An Evaluation of
Error Management in Transmission

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by

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STATEMENT OF WORK

All information contained in this document, as well as appendices is privileged and confidential and is under no circumstances to be made known to any person or institution without the prior written approval of Unisa SBL.

I certify that the report is my own work and all references used are accurately reported.

Reddy

Collin Sagren Reddy
14 December 2007

ABSTRACT

There have been a number of interventions intemationally in managing error but they are generally piecemeal (Reason and Hobbs, 2003). Transmission, a division of Eskom Holding Ltd have experience a large number of human errors similar to that of the aviation and medical organisations. The purpose of this research study is to provide a holistic error management model that could be applicable to the Transmission Division that incorporates all the facets of error management and not be piecemeal. The objectives were to get the perception of the experts on human error, identify the causes of human error and investigate if learning from human errors is taking place.

The research methodology was based on a mixed qualitative analysis. Through a series of expert interviews, review of current literature and case studies, a number of themes, findings and recommendations emerged. Some of the primary themes that resulted from the study included leadership and commitment, learning's, investigations, reporting, risk assessments, and error management systems.

The researcher found that even though there were pockets of excellence, no plans existed to systematically reduce human error risks in Transmission and that no individual or group seemed to have the accountability for driving human error reduction across the business units. There is no safety or error management system that embodies continuous risk reduction criteria and methodologies. The lack of a holistic system to promote continuous error reduction as lead to buzz words with no action plans.

A summary of the findings;

- *Finding (Leadership);* leaderships attitude to safety was positive but the positive attitude was absent of a deliverable expectation that is visible to all stakeholders.

- *Finding (Investigations):* The investigations are mainly based on a sequence of event model. Investigations may miss systemic causes by considering only causes in a direct, linear chain of causation.

- *Finding (Reporting):* Barriers to reporting included the lack of a reporting system, fear of branding and discipline, lack of reward and lack of time to complete reports.

- *Finding (Risk Assessment):* Risk assessment training is provided but the risk is not appreciated and tasks of significant risk are inadequately assessed.

- *Finding (Human Errors):* None of the interviewees could provide information in a coherent manner to indicate what the highest risks in human errors are.

- *Findings (Error Management System):* The responses indicated that there was an absence of a holistic error management model.

Based on the findings and other studies that were cross referenced, the following is a summary of the recommendations;

- Transmission leadership must ensure that the business units understand what is expected from them by providing clear targets. The targets must be specific to human errors, measurable, attainable and within some time frame.

- Epidemiological and systemic investigation models should also be used in investigations for Transmission.

- Transmission to set up a reporting system that is easy for all staff to report incidents. It should allow anonymity similar to the example used in the second case study as proof of concept for the proposed model. A non monetary reward system should be implemented.

A procedure providing guidelines for when disciplinary action will be taken should also be instituted.

- Risk assessments be done according to that high reliability organisations which follow a nine step process; system characterization, threat identification, vulnerability identification, control analysis, probability determination, impact analysis, risk determination, control recommendations, and results documentation.

- Transmission should establish and implement an integrated and comprehensive error (safety) management model like the one developed by the researcher in this research study supported by the appropriate management information system that systematically and continuously identifies, reduces, and manages human errors.

This study contributes by identifying the gaps in other models as well as Transmission and illustrated how the error management model can identify more failures in incidents and by taking the appropriate corrective action and learning from these corrective actions change behaviour and ultimately reduce the number of human errors.

The implication if Transmission adopts the error management model will be that more opportunities are created in a systematic and measurable manner for reducing human errors.

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First, I would like to thank my family for their patience, and support especially my wife Mala and my two kids Melitza and Kyle. It has been a tough journey and I learnt a few family values on the way.

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DEDICATION

Dedicated to all the men and women

who have lost their lives due to human errors

and

to all those that have had the courage to report near miss incidents

that resulted in many more lives being saved.

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CHAPTER 1 – ORIENTATION

"Knowledge and error flow from the same mental sources,
only success can tell one from the other"
(Ernst Mach, 1905).

1.1 INTRODUCTION

To err is human is a common term (Nordstrom, Wendland, Williams, 1998; Dekker, 2006; Peters & Peters, 2006) used when speaking about mistakes and errors humans make. When people err they may be embarrassed or angry with themselves, but often errors are minor and consequences irrelevant. The study of human errors, undertaken by Reason in 1990 (Woods and Cook, 2003), is as a result of the growing concern of the high cost financially, technically and tragically the lost of human life both locally and internationally in almost all organisations. Reason maintained that there is nothing new about the tragic accidents caused by human errors (Meshkati, 1991), but in the past the consequences were not that wide spread.

Some of the major and most visible world events caused by human error, have been the Three Mile Island nuclear accident, the Bhopal chemical spill in India, the Challenger and Columbia space shuttle disasters, and the 2003 North America power blackout that affected more than 50 million people.

Closer to home, with tighter power networks, constraints in energy and rolling load shedding, human error impacts are now not confined to a specific area on the power network but the entire South African national grid and therefore depending on the circumstances and time of day it is visibly seen and felt by nearly all South Africans.

The overall aim with this research study is to provide some information to the Transmission Division with respect to error management by evaluating human error trends, expert opinions, leadership, risk assessments investigations, and learning's.

1.2 BACKGROUND OF THE STUDY

As reflected in the Eskom Annual Report 2007, Transmission is a division of Eskom Holdings Limited. Eskom generates, transmits and distributes electricity to industrial, mining, commercial, agricultural and residential customers and redistributors. Eskom is one of the top 10 utilities in the world by generation capacity and is among the top 11 by sales generates approximately 95% of electricity used in South Africa, generates approximately 45% of electricity used in Africa and has 3 963 164 customers. Eskom has a nominal capacity of 42 618 megawatts and a net maximum capacity of 37 761 megawatts transported by 359 854 kilometres of power lines of all voltages levels.

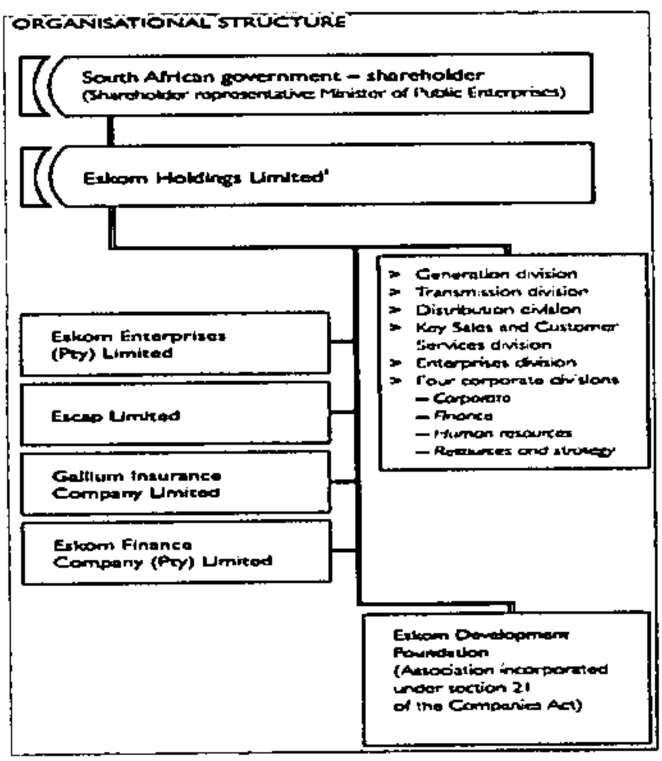

Figure 1: Eskom's Organisational Structure

The Transmission Division has 156 high voltage substations and just over 27000 kilometres of high voltage power lines. Transmission provides the vital link between Generation and Distribution. Transmission is seen as the main arteries in the value chain between the generating power stations and distribution.

As reflected in the organisational structure, Eskom has both centralised and decentralised functions. Within the Transmission Division there are two core business units namely Transmission Services and the Grids. Within the Transmission Services business unit there is a centralised safety function and within the Grids there are decentralised safety managers. Transmission Services set the standards and procedures while the Grids do the execution of the work.

Due to the nature of the interfaces between the operator and equipment the active failures are generally done by the Grids, while many but not necessary all the latent failures are from Transmission Services and Grid management. These failures sometimes have an impact on the power network.

Power failures occurred in many parts of the world due to active and latent failures. In 1998, the central business district (CBD) of Auckland, New Zealand, the largest city, suffered a power failure that lasted for five weeks (Seville, 2006). In 2003, a major blackout occurred on the North East Coast of the USA (U.S.-Canada Power System Outage Task Force, 2004). In the same year, Italy experienced a system-wide country blackout and capitals such as Denmark, and London experienced large outages (Paserba & Kundar, 2006). In South Africa, from November 2005, the Western Cape Province experienced numerous reliability problems ranging from full-scale regional power blackout to rolling power brown-outs.

South Africa has become no exception to this world trend. However, the problem in South Africa is slightly different due to the growing economy which is outstripping the supply of power.

With tighter power networks, constraints in energy and rolling load shedding, human error impacts are now not confined to a specific area on the power network but the entire South African national power grid. Therefore, depending on the circumstances and time of day it is visibly seen and felt by nearly all South Africans.

The number of human errors in Transmission is reflected in the Figure 2. The period reflected is for the financial years 1999/2000 to August 2007. The financial year starts in April of one calendar year and ends in March of the following calendar year. Not all human errors cause interruptions of power supply, injuries or fatalities. The human errors incidents however provide an opportunity to learn without the consequence of an interruption, injury or fatality. Operator error in the context of Figure 2 is a subset of human error.

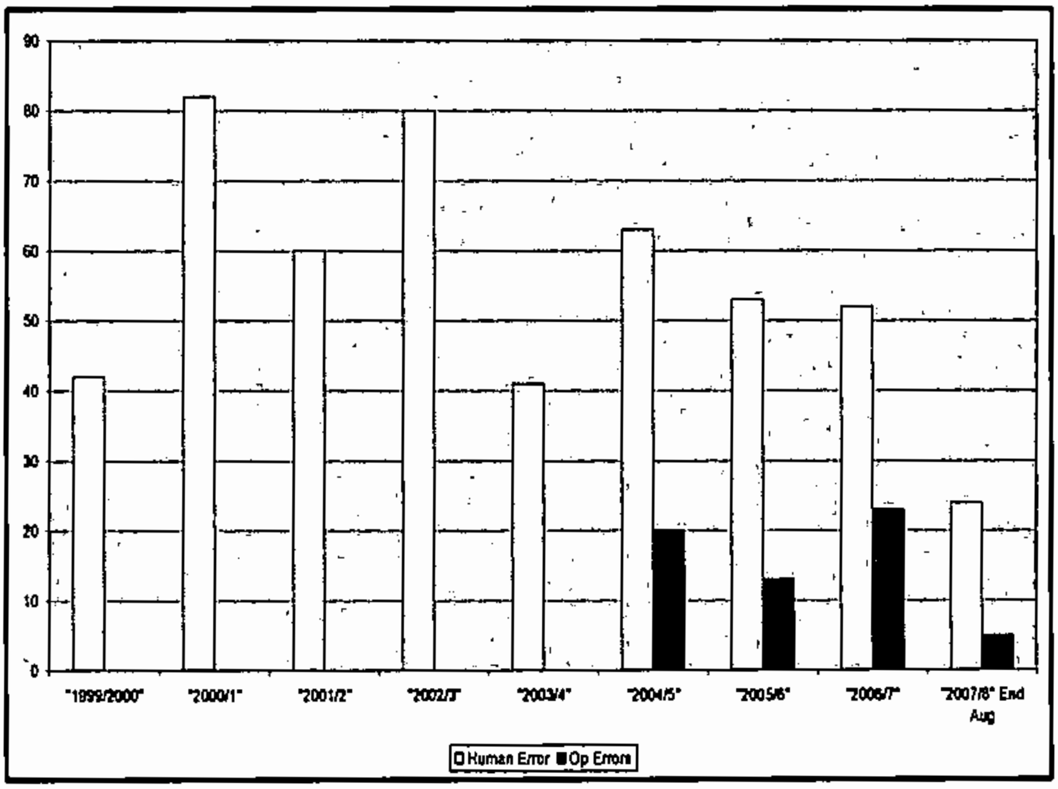

Figure 2: Human Error Trend (Financial Year 1999/2000 to 2007/2008)

The number of human errors and its consequences on the power network provides the background for the need for this research study. In addition, two of the business focus areas mentioned in the Eskom Annual Report 2007 is safety and ensuring a reliable electricity supply. An improvement in human errors and the management thereof can contribute to ensuring a reliable electricity supply by reducing the number of power interruptions caused by the errors.

1.3 PURPOSE OF THE STUDY

The purpose of the study is to provide an error management model that could be considered for use in the Transmission Division of Eskom Holdings Limited. The study will explore if incidents involving human errors are effectively investigated and the recommendations are appropriate for error reduction. Error reduction and containment should be supported by effective error management to ensure that appropriate leadership, risk assessments and learning is taking place. Opportunities to learn from near misses are not used by many organisations. (Helmreich, 2000).

The purpose of the study is also to ensure that operators at the 'sharp end' are not the only people identified as responsible for errors but that managers and designers at the 'blunt end' are also identified as possible contributors to incidents. As Reason (1990: 173) so eloquently describes "Rather than being the main instigators of an accident, operators tend to be the inheritors of system defects created by poor design, incorrect installations, faulty maintenance and bad management decisions. Their part is usually to put the final garnish to a lethal brew whose ingredients have already been long in the cooking."

An additional purpose was for the researcher to explore if analysing of precursors from the incidents were taking place to ensure effective continuous improvement in human errors.

The researcher also intended to bring awareness to the Transmission staff including management and subject matter experts on human errors and error management.

In order to achieve the above a conceptual error management model based on theory and some error management principles will be proposed, while taking the above intention into consideration and addressing some of what the researcher perceives are shortcoming or opportunities to improve on existing theoretical models.

1.4 RESEARCH PROBLEM AND OBJECTIVES

"The precise statement of any problem is the most important step in its solution."

(Edwin Bliss, no date)

The research problem:

There are a large number of human errors encountered in the Transmission Division. The aim of the research is to provide a holistic error management model that could be applicable to the Transmission Division that is based on theory, some error management principles and the qualitative survey feedback which will help in the reduction of errors.

The objectives are as follows:

- Perception of human errors
    - Identify primary themes on human error management from 'experts'.
    - Identify the 'safety experts' and management views and perception of human error and error management in the Transmission Division based on the identified primary themes.
- Causes of Human Errors
    - To identify causes of human errors in the Transmission Division
- Learning's from Human Error
    - Evaluate how learning is taking place from human errors

1.5 DELIMITATION

The study focused only on the Transmission Division of Eskom Holdings Limited. The researcher sought opinions and perceptions of experts in their specific areas from other divisions within Eskom and outside consultants. The focus of the study was based on human error that may be found in the national power grid operating environment.

Excluded from the study are errors and error management found in the control room environment.

The sample for the study was purposive. Due to the nature of the way the study was conducted, no attempt was made to ensure that the sample was random or that the sample represented the Transmission employee mix. Due to the exploratory nature of the study, the study is subjected to what Cooper and Schindler (2001: 139) refer to as "old biases about qualitative research: subjectiveness, non representativeness, and non-systematic design".

In this study human error, error and operator error were used interchangeably. The study was delimited by exploring errors from the perspective of the researchers "experts".

1.6 ASSUMPTIONS

Listed below are the key assumptions that the researcher believes has impacted this study,

- One of the key assumptions is that the opinions given by the interviewees are the reality of the situation and not what the researcher would like to hear but what the researcher should hear.
- Experts chosen for their specific field have had sufficient knowledge and information about the subject matter to correctly contribute to this study.

- The safety culture is assumed not to be homogenous for the entire company due to its enormous size of over 30 000 employees and its large distributed geographical base.

1.7 IMPORTANCE OF THE STUDY

"Never doubt that a small group of thoughtful, committed people can change the world. Indeed it's the only thing that ever has."

(Margaret Mead, 2004)

The importance of this study will be for the conceptual error management framework to be considered or the information provided to be used in guiding what components are deemed important, necessary and efficacious in the reduction, containment and continuous improvement of human errors for Transmission. The study will also bring awareness on the facets of human error and error management. It will also help close the gap in some of the existing theoretical models.

1.8 DEFINITIONS

The terms and concepts used in the context of this research study are defined or explained in Table 1.

TERM	DEFINITION
Accident	An accident is a short, sudden and unexpected event or occurrence that results in an unwanted and undesirable outcome (Hollnagel, 2004)
Active errors	Errors whose effect is felt almost immediately (Strauch, 2002)
Blunt End	Designers and managers at the higher echelons of the organisation (Strauch, 2002; Reason, 1990)
Error	Planned actions may fail to achieve their desired outcome either because the actions did not go as planned or because the plan itself was deficient. (Reason, 1990).
Grid	It is the Transmission power network which consists mainly of high voltage substations and power lines. The Transmission Division has eight grids.
Hazard	Something that is potentially dangerous
Incident	An incident is here defined as an event that involves no loss (or only minor loss) but with potential for loss under different circumstances. It sometimes includes near misses.
Latent error	Errors that are unnoticed and lie dormant for a long period of time
Operator	Engineering assistants, technician, senior technicians, controllers
Precursor	Unfavourable prior conditions, events, and sequences that precede and lead up to an accident or incident.
Resilience	Is the ability of systems to prevent or adapt to changing conditions in order to maintain control (Hollnagel *et al*, 2006)
Risk	The chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood (Frost, Allen, Porter & Bloodworth, 2001)
Risk assessment	Risk assessment is an overall process of estimating risk and determining whether it is a tolerable risk
Sharp end	Operators who interface with the equipment an are involved in the active errors (Reason, 1990)

Table 1: Terms and Definitions

1.9 OUTLINE OF THE RESEARCH REPORT

This research report is divided into seven chapters. The first chapter provides an introduction to human error, purpose and objectives of the research study, background or context of the research study and methodology used for the research study.

Chapter 2 discusses some of the theories of leadership, motivation, and learning that will have an impact on human error and error management.
It provides the contributory foundation for enabling the proposed error management model.

Chapter 3 focuses on the literature survey and is integrated with some of the direct theories that impact on the conceptual model. It begins with an outline of some of the thinking on human error. The literature survey reviews aspects of investigations and accident models. It describes and provides some shortcomings of certain accident models. It also considers risk and the role of risk assessments in human errors. Error management and it principles are described, identifying error reduction, error containment and continuous improvement in error management as the key aspects. A brief discussion on safety and resilience is also discussed focussing on safety culture.

Chapter 4 describes some error management tools and provides a conceptual model on error management. The chapter ends with a case study.

Chapter 5 describes the research methodology used in this research study. It describes why a qualitative survey method was used by looking at the advantages and disadvantages. It also describes the population, sample size, data collection, reliability, validity and data analysis.

Chapter 6 provides findings based on the qualitative survey, and incident reports. It describes the objectives identified in chapter one and the findings associated with each objective. It concludes by reflecting on the research problem.

Chapter 7 ends the research report on recommending suggestions to close the gap between the findings, Transmission practises and other high reliability organisations. It also suggests areas for further research.

The last section provides the references used in this research report together with the appendices referred to in the different chapters.

1.10 SUMMARY

This chapter begins with an introduction which provided the aim, and objectives of the research study, context and background to the study and provides an outline for the rest of the research report. The next chapter will focus on some of the theories that have an impact on error management.

CHAPTER 2: CONTRIBUTORY THEORIES

2.1 INTRODUCTION

In this chapter the researcher discusses the performance shaping theories that have a contributory impact on the management of human errors. In chapter three, the immediate theories i.e. theories which the researcher believes has a direct impact on human error management will be discussed and integrated into the literature survey. The performance shaping theories of leadership, motivation and learning will be the gatekeepers for effective human error management.

2.2 LEADERSHIP

'Leadership is like beauty, it is hard to define but you know it when you see it'
(Levinson, 1996)

The leadership literature is voluminous, and much of it leads to confusion or contradictions about what is leadership and what is an effective leader (Robbins, 1998). Over the last few years there has been a significant and sustained growth in interest in the area of leadership in organisations (Bagshaw & Bagshaw 1999). Whilst the interest in leadership is growing in its perceived importance to business, the interest in exploring its nature, and attempting to identify what makes for effective leadership, is by no means new (Higgs, 2002).

Researchers and consultants highlight the problem of building generic models to describe the nature of characteristics of effective leadership, by pointing to the difficulty of finding a consistent way of explaining huge variety of leadership styles, which lead to effective business performance (Collins, 2001; Higgs, 2002). For the context of this study, the researcher will highlight the transitions in leadership theories and suggest what will be appropriate for this study.

The transition begins with the trait theory of the 1920's in which leadership was understood by identifying and distinguishing different characteristics of great leadership such as personality, social, or intellectual traits (Robbins, 1998; Higgs, 2002). While some of traits increase the likelihood of a successful leader, none of the traits guarantee success (Robbins, 1998). Robbins points out that the trait theory overlooks followers, relative importance of each trait, does not separate cause and effect and lastly does not take situational factors into account.

These theories were then followed by the behavioural theories, contingency theory, charismatic theories, new leadership/neo charismatic school, and the new approaches in the 1990's are strategic leadership and change leadership(Connell, Cross, & Parry, 2002; Higgs, 2002, Robbins, 1998). Appendix A provides a summary of each of the theories.

In the context of this study, a successful leader will anticipate change, exploit the opportunities, motivate the organisation to higher levels of safety, correct poor performance (Day & Lord, 1988), and lead the organisation towards the objectives of reduction in human errors, containment of consequences of human errors and continuous improvement of the error management system. Day and Lord (1988), suggest that leadership is successful because they provide coordination and control. Coordination and control is achieved through rules, policies, job descriptions, communications, monitoring and authority hierarchies. However, Robins (1988) argues that rules, procedures, policies etc. constraint the leader. Because leaders exist in a social system and have little control of factors outside the organisations and environment their influence and therefore the leader's behaviour is constraint. The studies of high reliability organisations by La Porte and Consolini (1991); and Weick and Sutcliffe (2001) believe that accidents can be prevented by implementing certain organisation practises and processes which need to be lead from the top. This by implication means that leaders must overcome the barriers and constraints to provide the vision and direction in error prevention and error containment. They need to influence the sub-culture of safety of which error management forms part.

Due to the challenges in the organisations both from a human performance and a power crisis perspective the most appropriate leadership style to provide the vision and direction to create the one mindset culture with respect to error management will be a transformational leadership style (Connell, Cross, & Parry, 2002; Higgs, 2002; Robbins, 1998). In contrast to the transactional leadership style which merely manages the current objectives, the transformational leadership is the vision of change and the managing of the change process (Connell *et al.*, 2002). As highlighted in this study you cannot continue to do the same things and expect a different result. A change agent is needed and therefore the transformational leadership style is proposed. In addition there is evidence that a transformational style of leadership has significant benefits at an individual, group and organisational level, while a transactional leadership style is less successful (Bass, 1997; Judge & Piccolo, 2004; Clarke & Ward, 2006).

In trying to change the vision in the context of this study for error management and managing the error management process, leaders need to create trust. In this particular case the leader can be the Chief Executive Officer (CEO), the Managing Director (MD), the manager or supervisor. Trust is a more consistent mechanism to support organisational change than hierarchical power and direct surveillance (Connell *et al.*, 2002). Connell *et al.* (2002) point out that studies devoted to trust and leadership have concluded that trusting relationships, building on individual confidence and eliminating fear, are essential to the functioning of relationships between employees and their leader. This becomes very important for reporting and creating a learning culture to strive for continuous improvement of error management. A good organisational safety culture typically relies on good safety leadership (Conchie & Donald, 2006).

2.3 MOTIVATION

What will motivate people to learn? Very similar to describing that some people are error prone (Lawton & Parker, 1998), people are also mistakenly described as motivated or lacking motivation (Robbins, 1998).

Motivation is not a personal trait; motivation results from the interaction of the individual and the situation. Individuals differ in their basic motivation drive.

It is common to find that levels of motivation vary between individuals and within individuals at different times depending on the situation (Robbins, 1998; Swanepoel, Erasmus, van Wyk, & Schenk; 1998). Robbins (1998: 168) defines motivation as "the willingness to exert high levels of effort towards organisational goals, conditioned by the effort's ability to satisfy some individual need".

The definition highlights effort, organisational goals and needs. From the perspective of error management, the intensity and quality of the effort must be directed towards the goal of reducing human errors and containing its consequences in order to reduce the number of power outages and save lives at the tragic extreme.

There are many theories of motivation. Most motivation theories are complementary to each other (Robbins, 1998). The motivation theories help in understanding the way operators act. Using motivation theory we can predict (to some extent) and influence operators to act in a way that the organisation sees fit to meetings it goals (Swanepoel *et al.*, 1998). Swanepoel *et al.*, (1998) suggest that content, process and reinforcement theories are a popular categorisation of motivational theories.

Content theories focus on what motivates people, for example "needs". Some of the needs theories are Maslow's needs hierarchy, Alderfer's ERG theory, Herzberg's two factor motivation theory, McClelland's achievement motivation theory and Locke's goal-setting theory. These theories are well described in Robbins (1998) and Swanepoel *et al.*, (1998). What does this imply to error management? When one considers Maslow's need hierarchy or Alderfer's ERG theory, the fundamental lower level needs must not be put at risk, for example an operator wants to report a human error but fears that he may lose his job as a result of the human error.

Due to the fear of losing his job the operator will not report the error. In this particular case the consequences of the error may be insignificant but the organisation loses the opportunity to learn from the error which may have different consequences the next time depending on the operator, situation and environment.

With goal setting theory, if the goals are known, for example 'reduce operating errors by 5% by 2008', then the operator and management will know what needs to be done and how much effort will need to be spent (Robbins, 1998). People will perform better if they receive feedback on how well they are progressing towards the goal. The feedback will highlight the gap of what still needs to be achieved (Robbins, 1998; Swanepoel *et al.*, 1998).

Process theories try to analyse the process or manner in which people get motivated. It focuses on how are people motivated (Swanepoel *et al.*, 1998). Some of the process theories are cognitive dissonance theory, equity theory, and expectancy theory. If operators act a certain way, for example do maintenance according to all the rules and procedures, they expect the outcome to be no errors and a reliable plant. If the operator continues to be rewarded by not having any errors and having higher plant availability, the operator will expect to be rewarded accordingly and will be motivated to put in more effort (Robbins, 1998).

Lastly, reinforcement theories focus on how operators can be conditioned to exhibit desired behaviours. It answers the question of how can operators learn to exhibit the desirable behaviours. Reinforcement theory is a behavioural approach. Reinforcement theory holds that consequences shape subsequent behaviour (Swanepoel *et al.*, 1998). For example, if operators reporting near misses are rewarded, the probability that the behaviour will be repeated increases (the behaviour is reinforced) i.e. more reporting will take place which will provide more opportunity for learning and therefore improve the management of errors.

Therefore, in trying to answer the question of what motivates people to learn, in simplistic terms, the theory suggests that their needs must be met, they must see the benefit for themselves and their correct behaviour must constantly be reinforced.

2.4 LEARNING

The last topic for this chapter is learning. It is argued by Robbins (1998), that all complex behaviours are learned and if behaviour is to be predicted and explained, an understanding of how people learn is needed. Cooke (2003) suggests that by learning from incidents that occur in a complex system, an organisation can reduce errors and minimise loss.

Learning is defined as any relatively permanent change in behaviour that occurs as a result of experience. When an operator behaves, reacts, responds as a result of experience in a different way from the way he formerly behaved it is inferred that learning has taken place (Robbins, 1998). Learning involves change. Change may be good or bad. For example, if an operator who previously climbed high voltage structures without a safety harness has been taught through an error management intervention not to climb high voltage structures without a safety harness and during one of his jobs he does not have a harness and therefore refuses to climb the structure, it can be concluded learning has taken place. Learning takes place when there is change in actions and not just thought processes and attitude (Robbins, 1998). By implication, change in thought process or attitude that is not accompanied by change in behaviour would not be learning.

Learning takes places when new patterns of behaviour are acquired (Robbins, 1998; Swanepoel *et al.*, 1998). Classical conditioning, operation conditioning and social learning are theories which explain the process by which patterns of behaviour are acquired. Classical conditioning is a type of conditioning in which an individual responds to some stimulus that would not ordinarily produce such a response.

For example, whenever a manager walks passed operators, they wear their personal protective equipment. In this example the operators responded to the presence of the manager. Classical conditioning is passive. Something happens and an operator will react in a specific way. Robbins (1998) indicates that most behaviour is voluntary rather than reflexive.

In contrast to reflexive or unlearnt behaviour, operant conditioning is voluntary or learnt behaviour. Operant conditioning argues that behaviour is a function of its consequence. Operators learn to behave to get something they want or avoid something they do not want (Robbins, 1998). If operators believe that they will be disciplined for an operating error, they will behave in a cautious manner to avoid a human error and the subsequent discipline.

An extension of operant conditioning (i.e. it assumes that behaviour is a function of consequences) is social learning. Social learning takes place through observation, being told about something and direct experience (Robbins, 1998; Swanepoel *et al.*, 1998). Operators learn from models, for example other operators, supervisors etc. or from incident recall or errors they make themselves.

When the behaviours are modified, indicating that learning has taken place, the modified behaviours should be reinforced. By identifying and rewarding performance enhancing behaviours, management increases the likelihood that the modified behaviour will be repeated as indicated in the earlier section. Reinforcement is a better tool than punishment (Reason, 1997; Peters & Peters 2006).

The above discussion was from an individual's perspective. From the perspective of the organisation, an organisation that is a learning organisation is continually improving and developing (Swanepoel *et al.*, 1998; Reason, 1997). It has the continuous capacity to adapt and change. It is successful at acquiring, cultivating and applying knowledge that can help it to adapt and change (Robbins, 1998). The importance of change in error management is crucial for considering new techniques, new theories etc.

As the organisation learns from its reactive measures and its resilience management is able to forecast and adapt, learning must take place to ensure continuous improvement in error management.

2.5 SUMMARY

In this chapter the researchers reflected that Leadership is a complex issue. There are many theories that reflect what an effective leader is. From the perspective of this study the need for change through a transformational leadership style is supported. This does not mean that all the other leadership theories are not supported; on the contrary they compliment what is required of a leader. For example, the trait theory reflects personal traits such as resilience which will compliment a transformational leader. A leader that has resilience as a personal trait will be able to foresee, adapt and be flexible to the changing environment that is required for the error management process. Once the leader sets the vision and influences the culture it needs to be lived by motivated operators.

To ensure that operators are motivated this section highlighted how different theories affect their motivation and behaviour. It was emphasised that reinforcement of the correct behaviour is important.

For a reduction in human error or containment of consequences, both the organisation and the operator must have the ability to learn. It was pointed out that learning only takes place after the behaviour has been modified. By learning and correcting unsatisfactory behaviour it was inferred that the organisation can reduce errors and minimise loss.

This chapter provided a contributory perspective of three facets of error management. It lays the foundation for error management starting with leadership. It starts with leaders providing a vision, operators being motivated and learning from the operator and organisation taking place to ensure effective error management. The next chapter looks at the key facets of error management.

CHAPTER 3: LITERATURE REVIEW

3.1 INTRODUCTION

In this chapter the researcher shall review human error, investigations and accident models, risk, safety culture and resilience management, and error management. Some of the important facets of error management are reviewed in this chapter.

3.2 HUMAN ERROR

Human involvement often plays a major role in the occurrence of accidents in Transmission similar to safety critical systems such as in aviation, hospital systems, or nuclear power plants (Reason, 1990). Accident reports often resort to naming human error (operator error) as the 'reason' why the accident happened. This 'blame' approach (Reason, 2000) has frequently been criticized but still seems to prevail. Identifying human involvement in an accident's causation does not necessarily mean that "human error" is the cause, or the only cause, of that accident (Busse, 2002).

Human error can be defined as "...the failure of planned actions to achieve their desired ends without the intervention of some unforeseeable event..." (Reason, 1997: 71). Errors mean different things to different people. For cognitive theorists, they offer important clues to the covert control processes underlying routine action. To applied practitioners, they remain the main threat to the safe operations (Reason, 1997)

Modern error theory suggests that in complex systems, operator errors are logical consequences of antecedents or precursors that had been present in the systems at the time they are committed. Those that erred (Peters & Peters, 2006; Hollnagel, Woods, & Leveson 2006; Reason, 1997) were considered to be less effective and possibly more deficient than those that did not. Certain people were more likely to commit errors and were said to be accident prone.

Studies conducted by Lawton and Parker (1998) found it impossible to produce a profile for an accident prone individual or determine an accident prone personality.

Slips and mistakes are error types that reflect the cognitive and motor types of errors (Norman, 1981). Slips are action errors or errors of execution that are triggered by schemas, a person's organised knowledge, memories and experiences. Slips can result from errors in the formation of intents to act, or faulty triggering of schemas. Mistakes on the other hand are errors of thought in which a person's cognitive activities lead to actions or decisions that are contrary to what was intended.

The idea of cognitive based errors was expanded by Jens Rasmussen (1982). He defined three types of operator performance and three types of associated errors. The three levels of performance correspond to decreasing levels of familiarity with the environment or task. The first and the simplest of the three being skills-based performance. Skills-based performance relies on the skills that a person acquires over time and stores in memory. Skills-based errors are similar to slips which are errors of execution. The second is rule-based performance which relies on the operators experience and training. The rule-based level is applicable in tackling familiar problems in which the solutions are governed by stored rules of the type if (state) then (diagnosis) or if (state) then (remedial action). Errors in this category result from the operator's inability to recognize or understand the situation or circumstances encountered. This can occur when the information necessary to understand the situation is unavailable, or the operator applies the wrong rule to an unfamiliar situation.

The knowledge based level comes into play in novel situations for which actions must be planned on-line, using conscious analytical processes and stored knowledge. Rather than applying simple motor tasks or rules to situations that are similar to those previously encountered, the operator applies previously learned information, or information obtained through previous experience, to novel situations to analyse or solve problems associated with those situations.

The work done by Rasmussen was expanded by James Reason (1990). Reason divided the errors into unintentional errors/actions and intentional errors. Unintentional errors were slips, lapses and mistakes. Slips were minor errors of execution similar to Norman and Rasmussen. A necessary condition for a slip of action is the presence of a distraction or preoccupation. Cognitive activities are guided by a complex interplay of the conscious processing (controlled processing) and unconscious processing (automatic processing). The attentional control mode is associated with the working memory and consciousness. The working memory is limited, sequential, slow, effortful and difficult to sustain for more than brief periods.

Lapses, which is an additional error type is defined as memory failures. A lapse is less observable than a slip. It occurs when a person becomes distracted when about to perform a task, or omits a step when attempting to complete the task due to the limited attentional resource being redirected at that moment and will therefore not focus on the routine task at hand. In skills-based slips and lapses, the error triggering changes generally involve a necessary departure from some well established routine. It may also be caused by the deviation from normal practise or changes in physical circumstances in which the routine is normally executed.

Mistakes results from inappropriate intentions or incorrect diagnoses of situations. Mistakes arise from failures of the higher order cognitive processes involved in judging the available information, setting objectives and deciding upon the means to achieve them. Mistakes can be divided into rule based and knowledge based.

Intentional errors are violations. Violations are actions that are deliberately non-standard or contrary to procedures. Not all violations are negative or acts of sabotage. Operators often develop violations to accomplish tasks in ways they believe would be more efficient than they could with procedures that designers and managers develop.

The commission of unsafe acts is determined by a complex interaction between intrinsic systems influences and those arising from the world outside.

An unsafe act can only be defined in relation to the presence of a particular hazard e.g. there is nothing unsafe about not wearing a safety helmet, however if you are in the high voltage yard and operators are working above you and tools that can fall from above it is a potentially hazardous situation and will constitute an unsafe act. An unsafe act is more than just an error or a violation. It is an error or violation committed in the presence of a potential hazard which could result in injury or damage.

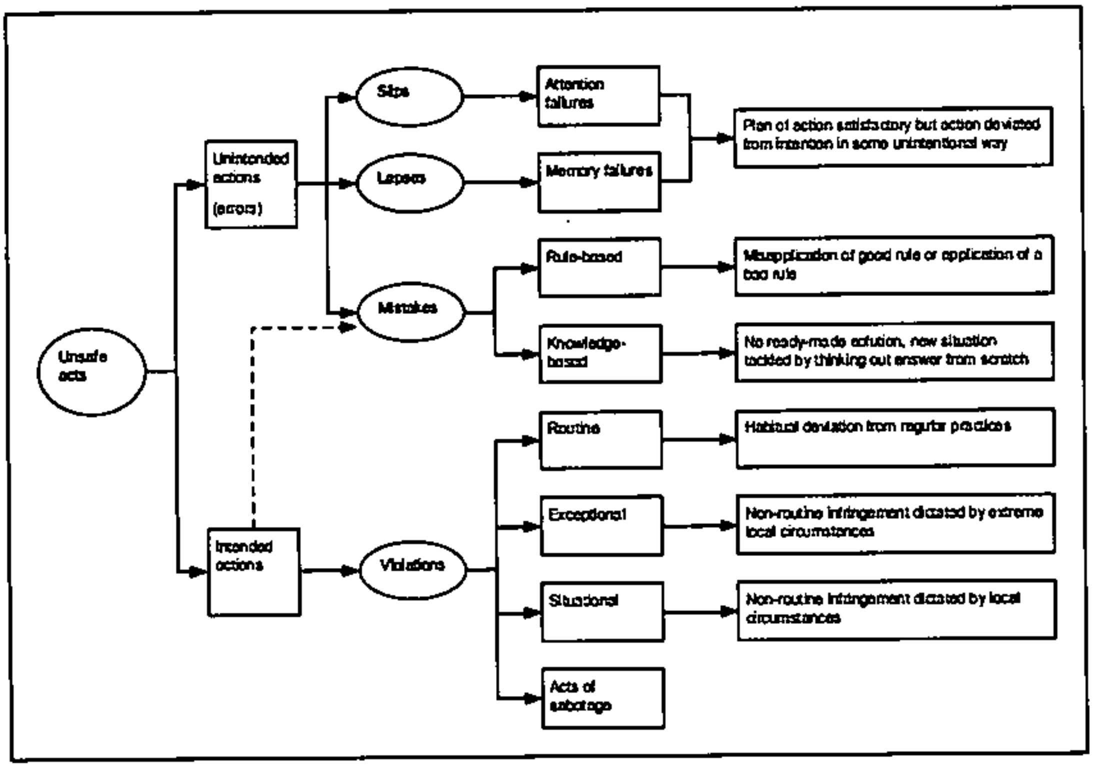

Figure 3: Summary of Error classifications
Source: Adapted from Reason (1990)

Errors manifest itself in a relatively limited number of ways and are inextricably bound up with the computational primitives by which stored knowledge structures are selected and retrieved in response to current situational demands (Reason, 1990). The three major elements in the production of an error are the:

- nature of the task
- its environmental circumstances, the mechanisms governing performance
- and the nature of the individual.

Most errors are insignificant and quickly forgotten due to the minor consequences that result from the error.

The nature of errors, the interpretation and determination of their significance are largely contextual. Under certain conditions an otherwise minor error can cause catastrophic consequences. Errors are differentiated by their context and relative severity of their consequences. Bird (1974), proposed a ratio of 1:10:30:600 , while other authors proposed further ratios to indicate the differences between no-loss safety insignificant actions to major fatal accidents. Hollnagel (2007) argues that it is foolish that more time is spent on such few incidents due to the increase in visibility while there is a lot more incidents which could be used for the basis of effective control for losses.

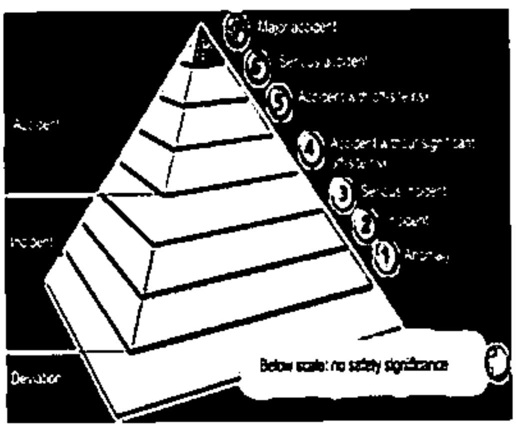

Figure 4: Ratio of losses

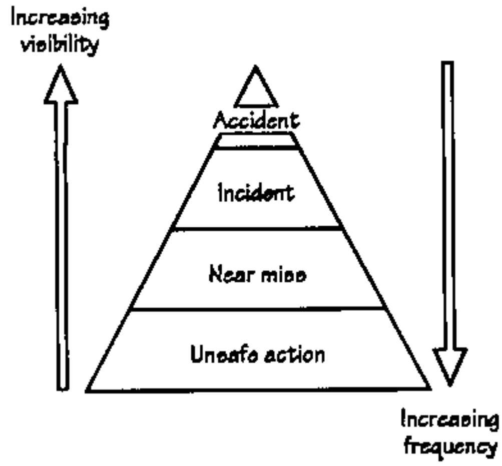

Figure 5: Visibility vs Frequency of incidents

Erik Hollnagel (1993) carried out a survey of the human factors literature over three decades to track the increasing prominence of the "human error" problem. In the 1960's erroneous actions of one kind or another were estimated as contributing about 20 per cent of the casual contributions to major accidents. By the 1990's, however, this figure had increased to 80 per cent. One explanation is that the reliability of mechanical and electronic components have increased while complex systems are still being controlled and managed by 'mark 1' human beings.

Perrow (1999) states our dependence on systems, which support our way of life, including water treatment, electrical power generation and transmission, financial systems etc. has increased in complexity and technical capability. As systems become more efficient, powerful, and diverse in the tasks they perform, the consequences of system failures have increased. Reason (1997) and Perrow (1999) have suggested that with the changes in the nature of the function of these systems, new and largely unanticipated opportunities for human error have been created. The social needs and different skills and perspective of teams that operate the transmission system, puts additional demands on operators, which has increased the pressure for them to perform without error.

Human fallibilities being what they are, there will always be a possibility of operator error (Peters & Peters, 2006). Hollnagel (1993) and Reason (1997) suggest that the impossibility of eliminating operator error should be recognised, by focussing instead on minimizing the consequences of errors. There is only one way of performing a task correctly, or at best a few. Plan each step in a sequence of actions or thoughts. Each of these steps or thoughts has an opportunity to go astray. This may therefore lead to an error which can lead to an accident or incident. However, major companies such as Du Pont believe that you should create the belief that you can perform to achieve zero incidents.

In summary, human errors can be categorised in many ways. Based on Norman's distinction between slips and mistakes (Norman, 1981) and Rasmussen's three level theory of human performance (Rasmussen, 1983) Reason (1990) categorises errors into unintentional skill-based slips and lapses, rule-based mistakes, and knowledge based mistakes. Furthermore, Reason (1990) distinguishes a separate type of unsafe acts called violations (intentional error), which refer to deliberate deviations from safe operating procedures, standards or rules. Errors can sometimes have catastrophic consequences.

3.3 INVESTIGATIONS AND ACCIDENT MODELS

"No new knowledge can be arrived at if there is no problem to be investigated."
(Carl Popper,no date)

Researchers have extensively examined error (Reason, 1990, 1997; Woods, Johannesen, Cook, & Sarter, 1994). It is however not clear from their material how to apply a formal process of inquiry into investigating error. Without the proper understanding, those investigating error may apply investigative procedures incorrectly and fail to understand how the error came about (Strauch, 2002).

A test of a good accident report is to what extent it directs appropriate and workable counter measures (Strauch, 2002; Woods & Cook, 2003). The investigations should provide more insight into the cause of an accident than to attribute it solely to operator error. When investigating an accident, the narratives of the accidents, must be translated into an event tree which is tracked back in time. During this period the investigator must consistently ask what factors were necessary to bring about the subsequent events. Which events if removed would have prevented the accident sequence? It is therefore important that investigations be done properly.

There are two groups of investigative error types, (Dekker, 2001) which are those that can bias attributions of blame (Reason, 2000) and responsibility, and those that can distort perceptions of cause and effect.

One of the problems with determining cause and effect in accident sequences is the tendency to confuse the present reality with that facing those during the actual accident sequence. This is normally known as hindsight bias (Woods, *et al.,* 1994). With hindsight, those investigating the accident can see all the warning signs and causal events that resulted in the accident. Unfortunately, those that are actually involved in the accident, with limited foresight, do not see the imminent accident (Strauch, 2002).

By oversimplifying the situation people face before an outcome is known, often hides tradeoffs between multiple goals. Hollnagel (2002: 9) said "...if anything is unreasonable, it is the requirement to be both efficient and thorough at the same time – or rather to be thorough when with hindsight it was wrong to be efficient".

When actions are treated in isolation, investigators tend to micro-match and cherry-pick (Dekker, 2001). Micro matching is a form of hindsight bias in which investigators evaluate discrete performance fragments against standards that seem applicable from their after the fact perspective. As Dekker (2001: 32) expresses it; "Knowledge of the 'critical' data comes only with omniscience of hindsight, but if the data can be shown to have been physically available, it is assumed that it should have been picked up by the practioners in the situation." The problem, as Dekker explains, is that it does not answer why the information was not picked up at that time. Cherry picking, another variant of hindsight bias, involves identifying patterns of isolated behavioural fragments on the basis of post-event knowledge. This grouping is not a feature of the reality, but an artefact introduced by the investigator (Hollnagel, 2007; Reason & Hobbs, 2006;, Strauch 2002).

In the urge to blame individuals (Reason, 2000), investigators confuse what might have been with what ought to have been. With counterfactual fallacy, the fallacy goes as follows: had things been otherwise (i.e. had this act not happened), there would have not been any adverse result; therefore, the person who committed the act is responsible for the outcome (Dekker, 2006; Hollnagel 2007). Another factor that leads to blame is the fundamental attribution factor (Fisker & Taylor, 1984; Hollnagel, 2007).

This is the universal human tendency to resort to dispositional rather than to situational influences when explaining people's actions, particularly if they are regarded as unwise or unsafe. It is said that the person was stupid or careless; but if the individual in question was asked, he or she is most likely to point to the local constraints.

He or she will explain how he or she coped with the complexity and conflict in the real world setting (Woods & Cook, 2003). The truth normally lies somewhere in between (Strauch, 2002). We need to move away from the person model of human error in which the search for causes and their counter measures is focused almost exclusively upon the psychology of the humans. If errors are predictable, operators will take steps to avoid them. The accuracy of error prediction depends largely on the extent to which the factors giving rise to the errors are understood. For most accidents, an investigators understanding of the complex interaction between these various causal factors are, and are always likely to be, imperfect and incomplete (Leveson, 2003). Leveson (2002) suggests that a systems view of accident causation needs to be taken.

Accident models form the underlying foundation for both the engineering techniques used to prevent accidents and the techniques used to assess the risk associated with using the system we design, build and operate (Leveson, 2002). Where investigators look for causes depends on how the investigators believe accidents happen. An accident model often explains why accidents occur and they determine the approaches taken to prevent accidents (Leveson, 2002; Hollnagel, 2004; Dekker, 2006). A model helps determine what things to look for. But models are also constraining in that it limits an investigating team to look for certain things, looks at those things in a particular way, at the exclusion of looking and interpreting things differently. Changes in technology are making fundamental changes in the etiology of accidents, requiring changes in the explanatory mechanisms used to understand them and in the engineering techniques applied to prevent them (Hollnagel,2007).

There are three popular kinds of accident models (Leveson, 2002; Hollnagel, 2007; Dekker, 2006), namely sequence of events model, epidemiological model and the systemic model.

The sequence of events model sees accidents as a chain of events that lead up to a failure. One event causes another, and another, until the entire series produces an accident. Very similar to one domino tripping another and is therefore also known as the domino model.

The domino model was presented by Heinrich in 1931. In the sequence of events model, accidents can be prevented by taking one link from the chain, or by inserting a barrier between any two dominoes (Hollnagel *et al.*, 2006). However as we shall see just as certain models have certain strengths, they also have certain drawbacks.

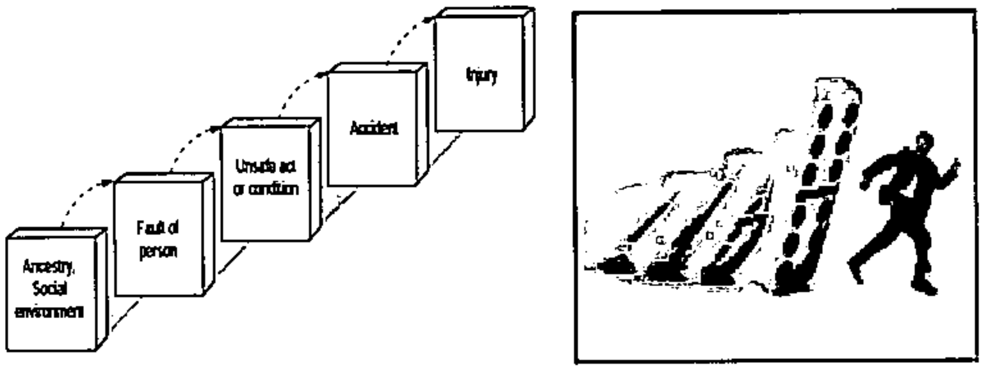

Figure 6: Simple Linear Accident Model (Heinrich's Domino Model)

The sequence of events model is very good for explaining the last few periods (seconds, minutes, hours and days) before an accident, and how the events during that time could be related to the outcome. The sequence of events model can deal well with cause-effect relationships. If causes and effects are pretty obvious, and if not too many causes lead to too many effects, a sequence of events model can help explain the outcome failure. This works well for events immediately before the accident. The model tells a relatively simple story of what caused the accident. Countermeasures can easily be determined by removing one event or putting a barrier between sequences to ensure that this sequence never happens again. It is very simple to use and explain.

However, the problem with this linear thinking behind the sequence of events model is that in complex systems failures are seldom linear, narrow or simple. In the sequence of events model, the choices of events are considered causal to one another and are subjective and always incomplete. The starting point is an arbitrary choice, as prior events can always be added. Humans often get painted as the weakest link.

The sequence of events model is too linear, too direct, too narrow, and too incomplete to capture organisational contributions to the accident. On the level of human performance, the context in which decisions and actions are taken is important because human action is always embedded in a context. Given a little thought this is obvious, but the preferred mode of representation that is used by analyses, the event tree is prone to be misleading, since it represents actions without a context (Hollnagel, 2005). The problem of context is a noticeable feature of other current theories. The consequence of acknowledging the importance of the context is that investigations should not attempt to analyse actions separately, but instead treat them as parts of a whole.

The sequence of events model works best for accidents where one or several physical components fail, leading to a system failure or hazard. Other models that are more effective for accidents in complex systems will need to account for social and organisational factors, system accidents and dysfunctional interactions, human error and flawed decision making, software errors, and adaptation (Leveson, 2002).

The epidemiological model sees accidents as an effect of the combination of active errors or unsafe acts, committed by those in the sharp end of a system and latent errors that hide in management decisions, procedures, equipment design etc. These latent factors lie dormant unless triggered by other factors (Reason, 1997). The epidemiological model does not look at the last few minutes of an accident but digs deeper into managerial and organisational contributions to the failures.

The epidemiological model also known as the Swiss cheese model first proposed by Reason (1990) allows thinking in terms of other than causal series. It allows you to see the complex connections between various factors including organisational issues behind the creation of an accident.

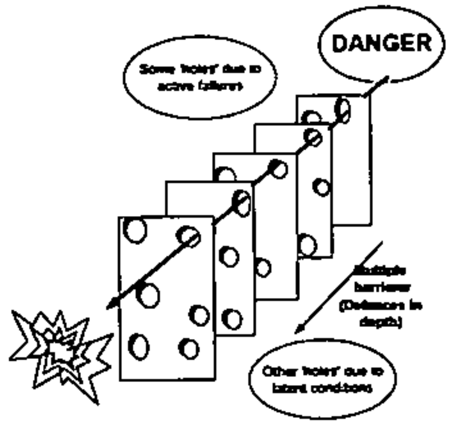

Figure 7: Reason's Swiss Cheese Model

Accidents in complex systems involve a combination of active failures and latent failures (Reason, 1997). Latent failures conditions are present in the system well before the onset of a recognisable accident sequence. Latent failures conditions can have several different causes such as organisational or managerial decisions, design failures or deficiencies, maintenance failures or deficiencies, and slow degradation of system functions or resources (complacency) which are undetected. The figure below reflects how barriers can be affected by latent conditions (Reason, 1995).

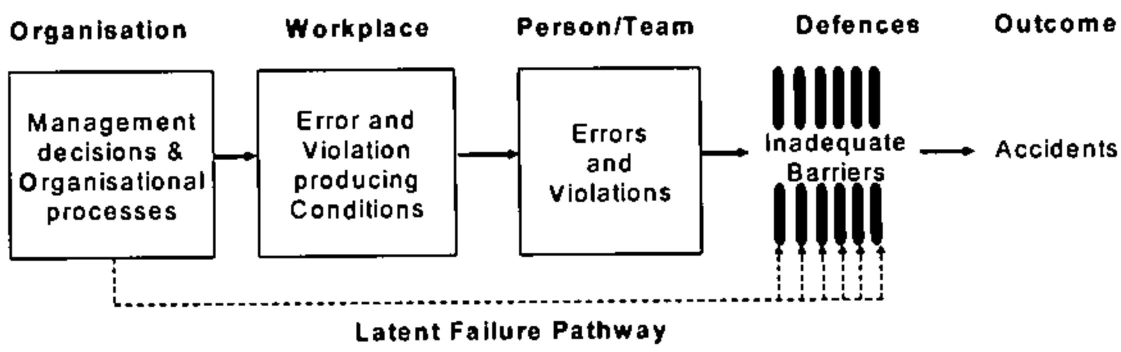

Figure 8: Reason's Model for Accidents in Complex systems

An accident indicates that one or more barriers have failed – either because they did not serve their purpose adequately or because they were missing or dysfunctional. The search for barriers that have failed should therefore be an important part of accident analysis (Einarsson, 1999).

Once the aetiology of an accident has been determined and the causal pathways identified, barriers are used as a means to prevent the same or similar accidents from taking place in the future (Hollnagel, 1999).

The systemic model sees accidents as emerging from interactions between system components and processes, rather than failures from within. Accidents come from normal workings of the system (Perrow, 1984; Sagan, 1994). They are a systemic by-product of people and the organisation trying to pursue success with imperfect knowledge and under the pressure of resource constraints (Hollnagel, 1999).

By focussing on the events preceding the accidents, event chains treat a system as a static, unchanging structure (Reason, 1997; Peters & Peters, 2006; Leveson, 2002; Hollnagel *et al.*, 2006). Systems and organisations continually experience change and adaptation to existing conditions. Systems dynamics models are one way to describe dynamic change in systems.

Leveson (2002) points out that systems defences or safety controls may degrade over time due to changes in the behaviour of the components of the safety control loop. The reasons for the migration of the system toward a state of higher risk will be system specific and can be quite complex. In contrast to the usually simple and direct relationships represented in event-chain accident models, most accidents in complex socio-technical systems involve relationships between events and human actions that are highly non-linear, involving multiple feedback loops. Leveson (2002) suggests the prevention of accidents in these systems therefore requires an understanding not only of the static structure of the system (the structural complexity) and of the changes to this structure over time (the structural dynamics), but also the dynamics behind these changes (the behavioural dynamics).

The accident models that are used must match the type of accident or error that investigators or practitioners are trying to analyse. System dynamics is particularly relevant when analyzing system accidents.

The world is dynamic, evolving, and interconnected, but investigators tend to make decisions using mental models that are static, narrow, and reductionistic (Hollnagel, 2007). Thus, decisions that might appear to have no effect on safety or even appear to be beneficial may in fact degrade safety and increase risk. Accident analysis can start with a static model and progress towards a system dynamic model to explain changes in structure over time.

An accident model should encourage a broad view of accident mechanisms that expands beyond the proximate events. A narrow focus on technological components and pure engineering activities may lead to ignoring some of the most important factors in terms of preventing future accidents.

In a systems view of safety, the traditional conception of accidents as chains or trees of directly related failure events and human errors is abandoned. Chain of events models encourage limited notions of linear causality and cannot account for the indirect, non linear, and feedback relationships common for accidents in complex systems (Leveson, 2002). A systems-theoretic approach to understanding accident causation allows more complex relationships between events to be considered. It also provides a way to look more deeply at events and why the events occurred (Marais, Dulac & Leveson, 2004).

Accident models based on systems theory consider accidents as arising from the interactions among system components and usually do not specify single causal variables or factors. Industrial safety models focus on unsafe acts or unsafe conditions and reliability engineering emphasizes failure events and the direct relationships among events whereas a systems approach takes a broader view of what went wrong with systems operation or organisation to allow the accident to occur. (Marais, Dulac & Leveson, 2004).

A systems approach concentrates on the analysis and design of the whole as distinct from the parts. Using a systems approach, to view accidents, reflects flawed processes involving interactions among components, interactions between people and the system or components, societal and organisational structures, task, the environment , engineering designs, procedures and conflicting standards.

No matter what the approach to accident models or investigations, what people are interested in is error (Woods, 2003). The motivation to explore error comes from accidents. For example, in the health care sector error is used synonymously for preventable harm to the patient. It will be too late to worry about the harm to the patient and find blame to a person. What practioners and line management are interested in is that error be the starting point of the investigation. Researchers and investigators (or at least some) are not interested in the harm itself but, rather, how the harm comes about. (Woods & Cook, 2003). The idea that something is preventable incorporates a complete albeit fuzzy model of how accidents happen, what factors contribute to them, and what sorts of countermeasures are needed to eliminate or mitigate against them.

In many cases the countermeasures are the introduction of barriers both physical and soft. In most cases there is more than one barrier - a concept known as 'defences in-depth' (Reason, 1997). Hollnagel (1999) indicates complementary to finding 'other' causes to accidents, failures of barriers could also contribute to accidents but are rarely included in the set of identified causes. On the most basic level, the function of a barrier is either to prevent an action from taking place, or protect the system and the people in it from the consequences.

One way to manage and protect people from these consequences is by keeping safety, accident and near miss reports on a common database program (Dijkstra, 2006). Dijkstra suggests each event should be assigned a risk level similar to the International Aviation Transport Association (IATA). Trend reports should be made from the above matrix so that appropriate countermeasures can be taken. Accidents and incident investigations are executed to create a learning opportunity for the organisation. (Cooke, 2003). Recommendations should help prevent re-occurrence of the mishap (Reason, 1997; Dekker, 2001; Srauch 2002; and Leveson *et al.*, 2003). However, if there is a delay in the final report with the appropriate recommendations or a lack of discipline from line management, after a few weeks or months, operations return to "normal" without any sustained learning or operational improvement from the incident.

Root or system causes are the most basic causes that can reasonably be identified, that management has the control to fix, and for which effective corrective actions for preventing recurrence can be generated. It must however be recognised that incidents typically have more than one cause. It is very unusual for an incident to have one single cause. Normally incidents result from a chain or combination of actions or errors, some going quite far back in time. This is why it is essential to have a systematic and thorough investigation, following a consistent methodology, so that the chain of causes can be tracked right back to its origins.

3.4 RISK

The subject of risk is broad; it encompasses risk management, risk analysis, risk assessment, personal injury risk, property damage risk, insurance risk, corporate risk, business planning risk etc. and can apply to every aspect of business or personnel activities. Risk is usually interpreted somewhat differently in different fields. A dictionary definition includes words like hazard, a source of danger, a possibility of incurring loss, etc. Sometimes the term risk is also referred to various gambles, which are entered in the hope of something favourable to happen. More formally, risks are often discussed as the triplet of possible threats together with their likelihood and consequences (Wahlström, 2005; Wilkinson, Elahi & Eidinow, 2003). For the purpose of this research the researcher will concentrate on risk as it applies to human error in an operating environment. When individuals make judgements about risk, they are usually describing, not a static quantity, but their own perceptions, which are influenced by their beliefs and knowledge, their personal circumstances and experiences (Wilkinson *et al.*, 2003). Risk in these instances relates to a personal evaluation: What is risky for one operator may not hold the same significance for another operator.

There are a number of approaches that can be used to classify human error risk and undesirable human performances (Peters & Peters, 2006). The best analogy is to use reliability and system safety.

Reliability engineering has emphasized parts failure (failure rates) while system safety failure as emphasized hazards and risks to physical equipment and software. Human error analysis is more directly related to the human side of equipment and systems, that is, the prevention of unwanted human performance. Human error is evaluated by assessing the frequency of each type of human error, the severity of consequences, and the degree of risk that results.

Risk standards have many definitions, each of which provides a different plan of action for the reduction of risk. In terms of the selected risk criterion, what is important is the predicted risk, which is compared to the amount of risk reduction achieved by various risk remedies; the final risk residual and the risk considered to be a tolerable or acceptable risk (Merrick, Grabowski, Ayyalasomayajula & Harrald, 2005). It is common practise in Eskom that the operators go through this process. However, from the researchers own experience and discussions with different operators in the field it is not unusual to observe that there is no appreciation for risk.

A common risk classification is minor (acceptable), moderate (action required), and major (intolerable). This classification is suitable when doing business planning but may not be suitable for operators that need to make on-line decisions.

Haimes (2004) suggest that risk assessment and risk management can be done answering the following questions; the first set represents risk assessment. What can go wrong? What is the likelihood? What are the consequences? The second set represents risk management (Haimes, 1991). What can be done, and what options are available? What are the trade-offs in terms of costs, benefits, and risks? What are the impacts of current policy decisions on future options?

One form of risk assessment, cost-benefit analysis, has commonly suffered from escalated benefits estimations and deflated cost estimates.

Typical examples in the operating environment are the reduction of time to get the power supply connected by taking short-cuts and not following the operating regulations for high voltage systems. There have been severe injuries due to operators not wanting to change into the correct personal protective equipment prior to switching high voltage equipment because the benefit of getting the job done quicker outweighs the cost of "wasting time" changing into the correct personal protective equipment for a one minute job. Balancing risks and benefits is fundamental to any consistent decision-making process.

Risk-based decision making consists of risk assessment and risk management. To assess risks, it is necessary to consider in some way the two basic risk criteria, probability of occurrence and extent of damage. Risk assessment evaluates and integrates these two risk criteria (Kirchsteiger, 2005). It is clear in the above example that the operator may have considered the probability of getting injured small but did not understand the extent of the damage. The operator did not therefore integrate the two risk criteria.

Another approach is the risk-action approach (Kirchsteiger, 2005). Risk action approach serves to tailor the preventive or corrective action to the estimated risk levels. The actions required may fall into the category of; immediate action priority, a high priority action, a moderate priority action, a low action priority or a no action priority. This approach allows the operator to change his actions as the circumstances and the environment changes. A task or activity that was evaluated using the risk action approach may start off with a no-action priority but as the operator goes into the details of the task, it may require an immediate action priority.

Risk assessment is central to occupational health and safety standards. Risk assessment is an overall process of estimating risk and determining whether it is a tolerable risk. The evaluation of risk can be found in Eskom's operating regulations for high voltage (ORHVS). The terminology used in the regulation refers to the term risk analysis. This is a very general term encompassing many different procedures.

This is in contrast to the term risk assessment, which requires the risk to be characterised for example as minor risk requiring no action or high risk needing immediate action as highlighted earlier (Peters & Peters, 2006).

The main cause of incidents was that risk assessments are not implemented sufficiently robustly. This was what was found in a recent study in a United Kingdom hospital, which highlighted that risk assessment was the dominant risk control failure (Peters & Peters, 2006). In a similar study in Eskom in 2007 it was highlighted that the risk assessments were not done correctly and there was no appreciation of the identified risk by the operators.

Risk assessments take many forms, ranging from the worthless to the extremely valuable. What may be a productive approach in one set of circumstances may be a blunder in another. Selection of the most appropriate method taking into account the competencies, the constraints, the defences etc. will provide the most effective risk assessment plan. The researcher acknowledges that given the skills required for the type of performance levels highlighted by Rasmussen (1982), a dominant risk assessment technique may be used for the different performance levels. Some of the elements that should be considered in the risk assessment may include, worst case assumption or fall back position (most conservative approach), appropriate caution should be exercised when there is any significant uncertainty about the risk (precautionary principle), calling of independent specialists to provide their expert judgement (expert elicitation), local consensus where operators together with in-house focus groups can be resolved through consensus uncertainties. Normally when there is residual risk it is an indicator of uncertainty.

As part of risk assessment a task analysis is needed in order to determine what job and tasks are to be undertaken by the operator. The task analysis serves to identify and break down a job or a task into smaller components. Patterns, sequences, and linkages may be discovered and analysed. It should also identify who performs the task, what decisions must be made, what type of action is required, the needed skills and training, the task critical analysis of the task, its difficulty, and the need to coordinate with others. During each of these aspects opportunities for human errors exist.

Taking this into account and providing countermeasures for the management of errors, the task analysis can be used to formulate procedures, checklists, cautions and rules.

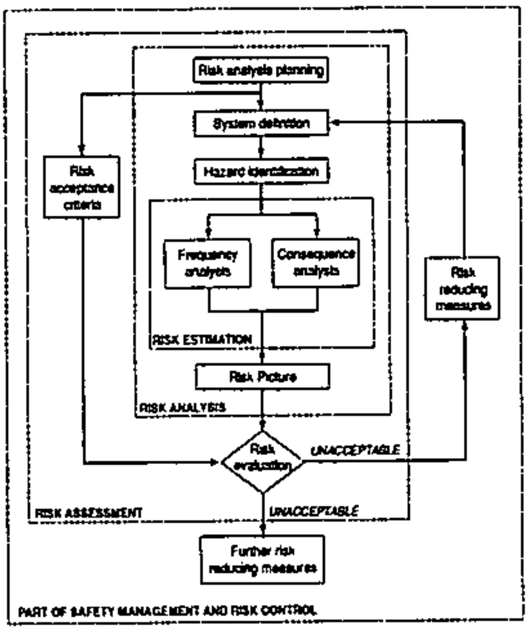

Figure 9: Risk Assessment
Source: Kirchsteiger,(2005)

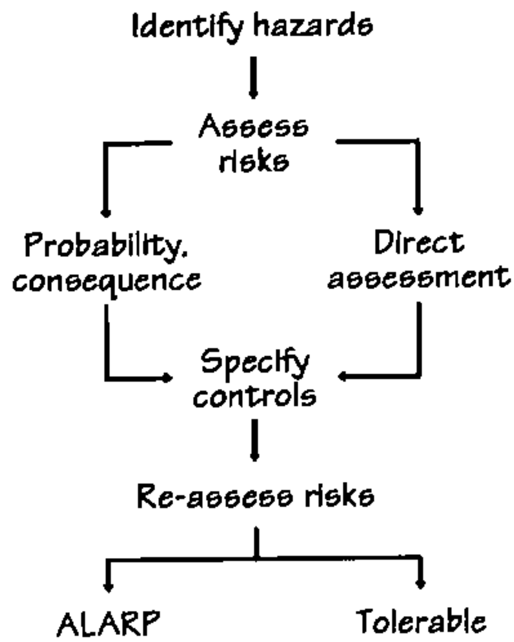

Figure 10: Risk Assessment
Source: Hollnagel (2007)

The two models above are similar but different. The main differences is that model one (Figure 9) uses only quantitative method to evaluate the risk whereas model two (Figure 10) uses both qualitative and quantitative methods.

Completing the risk assessment is not the end in itself, but a means to mitigate against errors. Operators should continuously be re-evaluating their risk. This is the oversight and review of the risk management system and any changes that might affect it. Monitoring and reviewing should occur concurrently throughout the risk management process. Therefore, effective risk assessment and risk mitigation, is crucial to ensuring safety (Connell, 2004).

3.5 ERROR MANAGEMENT

There is nothing new about error management. Error management has three components: error reduction, error containment and managing error management for continuous improvement

Effective error management involves targeting different counter measures at different parts of the organisation or outside the organisation. There is no one best way of error management. Different organisation cultures, different work risks and environments require a focus on different measures. For example within Eskom there are different working environments from construction, generation to transmission and distribution and due to the size of the organisation and the geographical spread the culture is no homogeneous. The error management methods need to be mixed and matched to these specific areas but keeping a holistic picture in mind rather than on just local fixes.

The key targeted areas that are normally within control are; the employee or contractor, the team, the task, the workplace, and the organisation as a whole.

Human error appears in many guises and has a variety of causes. It is therefore not surprising that no single, universally applicable error reducing technique is available (Reason, 1997). A wide range of remedial tools are needed to find methods best suited to the immediate and future needs. Some of the error management methods suggested by Reason (1997), Reason and Hobbs (2003), Peters and Peters (2006) and Busse (2002), that are common to high risk organisations included but are not limited to the following; policy, standards, procedures, manuals, rules and regulations, training (institutional and on-job) and retraining, work planning and work scheduling, work orders or job cards, work instructions, tags and reminders (Permit systems), selection of appropriate skills, handover procedures, human resource management, maintenance management, breakdown/emergency management, overtime controls, authorisations and certifications, checking and sign-offs, audits, disciplinary procedures, job observations ,risk analysis, toolbox talks and pre-job briefings.

The above error management measures or techniques have evolved over time but have failed to reduce or contain the errors significantly over time. Reason and Hobbs (2003) argue that the key limitation has been due to the management or techniques being piecemeal rather than principled, reactive rather than proactive, and fashion driven rather than theory-driven.

This is supported by the researchers own experience where each of the techniques are handled in isolation. The above techniques should support and compliment each other. Some of the unifying set of guiding principles on error management philosophy are as follows:

- *Human error is both universal and inevitable* – making human errors is part of human life. Humans are fallible (Dekker, 2006; Reason, 1997; Strauch, 2003; and Hollnagel *et al.*, 2006). Human error is the inevitable by-product of the pursuit of success in an imperfect, unstable, resource-constraint world (Dekker, 2006). Currently, the South African customers are on the receiving end of these constraints while the operators from Eskom make these errors in an imperfect system.

- *Errors are not intrinsically bad* - success and failure come from the same psychological roots (Hollnagel *et* al., 2006, Dekker, 2006; Peters & Peters, 2006). Errors help determine the boundaries between success and failure. It allows new skills to be acquired in order to perform tasks safely and efficiently. People provide a positive contribution to safety through their ability to adapt to changes, gaps in system design, and unplanned for situations. Operators make up for the holes in the designers work (Rasmussen, 1982). Failures represent breakdowns in adaptations directed at coping with complexity while success is obtained by operators that learn and adapt to create safety in a world fraught with hazards, trade offs, and multiple goals (Rasmussen, 1997).

- *You cannot change the human condition, but you can change the conditions in which humans work* - the two parts to error are the mental state and the situation.

Earlier it was pointed out that humans are fallible so state of mind moments of inattention are given but situations such as working on live equipment from a helicopter are not. Different situations may provoke unwanted actions. Identifying these error traps and recognising their characteristics will allow the conditions to be changed. (Dekker, 2006)

- *The best people make the worst mistakes* – Dekker (2006), Reason and Hobbs (2003) point out that it is not just a few ill-performing individuals that make most of the errors. Errors can strike at any time and no one is immune to making them. Some of the worst errors have been made by the most experienced people. Case studies in Eskom also reflect this. It is not only the young and inexperienced operators that make errors but many of the best performing and most experienced operators. Best people are normally promoted to more responsible roles so their errors have a greater impact (Reason, 1997).
- *People cannot easily avoid those actions they did not intend to commit* – Blame and accountability should not be confused. Blame and punishment make no sense when the intention was a good one but the action did not go as planned and resulted in a poor outcome (Reason, 1997). The operator must learn from the error and take accountability but not necessarily be punished for the good intentions. There can be pressure from all kinds of direction for seeking retribution, punishment and justice.
- *Errors are consequences rather than causes* - During investigations one of the key aspects in improving or learning from the incident is that investigators must find the root cause so appropriate defences could be put in place to prevent reoccurrence (Reason & Hobbs, 2003). However, Dekker (2006) claims that there is no such thing as the cause, or primary cause or root cause. He claims that a cause is something that is constructed and not something that is found. Where accidents arise out of complex interactions (Perrow, 1984) of many different factors and where the primary aim is to strengthen the systems defences, errors should be regarded as consequences of that interactions rather than causes (Reason & Hobbs, 2003).

- *Many errors fall into recurrent patterns* – Errors can arise from a combination of unique situations or from situations that recur many times.

  Unique situations provide random errors, however recurring situations such as people putting the wrong year on checks just after the New Year are systematic or recurrent errors. In Eskom as an example many maintenance related errors occur during reassembly of parts, or omission of checking that the operator is at the right panel after a distraction. While Dekker (2006) argues that there is a risk in categorising and counting errors, he acknowledges that if the context of the situation is understood, local rationality (local rationality principle: what people do makes sense to them given the circumstances at the time – given their goals, their attention and knowledge at the given situation) can be reconstructed and thereafter human error could be understood. Working on the Perato's 80/20 principle, targeting these recurrent error types is an effective method of using the limited resources to effectively manage error.

- *Safety significant errors can occur at all levels of the system* – Operators on the sharp end are not the only one's who makes errors as highlighted earlier. Errors occur throughout the system. The higher up the individual is in an organisation, the more dangerous the error. The Columbia space shuttle accident is a typical example where senior management gave the go ahead for the mission. The safety personnel asked the wrong questions when analysing the failures of the tiles. Instead of looking how many of the tiles came loose but did not dislodge itself from the shuttle, they concentrated on only the ones that dislodged. This lead to the ill-fated tragedy of the Columbia.

- *Error management is about managing the manageable* – One of the common errors in error management is trying to change the unchangeable e.g. the proneness to distraction, preoccupation, and moments of inattention and forgetting. It is easier to manage the situation or the system than to change human nature.

Error management needs to be vigilant against people blaming tendency (fundamental attribution error).

- *Error management is about making good people excellent* – One of the mistakes is the thinking that error management is about making a few error prone people (Dekker, 2006) error free. The principle aim of error management is to make well trained and highly motivated people excellent. It is therefore important that results from employee satisfaction surveys are analysed to check whether people are still motivated. In order to achieve excellence, the two crucial elements of technical skills and mental skills must be mastered (Reason & Hobbs, 2003). These two skills can be acquired by training and practise. Mental readiness which is rarely practised in engineering unlike surgery is just as important as the technical skill. Mental readiness involves mentally rehearsing responses to a variety of different situations and scenarios. Operators need to understand the different ways that the task or activities that they are carrying out can go wrong and mentally prepare their responses.

- *There is no one best way* – there is no one best technique for error management. Some of the error management techniques described above may apply to one level of an organisation or team but may be inadequate at another level. The underlying mechanisms for the error need to be understood so that the appropriate technique can be employed.

- *Effective error management aims at continuous reform rather than local fixes* – there is a tendency in different parts of different organisations, depending on their maturity and culture, to solve specific problems. Due to pride or image, organisation or departments tend not to share information on incidents. Focus is always placed on the last few incidents and prevention of recurrence is on individual errors. Focus should be on the whole system to reduce and contain whole groups of errors rather than individual or local fixes. High reliability organisations have the ability to identify commonalities across incidents.

Departments do not focus on the differences or uniqueness of incidents that happened elsewhere, they seek similarities that contain lessons for all to learn (Leveson, 2003).

- *Abandon the fallacy of a quick fix* – human error problems are organisational problems. For effective error management, human errors need to be seen as deeper problems inside your organisation and the peripherals that have an impact on your organisation. Responses to quick fixes are normally, retraining, reprimanding, new procedures and adding just a little bit of technology (Reason 1997; Reason & Hobbs, 2003; Peters & Peters, 2006). Hard fixes are evidence that the people in the organisation are taking failure seriously. The failure may show the trade off between safety and production goals. It may reflect how the system drifted towards the boundary edge of safe performance. Due to reward incentives, efficiency goals are encouraged and risk taking is wrongfully rewarded.

The test of a good error management process is the extent to which it directs those that regulate, manage and operate organisations and industries towards appropriate and workable countermeasures in order reduce and contain errors (Strauch, 2002).

Most attempts at error management are piecemeal rather than planned, reactive rather than proactive, event driven rather than principle driven (Reason, 1997; Reason and Hobbs, 2003). Many organisations have not moved towards resilience but are misguide by old often incorrect practises (Hollnagel, 2003). They tend to focus on the last error rather than anticipating and preventing the next error. Instead of looking at the complete timeline of the incident, focus is only placed on the active errors rather than including the latent errors (Dekker, 2006). The organisations only focus on the personal, rather than the situational contribution of the error (Reason, 1997; Hollnagel, 2007). Additional procedures and disciplinary actions seem to be the only solution yet they continue to have errors (Peters & Peters, 2006; Reason & Hobbs, 2003; Hollnagel, 2003; Dekker 2006).

Error management should include measures that minimize the error liability of the operator, reduce the error vulnerability of particular task, discover, asses and then eliminate error-producing factors, help diagnose organisational factors that create error producing factors within the task or operator, enhances error detection, increase error tolerance and make latent conditions more visible (Reason, 1997).

3.6 SAFETY CULTURE AND RESILIENCE MANAGEMENT

Safety is a system property that emerges from a conglomerate of components, subsystems, software, organisations, human behaviour, and their interactions. The increase in major accidents has made it clear that organisations must revise their handling of processes and capabilities to not only address the technical but also the human and organisational risk factors. (Hollnagel, Woods & Leveson, 2004). Safety is an emergent rather than a resultant property of a system and therefore cannot be predicted by considering only the parts of the system.

Safety in any organisation is affected by the organisations safety culture. Safety culture can be divided into two parts, which an organisation employs to achieve safety. These are:

- A shared set of beliefs, attitudes and values that are often unspoken (this is what an organisation is) (Cooper, 2000; Hale, 2000; Pidgeon, 1997; Reason, 1998)
- The structure, practices controls and policies (this is what an organisation does)

Safety culture is the subset of an organizational or industry culture that reflects the general attitude and approaches to safety and risk management. It is important to note that trying to change culture without changing the environment in which it is embedded is doomed to failure.

Superficial fixes that do not address the set of shared values and social norms, as well as deeper underlying assumptions, are likely to be undone over time. Leveson and Gershenfeld (2005) explain that this is partially why the changes at NASA after the Challenger accident were over time dismantled or became ineffective. Both the Challenger accident report and the Columbia accident report note that system safety was "silent" and ineffective at NASA. Understanding the pressures and other influences that have twice contributed to a drift toward an ineffective NASA safety culture is important in creating an organizational infrastructure and other cultural factors that will resist pressures against applying good safety engineering practices and procedures in the future.

The safety culture is the engine that drives the organisation goal of maximum attainable safety regardless of the production pressures or leaderships roles. Leadership from the top of the company, starting with the Board and going down, is essential. It is imperative that leadership sets the safety "tone at the top" of the organisation and establishes appropriate expectations regarding safety performance (BP Texas Oil Refinery Report, 2007). The commitment of the foremost leader namely the Chief executive and his senior management exerts a powerful influence on the organisations safety values and policy. Leadership is one of the most important factors in motivating employees (Connell, Cross & Parry, 2002).

While organisations have an aspirational goal of "no accidents, no harm to people," they do not provided effective leadership in making certain its management and workforce understand what is expected of them regarding safety performance (BP Texas Oil Refinery Report, 2007). Eskom safety policy indicates that no urgency of a job should endanger anyone's life. This was also clearly demonstrated by the Chief Executive and his executive committee in the August 2007 when he instructed all staff to stop certain types of activities due to safety concerns. This had major implications for projects, suppliers and customers but reflected powerful leadership and influence to show Eskom's safety values.

A safety culture reminds the organisation of the operational risks. It accepts that there will be holes in defences and builds contingency plans to cope with them. A safety culture knows where the boundary of safe and unsafe operations is without going over it.

Safety cultures can be engineered by creating an atmosphere of trust (Conchie & Donald, 2006) in which people are willing to confess their errors and near misses. The trust creates an informed culture. An informed culture is a just culture that distinguishes between blame free and culpable acts. No errors will require disciplinary action. A safe culture is a learning culture that uses both proactive and reactive approaches to improve safety. An example of a proactive measure will be job and behavioural observations, while measuring lost time injuries is a reactive measure.

In order to improve on human errors Reason and Hobbs (2003), highlighted the aspects of safety culture described above but also preferred to challenge the safety culture by indicating that one should focus on changing what the organisation does rather than just focussing on the person. This argument is supported by Hofstede (1994) who indicates that it is harder to change collective values than it is to change practises. They suggest that introducing practises and structures that are seen to work effectively have a way in changing people's values.

Resilience has gradually emerged as the logical way to overcome the limitations of existing approaches to risk assessment and system safety (Hollnagel *et al.*, 2006) however the researcher acknowledges that it is not yet an established discipline. Resilience engineering is a paradigm for safety management that focuses on how to help people cope with complexity under pressure to achieve success.

Accepting one of the accident models described earlier in this chapter has consequences for how accidents are understood and how resilience is seen. Hollnagel *et al.* (2006) maintains that in the simple linear model (domino model), resilience is the same as being impervious to specific causes.

Either the domino pieces cannot fall or fall so far apart that it cannot affect it neighbours. In the complex linear model (Swiss cheese model), resilience is the ability to maintain effective barriers that can withstand the impact of harmful agents and the erosion that is a result of latent conditions. In the above cases resilience is the ability to endure the harmful influences from the failure of a component or subsystem. He goes on to say that in a systemic model, resilience is an organisation's ability to adjust to harmful influences rather than to shun or resist them. An unsafe state may arise because system adjustments are insufficient or inappropriate rather than because it sometimes fails.

If resilience is used with its common meaning of survival in adversity, it will be of no use to safety, one of the key aspects of safety is preventing accidents and not just surviving accidents (Hale & Heijier, 2006).

CHAPTER 4: CONCEPTUAL ERROR MANAGEMENT MODEL

4.1 INTRODUCTION

In the last chapter the researcher looked at some of the key facets of error management. In this chapter the research will review some error management tools or models and propose a conceptual error management model based on some of the literature discussions and some of the models presented in this chapter. The chapter will be rounded off with a case study using the conceptual error model for error reduction and continuous improvement.

4.2 ERROR MANAGEMENT TOOLS

There are many error management tools that have been developed over the years. However, many of these tools focus only on one specific facet of error management without considering the interface or impact on the other aspects of errors. The model that will be proposed will create a complete circle so that when the organisation considers managing errors it has a holistic picture and is able to focus on specific aspects in which the organisation considers the defences are weak or a new barrier is required to strengthen the defence.

The table below provides a summary of some of the error management tools.

ERROR MANAGEMENT TOOL	APPLICATION
Tripod-Delta	Oil exploration, production and shipping
Review	Railway Operation
Managing Engineering Safety Health (MESH)	Aircraft Maintenance
Human Error Assessment and Reduction Technique (HEART)	Hazardous Operations
Influence Diagram Methodology	Hazardous Operations
Maintenance Error Decision Aid (MEDA)	Aircraft Maintenance
Tripod Beta	Oil exploration and Oil production

Table 2: Error Management Tools

4.2.1 TRIPOD – DELTA AND TRIPOD- BETA

The error management tool Tripod–Delta was created for oil exploration and production operations of Shell Internationale Petroleum Maatschappij (Hudson, Reason, Wagenaar, Bentley, & Visser; 1994). The Tripod-Delta has three elements, namely, a coherent safety philosophy that leads to the setting of attainable goals, an integrated way of thinking about the processes that disrupt safe operations, a set of instruments for measuring the disruptive processes termed General Failure Types that does not depend on incident or accident statistics (Reason, 1997).

During the development of Tripod-Delta, Shell's focus was on lost time injuries (LTIs). The Tripod delta did not address the LTIs directly but operated at one level higher by addressing the General Failure Types, the situational and organisational factors that provoked LTIs (Watts, 1999; Reason, 1997). Figure 11 shows the three part structure of the Tripod Delta.

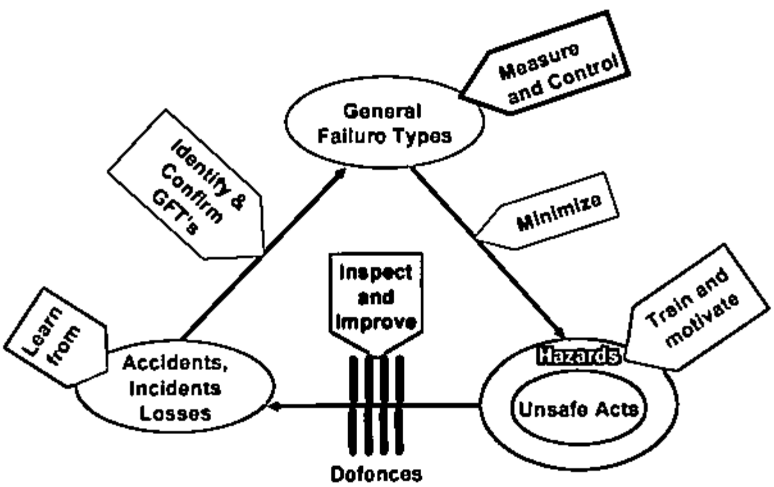

Figure 11: Tripod Delta: General Failure Types, Unsafe Acts, Negative Outcomes

Source: Reason (1997: 133)

This tripod method comprises of three main elements and includes the safety management actions necessary at each stage. The first element is the performance of unsafe acts which facilities usually attempt to remedy through training and employee motivation. If these unsafe acts breech the existing defences of the facility, an accident, incident, or loss may occur. Facilities should routinely inspect and improve the defences to protect against an accident, incident, or loss. Once an incident occurs, the facility should investigate the event to identify the latent conditions that may have contributed to the event. The facility should also establish a method for identifying and managing latent conditions, or General Failure Types. This in turn can result in a minimization of the performance of unsafe acts.

The Tripod-Delta approach identified eleven General Failure Types, namely, hardware, design, maintenance management, procedure, error-enforcing conditions, housekeeping, incompatible goals, communications, organization, training, and defences (Reason, 1997; Watts 1999). The approach requires that the facility derive a checklist of specific indicators for each of the General Failure Types. The indicators are directly observable and not influenced by the respondent's biases. The task specialists (e.g., operators, maintenance personnel) are then asked to complete the checklist. The checklist is then analysed and the two or three most frequently reported General Failure Types that need attention are attended to.

Reason (1997), indicates that the Tripod-Delta is deliberately non-comprehensive. It samples a limited number of dimensions so that each process supplements and augments one another.

The Tripod – Beta is a PC Based tool for conducting incident analysis in parallel to event investigations (Reason, 1997; Watts, 1999). It is based on four processes, identify, assess, control and recover.

4.2.2 REVIEW AND MESH

Review and MESH use the same principles and methods of assessments. Unlike the Tripod-Delta these instruments use rating instead of indicators. The Review and MESH use a five point rating rather than yes/no indicators. The risk with the rating system is that some operators will use it to complain while others will present a rosy picture. The operators and first line managers are asked how frequently particular kinds of workplace or organisational problems affect their work over a specific period of time. To overcome the bias rating it is suggested the responses are averaged (Reason, 1997).

The key differences between Review and MESH are while the Review assesses Railway Problem Factors, MESH measures both local and organisational factors.

Review measures sixteen Railway Problem Factors, namely, tools and equipment, materials, supervision, working environment, staff attitudes, housekeeping, contractors, design, staff communication, departmental communication, staff and rostering, training, planning, rules, management and maintenance. MESH measures eight organisational factors, namely, organisational structure, people management, provision and quality of tools and equipment, training and selection, commercial and operational pressures, planning and scheduling, maintenance of buildings and equipment and communication. The local factors measured are knowledge, skills and experience, morale, tools, equipment and parts, support from other sectors, fatigue, pressure, time of day, the environment, computers, paperwork, manuals and procedures, inconvenience, and personnel safety features.

For Tripod-Delta, Review and MESH the assessments are summarised in a bar chart. The success of the above techniques relies on management acting on the ratings. Management commitment to action the findings are necessary or the system will collapse.

4.2.3 HUMAN ERROR ASSESSMENT AND REDUCTION TECHNIQUE (HEART)

The HEART method (Kirwan, 1994) identifies nine generic task types and proposes nominal error probability values and their suggested bounding values (e.g. highest nominal error probability value of 0.55 percentile assigned to totally unfamiliar task, performed at high speed with no idea of likely consequence), together with thirty eight Error Producing Conditions (EPCs). For example, the highest rank EPC with a ranking of 17 is unfamiliarity with the situation that is potentially important, but which is either novel or occurs only infrequently.

Depending on the amount by which the EPCs are judged to affect the predicted error probability a selection of error reduction strategies are suggested to combat the most deleterious effects of any identified EPC (Reason, 1997; Reason & Hobbs, 2002; Synergy, 2004). Reason (1997), believes that the EPC list is one of the best available accounts of the factors promoting errors within the workplace. However, Einarsson (1999), states in his paper that the major problem lies in the identification of the most relevant EPCs and the assumption that EPCs act independently in their contribution to performance.

4.2.4 INFLUENCE DIAGRAM APPROACH (IDA) AND MAINTENANCE ERROR DECISION AID (MEDA)

The Influence Diagram Approach (IDA) provides tools for doing both a qualitative model and a quantitative measure of influences of various technical, human and organisational factors on the risk faced by a particular hazardous technology. The IDA charts the influences upon a particular failure mode. The levels are the influencing factor level (this includes the unsafe acts or technical failures immediately responsible for the event), the performance-influencing factor level (immediate workplace conditions that shape the occurrence of human or technical failures), the implementation level (these are the underlying organisation factors that create the performance influencing factors), and lastly the policy level (comprises the policy and regulatory processes that determine the organisational processes occurring at the implementation level).
This tool is used for any kind of hazardous system.

In contrast, to IDA, the Maintenance Error Decision Aid (MEDA) is a tool developed for investigating maintenance errors. MEDA is divided into five sections. The first three sections deal with the question "what happened", the second sections deals with how and why the error occurred and the last section pinpoints the failed defences and outlines possible solutions. (Reason, 1997; Reason & Hobbs 2002; Boeing, no date).

4.3 OTHER TOOLS

Hollnagel (2007) proposed two models for error management. The first model was a simple feedback control and a second was what he termed moving from reactive to proactive.

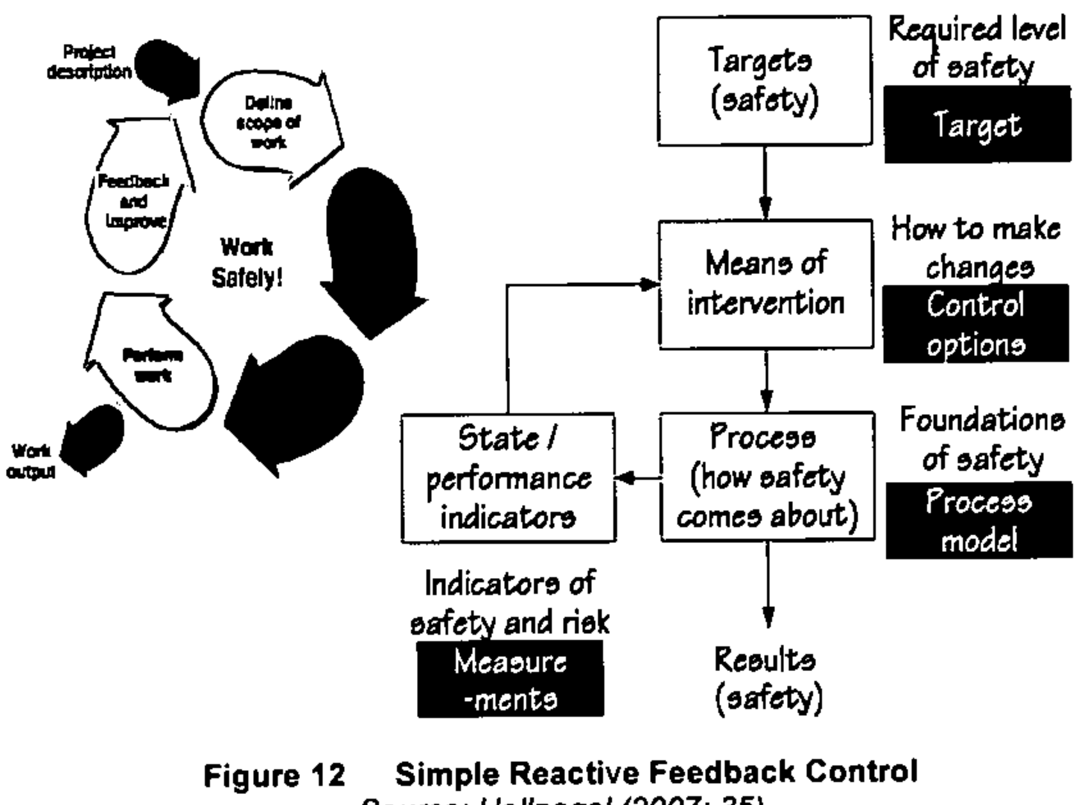

Figure 12 Simple Reactive Feedback Control
Source: Hollnagel (2007: 35)

Figure 13 reflects the proactive part built into the simple feedback control. Now the model looks at anticipating threats. Hollnagel (2007) highlights that control of the system needs prediction. He goes on to state that you cannot walk in a crowd looking backwards or control air-traffic looking at past events.

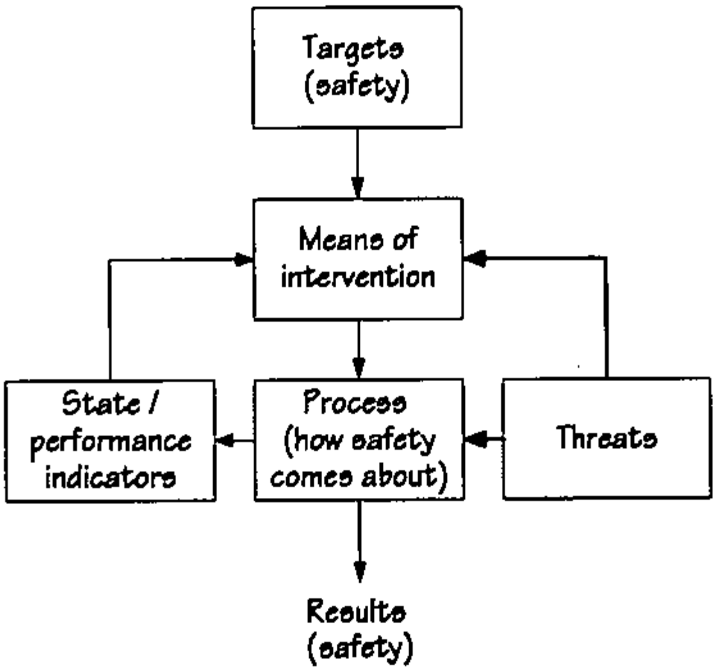

Figure 13: Reactive to Proactive Control
Source: Hollnagel (2007: 36)

The drawback on the above model is that it does not give a holistic picture. As much as there is feedback it does not reflect how the learning is taking place to ensure that behaviours are changed and that the response is not merely local fixes.

4.4 CONCEPTUAL ERROR MANAGEMENT MODEL

The conceptual error management model that the researcher is proposing is based on theoretical backgrounds of errors suggested by Norman (1981), Rasmussen (1982), Reason (1997), Perrow (1984), La Porte and Consolini (1991), Hollnagel (2007), Cooke (2004), Dekker (2006), and builds on some of the models reviewed above together with the feedback received during the qualitative research which will be discussed later in this research study.

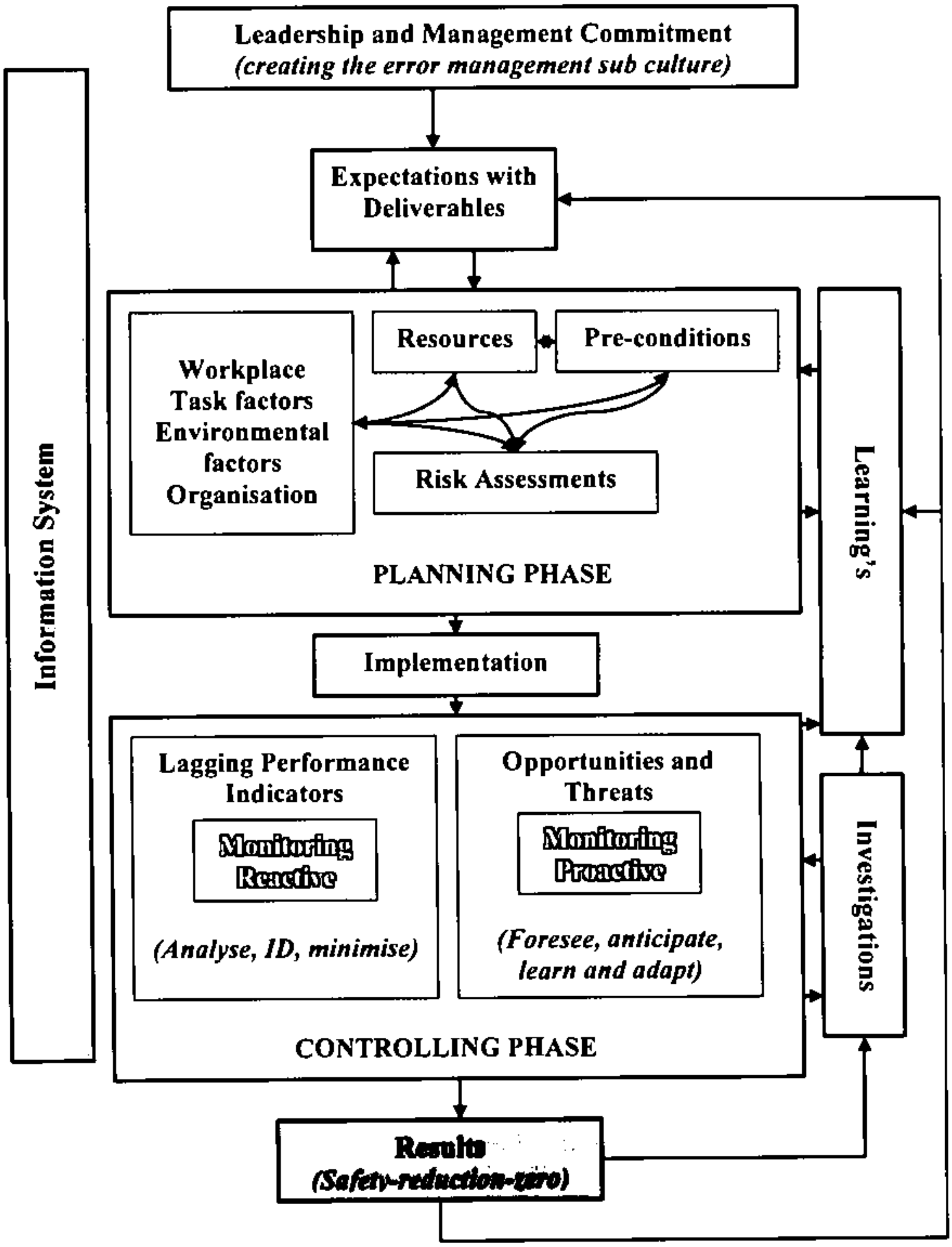

Figure 14: Conceptual Error Management Model

Moving to the planning phase and building on from chapter three, the planning phase takes into account the individual, the organisation, the task and the environment.

When considering the individual these are the aspects that need to be considered; unfamiliarity with the task, first time or second time on a task, lack of knowledge (mental model), new technique not used before, imprecise communication habits, lack of proficiency, inexperience, indistinct problem-solving skills, unsafe attitude for critical tasks, illness, fatigue, stress, habit patterns, complacency, overconfidence, mental short cuts or biases, and inaccurate risk perception.

When considering the organisation these are the aspects that need consideration; leadership, culture, communications, work patterns, and resources provided. The task factors should include time pressure, multiple tasks, repetitive action (monotony), irrecoverable acts, interpretation requirements, unclear goals, responsibility, and lack of procedures or standards.

The workplace, situational and environmental factors will include; weather, lighting, noise, distractions, interruptions, changes from routine, confusing displays or controls, unexpected equipment conditions, team dynamics, and lack of alternatives. All the above will be impacted by the pre-conditions, the resources required or provided which will form as inputs into the risk assessments.

The pre-conditions reflected in the planning phases are the conditions that must be fulfilled in order to perform the function safely. If they are not fulfilled properly, there will be a possibility of EPCs described in HEART. The pre-conditions help in the error prevention. As discussed in chapter three Reason (1997), Reason and Hobbs (2003), Peters and Peters (2006) and Busse (2002), suggest the policy, standards, procedures, manuals, rules and regulations, training (institutional and on-job) and retraining, work planning and work scheduling, work orders or job cards, work instructions, tags and reminders (Permit systems), selection of appropriate skills, handover procedures, human resource management, maintenance management, breakdown/emergency management, overtime controls, authorisations and certifications, checking and sign-offs, audits, disciplinary procedures, job observations ,risk analysis, toolbox talks and pre-job briefings as pre-conditions for error prevention.

The risk assessment receives input from the two facets described in the planning phase together with the resources provided. In some cases the risk assessment may indicate that more resources are needed and will therefore act as a feedforward and feedback loop. You may get a case that the resources are a constraint so no feedback loop will be provided. The organisation or the operator will then have to work on the principle of as low as reasonably possible (Peters & Peters, 2006; Hollnagel, 2007).

As soon as the risk assessment is acceptable following the models provided in chapter three, the "do" aspect of the quality management process (ISO 9001), can be completed. In the case of the model it reflects implementation.

In order to control the output towards safety and reduction of errors the models proposes monitoring or performance indicators similar to that of Hollnagel (2007). An error management model should define positive indicators and clear targets. The targets should reflect the criteria for acceptable performance. This requires in-depth knowledge of the nature of the organisation and its operators, task activities and the situation and environment where the interactions between designers, management, operators and equipment take place. The pro-active monitoring will evaluate the opportunities and threats. It is built into the proactive facet, resilience in which the operator or the organisation is expected to foresee threats not from that which was experienced previously but from new threats or error conditions that can be anticipated. The caveat will be that these do not materialise or unforeseen or anticipated errors are encountered. This may occur because the operator or management cannot ask the right questions, they do not know what it is they do not know (Metcalfe, 2005). Any learning from the proactive monitoring is looped back into the planning phase without going through an investigation so that it can be evaluated during the risk assessment.

With the reactive monitoring the goal is to reduce or eliminate known errors. The reactive monitoring sees the future as a repetition of the past. Error patterns are the same and no learning has taken place in the organisation.

Using proactive monitoring, the goal is to anticipate, look for opportunities and threats to respond to errors, both that have been encountered previously and those that might be encountered. This reflects that learning has taken place or learning is taking place. Recognition is given that the present is not the same as the past and the future may not be the same as the present (Hollnagel, 2007). By adapting the planning and controlling phase in the proposed error management framework, the organisation will reflect its striving towards continuous improvement similar to that practised by quality management systems such as ISO 9001.

If the process was done correctly, the results should be a safe error free execution or provide some precursors that can be investigated. What the model reflects is that the facets of investigations and learning can take place at any time during the process. It does not need to follow a sequential order. For example, an investigation may trigger a new performance indicator to be measured or a threat may lead to an investigation before an undesired error with subsequent consequences is experienced. During the process of implementing before the final result, continuous monitoring is suggested. New learning need not go through an investigation process. The investigation process can use accidents models suggested by Reason (1990) or Leveson *et al.* (2003).

One of the key aspects to the model is the learning facet. Learning implies that the behaviour needs to be modified as discussed in Chapter 2. In order to learn from the precursors it needs to be reported. Therefore in the model the learning facet is linked to the planning, controlling, result and investigation facets. The precursors are building blocks to accidents. One of the aspects that need to be set for the model will be the reporting threshold. Setting the threshold to high may lead to risk significant events that may not be reported. Too low a setting may mean that the system becomes overburdened and no analysis will be done which may lead to the perception that the system is of very little value.

Because you have more precursors than actual accidents (refer to figure 4 and figure 5), more data is collected which will help in trending the safety system and give an indication if the organisation is drifting towards the boundary of safety (Hollnagel, 2007; Leveson, 2002). Actions can be taken to reduce the risk. The learning from the precursors will help improve organisation awareness of the human error problems (Weick & Sutcliffe, 2001).

Even when zero accidents are achieved the learning through the higher number of near misses can help reduce complacency and encourage dialogue (Bird & Germain, 1996).

To benefit from the reporting, an information system is overarched across the complete error management framework as per the studies from Barach and Small (2000), Bier and Mosleh (1990), Jones *et al.* (1999) and van der Schaaf (1992). The information system should be available to all staff. It should be able to receive reports unanimously. It must be capable of providing the latest standards, procedures, policies etc. It must reflect the analyses of all incidents reported and what the learning points for implementation were. Ideally the screen saver should provide flash reports for any recent events and provide a cautionary warning.

The system should trigger each employee for a close out for any incidents that may have an impact on them. It should have an audit system that will facilitate objective evidence that learning has taken place and that corrective action has been implemented. It should also reflect the positive through email broadcasting of milestones achieved, for example, Lost Time Injuries or number of near misses reported that resulted in changes of procedures, designs etc. The information system must be the enabling tool for the error management system so that learning and continuous improvement is achieved.

Bagain (2004) suggests that the success is not about counting the reports but using the precursors to implement corrective actions. Analysis and actions are keys and success is manifested by changes in the culture of the workplace. He goes on to say that change does not happen overnight, it takes time.

Reason (1997) points to several shortcomings of what he calls error management techniques. Although it has proven value, these existing forms of error management have a number of limitations, particularly narrowness of focus. In brief, they tend to be piecemeal rather than planned, reactive rather than proactive, fashion-driven rather than theory driven (Maddox & Reason, 1996; Reason & Hobbs, 2003).

The error management model presented is holistic rather than piecemeal, provides for both reactive and proactive measures. The model is based on theory as well as established principles supported by the likes of Reason. During its application the organisation can determine areas in which more emphasis is required due to barriers that may be inadequate that may need strengthening or mindfulness. While focussing on a specific aspect of the model the organisation is reminded that the model will guide the reduction and containment of errors if all the aspects are considered due to their interdependence. The model reflects the complexity in which the organisational system works.

4.5 CASE STUDY

A case study will be presented in which the different facets of the model can be evaluated to reflect if there are any opportunities for error reduction through applying the model.

On 06 March 2006, at 18h38, Bridge 7 275kV breaker was energized with all three phase portable earths still applied on the transformer side of the breaker. This resulted in 100% dip lasting for 63 ms on the 275kV busbar. The loss of voltage on the 275kV busbar resulted in the station tripping and a loss of 790 MW import at Apollo and minor damage to equipment.

Summarised Sequence of Events - On Sunday 05 March 2006, the controller on shift started work at 7:00am. At about 11:00 while removing the earths on filter 1 he was distracted to do other work. At 13:00 he indicated he was tired and took a short lunch break.

During the short break he was requested to do further operating. He was asked to do this last amount of operating as further operating will be done by the afternoon shift. He was later informed that his reliever phoned in sick just 45 minutes before the start of his shift. This meant that the already exhausted controller now had to carry on working for an additional four hours (A total of twelve hours excluding travelling time). The controller wrote instructions for removing earths on bridge 7 but left out the instruction for the removal of earths on the transformer side. The senior controller on shift read the instructions and counter signed to acknowledge that the instructions were correct. The controller proceeded to remove earths from bridge 7 as per instructions. The controller did not see the earths on bridge 7 transformer side. The controller removed the portable earths on the valve tank and proceeded to the earth switch. As the controller went pass the transformer 7, the controller saw earths on the floor. In the controller's mind the earths on the ground was an indication that earths were already removed. The controller did not look up onto the conductor to see if the earths were applied. The controller reported back to a different senior controller - who had just arrived for the afternoon shift. The senior controller asked the controller if he had checked that the panel is clear of all earths and the controller responded by saying yes. The senior controller then recorded the operation in the log sheet. At 20h04 the senior controller switched bridge 7. The station immediately tripped with a very loud bang resulting in 790MW import loss from Songo.

Summarised recommendations - The line manager to withdraw the authorization of the controller and re-authorize him and consider the same for the other senior controller and controller. For pole and station outages, there should be two operators on shift during the start of the outage and at the end of the outage to cope with the volume of operating. Refresher training for the controller is needed. The line manager is to take appropriate disciplinary actions.

Additional Information - This is not the first time that earths have been left on equipment. Shortage of staff was a known problem.

Applying the error management model - The model in this case study will be used to show the gaps in the different facets identified by the model.

ERROR MANAGEMENT FACET	FINDINGS	COMMENTS
Leadership Commitment	No commitment due to outstanding issues not resolved.	Leadership in this case could be the line managers, senior controllers. If the line management were committed to safety staff shortages should have been resolved.
Planning **Task, organisation, individual, environment, situation factors**	There was no consideration given for the workload, the manpower skills needed, the physical task that had to be executed which led fatigue, work patterns, multiple task requirements, distractions, changes in routine working hours	Not all human factors were identified in the investigation or prior to the job being done
Pre-conditions	Working planning and work scheduling was inadequate, permit system deficient, handover procedures inadequate, human resources insufficient, overtime control, checking and sign offs by senior controller, task analysis There was no risk assessment done	By not filling the requirements of the pre-conditions, this led to the error producing condition (EPC)
Risk Assessments	Inadequate number of earths for the substations, Inadequate number of operators for the day	Not reflected in the investigation report
Resources		The resource requirement is impacted by the human factors, pre-conditions, and feedback from the risk assessment. Since none of these were done adequately, the resource provided for the day was insufficient.

Reactive Monitoring		Opportunity to analyse previous incidents not clear from the case study
Proactive active Monitoring	It is inferred from the holes in the defences discussed above that no proactive monitoring is taking place.	There was an opportunity to do job and behavioural observations which would have highlighted some of difficulties experience by the operator which could have resulted in a different plan of action or different mitigation for risk.
Investigations	The domino model was used. The stop rule for the investigation appears to be finding the operator guilty. The recommendations will not prevent a similar incident happening again. It reflects the trap of training and retraining and disciplinary action.	If the epidemiological model was used, it should have at least mentioned the shortcomings of management. See figure 7 and figure 8.
Learnings	Similar incidents from previous incidents have not been learnt due to the behaviour reflected by both management and the senior controllers.	To learn from previous incidents, a change of behaviour must take place. To enforce the correct behaviour management must use reinforcement theories to get the operators and themselves to exhibit the desired behaviour's.
Information system		Not clearly highlighted in the case study but should provide the opportunity to capture the incident and ensure that the learning takes place at all sites and not this specific site. It should also show how many similar incidents occurred and if this particular business unit closed out its actions or learning from similar incidents.

Table 3: Case Study using the Model

The case study using the error management model clearly illustrates the benefit of taking a holistic view of error management. If focus is only piecemeal then the solution will only be piecemeal. This will leave gaps in the defences which could lead to further incidents. In taking a holistic view of error management, effective correction actions will be made and by having a management information system that can track the implementations of the corrective actions learning can take place. Management must ensure that they reinforce the behaviours and keep the operators motivated.

In addition to this a second case study describes a virtual implementation that was done at the same business unit from the 15 November 2007. Management's expectations were expressed that there should be no accidents for the duration of the project at the said business unit. The human factors, preconditions and high level risk assessment (risk assessments need to be done on a day to day basis and detailed task analysis for each job) were discussed. Based on the discussion of the planning phase a supervisor that did not meet the pre-conditions was requested to leave the site, more resources were provided by the contractor. As part of the reactive monitoring previous incidents at other sites were discussed and shared by all. The proactive monitoring included seeing a risk that did not exist at other sites and as an example a new safety fence was installed. Job and behavioural observations were requested by all staff. As part of encouraging reporting, management made the commitment that nobody will be disciplined for reporting near misses or unsafe acts. A manual book was left in the control room for anyone to report near misses, unsafe acts or conditions without putting their names to it. In less than two weeks more than 23 unsafe acts or conditions were reported. To emphasis the learning and behavioural change the information was shared with all people on site. The behavioural change was reflected when one of the contractors requested an Eskom staff member to leave the high voltage yard because he did not have a fluorescent vest. Information from these reported observations is sent through email on a weekly basis to other business units. There has not been a serious incident to be reported at this stage. It is early in the process of evaluation but the changes in behaviour are very encouraging when people are able to see the big picture.

The current drawback is that the management information system is manual and not accessible to everyone. Secondly, error management is a long term process that needs to be internalised by all stakeholders to gain real benefit.

CHAPTER 5: RESEARCH METHODOLOGY

5.1 RESEARCH PROBLEM AND OBJECTIVES

The research problem:

As discussed in chapter one, the aim of the research is to provide a holistic error management model that could be applicable to the Transmission Division that is based on theory, some error management principles and the qualitative survey feedback which will help in the reduction of errors.

The objectives are as follows:

- Perception of human errors
  - To identify primary themes on human error management from 'experts'.
  - To identify the views of the 'safety experts' and management views and perception of human error and error management in the Transmission Division based on the identified primary themes.
- Causes of Human Errors
  - To identify causes of human errors in the Transmission Division
  - To evaluate subsequent mitigation measures.
- Learning's from Human Error
  - To evaluate how learning is taking place from human errors

5.2 METHODOLOGY

The method of research proposed for this study was one of a mixed methodological approach. It is argued by Cooper and Schindler (2001), that by using diverse methodologies, researchers are able to achieve greater insight than if the researcher followed the most frequent method encountered in the literature or suggested by a disciplinary bias.

The primary method was a qualitative study via structured in-depth interviews which was preceded by discussions with two focus groups. The first focus group was the senior leadership of Transmission and the second group was the safety experts and safety practioners. The second method was analysing investigation reports to identified causes of human errors and the recommended mitigation strategies. Thirdly, case studies of two events were used together with document analysis of historical or secondary data reports on human errors within the Transmission group to evaluate the conceptual error management model.

5.3 THE QUALITATIVE STUDY

The intent of qualitative research is "to answer questions about the complex nature of phenomena, often with the purpose of describing and understanding the phenomena from the participants' point of view" (Leedy & Ormrod, 2001:101). As human error in Transmission is complex by nature, it is important that the views of the Transmission leadership, management and operators who are generally vulnerable to human errors are heard. Through this qualitative design, content analysis will allow the researcher to be systematically examine human error in order to identify patterns, themes or biases in Transmission so that an error management framework can be conceptualised.

A qualitative approach was proposed for several reasons:

- the purpose of the research is to describe and explore,
- the variables are unknown,

- the research is context bound and encompass personal views,
- the samples size is small, and
- in-depth semi-structured interviews were used to collect data.

The in-depth semi-structured interview usually revolves around central questions (Leedy & Omrod, 2001). These questions were aligned with the objectives of the interview in order to extract useful information regarding these central themes.

The advantages of using in-depth semi-structured interviews for data collection are:

- Historical information is provided by respondents
- The environment and questions are controlled by the researcher
- Large amount of useful information is received
- There is flexibility which allows the researcher to prompt and probe as necessary
- It allows for clarification immediately where there is misunderstandings
- It enables the researcher to take cognisance of non-verbal behaviour

One of the key disadvantages is that the researcher by the very nature of his presence may alter what people say and how events unfold.

5.4 SAMPLING METHODOLOGY

The types of people interviewed have been selected in order to get a cross section of 'expert' opinion from safety advisors, safety practioners, management and consultants. Due to the nature of the 'expertise' required the targeted group can be regarded as purposive due to the specific interviewees being knowledgeable to answer the research questions.

Due to the nature of the way the study was conducted, no attempt was made to ensure that the sample was random or that the sample represented the Transmission employee mix. Due to the exploratory nature of the study, the study is subjected to what Cooper and Schindler (2001:139) refer to as "old biases about qualitative research: subjectiveness, non representativeness, and non-systematic design".

5.5 THE RESEARCH POPULATION

The population comprised of 'experts' in the Transmission Division as well consultants, who are involved in the study of safety. The research population was a cross-section of experts in their specific field. By the very nature of looking for experts in their specific field the sample size was small.

5.6 SAMPLE SIZE AND SELECTION

The sample size was small as highlighted above and the selection was purposive with the exception of the three overseas experts. The researcher intended to draw on the following mix of 'expert' interviewees, 1 Consultant, 3 safety advisors/internal consultants, 1 Managing Director, 2 General Managers, 5 line managers, and 7 safety practioners. During the period of the research the researcher was fortunate to interview an additional 3 safety experts from different countries overseas.

5.7 DATA COLLECTION

An iterative process of data collection was employed in order to incorporate new elements as they emerged from interviews (Strauss & Corbin, 1990). Following each interview, feedback was reviewed to identify emerging themes and highlight those previously suggested in the literature. Data collection was temporarily halted to review results and begin to name the key facets and primary themes.

A second set of interviewees were then conducted using the same process as the first. Once these interviews were reviewed, the first interviewees were re-contacted by phone to ask additional questions that emerged during the course of these interviews.

The prospective interviewees were contacted initially by telephone to inform him/her of the purpose of the study, subjects to be covered and the research process, including the expected duration of the interview. The researcher invited the prospective interviewees to participate in the study. If the person was willing, an appointment was set-up to explain the study in further detail and to conduct the interview. An email was sent thanking the respondent and the respective supervisor or manager for their willingness to participate in the study. The place, date and time of the interview were confirmed. In line with the expectancy theory discussed in chapter two, each respondent was offered a summarised presentation of the research findings. This was an incentive for participating in the study and highlighting what the benefit to the interviewee and to Transmission which may result from the study. Importantly, respondents were guaranteed that their responses would remain confidential and anonymous.

The in-depth semi-structured interviews took place at the site of most of the interviewees. Of the interviewees who were from the coastal areas, their interviews were held in Johannesburg when they came to attended meetings or perform other duties. This was done to save on cost. Their work sites were thought to be suitable locations as it was convenient for respondents and more likely to put respondents at ease while talking to the researcher. Each interview was minuted. In addition to field notes (minutes), some digital recordings were made for ease of cross-referencing of information. The duration of the interviews was on average two and a half hours.

The protocol format suggested by Creswell (1994: 152) was followed for each interview. The components of the protocol are a heading, instructions to the interviewer (opening statements), the key research questions, probes to follow key questions, space for recording the interviewer's comments, and space in which the researcher records reflective notes".

The objectives of the interview process were to explore the research problems and to meet the objectives identified.

5.8 RELIABILITY AND VALIDITY

The validity of an instrument is how well it measures what it is supposed to be measuring, while reliability refers to the accuracy and consistency with which the instrument produces results (Leedy & Omrod, 2001).

5.8.1 EXTERNAL VALIDITY

The sample used for the qualitative study is purposive in nature and small in number. It would not be possible to generalise the opinions and views of these subjects across all persons in the population. However, the purpose of the qualitative study is to validate the facets of error management in Transmission identified through the literature review.

5.8.2 INTERNAL VALIDITY

As already mentioned the main purpose of this qualitative study is to provide evidence of whether the theoretical facets of error management as identified through the literature review, adequately cover those experienced in practise. This study is therefore in itself an internal validity check.

Leedy and Omrod (2001) highlight the fact that in qualitative research the researcher's biases and values will always influence the interpretation of the data. It is for this reason the researcher will seek varying perspectives from multiple sources (safety experts, managers and consultants) during this phase of the study.

5.8.3 RELIABILITY

The researcher personally conducted all the interviews in order to ensure equivalence.

5.9 DATA ANALYSIS

The transcripts from the in-depth interviews were content analysed as indicated previously. The responses were arranged according to the error management facets developed through the literature review. The data was then grouped, analysed and compared with the facet to which it relates. Data that does not relate to a particular facet was grouped and assessed for any indication of a pattern or trend. The results from this analysis served to confirm, question the existence of, and suggested additional error management facets not already considered in the conceptual model for error management as proposed by the researcher.

The data analysis activity took place concurrently with the collection and interpretation of the data, and the writing of the report. This is different to quantitative research where the process is linear (Creswell, 1994).

In addition, each identifiable theme uncovered in the transcripts was tabulated and displayed graphically. This informed the researcher as to the perceived importance of the identifiable theme across the respondents. No statistical analysis was performed on these results.

CHAPTER 6: RESEARCH RESULTS

6.1 INTRODUCTION

This chapter will provide the findings from the expert interviews, group discussions and literature review, analyses of investigation reports and records from 1999 to August 2007. It also provides the findings from the case study. The findings will be presented against the objectives as set out in chapter one. The chapter will conclude with a review of the findings against the research problem.

6.2 PROFILE OF INTERVIEWEES

Initially, the researcher intended interviewing just one external expert but was fortunate to get four external experts. The four external experts were from Belguim, Ireland, Austria and South Africa. They had a minimum of five years experience. The expert from Belguim worked with the chemical industries, the expert from Ireland worked as an inspector for the Health Safety and Environment (HSE) inspector and therefore had exposure to many industries in ensuring that industries were compliant to the local occupational and safety act, the expert from Austria, was a in the oil and petroleum industry driving a program of safety improvement and the South African external expert was a director of a an international company but now consults in safety for a well recognised international brand.

The rest of the 'expert' interviewees had significant experience in Eskom. The interviewee with the least years of experience was twelve years. Many of the interviewees had an engineering background with the exception of the safety expert and safety practioners who have training and qualifications in safety.

6.3 PRIMARY THEMES AND EXPERT VIEWS

The first objective described in chapter one, was to identify primary themes on human error management from 'experts' and determine what are the 'safety experts' and management's views and perceptions of human error and error management in Transmission. The following has emerged from the group discussions, literature review, and expert interviews. The primary themes that have been identified are as follows:

- Leadership and Commitment
- Learning
- Investigations
- Reporting
- Risk assessments
- Error management system

Based on the content analyses, Figure 15 shows the findings as percentages relative to each theme. The theme with the highest percentage was *error management* with 22% while *support* was 1%.

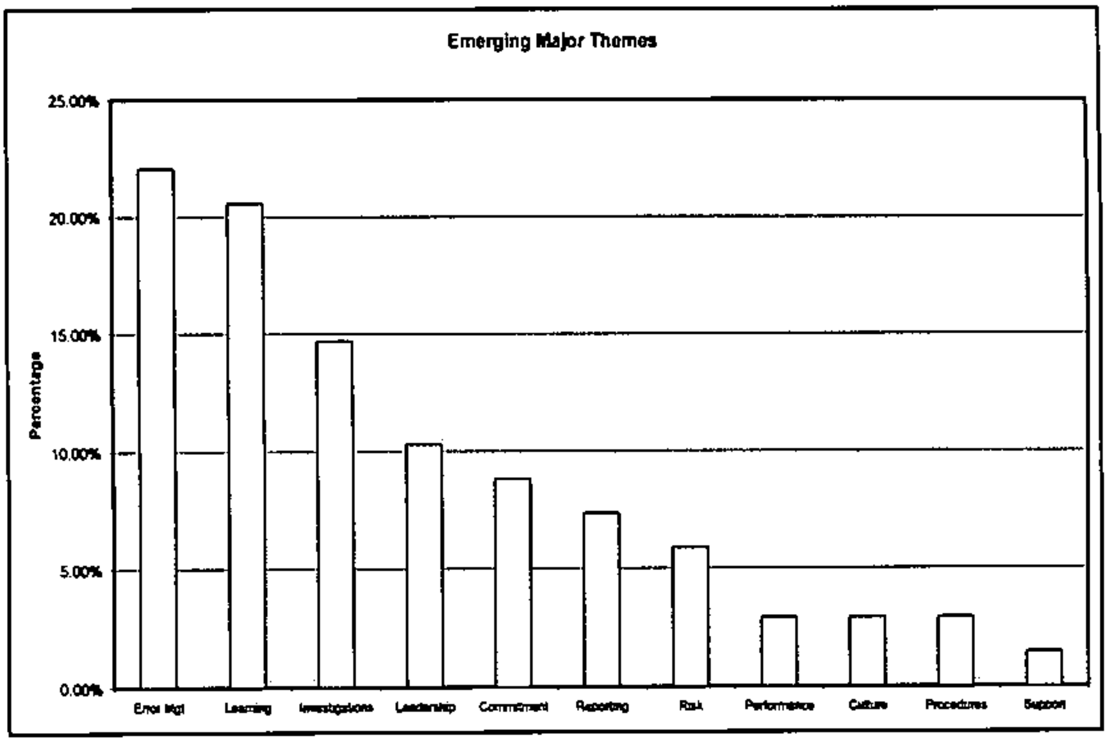

Figure 15: Emergence of Primary Themes from Group Discussions

The next few subsections describe the findings of the views and perceptions of the 'experts' based on the primary themes that emerged. The views are based mainly on the in-depth interviews.

6.3.1 LEADERS

There was a general feeling that the Managing Director, Transmission's Executive Committee members and Management are committed, but as some respondents noted that there is always room for improvement. The senior leadership of Transmission are going through some leadership interventions; these interventions are creating a positive belief system towards safety. Leaders' attitudes towards safety are generally positive; and they felt that safety is very important but did not express what was meant by important. There was, however, one respondent that had a strong opinion and expressed the following "My opinion is, Supervisors, Managers etc. just talk and do not express their expectations, they just go to interventions because it is expected of them, I don't think that it is real commitment."

In the view of the experts, leaders needed to be more visible to the coal face. The leaders needed to interact with operators to 'get back to basics'. The leaders need to express there expectation in a measurable manner so that when they are interacting with subordinates the distance to close the gap is visible to all.

Leadership expressed concern that due to operational pressures to get back the power some people cut corners but indicated that the safety policy is emphasised at every opportunity and people should be told that it is not acceptable to be unsafe or cut corners. Leaders indicated that they have never requested anyone to operator unsafe equipment or break the procedures.

There was also the perception that Supervisors and Managers did not know any better certain aspects of safety better than their own staff. While there was a visible change in the attitude from some of the senior leadership, it has not effectively filtered to the rest of the division.

The experts suggested that during senior leadership walkabouts safety must be re-emphasised. Leaders must be more committed by demonstrating their learnings and give clear direction by expressing targets and providing feedback on human error performance across the division.

Finding; The responses as described above, are supportive of the leaderships attitude to safety but is absent of a deliverable expectation that is visible to all stakeholders.

6.3.2 LEARNING

As learning emerged as one of the primary themes but was also the third objective of this study, the findings will be discussed under learning from human errors later in this chapter.

6.3.3 INVESTIGATIONS

It appears to be that different approaches are followed for technical investigations and safety investigations. However both tend to use a sequence of event model to varying degrees.

The safety investigations for personal safety use a domino form. One respondent indicated that "... I don't' follow any recommended report format, it is dependent on the incident." The technical investigations appear to use a sequence of direct causes, root causes, etc. In general there is support that there is a standardised form for technical reports which allows common data to be captured for long term comparison and trending.

In the investigations, the reviews, sequence of events and adherence to procedures does not really consider system related symptoms, as incidents are reviewed in isolation. Root causes are not always done to check deep for latent conditions. The short coming is that the domino form does not go all the way back to the highest accountable officer.

The domino forms take human factors into account at a superficial level. Human factors are not always established. Human factors tend to surface if no good technical explanation for error can be established.

There was mixed feedback on whether incidents are thoroughly investigated. Some of the respondents felt that the Business Unit Manager must be involved in the investigation, if not involved as a chairman of the investigation at least to be personally debriefed rather than just receiving the report. There was a suggestion that technical incidents were more thoroughly investigated compared to safety related incidents. The detail of the investigation also depended on the consequences. For example, for a fatality there is an internal, as well as an external investigation normally chaired by an advocate. The major technical investigation is investigated by the corporate technical audit department and in some cases external consultants. An example of external consultants was given of the investigations done due to the power shortages. The investigations were done by two independent consultants, namely, EPRI and CIGRE, both international bodies that generally set the technical standards and direction for utilities.

Audits are another form of investigation. It was suggested that technical audits add value but respondents were not sure that safety audits add value. Reference was made to the Risk Auditing System (RAS). There was consensus that it was in place but that concern was expressed that it was not effective because it was paper based. RAS did not help in showing the blind spots on improving safety or human errors. It only helped with compliance. There was a feeling that the audit should include operational and practical actions or observations. The audits should be unannounced.

There was also concern that too many audits adds distraction and results in distrust mentally. The conduct of the auditee during audits is therefore to highlight the good and see if the auditor can be kept in the dark on the risks. It was suggested that the organisation will require a culture change to view issues such as negative audit findings and non conformances in a positive light and view it as an opportunity to learn.

Finding: The investigations are mainly based on a sequence of event model. Investigations may miss systemic causes by considering only causes in a direct, linear chain of causation.

6.3.4 REPORTING

Reporting is neither encouraged nor discouraged. Respondents felt that there is generally no system for reporting. Reporting is seen as a hassle. There are some who do not know to whom the report should go. With respect to technical errors there is no forum to which the errors can be reported. There seems to be no clear indication on what is a near miss. The BU Management believe that it all comes back to management. The importance of reporting such incidents is not appreciated. It is felt that even when an operator is in a near miss situation, the operator feels that he has dealt with the situation so there is no need to report it. As one respondent said "the situation is dealt with and no value will be gained reporting it".

Some indicated that they may not be aware that they are breaking any rules. The reason why some do not report near miss errors is due to time, fear of blame or branding. It was also indicated that it could be due to lack of focus and reward. The one Line Manager indicated that it was too much paperwork. The system was not easy to report. One of the respondents felt it was perhaps our culture both in the organisation and the country. It is preferable to speak one on one rather than point at a "culprit" and provoke confrontation by reporting an action.

Respondents felt that if there was a shared belief that it really makes a difference and not just another paper exercise they would be encouraged to report. Some felt if there was something positive in it for them and there was no reprisal they would report.

Due to the current reward system that measures operating errors as a KPI, there was agreement that some errors are "covered up" to a certain extent but that it was not widespread.

It was repeatedly suggested that it may be cultural as suggested by the following quote "It is what our legal system teaches us that you do not plead guilty and are innocent until proven guilty". However, it was strongly felt that "covering up" errors is not sustainable and will lead to more and more deception. The Barring Bank was quoted as an example where the one investor kept hiding losses which led to the eventual collapse of the bank. A similar situation for the business unit or the organisation was possible. In many cases it was reflected that staff will rather fix issues than declare it. Respondent TSPM1 said "I have not seen Managers in our area try and incorrectly report incidents. There is a lot of haggling taking place about definitions and interpretations when it comes to KPI's. The objective is not to look worse than you can. This is a form of covering up of incidents. Stick to the rules of the definition and not the intended spirit."

When asked what could be done to encourage reporting the respondents felt errors occur on a daily basis of both hard technical errors as well as of soft non-technical errors. Managers and supervisors must be forced to submit a monthly report on incidents; zero lists should not be accepted.
More visibility from senior management encourages discussions and sharing. The discussions and sharing should take place not only with direct subordinates but with all staff and contractors. Open declaration and sharing of management errors will encourage others to declare.

Finding: Barriers to reporting included the lack of a reporting system, fear of branding and discipline, lack of reward and lack of time to complete reports.

6.3.5 RISK ASSESSMENTS

The response on risk assessment was as a primary theme low. All respondents reflected the need for training in risk assessments. It was highlighted that operators are trained in the identification of risk but as the one respondent replied "...the operators are well trained to identify risks. What we find however is lack of discipline in applying the training".

Risk analysis is often being done as a routine activity before getting on with the job. Experience is seen as valuable, but it can also create blind spots when considering new risks. There was a feeling that because the operators felt they were competent, this bred complacency, they think that they have the knowledge. Technical risks can also not always be anticipated given that it sometimes takes days to understand what went wrong in the first instance. Problems often occur when an operator deviates from planned activities and anticipated risks. There is a feeling that the risk assessment is done on instinct while some respondents felt that there is a high reliance on test features and procedures for doing risk assessments.

There are pockets of excellence but at the same time there is plenty of room for improvement. It appears that risk assessments are not done in the classic sense. It is a case of "hit and miss". There is no detail classification by the operators on how high or low a risk may be. It is left to the individual operator and this is where experience or the lack thereof plays an important role. It was noted that in some cases the biggest challenge is attitude not knowledge.

Finding: Risk assessment training is provided but the risk is not appreciated and tasks of significant risk is inadequately assessed.

6.3.6 HUMAN ERROR CAUSES AND ERROR MANAGEMENT

The experts felt that the current issues in human errors are: capacity, skills, distractions, discipline, workload, pressure, stress, under resourced with respect to manpower, motivation, disregard for consequences, no fear, training, managers need to believe that human errors are preventable, state or well-being of workers, organisation process that inhibit workers' performance. However, not all respondents were able to give a detailed list of the errors. Some were only able to provide three or four even after being prompted by the researcher.

With respect to an error management system there was not one co-ordinated system. Each business unit had stand alone databases that related to their local incidents. Some respondents clearly indicated that they do not know if an error (safety) management system existed. There is a need for a system that has wider access and visibility to all staff. The local system did not adequately feed into a central system with the exception of high level monthly reports. Transmission Services had one individual that tracked operating errors on his local computer. Some analysis was being done but the safety expert felt that there was much room for improvement. Only major incidents were tracked and in particular the specific category of human error i.e. operating error because it was measured on some of the manager's performance appraisals.

If there was a proper error management system then there will not be problems were investigations where only done after four months as quoted by a respondent. Late investigations lead to incorrect reporting to the corporate office. This is seen as an embarrassment which may lead to incidents not being reported.

The interviewees where asked if there was a systematic error management approach in Transmission. There was no consistent answer. Some respondents did not know or where not sure. Some indicated that the approach that is used is to investigate, share and prevent if possible. As the one respondent replied "........think the approach we have is not really effective judging by the number of errors that we have ....". A reply by another respondent "in our environment senior staff are encouraged to review designs before it is signed off". After receiving these incoherent comments, the researcher phoned the in-house expert who confirmed that there was no documented system similar to the quality management system.

The interviewees were then lead by the researcher into determining if there was a need for a holistic error management system. The response was unanimous that there is a need. The request was for the system to be "deep" but simple. It must be able to be used from the operator to the managing director. It should have the capability to be generalised for safety and technical errors.

Finding: Firstly, none of the interviewees could provide information in a coherent manner to indicate what the highest risks in human errors are. Secondly there was no error management system.

6.4 CAUSES OF HUMAN ERROR

The second objective was to identify causes of human errors in the Transmission Division and to evaluate subsequent mitigation measures. The researcher analysed all the incidents reports from the financial year 1999/2000 until 30 August 2007. When there was any uncertainty the business unit concerned were contacted to provide additional information. The following figures reflect the findings.

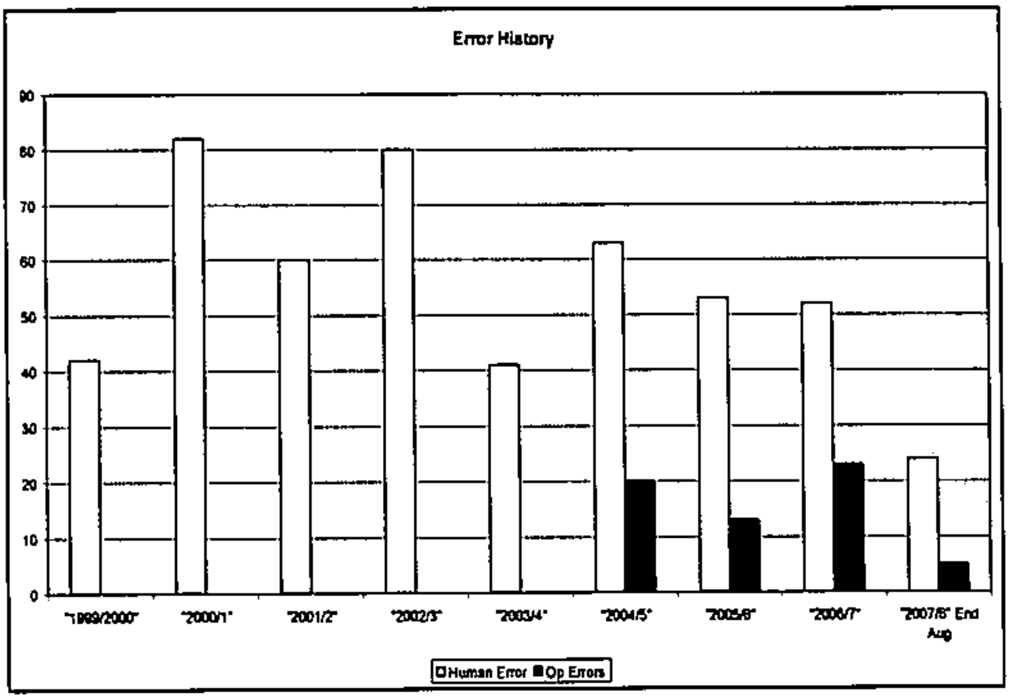

Figure 16: Reported Errors - 1999/2000 to August 2007/2008

Figure 16 shows the total count of reported errors during the period under evaluation. A total count 558 errors were recorded. The category of the human errors reflects errors by the secondary plant department, while the operating errors generally reflect errors made by the high voltage department and national control.

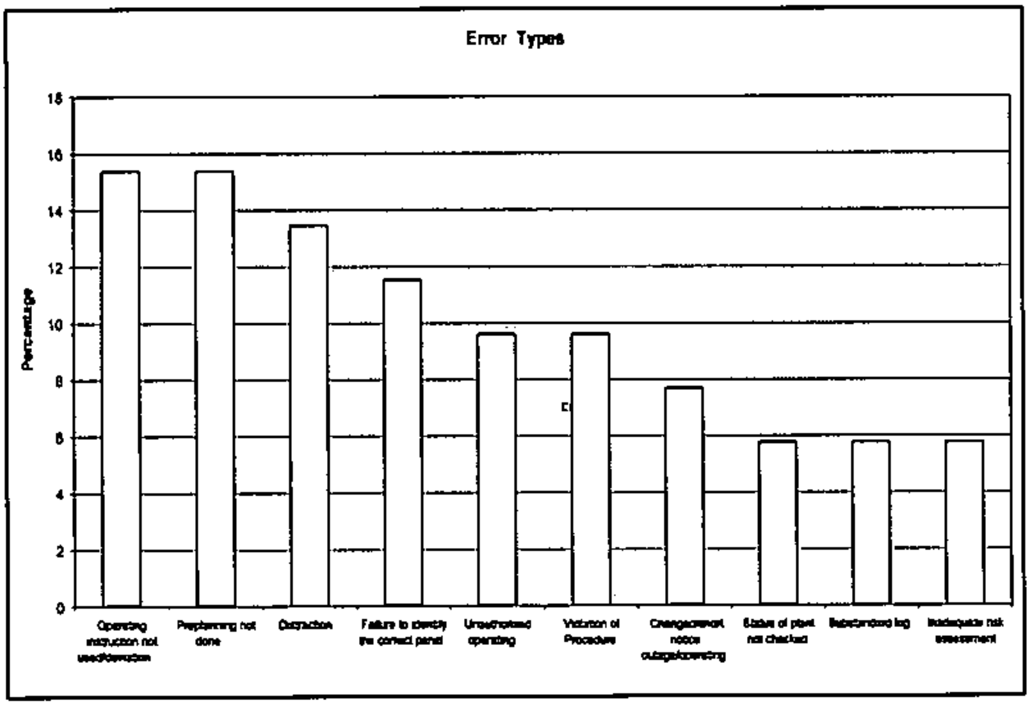

Figure 17: Error Types

Figure 17 reflects the causes of errors during the evaluation period. More than 70% of the errors are caused by not using or deviating from operating instructions, preplanning which is not done, distractions, failure to identify the correct panel, unauthorised operating and violation of procedures. If the above figure is evaluated against Reasons (1990) model for unsafe acts in Figure 3, the majority of the actions fall under unintended actions. The plan of action is satisfactory but the actions deviated from the intention in some unintentional way. This is as a result of attention failures or memory failures. However, what is also highlighted in the Figure 17 is violation of procedures. Reasons model sees violation as intended actions. The violation could be routine, exceptional, situational and acts of sabotage. The researcher could not find any evidence that any of the violations were due to sabotage. From follow up discussions with operators and managers it was established that violations were either routine i.e. habitual deviation from regular practices or situational i.e. non-routine infringement dictated by local circumstances.

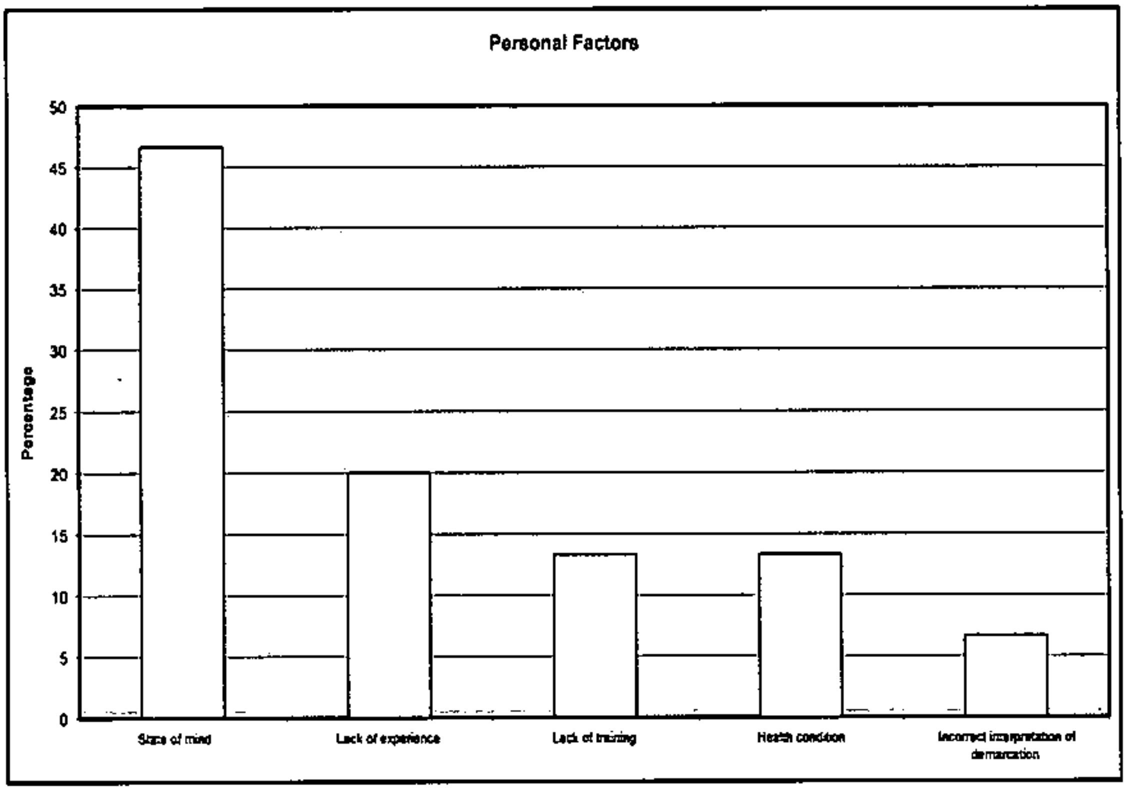

Figure 18: Personal Factors that contributed to Human Errors

A further cause that was identified included personal factors. This cause is similar to what Reason (1990) refers to as one of the major elements in the production of an error. What was very interesting was the high percentage (46%) that was attributed to state of mind. Upon further enquiries on this disproportionate cause relative to the others, it was identified that if an operator had problems at home as an example then the investigator put state of mind as one of the causes. It was never established that the period of the actual error; was when the operator was pre-occupied with his personal problems. There was no psychologist present in any of the investigations and none of the investigators had training in psychology to properly establish state of mind as a cause. In discussions with the experts it was agreed that the findings may be flawed. State of mind could possibly be a contributory factor.

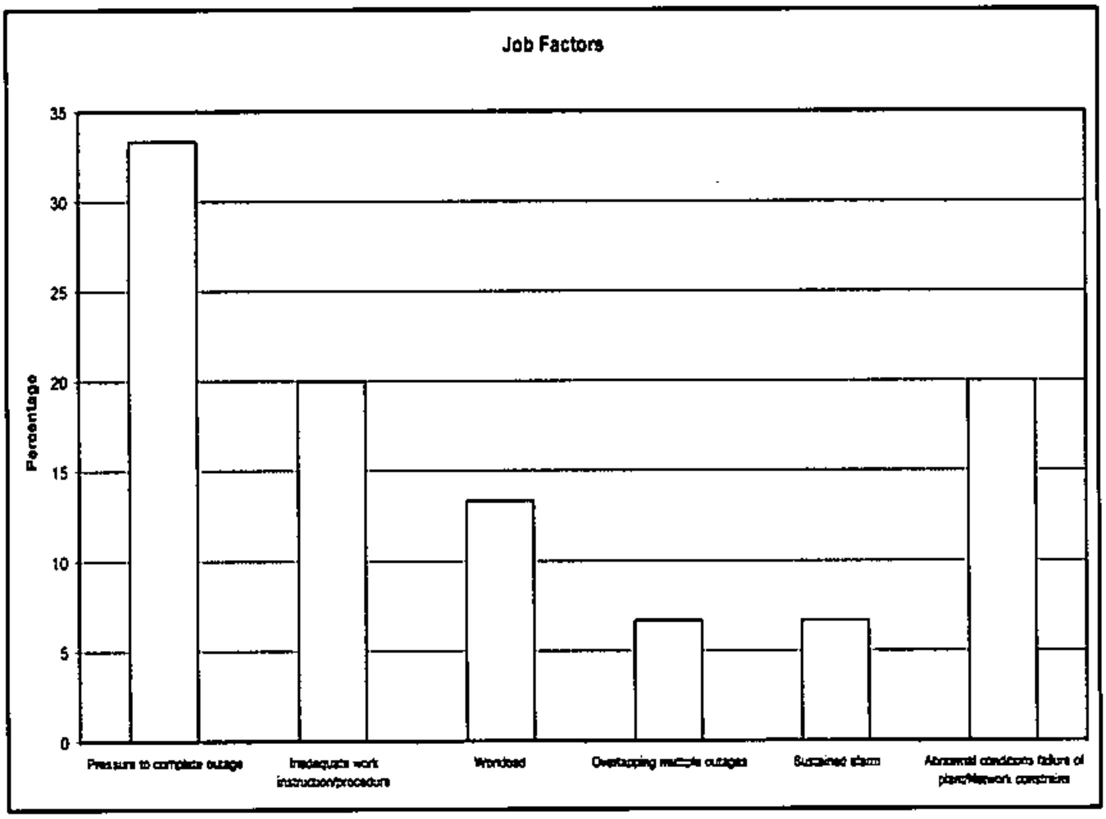

Figure 19: Job factors that contributed to Human Errors

The main job factors that contributed to human errors as shown in Figure 19 were pressure to complete the outage i.e. there was not enough time to complete the task because the power needed to return to service.

Even with the voluminous amount of procedures, some procedures were inadequate to effectively carry out the assigned task. Workload was also found to be an additional cause that contributed to human errors. Due to the nature of the power network workload was not a constant stream but came in "peaks and valleys" because it was not easy to switch off customers. Some of the maintenance work needed to be co-ordinated with customers, which meant that in some cases work needed to be carried out at odd hours of the day for extended periods.

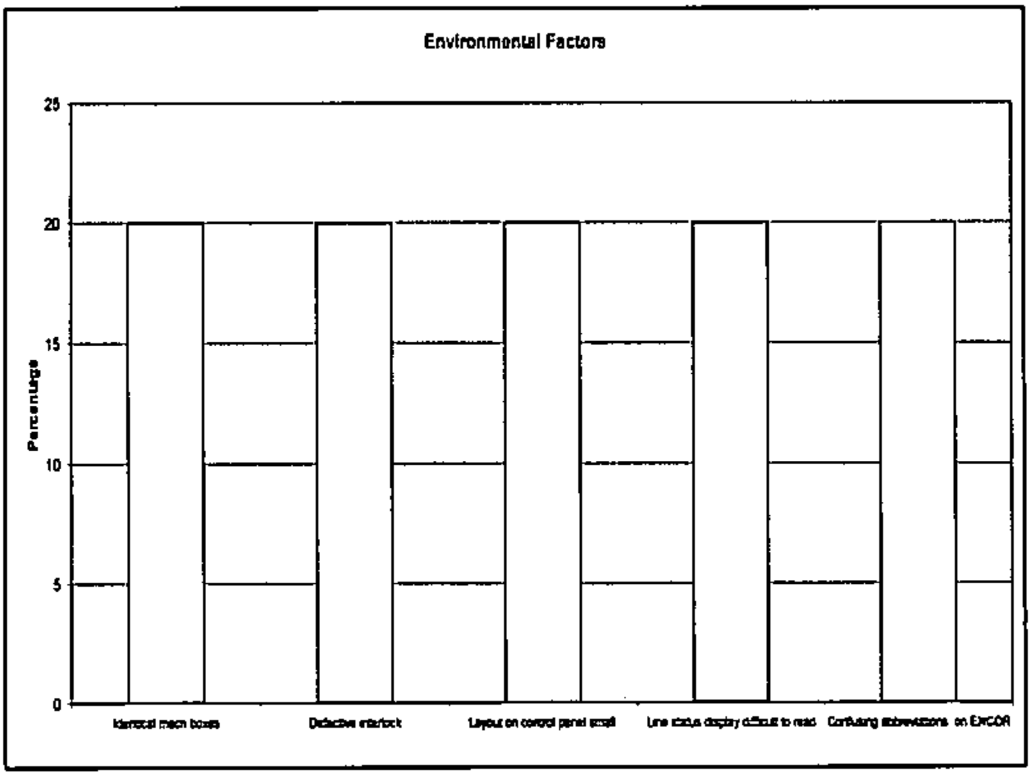

Figure 20: Environment factors that contributed to Human Errors

As environmental circumstances is identified as one of the three major elements in the production of an error, the evaluation of the errors with respect to environmental factors did not reveal any significant findings.

6.5 LEARNING FROM HUMAN ERRORS

The third objective was learning's from human error by investigating how learning is taking place from human errors. This was done by asking in-depth questions of the experts and managers. Learning was also identified as a primary theme.

There are many interventions and feedback from major accidents but these are not internalised by the staff. There is a view that it will not happen to me so the benefits of changing behaviour and attitude to some of the incidents are lost. Some of the respondents perceived that learning takes place but too many issues needed to be covered. They felt that issues are not sufficiently confronted. People do not like negative feedback even if it is constructive. Political games and image games are played.

There is always a political struggle although it is never admitted between different divisions, different business units and departments. Everyone wants to be the best or conversely no-one wants to be the worst relative to others. Managers and operators do not want to show weaknesses and would rather pretend that all is fine. There is insufficient trust between business units and between individuals. The opportunities to disclose errors so that learning takes place is lost by the distrust and politicking.

When asked if the interviewees believed that the collection and analysis of accident precursor data could improve safety, the finding from the feedback was positive i.e. there was support for precursor data to be collected and analysed. The respondents suggested that data to be collected should include results from audits, senior management walkabout, near misses, job observations, suggestions from safety, vehicle accident findings, spot checks, amount of work completed slower or faster than normal, traffic fines, pre-trip inspections and non-catastrophic plant failures.

As part of learning and changing the behaviour from the analyses of the precursor data, implementation of corrective action needed to be followed up due to various reasons including an inadequate reminder system and discipline, as was perceived by most respondents. There was a feeling that corrective action is not implemented consistently. It is dependent on the attitude. There is an initial surge of activity that decays as the reason for actions become old. There is a concern that what may be identified as corrective action may not be the true correction. Effectiveness of recommendations is not checked.

There was a general feeling that accidents can be prevented. However, there was a concern that some accidents are due to third parties, unpredicted failures and nature amongst others. Making mistakes was part of the process of learning but the experts felt that operators and managers do not understand the interaction of things before accidents will happen. The emphasis was not to repeat mistakes. They believed that operators and managers do not break things into smaller parts to understand the details. However some believed that operators and specialists concentrated on too much local detail and did not look at the complete system.

People tried to fix the issues themselves without seeking the help of the bigger division. There was overwhelming consensus that by learning and with dedicated effort changing behaviour that cause accidents by human error can be prevented over time.

What was also very interesting is that there are technical trainers in some business units but that there was no training department for the complete division. It was up to the local line managers and human resources managers to determine and locate the training that was required. This in some instances lead to frustration and overburdening on line managers.

Finding: Sufficient learning is not taking place even though efforts to teach are taking place.

6.6 ERROR MANAGEMENT MODEL

The aim of the research is to provide a holistic error management model that could be applicable to the Transmission Division.

An error management model was provided that is holistic and takes into account some of the advantages of existing stand alone models and builds on shortcomings from the model provided by Hollnagel (2007) and addresses Reason and Hobbs (2003) piecemeal approach to error management.

A case study was used to evaluate the model and it clearly indicated the advantage of using a holistic model to identify gaps that could be used from learning and which could contribute to human error reduction. The findings from the case study reflected gaps that were not identified for effective reduction of human errors. The model also reflects the interdependence of the different facets of human error and they are not always in a sequence. Through feed-forward and feedback loops continuous re-evaluation of the different facets can be reassessed.

Figure 21 was used in the case study and the results reflected in Table 3.

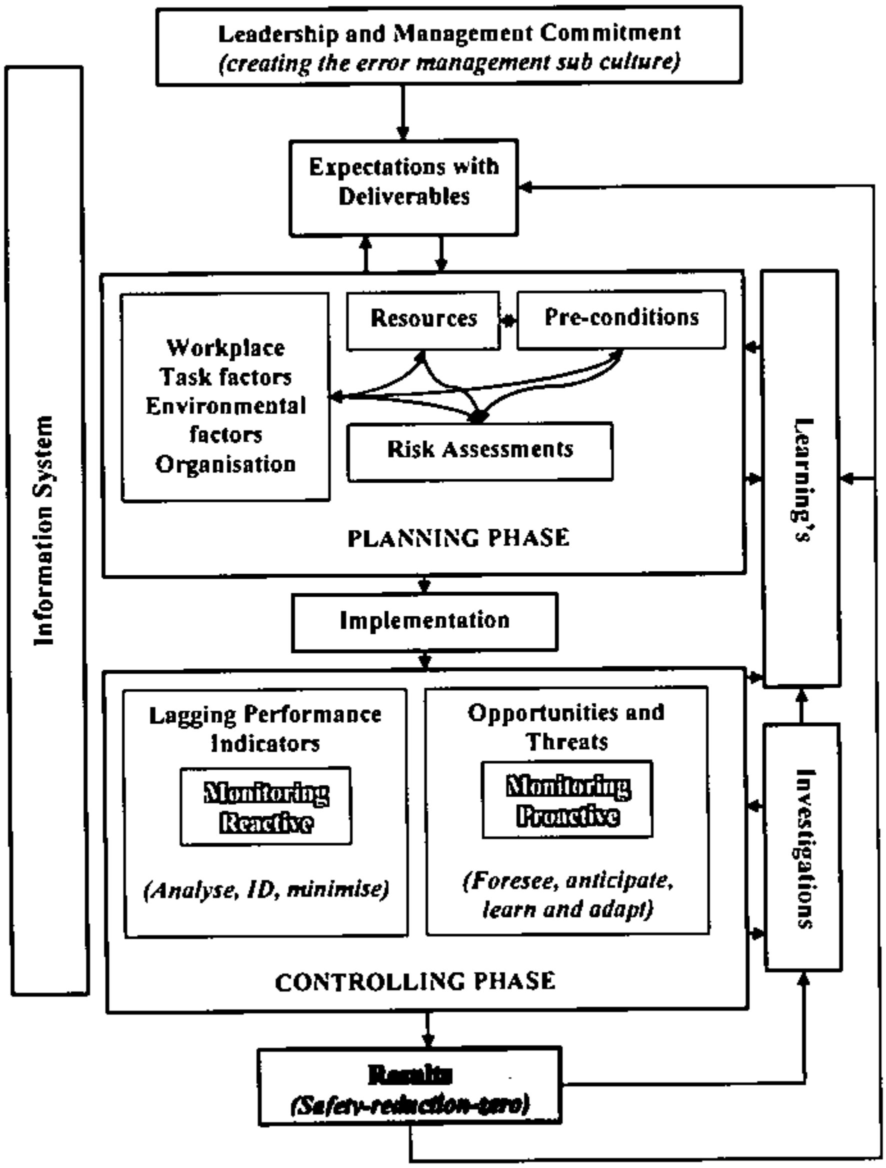

Figure 21: Error Management Model

The virtual implementation also provides support that the facets of this holistic error management model if implemented correctly can bring a reduction in human errors. The models also address concerns raised during the in-dept interviews.

The model is robust enough to be generalised but at the same time it takes into account the complexity of human performance by allowing other models to be incorporated. It is also good for directing the attention of the investigator to specific questions within the facets of concern such as local actions, immediate realities of the operational environment, and influences of organisational functioning. A final benefit is that the model is expressed in terms of general processes which are independent of functioning within any specific domain. This allows information from other models to be used in this framework

Findings: The responses indicated that there was an absence of a holistic error management model. The model presented provides Transmission with an error management model which closes the identified gaps.

6.7 SUMMARY OF FINDINGS

In summary, the responses indicated an absence of a comprehensive, holistic plan to reduce errors. The variety in the responses also indicates that the business units do not know what is expected of them in terms of continuous error reduction programs.

- *Finding (Leadership);* The responses as described above, are supportive of the leaderships attitude to safety but is absent of a deliverable expectation that is visible to all stakeholders.

- *Finding (Investigations):* The investigations are mainly based on a sequence of event model. Investigations may miss systemic causes by considering only causes in a direct, linear chain of causation.

- *Finding (Reporting):* Barriers to reporting included the lack of a reporting system, fear of branding and discipline, lack of reward and lack of time to complete reports.

- *Finding (Risk Assessment):* Risk assessment training is provided but the risk is not appreciated and tasks of significant risk are inadequately assessed.

- *Finding (Human Errors):* Firstly, none of the interviewees could provide information in a coherent manner to indicate what the highest risks in human errors are. Secondly there was no error management system.

- *Findings (Error Management System):* The responses indicated that there was an absence of a holistic error management model. The model presented provides Transmission with an error management model which closes the identified gaps.

The researcher found that no plans existed to systematically reduce human error risks at Transmission and that no individual or group seemed to have the accountability for driving human error reduction across the business units of Transmission. There is no safety or error management system that embodies continuous risk reduction criteria and methodologies. The lack of a holistic system to promote continuous error reduction as lead to buzz words with no action plans. Safety management audits did not address the key risk areas in Transmission of which one is operating error. The risk audit system in Transmission only focuses on compliance to the OHSACT and certain procedures. Transmission's investigation system (non technical) has not instituted effective root cause analysis procedures to identify systemic causal factors. As shown by the case study investigations focus only on the 'sharp end' and not on the 'blunt end'. Some of the recommendations are ineffective because it falls into the trap of training and retraining. Transmission's safety management system likely results in under reporting of incidents and near misses.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 OUTCOME OF STUDY

The purpose and objectives of the study were achieved. The researcher was able to provide an error management model that can be considered for application in Transmission. The perceptions of the experts were categorised into primary themes. The subsequent interviews led to seven findings. The causes of human error in Transmission was also identified and related to the one's of Reason's (1990) error classification shown in Figure 3.

7.2 CROSS REFERENCE TO OTHER STUDIES

With respect to the causes for human errors found in Transmission, the causes are similar to findings done by Reason (1997) and Hollnagel (2007). However, there appears to be under reporting of incidents similar to the findings of Bagain (2004).This could be as a result of different definitions used by different studies or a cover up do to fear or blame (Reason, 1990).

It is *recommended* that Transmission develop an easy anonymity reporting system with same conditions described later in this chapter.

With respect to the *finding on leadership* - The response above is supportive of the leadership's attitude to safety but is absence of a deliverable expectation that is visible to all stakeholders. The study by Clarke and Ward (2006) on U.K based manufacturing organisations highlights the role the leader plays in influencing safety. They go on to indicate if the group has been set a collective goal to become more involved with safety, then members within the team are likely to expend more effort and persist longer in the pursuit of this goal in comparison with teams without a collective goal. In a similar manner if the goal or expectation for the Transmission team is set more active participation can be achieved.

One of the leader influence tactics that is suggested is safety participation by the leader mentioning " I am involved in setting health and safety objectives and/or improvement plans. I am involved in discussing the effectiveness of the health and safety systems. I am involved in conducting risk assessments." (Clarke and Ward, 2006:1183). In the BP Texas Refinery Report (2007), the study express the following opinion that BP's leadership should set the process safety "tone at the top" of the organization and establish appropriate expectations regarding process safety performance. The study went on to say (2007: xii) "While BP has an aspirational goal of "no accidents, no harm to people," BP has not provided effective leadership in making certain its management and U.S. refining workforce understand what is expected of them regarding process safety performance."

It is *recommended* that the Transmission leadership must ensure that the business units understand what is expected from them by providing clear targets (see chapter two). The targets must be specific to human errors, measurable, attainable and within some time frame.

With respect to the *finding on investigations* - The investigations are mainly based on a sequence of event model. Investigations may miss systemic causes by considering only causes in a direct, linear chain of causation. It is clear from studies conducted on NASA by Leveson *et al.* (2003), Leveson (2004), and by work done by Peters and Peters (2006), Reason (1997) Strauch (2002) and Hollnagel (2007), that using the simple Domino model for investigation accidents is insufficient. When true root causes are not identified, corrective actions may address superficial causes and not the root problem (BP Texas Refinery Report, 2007). The epidemiological model differs from sequential accident models on four aspects. It considers performance deviations, environmental conditions, barriers and latent conditions (Hollnagel 2005) and is therefore more encompassing to look at greater detail of incidents.

It is *recommended* that epidemiological and systemic investigation models based on those suggested in chapter three by Reason (1997), Leveson (2004) and Hollnagel (2007) should also be used in investigations for Transmission.

With respect to the *finding on reporting* - Barriers to reporting included a lack of a reporting system, fear of branding and discipline, lack of reward and lack of time to complete reports. To benefit from near misses, organizations ranging from hospitals to manufacturing facilities and airlines to power plants have set up management systems for reporting and analyzing near misses (Bier and Mosleh, 1990; van der Schaaf, 1992). Phimister, Bier, & Kunreuther (2004), suggest that similar to the aviation industries, individuals should be protected from punishment if they report incidents as long as they do not break any cardinal rules. They go on to say that adhering to non punitive guidelines encourages trust and thereby increases reporting. Kunreuther is cited for indicating the other incentives such as monetary or other rewards are used to encourage a reporting (precursor management) system and uses the insurance industry as an example. They also cited a number of other industries such nuclear power stations, railways and health care that have implemented programs for taking advantage of precursor information.

It is *recommended* that Transmission set up a reporting system that is easy for all staff to report incidents. It should allow anonymity similar to the example used in the second case study as proof of concept for the proposed model. A non monetary reward system should be implemented. As one respondent during the interview sessions indicated, "the reward for reporting is life, either your own or someone else can be saved by taking corrective action from near misses." A procedure providing guidelines for when disciplinary action will be taken should also be instituted.

With respect to the *finding on risk assessment* - Risk assessment training is provided but the risk is not appreciated and task of significant risk is inadequately assessed. Similar findings were reported by Leveson and Gershenfeld (2005), where risk assessment was unrealistic and where credible risks and warnings were dismissed without appropriate investigation. In the BP Texas Refinery Report (2007), the report indicates that while all refineries have active programs to analyze process hazards, the system as a whole does not ensure adequate identification and rigorous analysis of those hazards.

Phimister *et al.* (2004) suggest by using a probabilistic risk analysis (quantitative risk assessment) method together with the precursor data that is reported, a complex system can be broken down into component parts and potential failure sequence can be identified. They indicate that the method as been used in a variety of applications, including transportation, electricity generation, chemical and petrochemical processing, aerospace, and military systems. Sometimes minor errors or flaws in systems can lead to serious incidents or accidents, the challenge of maintaining safety is significant. Therefore, effective risk assessment and risk mitigation is crucial to ensuring safety (Connell, 2004).

It is *recommended* that risk assessments be done according to that high reliability organisations (Connell, 2004, Leveson. 2004), which follow a nine step process; system characterization, threat identification, vulnerability identification, control analysis, probability determination, impact analysis, risk determination, control recommendations, and results documentation. For the appreciation of the risks videos like the alpha piper disaster or actual cases in Eskom can be used reflecting fatalities when the risk is not appreciated. Survivors of incidents such as burnt victims can also address operators.

With respect to the *finding on human error causes and error management* - None of the interviewees could provide information in a coherent manner to indicate what the highest risks in human errors are. Secondly there was no error management system. In a study of the BP Texas Refinery Report (2007) there where concerns on the safety management system. In the BP Texas Refinery Report (2007), the study urge companies to regularly and thoroughly evaluate their safety management systems, and their corporate safety oversight for possible improvements. The study reported that even though there were internal standards for managing process risk, the safety management system did comply with those standards. Similarly there are risk standards and human error data in Transmission but it is not co-ordinated because there is no error (safety) management system. The study also believes that BP has an incomplete picture of process safety performance at its refineries because BP's process safety management system likely results in underreporting of incidents and near misses.

It is *recommended* that Transmission install a country wide error (safety) management system in order for human errors to be known and corrective actions to be taken by operators and management to reduce human errors. The error management system should reflect whether steps taken through the corrective action is improving human errors.

With respect to the *finding on learning* - Sufficient learning is not taking place even though efforts to teach are taking place. Learning has been identified as a primary organisational characteristic to limit accidents and failures (Marais *et al.* 2004). They go on to add the difficulty of implementing effective organizational learning should not be underestimated. The practice of searching for and learning from accident precursors is a valuable complement to other safety management practices, such as sound system engineering, adherence to standards, and the design of robust, fault-tolerant systems (Phimister *et al.* 2004). Bagain (2004), indicates that in the certain health care industries near misses are not reported and therefore learning is not taking place. Chapter two of this research study suggests that reinforcement must take place for behavioural change to take place and be sustained. The behavioural change will indicate that learning as taken place. Bagain (2004) explains that most errors will continue to happen if sometime different is not done. He suggests one of the most important steps in creating a learning system is to demonstrate to participants is not punishment but systematic improvements to prevent future errors. People need to understand why learning is important what the benefits might be. Cooke, (2003) in is study suggests an implementation of a learning system and provide examples of a Shell accident in 1997 and the 9/11 tragedy in New York because the stakeholders did not change their behaviour and learn and share information from precursor incidents. He indicates that an error (safety) management system must be put in place and avoidable risk addressed before effective learning can take place. Bagain (2004) also indicates that operators don't learn because all risk are known by everyone including management and nothing gets done about it. By implication no need to learn if nothing gets done about the risk by management.

The stronger the organizational response to unacceptable losses the more incidents are reported, the more corrective actions taken and the lower the severity of the incidents. The nature of the organizational response to incidents may explain why incident learning is successful in some organizations (Cooke, 2003).

It is *recommended* that Transmission implement an error (safety) management framework incorporating a learning facet similar to the model proposed. Continuous reinforcement of the consequences of not learning must be provide and where learning is taking place positive reinforcement of the behaviour must be encouraged for effective continuous improvement.

With respect to the *findings on a error management model* - The responses indicated that there was an absence of a holistic error management model. The model presented provides Transmission with an error management model for consideration. Many of the findings identified above are addressed by the error management model. The model is also good for directing the attention of the investigator to specific questions within the facets of concern such as local actions, immediate realities of the operational environment, and influences of organisational functioning. A final benefit is that the model is expressed in terms of general processes which are independent of functioning within any specific domain. This allows information from other models to be used in the proposed error management model.

It is *recommended* that Transmission should establish and implement an integrated and comprehensive error (safety) management model like the one developed by the researcher in this research study supported by the appropriate management information system that systematically and continuously identifies, reduces, and manages human errors.

7.3 SUMMARY OF RECOMMENDATIONS

- It is *recommended* that the Transmission leadership must ensure that the business units understand what is expected from them by providing clear targets. The targets must be specific to human errors, measurable, attainable and within some time frame.

- It is *recommended* that epidemiological and systemic investigation models based on those suggested in chapter three by Reason (1997), Leveson (2004) and Hollnagel (2007) should also be used in investigations for Transmission.

- It is *recommended* that Transmission set up a reporting system that is easy for all staff to report incidents. It should allow anonymity similar to the example used in the second case study as proof of concept for the proposed model. A non monetary reward system should be implemented. A procedure providing guidelines for when disciplinary action will be taken should also be instituted.

- It is *recommended* that risk assessments be done according to that high reliability organisations (Connell, 2004, Leveson, 2004), which follow a nine step process; system characterization, threat identification, vulnerability identification, control analysis, probability determination, impact analysis, risk determination, control recommendations, and results documentation. For the appreciation of the risks videos like the alpha piper disaster or actual cases in Eskom can be used reflecting fatalities when the risk is not appreciated. Survivors of incidents such as burnt victims can also address operators.

- It is *recommended* that Transmission should establish and implement an integrated and comprehensive error (safety) management model like the one developed by the researcher in this research study supported by the appropriate management information system that systematically and continuously identifies, reduces, and manages human errors.

7.4 GENERAL CONCLUSIONS

The study suggests that the error management model can close many of the gaps identified in Transmission. Without such an error management model the human error rate will not reduce. The model provides a process for error management which can address the reduction of human errors if the operator, management or the Transmission addresses all the identified facets in the model. Given the importance of reducing human error, a holistic error management needs to be central in addressing the finding in this study. The model presented reflects its ability to direct attention to the specific facets of error management, for example, pre-conditions, risk assessment, pro-active monitoring, investigations and learning as demonstrated in the case studies. This helps provide better indications of all the possible causes of human errors starting at leadership's ability or inability to set expectations all the way to learning for continuous improvement and reduction of human errors.

Managing error is an ongoing, dynamic process that does not stop. Management must demonstrate that commitment through its actions and decisions.

7.5 IMPLICATIONS OF RESEARCH RESULTS

There are many gaps in the Transmission system with respect to error management that needs to be addressed. Reason and Hobbs (2003) and Maddox and Reason (1996) point to a piecemeal approach in error management which is addressed by the error management model presented by the researcher. Table 4 shows the current gaps and the conceptual error model proposals to close the gaps.

GAPS OF THE CURRENT APPROACH	PROPOSALS TO ADDRESS GAPS
Human Factors – general focus on the individual	Focuses on individual, task, situation/environmental and organisation
Accident Models – domino models only address only active failures	Epidemiological and systemic models - addresses active and latent failures
Monitoring – reactive – risk analysis is based on past events	Reactive and Proactive – risk analysis is based on past events and foreseeable encountered risk
Learning - inadequate	Learning system and reinforcement of behaviours

Table 4: Benefits of the Proposed Model

As described in Table 4 the proposed error management model provides an opportunity to address some of the gaps found in Transmission and other studies cited in this research study. This research study contributed by identifying the gaps in other models as well as Transmission and illustrated how the error management model can identify more failures in incidents and by taking the appropriate corrective action and learning from these corrective actions change behaviour and ultimately reduce the number of human errors. The implication if Transmission adopts the error management model, should more opportunities for improving error management.

7.6 FURTHER RESEARCH

Based on the findings and recommendations presented in this research, three suggestions for future research are provided. These suggestions are offered as next steps for additional understanding of error management:

- Investigate a management information system to support the error management model, easy reporting, and tracking of learning.
- Investigate the new accident models that are suitable for Transmission but can generally be applied.
- A quantitative study of the error management model after long term trial and it suitability for general application to the organisations.

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APPENDIX 1: HUMAN ERROR SURVEY

HUMAN ERROR SURVEY
2007

This survey is being administered to explore reasons for human errors in the Transmission Division of Eskom's Holding Limited. The survey contains questions and statements about, human error, risk assessment, error prevention, error management, investigations, leadership, safety culture, communication and learning. The statements and questions relate to the Transmission division. Your response will help identifying and document problems and possible solutions with respect to human error incorporating error prevention and error management.

Participation in the survey is voluntary. However, your inputs will assist in helping to determine what further work will be required to prevent and reduce human errors and how the errors should be managed.

Due to the nature of the survey i.e. face to face interviews your identity will only be known to the researcher. In the attached written survey document you will be identified by a unique alphanumeric identification in order for the researcher to do follow up questions should the need arise. Your opinions and perceptions will be anonymous with the production of survey results.

Unique identification: ____________

Type of position held : ___________

No. of years in position: _________

No. of years in Eskom : ___________

Thank you for your participation.

Collin REDDY 0829014050

Human Error: Interview questions

1. Do you believe that the collection and analysis of accident precursor data can improve safety? How. Prompt what are precursors.

2. Do you think we are implementing the corrective action or do we just talk about it? Check for validity, how many accidents did we have? How should we go about implementing it?

3. Do you think that we have clear safety and human error objectives in the Transmission Grid business? Explain. What would you like to see in the objectives?

4. The task that you do or your staff as potential risks, do you believe that appropriate risk, hazard analyses is done that helps you identify the precursors. Can they apply the knowledge, Can the risk be identified? Can they assess how high or low the risk is - probability of occurrence, frequency of occurrence, cost or impact of occurrence.

5. Why don't you report near misses, unsafe acts, unsafe conditions, breaking of procedures by yourself or co-workers. (Check for blame, no time, no structure, nothing gets done etc.)

6. Do we encourage reporting. Do you know how to report any of the above? Do we have a system for reporting? Do you believe if the information is reported it will be managed properly?

7. Do you think that you, your supervisor and manager are committed to reducing human/operating errors and improving safety? How is it demonstrated? Check for clear targets and action plans. Check for resources provided.

8. Do you think that your BU manager is showing enough leadership? Related this to culture. (Beliefs –positive or negative about safety, do as I say and not as I do mentally, review of outstanding actions, structure of safety meetings, involvement in investigations etc.)

9. Do you believe that we have measurable safety improvement programmes? (Check how it is measured) can the safety improvement programme be explained. What it the safety improvement programme going to achieve? Is it addressing the right things?

10. Do you think that risk related information is properly shared with your department, grid, and the grid business?

11. What will encourage you to report all near misses, unsafe acts, and unsafe conditions?

12. Do you believe it will be fair to have a blame free system where we do not discipline people but only reward people? (What should a blame worthy act be, intentional unsafe acts?)

13. Where do you think that the next accident or human error is coming from?

14. Do you think safety is structured properly? Do you get support? Do you get direction from safety?

15. What are the issues in human errors? What are the specific areas that we need to focus on? What do you think are the contributory factors causing the incidents?

16. Do you think that we have a proper error (safety) management system? We have a place where all investigations are done? All recommendations are kept. Are able to do trend analysis? You are able to predict the type of error. The system is able to monitor the leading and lagging indicators? Monitor the type of safety related issues. Allows for review? Ensure that standards are maintained. Is user friendly?

17. Do we have a recommended accident report format similar to ones used in airlines? Is there a specific reason for using report?

18. What accident model do we use for our investigations? Is there a specific reason for using that model? Is the model all inclusive of all the possible causes and contributory factors? Check for short coming? Enforcements from the regulator, poor management decisions etc.

19. Does the investigation model take account of human factors? The job (nature of the task, workload, environment, design of displays, controls, signs, role of procedures, human limitations and strengths, mental aspects such as perceptual, attentional and decision making capabilities). Individual (competence, skills, personalities, attitude, risk perception) Organisation (work patterns, culture of the work place ,resources , communications, leadership).

20. Communications of incidents are seen as crucial in the overall strategy of future accidents preventions. How do we do this in Transmission? Do we just send out the report? Do we present a summary? Who is responsible to ensure that there is knowledge transfer? How do check for the effectiveness of the knowledge transfer? How many operating errors did we have YTD? Do you know what the major causes were?

21. Are employees trained in making decisions?

22. Do you believe that your supervisor, manager, general managers are providing effective leadership for safety?
    - Are their expectations expressed and are supported by how to achieve the expectations or is it just talk?
    - Are they committed to safety?
    - Have they created a mind set that accidents are not acceptable?
    - Do they make the time for safety or indicate that they are busy?
    - Do they identify or undertake safety course or forced to take safety courses?

- Are their messages matched by their actions they take e.g. providing the necessary resources?

23. Do you think that the existing safety committees are effective?
    - Do the committees have an impact on the safety culture?
    - Do they promote adherence to good safety practises?

24. Are you encouraged to report unsafe acts or conditions which you may have caused without fear of punishment? In general do you think that you and your colleagues report minor incidents, accidents or near misses?
    - Do you ask challenging questions to your colleagues, supervisors or management without a slight fear of reprisal?

25. Do you think you or line management get enough effective and co-ordinated support?

26. Do you believe that we have the right balance of leading and lagging indicators? What indicators will you recommend that we develop or measure? Do you think that our current indicators measure our significant risks? No single performance measure addresses all the safety risk.

27. Do you think we have an effective auditing system for safety? As it help us in improving safety?

28. Some people believe that errors or accidents are normal in a complex system (Perrow's Normal Accident theory) and others think that accidents are preventable (HRO). What you think? Are accidents normal or can they be prevented? How do we close the gap between the thinking that accidents will happen no matter what you do and accidents can be prevented? (You can close the gap by learning, focussing on continuous improvement similar to ISO 9001.) Look at both error prevention (first line of defence) and error management (second line of defence) to strive towards a high reliability organisation.

29. Due to the reward system and fundamental attribution bias, errors are covered up. If genuine errors are not hidden then the operator does not have the additional strain of hiding the errors, dealing with the task and worrying about self image. Management themselves do not have to worry of the image of their business units but promote open communication so that learning from others become possible.

30. Do you know what the average employee satisfaction is for Transmission is? What dimensions are causing it not to be 100%?

31. Why don't we have learning at the GMM? What is our culture? Are we are a learning organisation?

32. Why do you think that we have a strong error prevention and error management culture in some business units and not in other business units?
    - Check for leadership
    - Support from safety
    - Don't know about error prevention
    - Don't know about error management

33. Error aversion culture – covering up of errors. Are you aware of any error that was not reported or not reported correctly in your BU? Do you believe that in your BU errors are covered up? What do you believe is the reason for not reporting the error or incident?

34. What do you think we can do to encourage report?

35. Do you have clear goals for errors in your business areas? What is the goal? Do you know how to achieve the goal. If the response is work safely, prompt a response on how do you work safely. What are the aspects do you consider when you work safely?

36. What is the approach that you are using towards error management? What is the rationale for using such an approach? Do you think that we have a systematic error management approach in Transmission? Explain.

37. What are the reasons for errors?

38. What are the typical types of errors?

39. What methods are used to detect errors?

40. Once errors are detected how they are communicated. How widely do you share them? Do you think others use the information that is communicated to them? Substantiate.

41. Do you think we have a blaming culture?

42. What can we do to improve error prevention?

43. What can be done to improve error management? What do you think are the attributes for an effective safety management program?

44. What do you think your attitude safety is? Why? Brother keeper, short cuts etc. Look for objective evidence to support the attitude. What are the attitudes of others towards safety?

45. Is there any correlation between the BU that had the most operating error and performance?

46. What are the attributes of operating the network safely and not making human errors?

47. What is it that makes our current safety practise effective and what is it that makes it ineffective?

48. What is it that we are not doing that leads to poor safety practises and human error?

49. Have you been trained in risk identification and reporting? Does the training you received provide you with a clear understanding of risk that you work with? Identify the training.

49. Do you think that safety issues are thoroughly investigated and appropriately resolved? Do you just fill the domino forms?

50. Due to operational pressure, corners are cut? Do you agree? Check for urgency to get the power back. Do they know the safety policy?

51. Does your supervisor sometime us you to operate unsafe equipment? Does your supervisor take actions when you engage in a poor safety practise? How long does your supervisor take to respond to your safety suggestion or concern?

52. Are procedures regularly followed? Are procedures kept up to date? Do you know how many procedures are applicable to your work environment? When last did you use a procedure? When last did you see one of your colleagues referring to a procedure after receiving a work order? Are the procedures easy to use and easy to understand? If there is a problem with a procedure do you work around the procedure or do you report the problem with the procedure before continuing work? Do you comment on the procedures that come out?

53. Would you agree with the statement that young operators are unskilled and experienced operators are complacent and are therefore responsible for most of the errors? How do we address this concern?

54. Are there any other suggestions or comments you would like to make?

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I once again thank you for your valuable time. Your input will provide an important contribution in help reducing human errors and setting up a framework for error management. As part of the continuous learning aspects that were asked earlier in order to move towards a high reliability organisation, a PowerPoint presentation will be made and shared with all employees and external participants.

APPENDIX 2: SUMMARY OF LEADERSHIP THEORY

PERIOD	PREDOMINANT 'SCHOOL'	PREDOMINANT CONSTRUCTS	KEY REFERENCES
1920s	Trait Theory	Leadership can be understood by identifying the distinguishing characteristics of great leaders	• Weber (1947)
1950s	Style Theory	Leadership effectiveness may be explained and developed by identifying appropriate styles and behaviours	• Tannenbaum & Schmidt (1958)
1960s	Contingency Theory	Leadership occurs in a context. Leadership style must be exercised depending on each situation	• • Fiedler (1967) Hersey & Blanchard (1969)
1970s	Charismatic Theory	Leadership is concerned with the charismatic behaviours of leaders and their ability to transform organisations	• • House (1976) Burns (1978) Conger & Kanungo (1988) Bryman (1992)
1980s	New Leadership/Neo-Charismatic School	Leadership and management are different. Leaders require a transformational focus which encompasses a range of characteristics and behaviours in addition to charisma	• • • • Bass (1985) Avolio & Bass (1995; 1997) Conger & Kanungo (1988) Shamir (1992) Bennis (1985) Alimo-Mecalfe (1995)
Late 1990s	Emerging Approaches a) Strategic Leadership b) Change Leadership	a) b) Leadership may be understood by examination of strategic decision- making by executives Leadership is inexorably linked to the management of change. Leader behaviours may be understood in the context of the work of delivering change	a) • b) Finhelstein & Hambrick (1996) Hambrick & Brandon (1998) Kotter (1994) Higgs & Rowland (2000)

Source Higgs M (2002)