurately, thereby causing confusion. Sight and hearing are the two senses most commonly used.

### **Decision**

Good quality information needs to be received in order to enable a reliable decision to be made. If the information is inadequate or confusing, then the reliability of the decision is likely to suffer. Similarly, the information received often needs to be compared with the operator's mental picture of what he is trying to achieve. If there are incompatibilities, then there is an increased probability of error. If the decision is based on some form of operating rule, the quality of the decision is influenced by whether the operator knows the rule, whether he remembers it and whether the information is presented in a reasonable way.

### **Output**

The successful completion of any task depends on the undertaking of output actions. Users commonly interface with machinery by operation of controls. Errors are likely to result if the operator is unable to reach a control, if he is unable to activate it accurately enough, or if a series of similar controls are placed close together, thereby causing confusion and activation of the wrong control. In addition to operational controls, machine operators may have to action decisions by giving verbal or written instructions to others, or by performing other physical tasks.

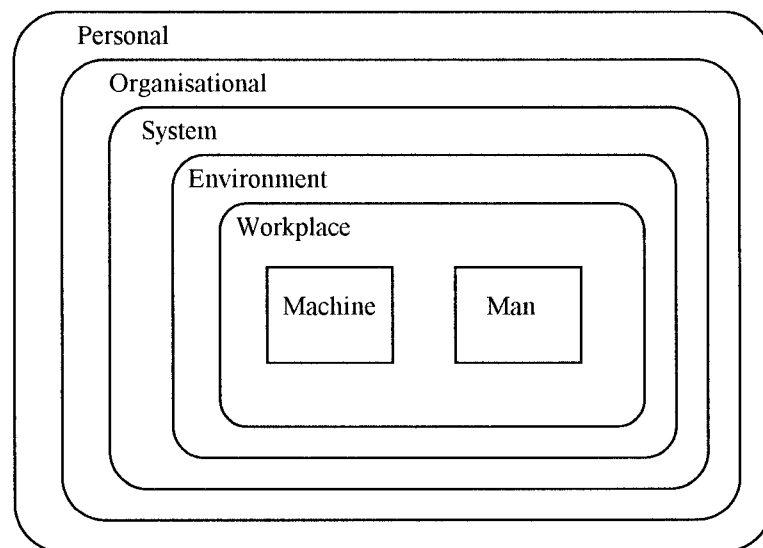
### **Feedback**

The feedback element concerns the question of how an operator knows when he has completed a task. Operators rely on two forms of feedback. Internal feedback occurs through a series of sensors in the body which ensure that, for example, they know, where their limbs are without having to look at them. These feedback sensors are crucial to safe operation, but it can be assumed, under normal circumstances with healthy

individuals, that they function effectively. External feedback concerns any information about the change to the system which comes from outside the operator. This can be, for example, direct visual information [you see the vehicle beginning to turn into the bend after you've turned the steering wheel] or "artificial" information presented by a dial or computer screen. In the latter case the operator would see the reading begin to fall on a speedometer as he applies the brake. External feedback can, therefore, be regarded as a special form of input.

### External Influences

The operator control functions described above should not be considered in isolation. It is also essential to take cognisance of the wide range of external factors that may influence operator performance significantly. Figure A1.3 shows the spheres of external influence that should be considered.



**Figure A1.3 Spheres of External Influence**

The central area within Figure A1.3 represents the traditional man-machine system, but it is shrouded by clearly defined, though complex, spheres of influence. These include:

- **Environment** which includes working headroom, air temperature, humidity, presence of dust or noise, etc.
- **System** which addresses interactions with other interdependent equipment or processes.

- **Organisational issues** which include training, communications, supervision, management style, etc.
- **Personal** which refers to the difficulties that people bring to the job. All people are different both mentally and physically. There are behavioural problems and different attitudes to safety to contend with.

These spheres of influence can have both a direct and indirect influence on the efficiency of the man-machine system and therefore can contain factors that are likely to predispose error potential i.e. *Active Failures*.

A complete and systematic working framework for identifying the potential for human error using the operator control function involves the following five steps:

1. All the primary elements in the task or operation under investigation should be listed.
2. All the safety rules associated with the operation of each task element should be listed, and all the decisions which the operator has to make during the completion of the element should be identified.
3. For each decision, all the information requirements to enable the decision to be made reliably should be identified.
4. All the actions relating to each decision should be listed. For each decision, all the physical requirements to enable the actions to be practically implemented reliably, should be identified.
5. For each task element a note should be made of the feedback required to enable the operator to know that he has successfully completed an operation.

When using this approach, the volume of information available and the number of decisions and actions made, even during the performance of relatively simple tasks, can be enormous. However, it is possible to rationalise this approach and produce a series comprehensive checklists which cover the main issues that need to be considered. These checklists are designed to act as aides-memoir to ensure that trained users of the IMC BeSafe system thoroughly address the potential for:

- Visual input errors

- Auditory input errors
- Control operating output errors
- Verbal output errors
- Written output errors
- Other physical output errors

An extract from the control operating error checklist is shown below in Figure A1.4.

<b>The Potential Human Error</b>
<b>What could happen if:</b>
<ol style="list-style-type: none"> <li>1. Control operated too early or too late?</li> <li>2. The adjacent control was accidentally operated?</li> <li>3. The control was inadvertently operated in the wrong direction?</li> <li>4. The control was not operated at all?</li> <li>5. ....</li> <li>6. ....</li> </ol>
<b>Potential Causes of the Error</b>
<b>Which of the following could increase the likelihood of the error?</b>
<ol style="list-style-type: none"> <li>1. Poor control positioning-out of easy reach</li> <li>2. Poor control positioning-not easily seen</li> <li>3. Poor labelling</li> <li>4. Operating forces too stiff</li> <li>5. Control is too sensitive</li> <li>6. Stereotype wrong</li> <li>7. ....</li> <li>8. ....</li> </ol>

**Figure A1.4 Aide Memoir Checklist for Control Operating Errors**

These checklists are structured to raise two fundamental questions.

**What could go wrong or what could happen if?**

**What could cause the error or increase the likelihood of the error?**

A list of points are provided under each question to prompt careful thinking about the sort of errors that can occur, the “what could go wrong elements” and then to consider the potential causes of these input or output errors.

### A1.3. From Active to Latent Failures

While it is a considerable step forward in terms of accident prevention to have identified potential *Active Failures* and defined the best route to reducing their probability, unless the factors which increase the likelihood of an *Active Failure* occurring are identified, i.e. the *Latent Failures*, the problem has only been partially addressed.

While the process outlined above provides the means of identifying solutions to *Active Failures*, it also provides the first step in identifying the *Latent Failures* associated with a given error. Consideration of the following error description provides a straightforward example of how *Latent Failures* can be identified.

*The visibility from the driver's position on LHDs was very limited in all four quadrants. On many occasions these restrictions were sufficient to restrict the operator's ability to identify pedestrians in time to take corrective action. Furthermore, operators were often seen leaning out of the machine profile to enhance their view.*

The *Active Failures* which increase the probability of accidents are (a) the failure to see pedestrians and (b) leaning out of the cab. (a) and (b) describe **what** happened. In identifying the potential route to solution, it is evident that the problem arose from the initial design of the machine where little consideration appeared to have been given to driver vision. This is **why** it happened, and is therefore an indication of a *potential Latent Failure*. In this context, therefore, equipment design is a potential *Latent Failure* which predisposes the two *Active Failures*, which in turn increase the probability of transport accidents.

The above example is relatively simplistic and often a number of potential *Latent Failures* can be identified which affect a single *Active Failure*.

### A1.4. Results

Potential Human Error audits were undertaken at four mines. These mines were selected in consultation with the SIMCOL committee and included two large mines and two smaller mines. One of the large mines was an underground mine and the other a surface mine.

The two small mines conducted both surface and underground mining operations. The range of transport and tramming operations investigated across these four mines included the following:

#### ◆ Surface Operations

- ◇ Loading and tipping activities involving shovels, dozers, loaders and haultrucks.
- ◇ The transport of run-of-mine coal and discard material.
- ◇ The transfer of coal to tips using haultrucks.
- ◇ Transport operations associated with rehabilitation work.
- ◇ Transport and tramming operations associated with other support/service vehicles.
- ◇ Operations in an open cast area operated by private contractors.
- ◇ Operation of a railway system between a marshalling area and a processing plant.
- ◇ Loading and tipping operations in processing plants involving loaders, tractors and trailers, haultrucks and railtrucks.
- ◇ Transport operations associated with loading, tipping and rehabilitation work in an open cast re-processing area.
- ◇ The impact of maintenance activities on the safety of surface transport and tramming operations.

#### ◆ Underground Operations

- ◇ Transport and tramming operations in production areas.
- ◇ The transport of vehicles and workmen in a lift and activities in shaft station areas.
- ◇ Transport and tramming operations on inclined shafts and ramps.
- ◇ Transport and tramming operations on main travelling roads.
- ◇ Transport of workmen to production areas.
- ◇ The impact of maintenance activities on the safety of underground transport and tramming operations.

## A1.5. Potential Active Failures

A total of 250 potential active failures i.e. potential “accident likely situations” were identified across the four mines studied.

The potential active failures are recorded in a standard format as shown in the example below. In addition to describing and classifying the errors, preferred routes to solution are also included.

<p><b>Example Potential Active Failure:</b>      <b>Failure to lock-out parked machines</b></p> <p><b>Potential Error Type:</b> Violation</p> <p>Limitations in the design and provision of effective lock-out devices across a range of underground machines, created a situation in which the machines were routinely left unattended in a condition where they could be driven off by anyone. Examples of the problems identified are outlined below:-</p> <ul style="list-style-type: none"><li>• The padlocks issued to tractor and loader operators were not always compatible with the associated lock-out mechanisms provided on the machines and therefore could not be used.</li><li>• On some shuttlecars, the chains used to retain the power levers in the ‘isolate’ position were too long and, after the padlocks had been applied, it was still possible to return the lever to the ‘power on’ position and operate the machine.</li><li>• Restricted access on some of the shuttlecars that had been refurbished by the Colliery prevented operators from getting their hands in place to apply the lockouts.</li><li>• On some loaders, the configuration of the lock-out mechanism enabled padlocks to be applied with the power switch in both the ‘isolate’ and the ‘power on’ position. Error potential was compounded because no labels were provided to define the two positions.</li><li>• The method of locking out some tractors was to apply a padlock to the gear lever when it was located in the ‘reverse’ position. This did not prevent the engines from being started and the tractors from being driven off in reverse. Failure to release the clutch in such a situation could result in the tractors taking off abruptly out of control.</li><li>• Some drivers were not provided with padlocks, even though they claimed to have asked for them repeatedly.</li></ul> <p><b>Preferred Route to Solution:</b> Organisation/Supervision/Design</p> <p>A check should be made to ensure that all machine operators are provided with padlocks that are compatible with the lock-out mechanisms on the machines which they are required to operate. Managers and supervisory staff should then consistently monitor lock-out practice as a matter of routine, ensuring that any breaches are recognised and that the appropriate remedial/disciplinary action is taken.</p> <p>With regard to the design issues, all machines should be examined to identify the existence of any limitations in the system such as those typified by the examples described above. Any limitations identified should be addressed by appropriate retrofit improvements.</p>
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## APPENDIX 2

### A2. Summary of Potential Active Failures Identified and Best Routes to Solution

The 250 potential active failures were used to identify the latent failures underlying transport and tramming operations on coal mines. The detailed description of each of the potential active failures [in the format described in Section A1.5] has not been included in this report. However, the detailed listing of all of the potential active failures can be made available to enable individual mines to identify whether similar problems exist at their operations.

In analysing the data, a range of common problems were found to exist across all or most of the mines studied. A summary of the potential routes to solution recommended in relation to these problems is provided below. This information gives an indication of potential generic action areas for safety improvements that may be applicable and hence worthy of consideration by all mines.

#### SUMMARY OF GENERIC POTENTIAL ACTIVE FAILURES IDENTIFIED

<b>Generic potential active failure</b>	<b>Section describing 'Best route to solution'</b>	<b>Page</b>
Limitations in cab design	A2.1	90
Overspeeding	A2.2	92
Substandard road conditions	A2.3	92
Limitations in access and egress to vehicles	A2.4	93
Vehicles/equipment in substandard condition	A2.5	94
Lack of audible warning and communication systems	A2.6	95
Unsafe parking practises	A2.7	95
Lack of maintenance of fire fighting equipment on vehicles	A2.8	96
Limitations in design and deployment of material transport vehicles	A2.9	96
Ineffective use of, or lack of, road signs	A2.10	97
Inadequate provision, or maintenance, of lighting facilities	A2.11	97
Inadequate control of vehicle movement in yards	A2.12	98
Inadequate control over contractors and civilians	A2.13	99
Lack of control at loading, tipping and dumping sites	A2.14	100

Inadequate control of vehicle movement in incline shafts and ramps	A2.15	101
Lack of control at railway system operations	A2.16	102
Lack of control of safety standards, procedures, rules	A2.17	103
Limitations in safety training	A2.18	103

Best routes to solution for the generic potential active failures described above, follow.

## **A2.1. Improvements to cab design**

- More detailed ergonomic assessment of existing cab designs should be undertaken to identify limitations.
- Minimum ergonomics requirements should be included in purchase specifications produced for new vehicles.
- On vehicles already purchased, ergonomic limitations should be addressed by increasing the knowledge of ergonomics among engineering staff at mines to enable the effective implementation of retrofit improvements.
- Information on the ECSC, USBM and previous SIMRAC mining ergonomics research programmes, particularly with regard to identifying effective retrofit improvements, should be considered.
- Retrofit improvements based on sound ergonomic principles should be considered, instead of simple repairs to items prone to repetitive failure.
- Worker conspicuity should be maximised through the issue and use of high visibility clothing, especially in situations where driver visibility is known to be less than ideal.
- Pedestrians should be trained to maintain a safe distance from vehicles and within the field of vision of the drivers.
- Studies should be undertaken to identify where unsafe driving practices are adopted to overcome ergonomic limitations [e.g. leaning out of the cab], and remedial action initiated through improved design, more effective supervision, and special training in hazard awareness.
- Specific improvements that should be considered include:
  - ◊ The provision of additional mirrors or visual aids to minimise sight line limitations and/or the more effective use of spotters.

- ◇ The use of seats that are adjustable and which can accommodate body-worn self rescuers.
- ◇ The provision of greater protection to upper body regions of the drivers of some classes of equipment.
- ◇ The provision of alarms or switching devices to prevent vehicles from being operated in an unsafe condition, for example, without driver in position, with doors or windows open, etc.
- ◇ The provision of air conditioned cabs for surface vehicles to reduce driver fatigue, exposure to noise, and the temptation to operate with windows and doors open.
- ◇ Provision of colour coded gauges to reduce errors in checking vehicle condition.
- ◇ The provision of canopies for all LHDs. Physical selection criteria should be considered to exclude tall persons from driving this equipment where operating clearances are seriously restricted.
- ◇ Machines which require operators to walk alongside them to control tramming operations should be avoided wherever possible.
- ◇ More effective hooters should be provided in noisy areas.
- ◇ Improved systems of communication between drivers and guards on loco haulages to be provided.
- The following improvements for LHDs should be considered:
  - ◇ Improved sight line and headlight arrangements.
  - ◇ Improved seating arrangements to enhance vision and reduce postural difficulties, fatigue and problems restricting easy access to controls.
  - ◇ More effective use of workspace to provide adequate freedom of limb and body movement.
  - ◇ Safer access conditions.
  - ◇ Safer and more effective design and positioning of controls.

## **A2.2. Reducing the risk of speed related transport accidents**

- Vehicles should be provided with speedometers that conform to acceptable ergonomic design standards. In particular they should be colour coded to help overcome problems of literacy/numeracy within the driver population.
- All speedometers should be located where they can be reliably read from the driver's normal operating position.
- Speedometers should be incorporated in vehicle safety checks and routine maintenance as a critical item.
- Consideration should be given to fitting all haultrucks with over-speed devices.
- The fitting of over-speed devices to other classes of vehicle where speed limit violations are difficult to control should also be considered.
- Speed limits should be defined, and conflicts in the limits specified in the various sets of 'rules' at individual mines removed.
- More effective signposting of speed limits should be provided.
- More effective monitoring and disciplining of speeding offences should be undertaken.
- Training on the hazards associated with over-speeding should be given using case studies of speed related accidents.
- Refresher training and the re-issue of driving licenses should specifically address speed related accident potential.

## **A2.3. Improving road safety standards**

- Reviews of roadway standards should be undertaken and appropriate remedial action taken.
- Regular and reliable roadway inspection and maintenance programs should be implemented.
- Training initiatives should be used to address the failure of drivers and supervisors to recognise unsafe conditions.
- Airborne dust should be reduced in surface operations through more effective watering down, especially in areas of high vehicle activity.

- Supervisors should more positively monitor deteriorating conditions and initiate remedial action before conditions become critical.
- Appropriate grades of material should be used for roadway repairs to create a more solid footing
- Effectively planned operational cycles should be developed for water cars to reduce problems of under and over-watering.
- Surface roadways should be examined to identify places where vision is critically impaired and appropriate remedial action taken.
- Reliable reporting of unsafe roadway conditions by drivers, operators, supervisors and those having the specific responsibility of carrying out such inspections should be encouraged.
- Roadways should be clearly demarcated, particularly through open areas of the mines and reflector markers should be regularly cleaned and maintained
- Greater consistency in the maintenance of bermwall standards should be applied.

## **A2.4. Improving vehicle access and egress conditions**

- Solution routes to access problems for drivers are essentially the same as those identified in relation to limitations in cab design, namely:
  - ◇ Introduction of minimum safe access requirements in purchase specifications.
  - ◇ Implementation of retrofit improvements on existing equipment e.g. raising canopies on underground plant, providing/improving handholds and steps, relocating impeding items, etc.
  - ◇ Identifying and implementing applicable retrofit ideas from international sources and previous SIMRAC research.
  - ◇ Improving standards of maintenance and repair.
  - ◇ Identifying unsafe practices stemming from poor access conditions [e.g. operating roadheaders without driver in position] and implementing appropriate remedial action through improved design, more effective supervision and special training in hazard and risk identification.
- More effective, purpose designed, safe access facilities and working platforms should be provided, especially for jobs that are repetitive.

## **A2.5. Improving the condition of vehicles**

- More reliable and effective pre-use inspection systems should be implemented. In particular:
  - ◇ Inspections should include all items that are critical to safe operation e.g. driving mirrors, windscreens, lights, protective guards, brakes, important controls and displays, seats, hooters as well as critical engineering components/items.
  - ◇ Reliable over-inspections on pre-shift checks should be made by supervisory management.
  - ◇ Practical training on pre-shift inspections should be considered with emphasis placed on the potential hazards arising from using unsafe equipment.
  - ◇ More timely action taken on reported defects.
  - ◇ Documentation should be suitable for its purpose and take into account any potential literacy problems.
  - ◇ Drivers/operators should not be pressed into operating defective equipment.
- Drivers knowingly using defective equipment should be effectively monitored and disciplined.
- Routine workplace inspections should include safety checks on vehicles.
- There should be a greater commitment by both maintenance and production staff towards the efficient operation of planned maintenance systems.
- Management and supervisors should take vehicles that are known to have critical defects out of service.
- There should be more reliable ordering, delivery and control over stocks of critical replacement components.
- Training should be provided for operators and maintenance staff on the risks associated with operating poorly maintained equipment.
- More resources should be provided to deal with unexpected maintenance demands.
- Machines should be selected that are 'maintenance friendly' to reduce the temptation among maintenance staff to improvise, take short cuts or neglect some tasks.
- Wherever possible, standardise on the type/make of equipment/vehicle used on an operation.

## **A2.6. Improving audible communications and warnings**

- Refresher training should be given to drivers, emphasising the importance of reliable use of hooters in accident prevention and using accident reports to illustrate the potential hazards.
- The relocation of hooter controls to a standard easily and rapidly accessible position on each class of equipment should be considered.
- Effective monitoring and disciplining of signalling offences should be undertaken by supervisory management.
- Where possible, high noise emitting sources should be muffled, or located or moved to positions where they are unlikely to mask or interfere with warning or communication signals.
- Automatically activated reverse hooters on haultrucks and for other classes of vehicles should be considered.

## **A2.7. Reducing accident potential resulting from unsafe parking practices**

- Traffic should be prevented from parking in 'no-parking' areas, etc.
- During driver/operator training for all classes of vehicle, greater emphasis needs to be placed on correct parking practises. By raising hazard awareness and risk perception, the reasoning behind the various parking rules and procedures should be more fully understood and a more effective level of compliance achieved.
- Training on parking should be backed up by higher standards of supervisory and management vigilance to ensure that potentially dangerous practices are actively discouraged.
- The reliable use of appropriate warning devices to denote parked vehicles should be enforced by supervisory management wherever a vehicle poses a potential restriction.
- Checks should be undertaken to ensure that lock-out devices are provided on all powered mobile plant and that they are in correct working order.
- Managers and supervisors should monitor lock-out practice more consistently and ensure that any breaches in procedure are identified and appropriate remedial/disciplinary action taken.

- Management should increase the availability of lock-out devices, wheel chocks, warning devices, etc.

## **A2.8. Reducing the risk of fires**

- Reliable safe working procedures should be produced for tasks where there is a potential fire hazard e.g. re-fuelling operations. These procedures should be based on risk assessments undertaken to identify the extent of the specific hazards involved, and the most effective hazard control measures that need to be applied.
- Consideration should be given for more effective training in the general use of fire fighting equipment and appliances.
- Relocation of fire extinguisher controls and release mechanisms to a standard easily and rapidly accessible position on each class of mobile equipment should be considered.
- The functional reliability of fire extinguishers carried on vehicles should be increased by:
  - ◇ Improving the integrity and ease of operation of the release mechanisms.
  - ◇ Undertaking more reliable checks on the general state and condition of the extinguishers.
  - ◇ Ensuring common positioning of extinguishers on each class of vehicle.
- Drivers, and those involved in inspecting vehicles, should be given more effective training on the correct methods of carrying out the above checks. The training instruction should encompass all the various types of extinguishers provided.

## **A2.9. Improving the deployment of materials transport vehicles**

- Assessments should be made of the compatibility of present fleets of transport vehicles in relation to the loads that have to be moved.
- The allocation of vehicles should be based on their appropriateness for the nature of the loads that have to be moved rather than on convenience and immediate availability.
- Where no suitable vehicles are available, risk assessments should be undertaken to identify the specific hazards concerned to determine whether a safe method of work



can be produced. This is particularly relevant to small mine owners who have to operate with limited resources. The risk assessments should consider issues such as:

- ◇ Personal positioning.
  - ◇ Methods of lifting and unloading.
  - ◇ Load security and stability.
  - ◇ Ground conditions.
  - ◇ Sightline restrictions.
- Investment in new vehicles should be considered where the hazards associated with using existing stock cannot be adequately controlled.
  - Tractors should not be coupled to trailers without safety chains being attached.
  - To discourage unsafe improvisation, management should ensure that approved lifting chains and equipment for lifting and carrying loads are always provided.

## **A2.10. Improving warning signs, road signs, etc.**

- Abrupt changes in roadway section and obstacles should be clearly indicated.
- All road and warning signs should be positioned to be easily seen from the driver position on mobile plant. Particular care is needed in areas of high dust make or low illumination.
- All signs should be pictorial or in very simple language to minimise language/illiteracy problems. Where possible public road traffic sign conventions should be used.
- All road and warning signs should be of reflective type material.

## **A2.11. Improving vehicle and general lighting standards**

- The safety critical visual attention areas for the drivers of all mobile plant should be identified and existing lighting examined in relation to their effectiveness in illuminating these areas.
- Mobile equipment with defective lights should be removed from service until repairs have been completed.

- Brake and indicator lights on vehicles should be clearly visible to a following driver at a point equivalent to at least the braking distance at maximum speed on a down gradient plus 25% to allow for reaction and response time.
- Particular care on lighting needs should be taken in areas of high dust make and/or low levels of ambient lighting. In such circumstances it may be beneficial to increase the local ambient lighting to supplement machine mounted lights [especially in cases where the latter is less than adequate].
- Where feasible, action should be taken to increase the conspicuity of important visual targets through the provision of, for example, reflective warning signs, high visibility clothing or reflective materials.
- Machine mounted lighting should be a primary issue in relation to pre-shift checks, both in terms of defects and the need for clean lens, etc. This should be subject to over-inspection by supervisors, and drivers should be given the means to ensure that lights are kept clean.
- Where the working environment is particularly poor, for example, where dusty, wet, muddy conditions exist, or where access for routine cleaning is difficult, a means of protecting the lights and/or a mechanical means of cleaning them should be considered.
- Checks should be made to ensure that operational areas are illuminated in accordance with the Mine Health and Safety Act. Furthermore, effective plant lighting should be provided at all points where there is a potentially high collision risk.
- SIMRAC Project COL 451 (Talbot *et al*, 1998), "Recommendations on setting illumination and visibility standards in South African coal mines" provides detailed guidance on how to address the visually related hazards associated with a comprehensive range of operational situations most frequently encountered.

## **A2.12. Reducing the risk of accidents in colliery yards and processing plants**

- Drivers should not be allowed to climb on their vehicles to direct loading operations. If such direction is necessary, where possible, platforms should be provided from where observations can be made in safety.

- The drivers of vehicles owned by coal merchants and transport contractors should be required to conform to mine safety standards with regard to condition, working procedures and use of PPE.
- High visibility clothing should be worn by all persons, especially at night and when visibility is poor.
- In order to counter the changing nature of plant layout and activity, regular task/operational analyses should be carried out in order to maintain safe operational procedures and systems of traffic flow. This analysis should consider potential interactions between different transport activity e.g. shunting railtrucks, movement of haultrucks, etc.
- Effective lighting should be provided at places where there is a potentially high collision risk.
- Plant structures should be clearly demarcated with high visibility markings to reduce collision risk.
- Where coal is sold to small traders and private individuals, special provisions should be provided to enable loading activities to be carried out where there is no risk of being struck by large haultrucks and other heavy mobile equipment.
- While waiting for loading operations to commence, contract drivers should be required to wait in their vehicles where they are not exposed to the risk of being struck by other mobile equipment in designated parking areas.
- Where entry to plants is provided by steep ramps, barriers, drop gates and other appropriate safeguards should be provided to prevent runaways from entering the plant.
- All traffic routes through plants should be clearly identified and marked.

### **A2.13. Reducing the risk of accidents involving contractors and other people not employed by the colliery**

- Management should increase their level of monitoring and control over activities undertaken by contractors.
- Management should institute a system for checking the condition of all vehicles entering the mine, and ensure that drivers and passengers in these vehicles are fully

aware of and understand the safe working procedures that they are required to comply with and that they possess the essential PPE.

- People entering the mine for the first time should be made aware of the potential hazards that may exist in the areas of the mine that they are required to visit.
- Delivery vehicles and vehicles driven by company representatives, service engineers and visitors to a mine should not be allowed to travel around mines freely, particularly through the working areas, without being checked, and where necessary, escorted.
- Perimeter fences should be erected around mines, and no housing/squatting should be allowed within this area. Ad hoc patrols should be undertaken to discourage entry into the mine and offenders should be prosecuted.
- Private 'civilians' [i.e. non-mine personnel] should not be allowed on mines other than those authorised to do so via the management/security systems.
- No person on foot or bicycle should be allowed to enter the premises of a mine. Such persons who have legitimate business on the mine should be collected at the security gate point and transported to the person with whom they have made arrangements.
- Where 'civilians' have the right to use roads running through a mine, drivers should be made aware of the likelihood of the presence of pedestrians. Vehicle activities should be suspended for short periods at crucial times to allow large groups of, for example school children to be safely escorted through the mine area, and, where possible, protected walkways should be provided that are free from vehicular traffic.
- The condition of buses and the proficiency of the drivers of buses contracted to transport employees to remote parts of a mine, should be checked regularly. During these transport operations, 'civilians', for example, school children, should not be allowed to travel in the buses.

#### **A2.14. Reducing the risk of accidents at loading, tipping and dumping points**

- An adequate standard of plant lighting should be provided at all loading, tipping and dumping points.
- All workmen should be required to wear high visibility clothing at these points, particularly at night.

- Mines should increase their level of monitoring and control of safety issues in these areas.
- Dusty areas where loading takes place should be routinely watered down to avoid visibility and health problems.
- Loading operations should be examined to reduce the incidence of spillage during subsequent mineral transport operations.
- Management should set in place systems which prevent loading operations taking place within the swing radius of draglines. Operators should not be pressed into operating in these conditions.
- Clear instruction should be produced covering safe parking distances between vehicles and between vehicles and highwalls. Training, in which the potential consequences of failing to adhere to the instruction, should be given to both operators and supervisors.
- Where possible, dedicated dust extraction/control systems should be considered to limit the amount of dust taken into the air at tips. Until such systems can be introduced, vehicle activities should be controlled to limit tramming operations until dust clouds have settled.
- Intensive activities involving the movement of haultrucks, dozers, loaders, utility/support vehicles and spotters/attendants on foot are typical of the operations at coal tips. The individual movements and interactions between vehicles and between vehicles and pedestrians need to be more effectively co-ordinated and controlled if accident potential is to be reduced.

## **A2.15. Reducing the risk of accidents on ramps and inclined shafts**

- Test ramps should be provided at the top of inclined shafts and drivers should be required to test the brakes of their vehicles – in both directions of travel - before entering the shaft.
- Risk assessments should be undertaken to determine the need or otherwise to restrict vehicle movement on inclined shafts, while men are working or travelling in the shaft.
- Control systems should be introduced to prevent collisions between vehicles operating simultaneously on inclined shafts.

- Flatbed trailers should not be used on steep inclines. Only trailers fitted with tailgates should be used and the security of tailgates on the trailers used in such circumstances should be checked regularly.
- In cases where the ground falls away at the sides of ramps and inclined shafts, bermwalls or barriers should be provided to prevent vehicles from being inadvertently driven over the edge.
- Management should set in place systems which provide regular monitoring of ground conditions in adverse weather and a mechanism for suspending operations when such conditions become hazardous. Drivers should not be pressed into continued operation in such conditions.

## **A2.16. Controlling the risk of accidents associated with railway system operations**

- Regular and reliable track inspection and maintenance programs should be implemented.
- Training initiatives should be used to address the failure of supervisors to recognise when conditions become unsafe, and the potential consequences arising therefrom.
- Loading operations should be examined to reduce the incidence of spillage on the tracks.
- Safe procedures should be produced covering the marshalling of railtrucks, and supervisory management should be required to ensure that such procedures are routinely adhered to.
- Clearly visible clearance markers should be provided at track junctions to reduce collision risk.
- Solution routes to access problems for locomotive drivers and shunters are essentially the same as those identified for other mobile equipment, namely:
  - ◇ Introduction of minimum safe access requirements in purchase specifications.
  - ◇ Implementation of retrofit improvements on existing equipment e.g. providing/improving handholds and steps, relocating impeding items, etc.
- Working procedures should not require shunters to get on and off moving trains.

- The South African Transport System [SATS] should be required to reduce the percentage of defective railtrucks supplied to the mines since there is considerable accident potential associated with the use of this equipment. Ideally, mines should not accept and use defective trucks.
- Propelling [as distinct from hauling] railtrucks was identified as a potentially hazardous operation. Risk assessments should be undertaken to identify the hazards associated with this activity and the effective hazard control measures that need to be considered for implementation.

### **A2.17. Improving safety codes, rules and procedures**

- All rule sets should be critically re-examined to ensure practicality, easy of understanding and to eliminate conflict.
- The re-examination of rule sets should be undertaken by a multi-disciplinary, multi-level team involving both workforce and supervisors, as they know, first hand, the difficulties of implementation.
- The creation of new codes, rules and procedures should always involve input from both the workforce and supervisory grades.
- The training process for new rule sets should be examined to ensure that emphasis is placed on hazard identification and awareness,
- If supervisors are to continue to play a major part in the training on codes, rules and procedures they need support in terms of instruction/tuition on training and in the provision of adequate material/information to form the basis for their training input.

### **A2.18. Improving safety management and general safety training provision**

- There is a pressing need for a more integrated and managed approach to safety on mines.
- Some mines appear to have a wide range of safety initiatives but no safety system.
- Roles, responsibilities and accountabilities for safety need re-examining both within and across mine functions/departments.
- Safety departments need a more pro-active role and more systematic input from other departments in order to carry out such a role.

- The range of safety audits, inspections and reviews conducted on mines seem disparate and un-coordinated. A more structured approach is needed to obtain proactive safety information and to the monitoring of safety standards.
- To reduce the prevalence of unsafe practices identified during night shifts mines should:
  - ◊ Undertake more safety inspections and increase the presence of management during this period.
  - ◊ Train and test drivers and members of transport teams during periods of darkness as well as during daylight hours.
- Active participation of the workforce and supervisory staff is needed if safety standards are to be improved for it is they, much more than management, who routinely see where current action is limited/failing.
- A revised approach is needed to occupation health and safety training. In particular, a more systematic approach to safety training needs analysis is required. Carefully conducted systematic risk assessment could provide a sound basis on which to initiate such action.
- Training departments, like safety departments, need more systematic, constructive and routine feedback from operational departments if occupation health and safety training provision is to be improved.
- A greater emphasis during occupational health and safety training on hazard awareness and risk perception is required.
- Methods to evaluate the effectiveness of occupational health and safety training are essential if the additional training required is to prove cost-effective.
- Consideration needs to be given to the training of supervisory staff, especially as they are themselves an integral part of the training process on mines.



## APPENDIX 3

### A3. Questionnaire technique to gauge attitudes to rules and procedures

The study provided a strong indication that, in addition to the formulation, composition and communication problems detailed in Section 2.6 'Codes, Rules and Procedures' [page 27], there were problems associated with real or perceived pressures to break rules and procedures. This was reflected in a number of potential active failures identified and was alluded to on a number of occasions in the latent failures discussed in Section 2. A specific study undertaken at the three mines which had sets of written procedures covering transport and tramming operations confirmed that 'attitudes to rules and procedures' was indeed a problem.

The study was based on techniques developed in the previous SIMRAC project GEN 213 "Improve the safety of workers by investigating the reasons why accepted safety and work standards are not complied with on mines". The methodology was designed to identify potentially critical compliance risks and to suggest basic remedial routes which should be considered. It involved the presentation of a short questionnaire on attitudes to codes, rules and procedures to staff whose work involved transport and tramming operations. The staff ranged from mining managers to artisans and drivers and to staff associated with safety and training functions.

The questionnaire enabled an examination of the following thirteen factors which had the potential to influence the standards of compliance with the codes, rules and procedures.

Rules: Aims and objectives	Supervision: Style
Rules: Application	Plant and Equipment Design/Modification
Training: Rules and Procedures	Job Design
Training: Hazards and Risks	Working Conditions
Safety Commitment: Workforce	Logistic Support
Safety Commitment: Management	Organisation
Supervision: Monitoring and Detection	

For the purposes of analysis, the total pool of people answering the questionnaire was divided into the following three groups.

1. **Management:** including Mining Managers, Mine Captains/Overseers, Section Engineers, Shift Bosses and staff associated with Safety and Training Departments.
2. **Drivers/Operators:** including LHD, haultruck, shuttlecar, tractor, LDV and general utility vehicle drivers.
3. **Artisans:** including both mechanics and electricians.

Of the factors that were seen as being most likely to reduce the ease of compliance, the following were the most significant and should be regarded as the major areas of concern:

### **A3.1. Rules: Aims and Objectives**

This category identified where people perceived a lack of clarity in terms of the actual aims and objectives of written procedures. This was perceived to be a problem by all three subject groups.

A badly thought through procedure might prove impractical or impossible to apply in certain circumstances. One procedure may actually contradict another. Codes, rules or procedures may be over-restrictive in some situations. On the other hand, they may be so general that they offer no genuine help and may be so vague that it could be argued that they were complied with - even following an accident. As a result of a too vague or general procedure, many violations are actually necessary in order to perform the job. Over-restrictive procedures are broken in a genuine attempt to help mines meet their performance goals. All of these problems were identified in potential active failures and are discussed in Section 2.6 'Rules and Procedures' [page 27].

### **A3.2. Training: Rules and Procedures**

The management group saw training in rules and procedures to be a problem. An indication of this perception was also gained in structured interviews with individuals from within this group who believed that a high proportion of incidents resulted from a failure by the workforce to follow written procedures. While the project has indicated a number of factors which contribute to the failure to follow written procedures, training can be regarded as a significant issue. Several of the active failures have shown, for example,

that training in new codes, rules and procedures is often provided on an ad hoc basis and by people who have little experience or qualifications in training.

A probable reason why the workforce did not recognise this as a problem is that they are often provided with 'on-the-job' training rather than formal training and in many cases are unlikely to be aware of the existence of written codes, rules and procedures.

### **A3.3. Training: Hazards and Risks**

This category reflected a lack of appreciation of the actual hazards and risks to which the codes, rules and procedures related. It was again only the management group who saw training in hazard and risk awareness as being a problem. However, it was considered significant that within this group, Safety and Training departments did not see this issue as being pertinent. If these departments are to fulfil their primary function of providing proactive safety, the identification and amelioration of potential hazards and risks is crucial.

### **A3.4. Safety Commitment: Management**

Previous SIMRAC studies have demonstrated the importance that the safety commitment of management has on the subsequent attitudes of those operating below them in the organisation. The vital point is that it is not sufficient for a manager to be personally committed to safety if this commitment is not actually continually demonstrated to the workforce by the day-to-day implications of his decisions/actions. Questionnaires completed by the drivers and artisans suggested that some management were seen to be less committed to safety than was expected by the managers themselves.

This issue, as perceived by the driver/operator and artisan groups, reflected an attitude of mind among management that "the rules apply when it suites them". This view was substantiated by the study team on a number of occasions. For example, management were seen in the mines not wearing the required personal protective equipment and the provision of essential safety equipment were sometimes ignored.

The fact that management also identified this as a problem seemed at first to be surprising in that it appeared to be a case of self-enlightenment. This group, however, was comprised predominantly of representatives of middle management who clearly saw a lack of commitment to safety by senior management.

### **A3.5. Supervision: Monitoring and Detection**

A strong disincentive to rule violation is a high probability of detection and possibly of disciplinary action. This factor, therefore, reflected the view that, regardless of how well written procedures were advocated, their credibility was eroded by the lack of consistent monitoring.

All three subject groups recognised this factor as a significant issue. 'Inadequate Monitoring' featured in a number of potential active failures and has already been discussed as an influential factor in shaping perceptions of the workforce in relation to safety commitment - see Sections 2.2.6 [page 12], 2.8.1 [page 35] and 2.8.7 [page 39].

The fact that supervisors within the management subject group identified this as a problem may seem, at first sight, to be surprising. It was however, not uncommon and reflected the fact that potential safety/productivity conflicts were at their most tangible at their level.

### **A3.6. Plant and Equipment Design/Modification**

This issue indicated that limitations in the design of plant and equipment was seen as making compliance with written procedures difficult, or even impossible on some occasions. In short, it reflected instances where the equipment was not "user friendly" i.e. where it failed to comply with sound ergonomic standards.

The groups who saw this as being especially significant were the drivers and artisans. A wide range of poor design features which contributed to the difficulty in operating and maintaining equipment were identified by the project. Predictably, these poor design features provided a strong motive for operators and artisans to violate some procedures.

Significantly, this issue was not seen as being such a problem by the management group, yet it was management who had responsibility for the selection and procurement of new equipment and it was the safety and training departments who had the responsibility for providing training and instruction on the risks associated with the operation of this equipment.

### **A3.7. Working Conditions**

Working conditions, particularly the physical/environmental conditions, were also seen as making compliance with written procedures difficult, or impossible on some occasions. Poor working conditions were also seen as the cause of intentional violations.

Not surprisingly the group which saw this as being influential on compliance were drivers and operators since they were the ones who had to contend with poor conditions. It was however significant that working conditions were not seen as being a problem by management, particularly supervisors and safety staff since it was they who had the ultimate responsibility for ensuring that safe conditions existed at the mines.

## **A4. Copy of project scope of work**

DEPARTMENT OF MINERALS AND ENERGY  
PROPOSAL FOR A PROJECT TO BE FUNDED IN TERMS OF THE MINERALS ACT  
- CONFIDENTIAL -

DMEA REFERENCE NUMBER

(FOR OFFICE USE ONLY)

1. PROJECT SUMMARY

PROJECT TITLE : Investigate the causes of transport and tramming accidents on coal mines  
PROJECT LEADER : F H von GLEHN  
ORGANISATIONS : BLUHM BURTON ENGINEERING (PTY) LTD (BBE)  
ADDRESS : PO BOX 786012, Sandton 2146, RSA  
TELEPHONE : (011) 886 3002 FAX : (011) 886 3566

**PRIMARY OUTPUT :**

A detailed understanding of the design, organisational, environmental, management and human factors contributing to transport and tramming accidents, together with suggestions for solutions to both specific and generic potential accident causes.

**HOW USED ? :**

The results will provide a detailed and extensive listing of the potential accident factors in coal mine transport and tramming systems which will indicate accident reduction actions applicable at the corporate level, within individual mines and for the industry's equipment suppliers.

**BY WHOM ? :**

Production, safety and training specialists in the industry both at the corporate and individual mine level and the equipment designers in supplying companies..

**CRITERIA FOR USE :**

A working knowledge of the recommendations produced by the project combined with a positive programme to commit the project output into practice..

**POTENTIAL IMPACT :**

The research will provide a detailed and systematic knowledge of the factors likely to predispose transport and tramming accidents across the full range of operations. In particular, recommendations will be produced for the reduction of such accidents in a form suitable for generic application within the South African coal mining context. The proposed approach was used very successfully in a previous project to investigate the causes of transport and tramming accidents on mines other than coal, gold and platinum. The approach has resulted in improvements in accident rates of up to 80% in British coal mines. In addition, although the approach has previously been applied to specific issues (e.g. haulage and transport, face operations, development operations etc.) the benefits achieved were across the mine rather than limited to the specific system under study.

## 2. PROJECT DETAILS

### 2.1 Primary Output :

A detailed understanding of the design, organisational, environmental, management and human factors contribution to transport and tramming accidents together with suggestions for solutions to both specific and generic potential accident causes.

### 2.2 Other Outputs :

The detailed understanding of the range of issues likely to predispose accidents in transport and tramming operations.

Generally applicable solutions to many of the factors identified and the possibility, on design related issues, of improving safety consideration in specifications to supplying companies. (This has been achieved within the UK, most notably in relation to the design of the cabs of underground locomotives and LHDs and has been copied into the New South Wales Inspectorate requirements for the design of underground locomotives).

Confidential reports to the participating mines containing specific potential accident reduction measures.

### 2.3 Enabling Outputs :

No.	ENABLING OUTPUT	MILESTONE DATE*
1	Collation of accident statistics and reports over 12 months for examination of the nature of accidents to provide initial targeting of the IMCL BeSafe procedures.	4 weeks
2	Organisation of visits to collaborating mines	7 weeks
3	Conduct and analyse audits at 4 mines, 2 underground and 2 surface mines. Produce individual mine reports and listings of the active failures, human factors and management system limitations, and the potential solutions proposed.	29 weeks
4	Analysis of active failures, human factors and management system limitations across the 4 mines to identify common latent failures and propose generic solutions. Prepare for feedback and discussions of potential generic solutions.	37 weeks
5	Discussion of results and implications for participating mines and 'expert panel' discussions on the suitability of proposed generic solutions to the latent failures in a RSA mining context.	41 weeks
6	Complete final report and supporting material	52 weeks

\* Number of weeks of elapsed time from start date (presented cumulatively).



## 2.4 Methodology :

No. OF ENABLING OUTPUT	STE P No.	METHODOLOGY TO BE USED TO ACCOMPLISH THE ENABLING OUTPUT (INDICATE STEPS/ACTIVITIES)
1	1	Examination of RSA transport and tramming accident statistics for coal mines over 12 month period..
	2	Identification of specific targeting for the IMCL auditing procedures
2	1	Identification of, and agreement with, four collaborating mines..
	2	Visit mines to discuss project requirements and familiarise audit staff with transport systems used.
3	1	Conduct audit at first mine
	2	Analyse first audit
	3	Complete report on first mine and listings of the active failures, human factors and management system limitations, and the potential solutions proposed..
	4	Conduct audit at second mine
	5	Analyse second audit
	6	Complete report on second mine and listings of the active failures, human factors and management system limitations, and the potential solutions proposed.
	7	Conduct audit at third mine
	8	Analyse third audit
	9	Complete report on third mine and listings of the active failures, human factors and management system limitations, and the potential solutions proposed.
	10	Conduct audit at fourth mine
	11	Analyse fourth audit
	12	Complete report on fourth mine and listings of the active failures, human factors and management system limitations, and the potential solutions proposed.
4	1	Identification of common latent failures across the four mine study
	2	Selection of expert panel
	3	Preparation for "expert panel" discussion on practical generic solutions suitable for RSA
5	1	Attend "expert panel" meeting
	2	Preparation and presentation of SIMRAC paper
6	1	Preparation of final report and support material

### Key Facilities and Procedures to be used in the Project

The key procedure to be used is IMCL's **BeSafe** Potential Human Error Audit which has been extensively proven in both UK and South African mining operations.

The three key facilities required during the research are:

Access to the accident statistics and reports of the South African coal mining industry over the 12 month period prior to the start of the project. Access to research results from previous related SIMRAC projects.

Agreement of and collaboration with the mines selected for the detailed potential human error audit studies.

The availability, towards the end of the project, of a small team of RSA mining management, safety and training specialists to act as an "expert panel" to review and shape the project recommendations into a form most suitable for generic exploitation within the South African coal mining context.