THE IDENTIFICATION AND MEASUREMENT OF SAFETY MANAGEMENT SYSTEMS : TOWARDS A BEHAVIOURAL RESPONSE APPROACH

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SYNOPSIS: THE IDENTIFICATION & MEASUREMENT OF SAFETY MANAGEMENT SYSTEMS

This thesis presents a model for identifying, measuring and managing the risks of hazardous technologies. This paper is not targeted at any one domain, but identifies specific principles of safety management applicable to mining, manufacturing, maritime and aerospace industries. Further, the application of a principled and comprehensive programme intends to provide an effective safety culture for general industry.

The model addresses safety management at three levels – senior, middle and supervisory – with the aim of identifying latent conditions and active errors in terms of accident causation.

The author intends to show that human error is a consequence, not a cause, and that is shaped and provoked by upstream workplace and organisational factors. Only by understanding the context that caused the error can we hope to limit its recurrence.

The thesis rejects the popular notion that "human error" is implicated in roughly eighty percent of all major accidents, and proposes that lack of guidelines at the managerial levels of organisations is responsible. This hypothesis was tested and proven at Koeberg Nuclear Power Station by the process of assigning programme elements with steering mechanisms to managers to facilitate evaluation of programme effectiveness. This programme was designed to locate, identify and track errors due to the existence of latent

conditions and active failures in operational processes. Human error is thus conceptualised as a symptom.

The validity of this approach was established by both qualitative and quantitative assessments. Evaluation of questionnaires clearly indicated the effectiveness of steering controls assigned to the three management levels. It confirmed that specific safety programme elements need to be assigned to managerial levels to facilitate effective behavioural response at the operational level. Significantly, the programme elements utilised provided three essential management functions to the organisation: the human, engineering and organisational management models. Scientific opinion has recognised the need to incorporate these models into management procedures. But current safety management programmes conceptually exclude the above models for lack of appropriate steering mechanisms.

The author concludes therefore that the model implemented provides a practicable framework for safety management in general industry. Stressed is the function of error identification and containment in a framework of continuous evaluation of process safety.

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1. CHAPTER ONE

1.1 THE DISSERTATION

Safety management systems are designed to maintain and defend hazardous technologies. Despite the sophistication of current safety programmes, the human factor is still instrumental in both causing and preventing accidents in industry. Although it has become fashionable to claim that human error is implicated in 80–90 per cent of all major accidents, perceived errors may be symptomatic of a more profound, yet less obvious cause, namely poor managerial controls. Thus in the USA, Canada and South Africa, safety management systems are characterised by rigorous measurements of control which do not take into account human psychological response. Where appropriate behavioural response is constrained by prescriptive controls, the management system - and not the operators – carry the liability.

Strategic industries or essential services have been characterised by safety system failures in the last two decades. The analysis of major accidents in the mining, manufacturing and maritime industries has invariably identified managerial failure as a basic causative factor. The following (by no means exhaustive) tabulation speaks for itself:

Chernobyl	Loss of nuclear reactor core inventory – design problems, managerial failure
Vaal Reefs (SA)	Locomotive plunging into mine shaft – procedural non-compliance, managerial failure
'Piper Alpha' Oil Rig (North Sea)	Fire genesis induced by inappropriate procedure, managerial failure
Zeebrugge	Roll-on/Roll-off ferry capsizes – design problems, procedural non-compliance, managerial failure
Space shuttle 'Challenger'	Leaking seals precipitate hydrogen explosion – design problems, managerial failure
Bophal (India)	Methyl Isocynate (pesticide) leaks into the environment (6 000 fatalities, 225 000 injured) – procedural problems, managerial failure

These organisational accidents were analysed by leading authors in the field, and failures in terms of behavioural response have been attributed to failures in managerial controls. From the above we can deduce that the basic or root cause of major incidents is attributable to the degree of behavioural response induced by managerial controls. There is a lacuna in our knowledge and research base here. Several studies have shown that some of these accidents are caused by a combination of many factors whose roots can be found in the absence of human factors. While pioneering studies by Bird et al. (1974) identified the need for structured safety programmes in industry, these early researchers did not include measurements of behavioural response to safety control systems. There is now convincing evidence that unless persons respond favourably to system requirements, the structure of safety systems remains dangerously ineffective.

Current safety management systems lack the process to guide the behavioural response of persons. It is furthermore evident that existing safety management systems are programmed for acts of compliance only (ISRS, NOSA, Safety programmes: 1976-1998). All major recent accidents are characterised by acts or omissions indicating behavioural response managerial failure. Demonstrably, measurements of consequence were not carried out to establish how the required acts of compliance would affect the behavioural response of persons. Put differently, the stated objective of every safety system is to secure favourable compliance to programme standards. Implied, therefore, is the notion that the compliance factors can be sufficiently motivated by managers and supervisors to assure favourable behavioural response. The global experience of organisational accidents indicates, however, that the controlling function at the various management levels consistently fails to assure appropriate behavioural response. What we have, in effect, are national and international safety systems which have largely ignored the psychological response of people affected by those controls.

As managerial failure constitutes the basic or root cause of accidents in organisations, the objective of this dissertation will be to analyse the controlling function at the various management levels. Accordingly, a controlling framework for each management level will be developed to assure behavioural response. The aim of this dissertation therefore, lies in the provision of a safety management programme to industry that will facilitate behavioural response in all operational facets. This programme will be implemented and evaluated at South Africa's only commercial nuclear power plant, namely Koeberg Nuclear Power Station. See **Fig. 1**.

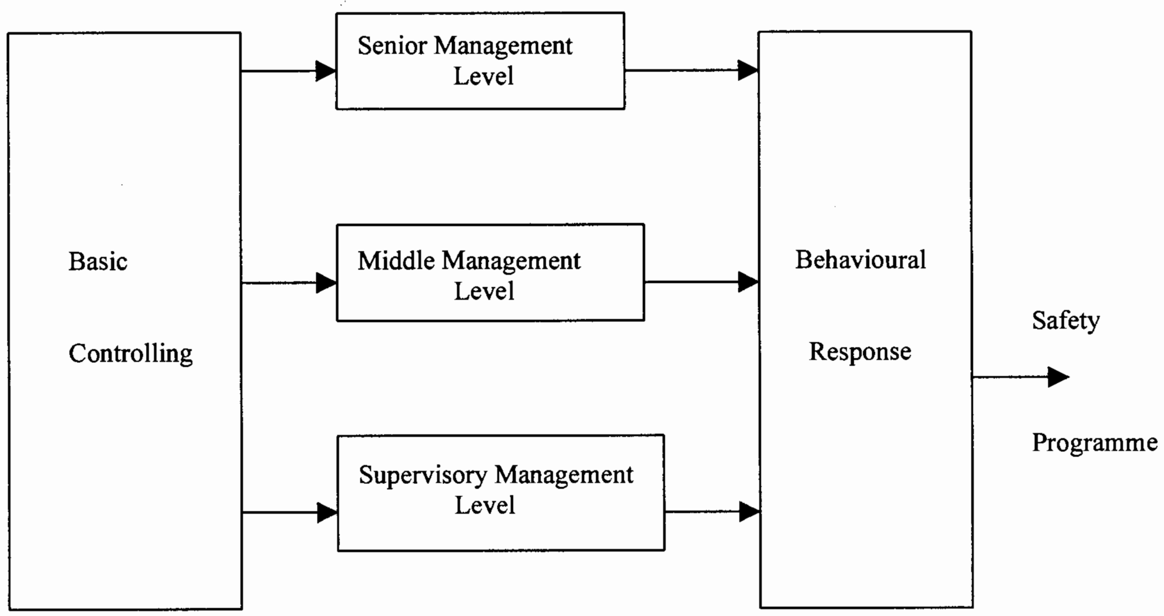

Fig. 1 Exhibit 1A Koeberg: basic controlling, management levels and behavioural response

Koeberg, with its 3-tier management structure, will provide the basis for the evaluation of the controlling function at the various management levels. The safety programme previously followed at Koeberg, which conceptually excluded the specific controlling function for managers, will be extended or upgraded.

This upgrading will include assigning steering or evaluatory mechanisms to the various managerial levels, the primary purpose being the continuous evaluation of safety programme effectiveness. Measurements and evaluations of behavioural response by both managers and workers are to be conducted throughout a four year assessment period.

1.1.1 On the main hypotheses:

Central to the discussion presented in this analysis is the hypothesis **that basic types of control can only be identified and measured in relation to an organisation's management levels.** Accordingly, much of the argument developed in this paper is committed to: (a) demonstrating that writers in the field have failed to establish a relationship between the basic controls of a safety programme and managerial levels and therefore to: (b) develop a safety programme whereby the identification and measurement of basic controls is conceptually integrated with management levels.

A secondary hypothesis is that **basic types of control, conceptually integrated in safety programme elements, can induce persons to respond appropriately to the needs of a safety system.** Secondary aims therefore are: (a) to analyse the effectiveness of steering controls integrated in safety programme elements (b) to assess the effectiveness of steering controls in relation to the behavioural response of persons and (c) to complete a reference work containing details of models which have been used in the identification and measurement of safety programme elements. **Both the central and secondary hypotheses embrace concepts not previously applied to safety management systems.**

Finally, a dissertation of this nature raises a social dichotomy – the extent of moral and legal accountabilities of strategic industries in the broader framework of society. It follows that the overt purpose of this dissertation lies in the provision of a safety mechanism designed to comply with the moral and legal obligation of business which is, in the words of NASA specialist J.Lederer to Congress, 'ultimately to prevent safety system default as the consequences of failure are becoming less and less permissible as we continue to take risks of greater magnitude than in the past' (1984). The author of this dissertation is thus concerned with the Achilles heel of current safety management systems.

committee with evaluatory powers. Such a safety committee will be chaired by the middle manager, with a designated membership comprising of supervisors and worker elected safety representatives. This committee will be empowered to evaluate programme effectiveness at the supervisor/worker level. The function of the support programme elements is to measure compliance to existing programme standards at the supervisory management level. Further, accident/incident causative factors will be established by the support programme elements and submitted for a final evaluation to the senior management level.

1.2.4 Third Tier: Supervisory Management Level

Here a strategic programme element linked to five support programme elements is identified. The purpose of the strategic element lies in the provision of operational safety standards for the worker level. This element will not provide a steering or evaluatory mechanism. This function is provided by the support programme elements, with measurements of compliance controlled by supervisors and workers. Research emphasis will endeavour to determine whether latent and active errors are identified at the 'rock face' or operational levels. This area is considered critical for it will test, *inter alia*, the effectiveness of the role of middle and senior management in terms of basic controlling.

1.2.5 Research Process

Because the safety mechanisms tested in this study were, of necessity, limited to the South African context (and moreover, to Koeberg Nuclear Plant itself), the thesis cannot categorically assert a universal applicability. However, the analysis of major accidents by world experts suggests that the central tenets of this thesis are germane to the entire industry.

1.2.5.1 reliability and accuracy

Safety system analysis involves a mix of factual observations and measurements of compliance. Assessors must recognise this fact, as well as the fact that questionnaire construction and evaluation can result in biased assessments. The method is qualitative and utilises questionnaires to assess the measure of behavioural response induced by a restructured safety system. The main advantages of the qualitative method over detailed audit reports (which include detailed inspections of the place of work and in loco inspections) are the rapidity with which individual and group opinions can be obtained and evaluated. Further, this includes a reduction of individual bias. It is known that personal bias arising during personal communication and group consultation significantly influences surveys conducted in this manner. Evaluations are not based on interpersonal assessments of 'old hands' or the deployment of 'field agents' to provide qualitative data in terms of the measurement function. There is also a significant decrease in the amount of individual effort required when using the qualitative method to produce evaluations. A further function implied by this method is forecasting – assessments of this type provide a basis for the planning of safety programme requirements (Andrews, 1995:53).

1.2.5.2 qualitative assessments

The basic principle behind the behavioural response assessment questionnaires is to measure human behaviour and organisation at three management levels, as well as change in managerial perceptions and the effectiveness of safety programme elements.

The assessment method is designed to minimise possible biasing effects in decision-making due to dominant individuals, to enunciate biasing communications among members of management and to minimise group pressure towards conformity of opinion. The assessment procedure has three main elements: anonymous response, iteration and controlled feedback. The intention is therefore to achieve statistical definitions of the various groups of managers which is also, *inter alia*, an avenue of reducing group pressure for conformity. This furthermore ensures representation of all opinions. Anonymity, and the suppression of dominant individuals, is assured by means of the application of structured questionnaires. Extraneous communication between members of management and workers may, however, generate certain biases with regard to questionnaire completion. The above techniques are therefore considered to reduce bias due to known factors such as individual dominance or extraneous communication. These assumptions were justified when significant correlations were found between the groups of managers and workers assessed during questionnaire evaluation.

Group assessment

All three groups of managers – senior, middle and supervisory – questionnaires which are assessed. Contextually different questionnaires are evaluated from the worker level. Groups need to meet certain criteria before response assessments are conducted with personnel. The lateral safety programme must have been in operation for a minimum period of 12-18 months and there must have been continuity of group leadership for the same time period. In other words, new managers or supervisors at worker representative levels would be disqualified from assessments. Questionnaires are assessed on an in-house basis, and evaluations led by the programme analyst.

Oral confirmation

In order to minimise possible biasing effects, interviews with front-line supervisors and managers are utilised as a means of verifying the data established by both assessment typologies. Interviews will comprise of assessments conducted with managers/ supervisors in the actual work situation. Put differently, interviews will not be carried out in isolation from colleagues or workers.

1.2.5.3 quantitative assessments

Introductory remarks

The quantitative assessments conducted in this area primarily include measurements of compliance to programme elements. These are best described as safety audits. The purpose of safety audits is twofold. In the first place, they measure compliance to programme elements standards. In the second place, safety audits evaluate compliance to standards. The effectiveness of a safety programme can be gauged from this evaluation.. Safety audits are, *inter alia*, utilised to test qualitative assessments obtained by way of questionnaires. Put differently, changes in behavioural response to safety systems should be measurable as effective acts of compliance. Safety audits are used, therefore, to confirm response assessments obtained via questionnaires.

Safety audits

Safety audits represent a quantitative method for the macro-assessment of safety programme standards, based on expert and co-opted opinion. Current audit systems are based on the National Safety Associations audit index (NOSA) and Chamber of Mines International Safety Rating System (ISRS). Both systems are modifiable by experts to cater for the specific needs of industrial operations. Both NOSA and ISRS include 100 page reports, and both systems are number orientated. NOSA auditors rate 76 programme elements with substantial subdivisions that can affect a safety programme; ISRS auditors are limited to 20 programme elements but with greater subdivisions. Audit standards include primarily the measurement of managerial compliance and physical conditions as reflected in programme elements. Both safety audit systems are weighted in terms of a star rating where 5 is superior and zero signifies unacceptable conditions.

1.3 OVERVIEW OF THE DISSERTATION

1.3.1. Chapter by Chapter

The dissertation concerns itself primarily with the identification of safety programme elements for 3-tier management structures and related measurements of programme effectiveness. The thesis commences with a discussion of the background to safety programme management (Chapter 2). Definitional and conceptual issues are covered, and the function of basic types of control is discussed. Chapter 2 also analyses human responses to control in a safety management system and provides an appraisal of some of the literature on the principles governing behavioural response as applied to actual situations occurring during task performance.

Chapter 2 promotes the concept that behavioural response is primarily governed by specific key programme elements assigned to the various management levels of an organisation. The writer of the dissertation advances certain reasons for safety programme failures and proposes solutions.

Chapter 3 introduces the framework of the first safety management system. The steering mechanism, conceptually critical to senior management, is evaluated in broad detail. Safety programme elements in a supportive role are developed to enhance:

- Measurements of safety system effectiveness.
- Co-ordination of safety programme.

Measurements of compliance to programme elements are introduced. Furthermore, the effect of the safety system on the behavioural response of senior managers is evaluated.

Chapter 4 repeats the framework of the previous chapter by discussing the function of a safety system designed specifically for the middle management level. The co-ordinating function of the key programme element is evaluated together with supporting programme elements. After implementation an analysis of the co-ordinating function will be carried out, and results discussed to determine the degree of effectiveness. The underlying causes for programme failures are reviewed.

Chapter 5 concerns itself with the identification of areas of critical task performance at the supervisor and worker level. Critical linkages are established to measure and evaluate worker task performance. Similarly, an evaluation of programme effectiveness is carried out to determine the degree of behavioural response at this level.

Chapter 6 concludes the dissertation by reviewing the aim of the investigation.

2. CHAPTER TWO

2.1 BACKGROUND TO SAFETY MANAGEMENT ANALYSIS

2.1.1 Introductory

Safety programme analysis involves the identification, measurement and incorporation into managerial procedures of actual and potential hazards which threaten the safety of industrial operations. In Chapter 1, it was shown that safety management programmes lack the controlling function to guide the behavioural response of persons. Hence, the process of analysis involves three phases which can be described as identification, measurement and management. The dissertation concentrates on the first two dimensions of the analytical process, and relates them to a model of safety management with steering mechanisms to guide behavioural response (as opposed to current safety management programmes which do not link steering mechanisms to management levels).

In this chapter the required link between steering controls, management levels and behavioural response is examined in broad detail..

It needs to be stressed that manager/worker behavioural response lacks an epistemological basis in today's safety programmes. At the very least, this tends to limit participation by both managers and workers in safety programme activities, hence the persistence of active errors and resident accident pathogens. The primary objective of this dissertation is to implement the framework for a workable safety management system in nuclear power generation (Koeberg) which is transferable to other branches of industry or essential services.

This chapter is divided into two sections: an analysis of safety management practices and background to current safety programme failures. Koeberg Nuclear Power Station is the research object.

2.1.2 Influence Of Historical Events

With the onset of the Industrial Revolution the first legislation (1802) was enacted to ensure minimum standards of heating, lighting, ventilation and work hours. It was, inter alia, primarily intended to stop the widespread abuse of the children from poor houses. As years went by, progressively restrictive laws were passed to deal with specific hazards. In Germany, Chancellor Bismarck introduced worker compensation (1880) to stem the rise of communism, as well as to respond to increasing dissatisfaction of workers labouring in hazardous workplace conditions. In Canada and the United States, events followed much the same course. Laws were passed to enforce safety standards and deploy factory inspectors. Notably, common law began to be altered in the worker's favour. A landmark study - the 'Pittsburgh Survey' - exposed industry's poor safety record and laid the foundation for the National Safety Council of America.

The evolution toward integration of safety into a professional management system experienced many significant advances in the late twentieth century. Certain landmark publications, such as W.G. Johnson *The Management Oversight and Risk Tree* (1973), F. Bird *Practical Loss Control Leadership* (1986) conceptually broadened the scope of safety management. Significantly, legislation in the U.S., Canada and Europe started incorporating the concept of safety management in their safety standards. The past two decades have seen the rapid spread of safety management systems in America, Australia and South Africa. Safety management systems have begun to include key programme elements designed to identify hazards and evaluate risks in terms of process safety. This evolution into a safety management system was prompted by an acknowledgement of three main shortcomings perceived within traditional safety systems:

(i) They addressed physical conditions and administrative requirements primarily.
(ii) Managers and workers rarely participated in the setting of safety standards.
(iii) Safety systems were not measurable and thus it was impossible to assess the potential of risk.

The structure of safety systems in South Africa was strongly influenced by a US paradigm in the late 1960s. The empirical basis for this belief was provided by Frank Bird's analysis of 1 753 498 accidents reported by 287 companies, representing 21 different industries. This laid the basis for the conviction that organisations as well as bodies needed to address specific principles of safety management.

Firstly, safety congresses in the US identified that current safety systems were limited in their controlling function, i.e. controls involved exclusively the object, not the manager or worker. To be effective, safety systems must enable managers and workers to participate in the controlling function. Secondly, managers and workers need to be in a position to identify and measure those risks which impact on worker and process safety. As later discussions will show, safety systems were indeed restructured, but the participation of management levels and the implementation of related steering mechanisms were not defined.

This was recognised in SA by large mining houses such as De Beers Consolidated Mines and Anglo American Corporation. In a paper presented in May 1990, H Strohbach, Group Safety Engineer of Anglo American Corporation, stated categorically that 'senior managers' commitment is essential to safety programme effectiveness'. Further, mining management circles recognised early the importance of steering mechanisms. De Beers Consolidated Mines, for example, utilised safety co-ordinating committees as early as 1976 . The function of co-ordinating committees was to provide a steering mechanism for the management of safety systems. The role of steering mechanisms was, however, not recognised in national or US safety programmes. As a result, safety audits carried out in mining and general industry did not include steering mechanisms as an item of measurement. This in turn meant that safety programmes in the SA context largely overlooked steering mechanisms, thereby limiting managerial involvement nationwide.

This dissertation seeks to link the recurring failure of safety systems in a South African and international context to the omission of steering controls in safety management systems. The recently promulgated Occupational Health and Safety Act (1993) provides for legal compliance by employers. However, this Act does not provide guidance with regard to safety management systems. A further source of concern is that figures released by the SA Department of Labour (1996) show an increase in accident frequency rates in the SA industrial sector.

2.1.3 Resource Limitations

Current publications in the field do not address the function of managerial levels in safety programmes, nor are distinctions made with regard to primary and secondary controlling functions of programme elements. Epistemologically therefore, the above concepts could not be reviewed by consulting existing literature. Current writers on safety management systems conceptually exclude steering controls and behavioural response elements; consequently the author was compelled to draw on own and peripheral materials. Only three researchers who had based their analyses on the exposition of behavioural response and steering mechanisms (JT Reason, 1991, 1997; WH Newman, 1975; F Bird, 1985) supplied concepts for the main hypotheses. Not one of these viewpoints, however, incorporates the key principles of steering controls and behavioural response in safety management systems.

2.1.4 Agenda for Future Research

Despite the fact that South Africa hosts some of the world's largest (and deepest) mining operations, the concept of safety management is regrettably not taught here at tertiary level. It is strongly recommended that future curricula at the universities of Cape Town, Pretoria and Witwatersrand introduce students to the principles of safety management. Safety professionals note with dismay that engineering and business management graduates often fail to give direction and control to safety programmes when in managerial positions. This is, in turn, attributed to the existing void in university curricula.

After a preliminary discussion of the linkages between steering controls, management levels and behavioural response, the next section of this chapter investigates the impact of these concepts on safety management in more detail.

2.2 CONCEPTUAL AND DEFINITIONAL DETAIL

2.2.1 Basic Types of Control

2.2.1.1 defining steering controls

Steering controls constitute one of the basic phases of managing and always include evaluation and feedback. They have been defined by Newman as 'providing a mechanism for remedial action while the actual results are still being shaped' (1975:7). Newman particularly stresses the positive effect of steering controls on the behavioural response of persons. He attributes this to the design elements of steering controls which provide effective measurement and evaluation mechanisms, which in turn lead to high levels of personal involvement in the control cycle. This analytical distinction underlines the fact that behavioural response is far more important than the mechanics of a control. Significantly, current safety management programmes do not assign steering controls to the various organisational levels of management (ISRS, NOSA Safety Programmes, 1998). This dissertation seeks to establish steering controls as the missing link that guides behavioural response during person – machine interactions Further, this dissertation seeks to attribute the persistence of latent conditions and active errors in industrial operations to absent or defective steering mechanisms .

An alternative definition which is not as precise as Newman's is that of F Bird (1986:47). Bird understands the concept of steering controls loosely as a management tool to devise safety programme standards. He does not, however, link steering mechanisms to behavioural response; the usage of steering controls is limited to specific controlling functions required by a safety programme.

2.2.1.2 role of steering controls

The persistence of latent conditions and active failures in hazardous technologies today is attributed to two causative factors:

(i) failure to identify resident accident pathogens and hazards in operational processes,

(ii) failure to evaluate existing known hazards effectively.

Reason (1997:10) demonstrates the validity of this hypothesis with his 'Swiss cheese' accident causation model. Like resident pathogens in the human body, latent conditions – such as poor design, gaps in supervision or maintenance failures – may be present for many years before they combine with local circumstances and active errors to produce an accident. Despite safety programmes currently in operation, major accidents in organisations point to failures in managerial control - such as strategic and top-level decisions by organisational managers. The impact of these decisions spreads throughout the organisation like the holes in a Swiss cheese, creating conditions where errors can occur.

Upon analysis of accident causative data, it is evident that precursors of accidents (i.e. near-miss incidents) as well as active failures were not timeously identified. Where precursors were identified, a deficient evaluatory mechanism failed to signal impending disaster to the organisation. This is confirmed by accident studies conducted by both Reason (1991:173) and Bird (1986:57). It follows that the organisation's basic controlling function failed to recognise and evaluate the threat posed by a particular condition or process.

Upon closer examination, the failure to (a) identify hazards and (b) evaluate hazards leads to the conclusion that steering controls were not effectively utilised. This hypothesis is only indirectly confirmed by existing literature (see Reason, 1991). Hence, the writer's intention to show that steering mechanisms, linked to the organisational management levels, will facilitate the identification and measurement of resident accident pathogens and active failures.

For example, the steering mechanism assigned to the senior management level is to evaluate the effectiveness of the organisation's (Koeberg's) safety programme, whilst assisting in the identification of latent conditions and causative factors of accidents. Similarly, middle managers are required to evaluate safety programme compliance with supervisors, with particular emphasis on the evaluation of active failures during operational processes. Finally, supervisors are required to measure compliance to actual task procedures plus examine areas of task performances for the existence of hazards.

The steering mechanisms described above will be reflected in specific safety programme elements assigned to managers. Typical examples will be task observations conducted by supervisors, hazard identifications evaluated jointly by supervisors and middle managers, and safety programme effectiveness evaluated jointly by senior and middle managers. The application of steering controls will be discussed in greater detail in Chapters 3, 4 and 5.

The design elements of steering controls – identification, measurement and evaluation – are known to facilitate personal involvement in the control cycle. This Newman attributes to a beneficial feature of steering controls: they provide early evaluation which enables timeous control adjustments to be made. Operational personnel thus have the distinct advantage of identifying a problem area (or hazard), measuring the magnitude of the problem or hazard, and evaluating the process necessary to resolve the problem. Moreover, managers or operational personnel are given an opportunity for personal involvement in the control cycle. In this way they are able to influence the outcome by drawing on their resources of experience, training and creativity.

In view of the absence of literature on steering controls in a safety context, it seems appropriate to review the papers of two researchers (Newman, 1975; Bird, 1986) who have - to greater or lesser extent - integrated steering mechanisms into control cycles.

2.2.1.3 William Newman

WH Newman in *Constructive Control*, although not writing from a safety standpoint, conceptually integrates into a management system three basic types of control, i.e. steering, yes-no and post-action controls (1975:6). Newman views steering controls, however, as indispensable for the effective evaluation of a control cycle. Most importantly, he links the evaluatory mechanism of steering controls to effective behavioural response. The scientific method adopted by Newman for his study allows his hypothesis to be tested according to the principles of case studies, projects and programs. He therefore outlines a conceptual model of reality on which safety control systems can be based.

Newman's 'bottom line' is essentially this: managerial control is effective only when it guides someone's behaviour. Behaviour, not measurements and reports, is the essence of control.

This is in conflict with Bird and Germain who have adopted a single basic control activity for the identification and measurement of safety systems. Nor is this single control activity in the form of steering controls consistently applied in the framework which governs their safety systems. The structure of certain programme elements cannot be subjected to steering mechanisms, especially where control actions are complete, and results measured and compared to a standard. For example, a procedure detailing the execution of a critical task will not incorporate a mechanism for the evaluation of its own effectiveness.

2.2.1.4 Frank Bird and George Germain

Bird and Germain in *Practical Loss Control Leadership* (1985) discuss the conceptual and definitional aspect of safety programme elements in great detail. They contend (correctly) that management control of safety systems is based on the identification and measurement of programme elements. The authors rely on the motivational medium of management and leadership to ensure compliance with the standards set by safety programme elements. This approach, however, does not measure the behavioural response of persons to programme elements which are an integral part of safety systems.

The authors outline conceptually a safety management programme of reality, but programme elements are not identified in terms of managerial programme or controlling function. Their paper identifies the source of a rating process - the principle of the 'critical few' which can be utilised for hazard evaluations and may therefore be called scientific. It should be noted, however, that this principle cannot be utilised for steering control purposes. Rather, the authors describe the principle as useful for the implementation of a general safety programme (Bird, 1985:46).

Further, their functional assessment on management control does not identify the three main groupings of basic types of control - namely steering, yes-no and post-action controls. Their scheme for the analysis of programme elements is confined to the integration of steering controls only. It is the author's contention that the basic controls governing a safety system are variable and not confined to one taxonomy. Their work must be credited, however, for providing a workable safety system, with identified safety programme standards, to the international industry.

Since the influence of steering controls on behavioural response is a key element of this dissertation, an exploration of behavioural response in the context of organisational environments is imperative.

2.3 ORGANISATIONAL BEHAVIOUR

2.3.1 Organisational Influences on Behavioural Response

2.3.1.1 models

As briefly discussed in Chapter 1, 'human error' is one of a long-established list of so-called 'causes' often used by the press and accident investigators. But 'human error' is mostly a consequence, not a cause. In Reason's words, errors are 'shaped and provoked by upstream workplace and organisation factors' (1997:126). Typical error-inducing agencies are personal, task-related, situational and organisational factors. The often repeated statistic that human error is implicated in 80-95 per cent of all events generally leads to the conclusion that individual human inadequacies and errant actions are the principal causes of all accidents. Yet the fact remains that workplaces and organisations are easier to manage than the minds of individual workers. And, despite popular opinion, these individual minds are not among the primary causes of accidents identified by most writers on the subject. It is easier to change the conditions under which people work than to effect changes to human condition. In short, the solutions to most human performance problems are technical rather than psychological.

This dissertation seeks to resolve these apparent conflicts by recognising that steering controls can provide three distinct models. These important distinctions were first made in 1990 at a Safety and Reliability Society Symposium by Deborah Lucas who outlined the three concepts necessary to identify error producing conditions in operational processes. **The person model** identifies conditions that influence the choice between safe and unsafe behaviour. **The engineering model** views human error as a result of system designers failing to tailor the technical system appropriately to the cognitive strengths and weaknesses of its human controllers. **The organisational model** views human error as a result of fallible board decisions and managerial policy. Inappropriate human behaviour is largely determined by the existence of latent (unsafe) conditions caused by flawed decision-making processes in the management hierarchy. A typical example can be found in the accident scenario of the 'Herald of Free Enterprise', where fallible board decisions and unresolved line management problems caused the sinking of a passenger ferry.

The frameworks of current safety programmes largely exclude the above three approaches to safety management. Consequently, problems are experienced in terms of behavioural response which seemingly persist in all types of industry eg mining, manufacturing, maritime and aerospace. The guidelines of existing safety programmes are limited in their application of the above three models, particularly in the evaluation of conditions that would impact on the behavioural response of persons. Notably, the organisational model, with its emphasis on the evaluation of hierarchical decision making and latent system errors, is almost entirely neglected. Again, it must be stressed that the root cause of major accidents is attributable to managerial processes which fail to evaluate the safety of operational processes. Hence, human - machine mismatches and active errors continue to stifle appropriate behavioural response. This dissertation seeks to employ the three models for the purposes of controlling latent conditions and active errors, always operating from the premise that human errors are the symptoms of latent conditions in the system at large.

Another premise is that effective behavioural response depends on the basic controlling function provided by a safety management system. This factor was isolated during the analyses of major accidents, notable by authors such as Newman, Reason and Bird. As stated above, this dissertation will employ steering controls to incorporate the above distinct models – the person model, the engineering model and the organisational model – in safety management. The basic controlling functions of these models constitute, for the purpose of this dissertation, the key principle for influencing the behavioural response of persons.

Much of the discussion in the following chapters will focus on the design of effective steering controls to guide the behavioural response of persons. A further objective of this dissertation is the evaluation of concepts such as leadership, informal organisation, communication, decision making and their impact on behavioural response. According to Hersey and Blanchard, problems associated with the management of organisational behaviour indicate a deficient provision of organisational guidelines, notably in the area of controlling (1977:127-129). Although never attempted before in safety management, steering mechanisms will be employed to guide managers in the areas of leadership, informal organisation and the like.

Two new safety management concepts have emerged from the above discussion:

(i) the application of steering controls to provide three distinct management models,

(ii) the application of steering controls to guide the management of organisational behaviour.

Neither of these two concepts has been researched previously.

Overview of Four Perspectives

The following four authors' analyses of organisational behaviour are limited in terms of safety management, but are conceptually important for behavioural response assessment methodologies discussed in the latter part of this chapter, as well as in chapters 3, 4 and 5.

2.3.2.1 Felix Nigro

One of the early analyses of human behaviour and organisation, Nigro (1965) discusses the conceptual and definitional positions of leadership, informal organisation, communication, decision-making and controlling. Nigro correctly contends that leadership styles are subject to forces in the situation, a contention repeatedly confirmed in the analysis of this dissertation. Proceeding to the area of informal organisation, Nigro sketches the characteristics of small groups and their related influence on the organisation in great detail, but aspects of non-deliberate departures from the formal organisation plan are not clearly portrayed (1965:153) Nigro sketches primarily the social interaction of work and friendship groups, but does not identify specific processes which induce non-deliberate departures from the formal plan. This aspect, of great significance to the behavioural response required for safety systems, is effectively described by Simon, Smithburg and Thompson in *The Administrative Process and Democratic Theory* (1970:193).

Nigro distinguishes between three types of communication - lateral, downward and upward. Of particular significance is his assessment of lateral communication which he describes as being 'of great importance in assuring the co-ordination of organisational objectives' (1965:193).

Similarly, Nigro stresses that effective decision making is based on managers obtaining 'lateral clearances' by consulting with their counterparts. Extrapolating to safety systems management, lateral clearances of this type are essential for implementing safety policy in an organisation. Case studies in the SA context strongly suggest that the incidence of serious accidents is attributable to lack of effective policy decisions (See 'Vaal Reefs locomotive' and Cape Town 'container handling incident', courtesy Dept of Labour, 1996).

A typical definition of controlling, based on the medium of inspections and audits, is defined by Nigro. He contends that most management control systems include two standard procedures: written reports and inspections. It is acknowledged that the planned inspection is essential to an effective controlling function (Bird, 1985:121). Nigro does not, however, identify the elements required for the design of a control cycle, and notably excludes evaluation and feedback which are essential to managerial control (Newman, 1975:25). Without the evaluatory process of a steering mechanism, it seems unlikely that Nigro's controlling function would favourably impact on human behaviour.

2.3.2.2 Simon, Smithburg and Thompson

Smithburg and Thompson (1970) discuss the character of organisational influences in more detail. They distinguish between the pattern of behaviours that is deliberately and legitimately planned and the actual pattern of behaviours that depart slightly or widely from the formal plan of organisation. As such, the incompleteness of the formal organisation is sketched, with a gradual development into patterns of behaviour which supplement or contradict its formal plan. Particularly noteworthy is their assessment that non-deliberate departures from the formal organisation plans are occur frequently and are as significant as deliberate departures. This contention is particularly illuminating in the context of safety system analysis, as the nature of the informal organisations determines to a large extent the degree of behavioural response. Further, studies into safety system failures clearly indicate a prevalent pattern of non-deliberate departures from the formal organisation plan. Where the plan conflicts with deep-seated habits or attitudes it may be forgotten or ignored, without deliberate intent - for example, where the meaning of elaborate paperwork processes is not apparent to employees (Simon et al. 1970:193). Safety systems have been known to fail when design factors do not take cognisance of excessive plan complexity or of controls that require elaborate response or interfere with existing command structures (Reason, 1997:134). The authors indicate that where existing channels do not facilitate goal achievement, new or informal channels are employed to bypass or supplement the formal ones.

Nevertheless, the authors caution against a simplistic view about influences that determine the behaviour of organisation members. They rightly state that issues of legitimacy or authorisation of formal plans that affect behaviour are only a few among numerous influences, organisational and non-organisational, that determine the behaviour of organisation members.

This dissertation intends to demonstrate, however, that the steering controls utilised by the various management levels of an organisation will ultimately determine the effectiveness of behavioural response. This is the topic of our next discussion. As far as could be ascertained, papers do not exist on this hypothesis. Newman (1975:43) does demonstrate, however, the favourable linkage between steering controls and human response.

2.4 BEHAVIOURAL RESPONSE GOVERNANCES

2.4.1 Controlling Factors

2.4.1.1 management levels

Current safety programmes do not assign specific controlling functions to the various managerial levels of an organisation. Consequently, managerial input with regard to the safety of operational processes is limited. More importantly, the lack of basic controls prevent evaluation and feedback to the managers concerned. Typical examples of international safety programmes which fail to assign specific controlling functions to management levels are (a) National Occupational Safety Association (NOSA), (b) ISRS (USA), (c) ROSPA (UK). It is appropriate to recall here that managerial failure has been established as the root cause of all major accidents (Reason, 1991:251).

From the causal analyses of major accidents a critical factor emerges: the management hierarchy is implicated in accident causation (Reason, 1991:188). It is furthermore evident that existing safety programmes do not specify the type of managerial involvement necessary. Put differently, managers are not assigned specific actions to monitor and evaluate safety programme effectiveness. Consequently, the entire management hierarchy of organisations has limited opportunity to influence decisions and evaluate the safety of operational procedures. Nor, for that matter, does a mechanism exist which continuously measures compliance to existing safety programme standards.

This dissertation, therefore, seeks to provide a framework which will assign specific controlling functions to the various management levels of an organisation. Accordingly, a safety programme will be employed which will address the identified needs of senior, middle and supervisory management.

(i) Evaluation of operational processes

Analyses of accident scenarios indicate a deficient evaluation of causative factors. Hence a controlling function is required at every management level to evaluate operational processes for latent conditions and active errors. The evaluatory process of steering controls provides such a mechanism for every management level on a continuous basis.

(ii) Measuring compliance to operational safety standards

In view of active errors committed by operational staff, measurements are required to determine the degree of compliance to prescribed safety standards. In the past, such measurements were not extended to all management levels of an organisation. Consequently, the controlling function for measuring behavioural response – for example, task observations – was not carried out, making it impossible for managers to evaluate the effectiveness of behavioural responses.

Both the above controlling functions (i.e. evaluation of operational processes and measuring compliance to operational safety standards) are briefly discussed in the context of managerial levels applicable. As stated previously, all analyses in the context of this dissertation will be carried out at Koeberg Nuclear Power Station.

Senior Management Level

Three researchers who have implicated the senior management teams of organisations in accident causation are J Noyes, N Stanton (1997:109) and J Reason (1991:202). They have attributed accidents to fallible decisions taken by top-level plant and corporate managers. It is not so much a question of allocating blame, but rather of recognising the constraints facing senior managers during decision-making. Reason sketches two dilemmas that face executive leadership in terms of safety management. In the first place, resources directed at safety are not measurable in terms of cost benefit analyses (at least in the short term) and there is thus no 'certainty of outcome'. This is due to the stochastic, or random, elements in accident causation. Secondly, there is a problem regarding the nature of feedback – put simply, 'production feedback speaks louder than safety feedback'. Further, the feedback on safety problems is often filtered as subordinate managers also have 'interests to protect'.

This dissertation seeks to address these problem areas by providing an evaluatory mechanism for ensuring effective interaction between line managers. For this purpose a safety steering committee, staffed by the Power Station Manager and Heads of Department, will be utilised. The evaluatory function or steering mechanism assigned to this committee will be utilised to measure senior as well as subordinate manager's compliance to safety programme standards. This will include analyses of incidents with major loss potential, as well as of the trends in accident patterns, and co-ordination of safety programmes at middle management levels.

Interestingly, organisations which have experienced high accident rates are also experiencing problems with their safety steering committee functions. This is apparent when the minutes of these committees are examined and it is discovered that the evaluatory mechanism required to assess programme effectiveness is almost entirely lacking. Agendas of safety steering committees mostly do not require the mandatory evaluation of operational processes.

Further, the steering mechanism assigned to the senior management level incorporates the three safety management models discussed above – the organisational, engineering and person models. We recall here the analyses of Deborah Lucas, UK Health and Safety Executive.

Middle Management Level

The steering mechanism assigned to middle management will focus on the evaluation of programme effectiveness at group level. For this purpose a safety committee is utilised with the following functions:

(i) identification of latent conditions and active errors in the managers' area of accountability,

(ii) the degree of procedural compliance demonstrated by operational personnel.

Similarly, the three management models (organisational, engineering and person models), are integrated into the steering mechanism assigned to middle managers. Again, their primary function is to facilitate the identification of human error and precursors of accidents. The causal factors of the latter are subsequently evaluated at safety committee level.

Supervisory/Operative/Worker Level

The steering mechanism assigned to this level focuses primarily on the identification of active errors made during task performances/operational procedures. Active errors committed are evaluated by supervisory management to determine the root causes that led to failures in terms of behavioural response. Causative factors that pinpoint active errors are finally evaluated at group safety committee level. We can see from the above that there is a distinct application of steering controls in this 3-tier management structure. Again, the three management models – person, engineering and organisational – are integrated into the specific steering activities required for the supervisory management level.

As this dissertation intends to demonstrate that managerial steering mechanisms play a critical role during the identification and evaluation of accident precursors, Reason's analysis of managerial implication in accident causation is reviewed.

2.4.1.2 JT Reason

This author, noted for his comprehensive review and documentation of major disasters such as Bhopal, Challenger, Chernobyl, Zeebrugge and King's Cross, has developed a model which outlines the sequence of events necessary for the occurrence of an accident. In the postulated 'dynamics of accident causation' model, Reason describes a number of latent and active failures which produce an accident. Extrapolating both latent and active failures to actual accident scenarios, the efficacy of Reason's accident causation model can readily be established.

What distinguishes Reason's accident causation model from those of other authors (Bird, Kuhlmann, Heinrich) is his identification of a given sequence of managerial factors which result in events leading to an accident. Reason postulates fallible board decisions and policy of senior management as a primary precursor in an accident sequence. A further precursor is that of unresolved problems at line management level. This effectively implies that management in general fails to identify and evaluate latent conditions and active errors timeously. In contrast, Bird's accident causation model identifies generic management barriers, but does not specify the role of the various management levels in his accident causation model. Significantly, Reason's accident causation concept is the only model thus far which attempts to define specific failures on the part of management.

Reason does not identify lack of steering mechanisms as a problem area, but strongly advocates Lucas's three safety management models for the identification of precursors of accidents. The author of this dissertation contends however, that the mechanism of steering controls incorporates the three management models as an effective controlling function. Interestingly, to note that Reason's accident causation model can be effectively applied to analyse the causes of every major disaster that has occurred in the SA context, notably also the Merriespruit (1994) and Vaal Reefs (1995) incidents.

This concludes the systemic review of the factors that are likely to influence the behavioural response of operational staff. The effectiveness of key elements such as steering controls linked to management levels will be tested and evaluated in Chapters 3, 4 and 5. The management structure at Koeberg Nuclear Power Station will be utilised to test the effectiveness of steering controls. There follows a brief review of Koeberg's operational aspects and problems experienced with safety management programmes at the plant.

2.5 PLACE OF RESEARCH

2.5.1 Koeberg: Operational Abstract

The research for this dissertation was carried out between 1993 - 1998 in one of Eskom's Strategic Business Units, namely Koeberg Nuclear Power Station. Problems were experienced with behavioural response towards the conventional safety programme then in place and it was apparent that a different approach was warranted. Koeberg had at that stage obtained a 5 star rating but this had not resolved the punctuated recurrence of active errors. Consequently a line management-driven safety programme was proposed by the author of this dissertation during the latter part of 1993.

2.5.1.1 historical background

The construction of a commercial nuclear power plant on SA soil was first mooted during the late sixties, during an era of a world-wide tendency to 'to nuclear', primarily for strategic and political reasons. Coupled to the fact that Safari of Pelindaba had become operational, the availability of cheap uranium (with assured large reserves) in South Africa and Namibia (then South West Africa) confirmed the feasibility study carried out during 1972/3. South Africa at that stage did not possess the technical means to construct large commercial nuclear power plants. A turnkey contract was awarded to the multinational corporation Electricite de France (EdF) for the construction of a twin-unit N-plant capable of generating close to 2000 megawatt.

2.5.1.2 operational and legal

Current manpower complement for the day to day running of the station stands at roughly one thousand persons employed by Koeberg. During general equipment and refuelling outages this figure can increase to 1400, mainly through the addition of contractual staff for general and specialised functions of outage work. The organisational structure reflects nuclear engineering, maintenance, operating, manpower and nuclear safety assurance functions. Nuclear Power Generation in South Africa is governed by the Council for Nuclear safety (CNS), an umbrella organisation for the SA nuclear industry with full-time staff at Koeberg. The Occupational Health and Safety Act, promulgated in 1993, applies to Koeberg in its entirety, regulating electrical, mechanical and substance exposures in the workplace. Requirements of the Act are integrated into the safety programme. Koeberg follows Eskom policy by way of corporate hierarchy, with the Power Station Manager reporting directly to the Executive Director, Generation. This implies that Koeberg, like any of the other fossil power stations in the Generation enclave, is subject to Eskom strategy. Koeberg's chain of command follows the classical pattern of Chief Executive Officer (Power Station Manager) presiding over a 3-tier organisational structure which comprises of senior, middle and supervisory management levels. Participative structures include liaison with registered trade unions.

2.5.1.3 genesis of safety programme

Koeberg adopted the safety programme of the National Occupational Safety Association (NOSA) during 1986. Three objectives were to be met: (i) uniform safety standard to regulate premises and housekeeping, (ii) identification and correction of conditions posing hazards to worker safety, and (iii) legal compliance. Koeberg progressed from an initial 3-star rating (the NOSA system employs a star grading process for measurements of compliance) in 1988 to a 5-star rating in 1991.

However, the basis for sustained managerial commitment to the programme remained in question. This was reflected in the regular occurrence of accidents with considerable loss potential despite the achievement of a 5 star rating. Proposals made by the author resulted in the formation of a safety steering committee in 1993. The primary function of this committee was to ensure management involvement in safety programme activities, including the evaluation of safety programme effectiveness at Koeberg. The committee was empowered to determine safety policy at Koeberg and to act on the requirements arising from programme activities.

The latter part of 1993 saw the implementation of a 3-tier management safety programme. A middle bi-directional approach was utilised during safety programme co-ordination. This implied that programme elements for both the senior and supervisory management levels were simultaneously implemented. The programme element standards for the middle management level saw implementation only towards the end of 1994. This approach was adopted to ensure immediate involvement by supervisors and workers and to solicit their commitment. Further, senior management was then placed to evaluate programme effectiveness at the person – machine interface.

The safety programme was implemented under the leadership of middle managers in their respective groups and sections. Feedback indicated that effective programme leadership by middle managers was evident in groups with high programme acceptance – resulting in lower injury frequency rates. The author of this dissertation served as facilitator during group sessions of programme implementation.

Surveys were conducted by the author to assess safety programme effectiveness during 1994-1998. Questionnaires were submitted on an anonymous basis to managers, supervisors and workers to gauge the degree of behavioural response to the revised programme standards. **KEYPOINT**: it is of interest to note that groups with high programme acceptance consistently produced lower accident frequency rates than their counterparts displaying low or indifferent programme acceptance. This factor was repeatedly borne out during safety audits conducted by 'ombudsman' type groups measuring compliance to safety standards.

2.5.2 Testing of a New Concept

The remainder of this paper will analyse the effect of steering mechanisms on the behavioural response of operational staff. Chapters 3, 4 and 5 will evaluate this concept at the senior, middle and supervisory management levels respectively.

3. CHAPTER THREE: METHODS, MODELS FOR IDENTIFICATION AND MEASUREMENT AT SENIOR MANAGEMENT LEVEL

3.1 IDENTIFICATION - INTRODUCTORY

Identification of appropriate controls has remained a central concern for senior managers in terms of accident causation. As discussed in Chapter 2, managerial failure is cited as one of the root causes of all major accidents (Reason, 1997:173). Significantly, senior management levels are implicated for reasons of fallible board decisions and general inadequacy of safety policy (Noyes & Stanton, 1997:109).

Hence, this dissertation seeks to assign specific controls to the senior management level, namely regular safety evaluations of organisational processes and assessments of safety programme effectiveness.

Intended therefore, is the identification of resident accident pathogens in operational processes. For this purpose, specific programme elements are assigned to senior managers to control the accident potential. These safety programme elements will focus primarily on the evaluation of operational processes in terms of safety standards and compliance. To this end, steering controls will be utilised for the evaluation of the organisation's operational processes at the senior management level.

3.1.1 Function of steering controls

The function of steering controls lies in the continuous evaluation of Koeberg's safety programme. The intention is to provide senior managers with a steering mechanism for the identification of resident accident pathogens in operational processes and for continuous evaluation of operational processes throughout the organisation. This will require measurements of safety programme compliance at middle and supervisory management levels in order to determine programme effectiveness.

The mechanism utilised for this purpose will comprise a safety steering committee operational at the senior management level (to evaluate the organisation's safety programme) and support programme elements (to assist senior managers in the evaluation of programme effectiveness).

The safety steering committee, in terms of staffing representation, will require the mandatory participation of executive leadership, i.e. Power Station Manager and Heads of Department. The evaluatory mechanism of the safety steering committee will require review of incidents with major loss potential and latent conditions identified. Further, senior managers are required to carry out specific measurements of compliance stipulated by the support programme elements. For example, the evaluatory mechanism of these programme elements requires inspections, risk assessments and co-ordination of safety programmes at middle element levels.

The results or findings arising from these assessments are subsequently tabled at safety steering committee meetings and evaluated. Where measurements indicate compromised or inadequate compliance to programme elements, analyses are conducted to identify the root causes which impede behavioural response. Corrective actions may include revision of the support programme element standards which may render operator compliance difficult, revision of training or addressing managerial commitment and motivational factors. The specific functions of the steering mechanism, i.e. safety steering committee and support programme elements, are discussed below.

3.2 SAFETY STEERING COMMITTEE

From the above analysis of steering controls, the strategic importance of a safety steering mechanism can be deduced. The analysis identifies conceptually the facilitatory role of the steering committee in terms of effective leadership and other factors of organisational behaviour, including informal organisation, communication and decision-making. It is the author's intent, in view of managerial failure as the primary cause of industrial accidents (confirmed by Bird, Reason, Stanton, Noyes), to affirm the pre-eminence of this strategic programme element.

The agenda of the safety steering committee intended to facilitate the following processes: (i) identifying safety policy for the organisation, (ii) continuous development of safety programme elements for all management levels, (iii) measuring compliance to safety programme elements, (iv) evaluating the organisation's safety programme on a continuous basis. A participative approach would be required for the steering committee process. It was recognised that senior managers, special interest groups, programme analysts and worker representatives were required to participate if all levels of the organisation were to be reached.

The structure of the steering committee had to make provision for: (i) avoiding group 'hi-jack', (ii) opening and maintaining channels of communication.

3.2.1. Groupthink

The influence over thought processes by certain members of a group can pose a threat in terms of effective decision making. This aspect is particularly highlighted by the analysis of events that led to 'Pearl Harbour' and 'Bay of Pigs' (Lau & Jelinek, 1985: 24). More recently, the sinking of the 'Herald of Free Enterprise' has been attributed by Justice Sheen, Department of Transport UK, to a pervasive group norm which persistently failed to recognise resident accident pathogens. This type of managerial failure in a large corporation is also discussed by Reason (1991:232) when analysing the accidents of Chernobyl and space shuttle 'Challenger'.

Accordingly, the agenda of the safety steering was designed to counteract group norms. Firstly, the required participation by all committee members intended to counteract the reluctance of low-status members – i.e. union representatives, accident investigation respondees – to reveal potentially incriminating information to hierarchical supervisors. Further, a participative approach would ensure that low-status members initiated interaction as well, for example by putting proposals forward on how to prevent the causation of accidents. These aspects are correctly illustrated by Lau and Jelinek (1984:249) in their exposition of group communication. Third, in order to prevent the safety programme from being 'hi-jacked' by senior group members, specific 'frontline' programme elements (such as accident investigations and inspections) which require evaluation by senior managers, were included. This factor is particularly relevant during accident investigations where members will tend to rationalise the actual hazard away. As Robbins argues: 'No matter how strongly the evidence may contradict their basic assumptions, committee members behave so as to reinforce these assumptions' (1996:322).

It follows that inappropriate groupthink can compromise safety standards which in turn impacts on the behavioural response of persons. Indeed, groupthink was responsible for the unpreparedness of 'Pearl Harbour' and 'Herald of Free Enterprise' (Reason, 1991:193; Lau & Jelinek, 1984:249).

incidents where precursors pointed to latent failures and active errors, i.e. Challenger, Zeebrugge and Three Mile Island.

As a consequence of these latent and active factors, decisions were taken which in hindsight – the intention here is to avoid being a retrospective observer and slip into a censorious frame of mind – raise questions as to: (i) quality of causative data made available to senior managers; (ii) involvement of the organisational hierarchy in accident/incident investigation; (iii) evaluation of accident and 'near miss incident' causative data and resultant prescriptions for remedial actions. Bearing in mind how difficult it is to identify with any certainty the root causes of a specific incident, this dissertation will employ two therapeutic measures. The first entails the involvement of supervisors, middle and senior management in accident/incident investigation. The second prescribes the evaluation of accident causative data (including actual presentations by the respective subordinate managers at steering committee level) and an assessment of how effective remedial actions at safety steering committee level have been.

3.3.2 Risk analyses - baseline

A primary causative factor diagnosed in all major accidents – Zeebrugge, Bophal (India), Kinross (SA) Vaal Reefs (SA), Challenger – are latent and active errors not timeously identified (Reason, 1994:188-94; Noyes & Stanton, 1997:111). Conclusively, accident occurrences in the SA industrial sectors, as well as in-house analyses of incidents indicate that **precursors of accidents are not identified prior to occurrence** (see Department of Labour Statistics, 1996). By implication, if latent hazards are not identified and evaluated, existing resident accident pathogens are maintained. This is extremely unfortunate. In contrast to such widespread incidences of laxity, the multinational 'Electricité de Francaise' corporation has developed hazard-based assessments for their nuclear power plants to analyse risks threatening process safety on both nuclear and conventional islands. This foresight has led to a reduction in accident frequency rates.

Although these risk analyses exclude the identification of design-based errors, their effectiveness has been tested at Koeberg Nuclear Power Station. The risk analysis at Koeberg was expanded to include latent condition analysis for integration into the business of safety steering committees. Primarily, risk analyses facilitate the control of process safety, for example through a review of processes and engineering design, or through adaptive strategies intended to treat, tolerate, terminate, or transfer risk. Risk analysis, with its elements of identification, measurement and evaluation of all operational processes, constitutes a steering mechanism principle intended to facilitate managerial control over operational hazards.

3.3.3 Planned inspections

Inspection programmes are well documented in current literature and international safety programmes. A control critique however, is the lack of effective managerial participation in this programme. Consequently, the primary objective – identification of latent conditions – is only rarely achieved. This is evident from accident causative data such as the East Midlands Boeing 737-400 incident.

Frank Bird (1986) suggests a specific inspection programme for managers. The guidelines issued for this programme require managerial participation on all levels. From the analysis of the programme activities it is evident that latent conditions and to a lesser extent, active failures, will be identified. Evaluation of the safety programme implemented at Koeberg during 1988 indicated that senior managers were not involved in the planned inspection function. To redress this, the following guidelines were adopted:

- Participation of senior managers in the inspection programme.
- Participation of middle management, supervisors and worker-elected safety representatives in conjunction with senior managers.

To ensure that the inspection programme would demonstrate effectiveness, the following were included:

- Follow-up on the risk potential of hazards identified during previous inspections.
- Observation of critical task performance.

A further justification for managerial participation in the inspection programme is again based on JT Reason's identification (1991:251) of managerial failure to identify resident accident pathogens timeously. Further, R Kuhlmann (1986:121) has shown that inspections demonstrate to workers managerial commitment through visible activity for safety and health.

Major hazards identified by this methodology are tabled on the business agenda of safety steering committee meetings. The committee determines the type of adaptive strategy necessary to control risks threatening process safety. Planned inspections, therefore, constitute a primary function in terms of risk control – they provide the essential link to facilitate risk evaluation via the senior management level.

3.3.4 Programme co-ordination

None of the papers reviewed for the purpose of this dissertation addressed the function of programme co-ordination at subordinate management levels. Nevertheless, the failure of senior management levels to give direction and control to the organisation's safety programme, is well documented in case studies available from the Department of Labour and NOSA (National Occupational Safety Association, Pretoria). Mining houses such as De Beers Consolidated Mines and Anglo American can attest to this factor. In the case of Koeberg, safety programme development stagnated during the years 1989-1992 for lack of senior management involvement in safety co-ordination. The concept of co-ordination was introduced by the author of this dissertation to evaluate programme effectiveness at the middle management level and, ultimately, to guide the behavioural response of operational staff.

The function of safety programme co-ordination requires senior managers to direct and control the safety management programme at middle management levels. Based on the causative analyses of major national and international accidents (JC Howlett, 1994; JT Reason, 1991) four programme elements are identified as a means to identify, evaluate and control hazards threatening process safety.

3.3.4.1 hazard identification

Numerous papers have been written about hazard identification, but none of these analyses specify the criteria to be utilised to facilitate identification in the actual working environment. A specific hazard assessment chart was subsequently developed and implemented at the supervisory management level at Koeberg.

by Reason (1997:191) when examining the safety culture of organisations that had suffered major incidents. A fourth reason is supervisory acceptance of heuristics ('rules of thumb') applied by operational staff. If task observations recognise (and evaluate) the application of heuristics or rules of thumb, they will provide the organisation with a greater evaluatory safety culture, possibly the most significant aspect of this function. To be successful, task observations carried out at the supervisory level will require evaluation by middle managers, with feedback on major deviations identified to senior managers.

3.3.5 Management leadership

Current safety programmes address the managerial leadership function in generic terms, for example through presentations, public announcements, memoranda and addresses at functions. Leadership, as Newman has analysed, is not established by public announcement, it is based on executive behaviour (1975:159). Nor does a permissive leadership style lend itself to control strategies which require strict observance in terms of process safety (Newman, 1975:159). It suffices to say here that effective leadership is not 'underwritten' by safety programmes, which explains to some extent why managerial failure is repeatedly identified as the primary causative factor in almost every major incident in the past two decades. The following two programme elements attempt to facilitate safety leadership on the part of senior managers.

3.3.5.1 'rock face' communication

A programme of regular inspections facilitates communication in terms of housekeeping and existing hazards and demonstrates managerial commitment to supervisors and workers. As Cohen (1986) affirms, this activity affords informal top-down, bottom-up communication with supervisors and workers that is essential for evaluating operational safety. It puts senior managers in touch with actual task performance, and problems encountered in this area can be directly conveyed to management.

3.3.5.2 critical task procedures and heuristics

Arising from the above, planned inspections provide, *inter alia*, a means of assessing compliance to critical task procedures, particularly during engineering related task performances. Statistically, the frequency of disabling injuries is higher in engineering disciplines (maintenance or plant-intrusive work) than support services (non-intrusive work), a factor also identified by Reason (1997:85-90). A major cause of accidents is lack of guidelines on specific task performances. The inspection programme, therefore, is focused to identify the need for guidelines for critical task performances. The reason for this activity is two-fold: (a) identification of the use of heuristics by operational personnel and (b) evaluation of whether these 'rules of thumb' pose a threat to process safety.

The identification of programme elements representing steering controls for the senior management level is herewith concluded. The following discussion briefly analyses the conceptual function of the programme elements.

3.3.6 Conceptual framework discussed

The safety programme elements discussed so far (safety steering committee, accident/incident investigation, management leadership, etc) define the activities required by senior managers to direct and control the organisation's safety programme.

See graphic depiction below.

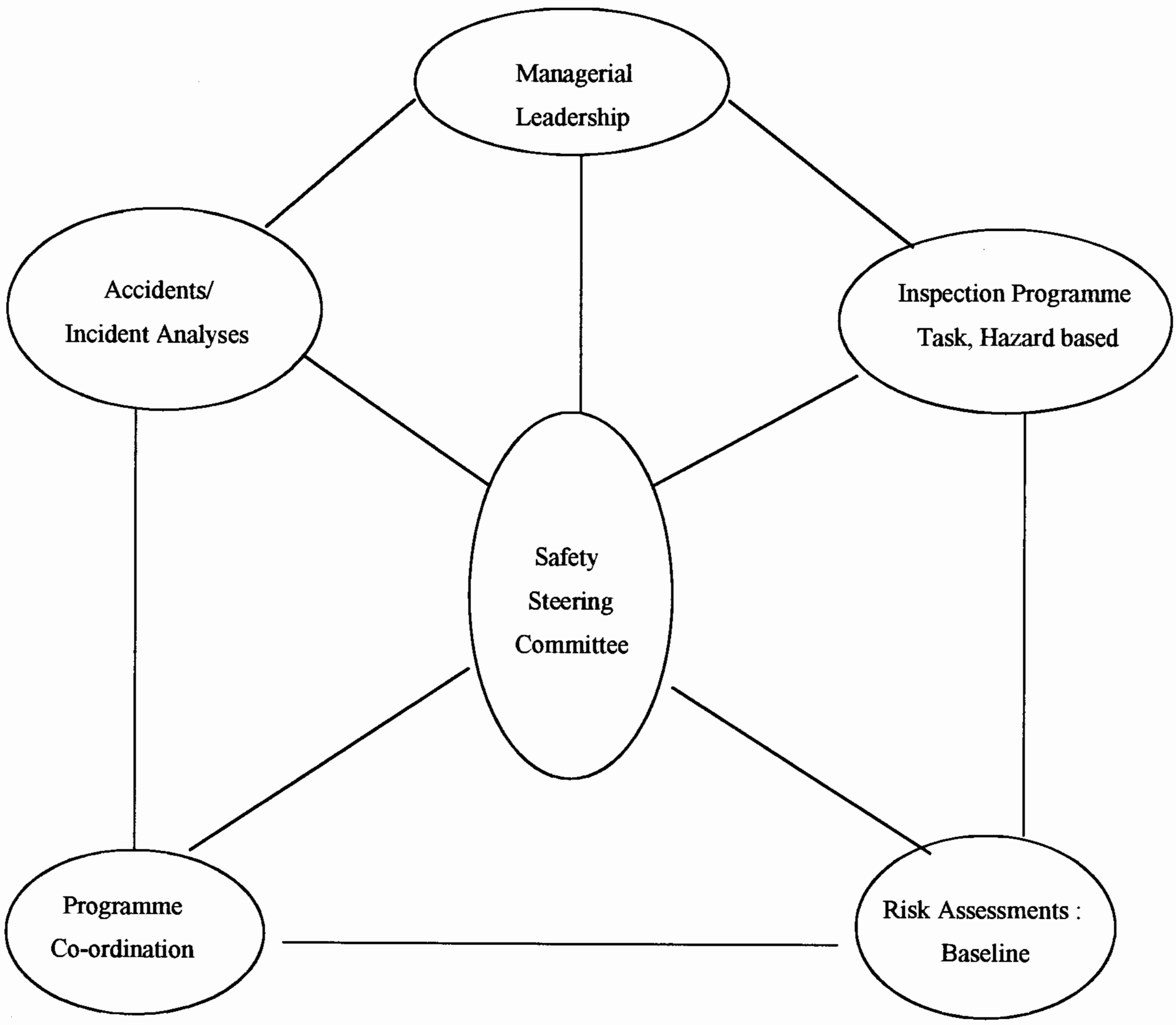

Figure 2 Exhibit 3A Conceptual framework of a safety programme: senior management level

The function of this framework is essentially threefold: (i) direction and control of the organisation's safety programme, (ii) evaluation of safety programme effectiveness at middle and supervisory management levels, and (iii) guiding the behavioural response of persons in terms of managerial leadership.

The programme elements the organisational engineering and personal models identified by Deborah Lucas in her 1990 Safety and Reliability Symposium paper, as necessary safety programme pre-requisites. The programme elements identified for the senior management level meet this requirement, primarily as a result of the steering mechanisms incorporated. For example, the organisational model views human error as a symptom that reveals the presence of latent conditions in operational processes. Programme elements such as inspections, risk analysis and programme co-ordination do identify, however, resident accident pathogens. The engineering model is represented by risk analyses and task observations which are elevated at safety steering committee level. Finally, the personal model, with its emphasis on active errors and personal responsibility, is met by elements such as management leadership, task observations and accident investigations. From the above we can see that certain programme elements are multifunctional, i.e. they represent two or more safety management models.

3.4 MEASURING CHANGE AGENTS: BEHAVIOURAL RESPONSE

3.4.1 Introductory

At the basis of safety programme analysis lie two problematic measurements: measuring the effect of safety programme elements on the behavioural response of persons and measuring acts of compliance which serve as indicators of behavioural response. The objective of these measurements is to identify changes in the behavioural response of senior managers as a result of the programme implemented. The safety programme to be evaluated was implemented during the latter part of 1993, and has run continuously since then.

Measurements related to behavioural response were conducted during 1994, 1995, 1996 and 1997. As stated previously, methods related to the analysis of behavioural response in a safety context are currently not available. Consequently, measurement and evaluation techniques were developed by the author of this dissertation. In order to exclude bias, qualitative questionnaires were repeatedly submitted to senior managers on an anonymous basis. Measurements reflected assessments on: (a) steering mechanism (basic controls), (b) behavioural concepts, and (c) effectiveness of safety programme elements.

Measurement methodologies were designed to answer two questions: (i) Is the steering mechanism guiding the behavioural response of senior manager? (ii) Do programme elements at the senior management level constitute an effective safety system?

3.4.2 Safety Steering Committee Evaluation

Multiple choice questionnaires were submitted to the entire group of eight senior managers. Questionnaires were completed by way of anonymous response. A 100% rate of return was received by the programme analyst for evaluation.

The primary objective of the questionnaire was to assess the effectiveness of the steering committee in terms of human behaviour and organisation. As a result of extensive management training, senior managers were considered proficient to assess the concepts of leadership, informal organisation, communication, decision-making and controlling.

3.4.2.1 results

a) The role of the steering committee was considered pivotal with regard to the direction and control of the organisation's safety programme. Significantly, the entire group of senior managers indicated this factor as critical to effective safety management.

b) The safety standard setting efficacy of the steering committee was confirmed. 20% of the managers, however, rated the effectiveness of the standards set by the steering mechanism between 60 and 80 percent.

c) Significantly, hazard identification and risk assessment techniques facilitated by the steering committee were rated highly by senior managers. The existence of the safety steering committee enabled senior managers to provide the necessary leadership and administration for the safety programme. Senior managers, for the first time, were able to evaluate the effectiveness of process safety at subordinate management levels utilising inspections and risk assessments. Corrective actions were implemented, as appropriate, at all three management levels and monitored for effectiveness. This enabled a participative approach with regard to safety management, and facilitated the implementation of changes to the safety programme.

3.4.2.2 human behaviour and organisation

The introduction of the safety steering mechanism required senior managers to utilise leadership skills for reasons of programme implementation and control. Unlike the 'quantitative' methodology of the then current safety programme initiated during 1988 (which limited the application of leadership skills), managers were required to exercise situational leadership skills which were applied to evaluate and direct compliance in terms of process safety.

3.4.2.3 leadership

Senior managers unanimously confirmed the provision of leadership by the safety steering committee in the following six areas of safety management : (i) developing and implementing safety programme controls, (ii) leading specific safety efforts, i.e. accident investigations, inspection programmes, (iii) leading safety programme evaluations, (iv) motivating subordinates in terms of safety awareness, (v) co-ordinating the safety programme at both middle and supervisory management levels, and (vi) having managerial safety leadership recognised by subordinates.

Further, senior managers rated the steering committee's effectiveness in terms of leadership provision at a more or less constant level of eighty percent. Analysis of these results indicated that the steering committee provides an appropriate platform from which to co-ordinate the safety programme. This hypothesis is based on the premise that executive leadership (i.e. top and senior management) are represented on the steering committee, enabling a participative approach which ultimately facilitates standardisation of programme elements, the strategic planning of programmes and the evaluation of programme effectiveness.

3.4.3 Leadership style assessments

Multiple choice questionnaires submitted to the entire group of eight senior managers achieved a one hundred percent rate of return. Listed were four current leadership styles :

1) authoritarian
2) democratic

3) *laissez-faire*
4) counselling

Senior managers were asked which leadership style they considered appropriate for obtaining commitment from middle managers. Results indicated that the 'situational leadership' style was primarily utilised by senior managers to direct process safety. Case studies confirmed Nigro's analyses (1965:273-274), that leadership styles are influenced and/or dictated at times by certain forces or scenarios governing a situation. More specifically, 'forces in the situation' refer to environmental pressures which a manager is exposed to. In a given situation, the urgency of a required safety instruction does not always lend itself to a democratic or *laissez faire* leadership style. Where lives are at risk, autocratic leadership styles may have to be utilised.

The forces in a situation, which may at times be critical environmental pressures which surround the manager and which may stem from serious safety concerns, can dictate his leadership style. Typical examples of environmental pressures surrounding the manager are:

- Inadequate existing safety precautions.
- A control standard 'circumnavigated' by a work group applying a loose set of heuristics or 'rules of thumb' to task performance instead of adhering to prescribed procedure.
- A specialised problem where the work group does not possess the knowledge and skill to perform a task safely.
- A non-supportive organisational culture. Deficient or lacking safety programme standards will induce a non-supportive culture. By contrast, Robbins (1996:685) demonstrates how a culture with strong organisational values creates an internal climate of high behavioural control.

The following narrative indicates the variance of leadership styles required for safety management.

3.4.4 Informal organisation

We recall here briefly that senior managers were not committed to support the safety programme. These 'non-deliberate departures from the formal organisation plan' were evident in the group norm amongst senior managers to remain 'not involved' in safety programme activities. The reason for this policy of non-involvement was found in the marked absence of safety policy at executive leadership level during the time period 1988 – 1992.

As a result, senior management abdicated their leadership role to subordinate management levels. This non-deliberate departure to limit participation in programme activities was triggered by the lack of cohesive safety policy, and thus of a structured safety programme for the organisation. This in turn meant that senior managers were not able to co-ordinate the safety programme of the organisation.

Multiple choice questionnaires were submitted to senior managers to measure their commitment to safety both prior to the implementation of the steering committee and post steering committee exposure.

3.4.4.1. measuring commitment after the steering committee

The introduction of a safety steering mechanism changed the informal organisation. Whereas senior managers had not supported the formal plan, i.e. co-ordination of the safety programme, the advent of the safety steering committee encouraged their commitment. Two related reasons for this change are:

(i) the health and safety steering committee facilitated determination of safety policy for the organisation;

(ii) as a consequence, the safety steering committee enabled senior managers to co-ordinate the organisation's safety programme. They were able to measure compliance to safety programme elements, evaluate effectiveness and implement corrective actions.

As a result of programme co-ordination, structured safety programmes were implemented at subordinate management levels. Evaluation of questionnaires (both quantitatively and qualitatively) indicated that the informal organisation at senior management level was supporting the formal organisation plan, i.e. safety programme co-ordination. This constituted an important paradigm in the managerial informal organisation. Senior managers supported the implementation of structured safety programmes for both middle and supervisory management levels. This was strongly indicative of a change in the informal organisation.

The evaluation process also indicated a notable change of commitment on the part of senior managers. Commitment to the safety programme, measured on a scale of 1–5, had increased fourfold!

What is emerging here is that steering controls are pivotal for the paradigm shift occurring in the informal organisation. Steering controls prevent non-deliberate departures and minimise the formation of a 'negative' informal organisation which does not support organisational safety objectives. It can be argued, of course, that a non-deliberate slip from the formal organisation is possible despite steering controls. It is put forward, however, that application of a steering mechanism will minimise departures and maximise commitment.

The informal organisation at the senior management level had changed its non-committed stance into that of support for the safety programme, primarily as a result of the organisation's steering committee with its required evaluation of programme effectiveness at subordinate management levels.

3.5 COMMUNICATION

Before the introduction of the Safety Steering Committee, the following received very little emphasis :

- safety programme information exchanges with peers on a regular basis;
- downward communication of safety issues to subordinate levels of management, including workers;
- guidance to middle and supervisory management enabling it to identify latent conditions and active errors.

Upon the introduction of the safety steering committee, senior managers were, for the first time, in a position to discuss aspects of the safety programme with their peers in a structured manner.

3.5.1. Lateral communication

Evaluations of multiple choice questionnaires indicated that, as a result of the safety steering committee's business structure, senior managers (heads of department) were discussing safety issues on a lateral level as often as once a week. This had not been the case before in this group of managers. Accordingly, process safety awareness amongst senior managers was heightened. This new awareness permeated down the line of command. Significantly, subordinate levels of management benefited from the channel of lateral communication facilitated by the steering mechanism :

- risks threatening process safety received the backing and support of senior management;
- senior managers identified with programme elements which governed process safety.
- lateral communication facilitated programme leadership at the worker level.

3.5.2 Downward communication

A planned inspection schedule for senior managers, developed via the steering committee process, facilitated downward communication as it enabled address of lower level managers and workers directly on safety issues. For example:

- The senior manager (e.g. during inspections) measured compliance to safety standards in his respective area of accountability. He communicated his observations directly to supervisors and workers.
- The senior manager, if so required, could directly address supervisory management and workers on relevant safety issues.
- The senior manager created 'a positive safety image' with his 'shopfloor' safety inspections, i.e. his involvement on the shopfloor demonstrated concern and commitment. This in itself communicated the unspoken viewpoint that safety was to be taken seriously.

Senior managers, chairing departmental safety committee meetings, would address subordinate managers on safety issues. This committee process facilitated the safety programme co-ordination with middle managers and the creation of a co-operative safety culture through participation and group interaction. The senior manager, moreover, was seen to be committed to safety.

3.5.3 Upward communication

Certain principles discussed under 3.4.2 'Assessing downward communication', facilitated upward communication, including planned inspections by senior managers.

During weekly safety inspections in his area of accountability, i.e. workshops, plant areas, etc. the manager would be in a position to discuss safety-related issues with supervisors and workers. This resulted in hazards being brought directly to the attention of the senior managers without the filter process of a further two management levels possible distorting information. It must also be stated that certain safety issues raised by workers were in this manner quickly and accurately resolved.

Further, the senior manager was in a position to receive feedback directly from the worker level. Consequently, safety hazards were resolved more timeously, bringing about a better understanding (by both manager and worker) of the magnitude of certain identified hazards.

Summary of achievements

The introduction of a safety steering committee facilitated structured communication in the organisation. Significantly, lateral communication was utilised to co-ordinate the safety programme at senior and subordinate management levels. The support programme element of planned inspections facilitated upward and downward communication, involving middle, supervisory management and worker levels

3.6 DECISION-MAKING

Senior managers, before the implementation of the safety steering mechanism, were not able to confer with one another on a structured basis to implement safety policy. As a result, decisions required for the management of a safety programme were taken on an ad hoc basis only.

The introduction of the safety steering committee enabled lateral communication which in turn facilitated decision making. These improvements were established via qualitative assessments. The participation of the Chief Executive Officer and senior managers on the safety steering committee facilitated interaction on the structure of process safety. Senior managers, therefore, were able to obtain lateral clearances from one another before decisions on safety control standards were taken.

The health and safety steering committee facilitated decision making as senior managers were able to communicate laterally on safety programme co-ordination. Managerial inspections made the process of measuring compliance easier. Evaluating programme effectiveness requires lateral clearances from participating managers.

3.7 CONTROLLING

3.7.1 Planned inspection programme

The planned inspection programme devised for senior managers included all areas of plant, process and equipment. Inspections were carried out on a monthly basis in conjunction with middle, supervisory management and employee representatives. The inspections were utilised to measure compliance to the following programme standards:

(a) **Measuring safety programme compliance at middle and supervisory management levels.**

Compliance with strategic and support programme elements was measured by senior managers. To this end, safety records of middle managers and supervisors were checked in terms of compliance, e.g. critical task observations, risk assessments or safety communication at the worker level.

Workers, on the other hand, were questioned by senior managers as to whether they had received communication on process safety.

(b) **Inspection of the place of work**

Actual physical conditions, i.e. equipment, materials and environment, were inspected. Premises were evaluated in terms of housekeeping and risks posed to workers by process activities. As inspections of this nature were carried out by team with the responsible managers participating, it was possible to rectify substandard conditions which posed specific hazards to operational safety timeously.

(c) **Inspection by team**

As indicated above, inspections were carried out by team. This implies that areas or groups were inspected with the responsible middle manager and supervisor participating. This required participation achieved the following objectives:

- Senior managers would visibly demonstrate their commitment to the safety programme to subordinate managers and workers.
- Problems identified during inspections would be directly brought to the attention of the responsible manager or supervisor.
- Team approach facilitated information exchange on perceived problem areas between managers and workers. Put differently, workers were able to access senior managers directly with regard to safety problems experienced in the work situation.
- During repeat inspections, managers would be able to assess whether remedial actions to assure worker safety had been effectively implemented.

3.7.2 Primary controlling function

The safety steering mechanism was utilised to evaluate major findings/issues identified during inspections which posed risks to process safety. Additionally, a review of risks was exercised by the programme analyst to ensure corrective remedial action. As required, risks were subjected to the adaptive strategies of treat, tolerate, transfer or terminate. Conclusively, the controlling function therefore relies on the identification and measurement of risk through the medium of inspections. Evaluation and control of risk is also, however, carried out at steering committee level.

3.8 CONCLUDING REMARKS

Attempts to implement a safety programme without the evaluation mechanism of a steering committee had induced programme failure at the senior management level. Significantly, methods and models employed for measuring programme effectiveness excluded the identification of strategic and support programme elements. Consequently, behavioural response at the senior management level failed to co-ordinate the organisation's safety programme. Analysis of programme failure indicated that managerial leadership failed for reasons of inadequately structured programme elements. Consequently, the informal organisation at this level responded with a non-deliberate departure from the formal plan. As the framework conceptually excluded lateral communication, decision making and the primary channels of communication remained ineffective.

Drawing on the insights gained through the analyses outlined above, the revised safety programme conceptually included steering controls at both the strategic and support programme element levels. The safety steering committee structure required mandatory participation by senior managers, thus facilitating lateral clearances required for the implementation of organisational objectives.

The inclusion of steering controls linked to the senior management level enabled evaluation of safety programme effectiveness, a concept not practised before at this level. Support programme elements were structured to enable measurements of compliance at both the middle and supervisory management levels. Methods of measurement for programme evaluations were incorporated in support elements/variables. The function and effectiveness of these elements was evaluated by the safety steering committee. The structure of these elements included the analysis of descriptive statistics and measurements of compliance, i.e. accident analyses and programme co-ordination, respectively. Methods of measurement differed in scope and domain, i.e. managerial inspections measured compliance in terms of operational processes whereas other variables measured compliance to safety control standards.

This safety management model facilitated measurements of compliance on all three managerial levels with feedback mechanisms to the safety steering committee.

The effect of the safety management system on the behavioural response of senior managers was evaluated by a mix of quantitative and qualitative methods of assessment. Qualitative assessments were also based on the purely descriptive analysis of statistics, i.e. measuring accident frequency rates. The concept of leadership, when measured, was strongly influenced by the safety steering committee and support programme elements. An outstanding paradigm shift occurred at the senior management level. An emergent inductive process facilitated safety programme implementation at subordinate management levels. Concomitantly, the non-deliberate departures from the formal organisation plan were reversed or, put differently, the noncommittal stance of managers was altered.

The lateral clearances afforded by the safety steering committee restructured communication and decision-making, and were conceptually aided by the support programme elements.

At the same time, the controlling function was restructured by adapting the support programme elements to measure compliance in areas critical to process safety. Significantly, the process of evaluation introduced by the safety management programme via steering controls provided the primary inputs in terms of behavioural response.

The following chapter repeats the discussion of a specific safety management system at the middle managerial level, continuing the conceptual framework outlined so far.

4. CHAPTER FOUR: METHODS, MODELS FOR IDENTIFICATION AND MEASUREMENT AT MIDDLE MANAGEMENT LEVEL

4.1 IDENTIFICATION – INTRODUCTORY

Middle management (also equated with line management) has been implicated in the causation of accidents because of its failure to identify latent conditions and active errors. These are the two factors consistently singled out by authors such as Reason (1991:203) and Stanton and Noyes (1997:109). Both failures are, moreover, generally confirmed by principal investigators tasked with the identification of causative factors of major accidents (for example Legasov in his 1986 investigation of Chernobyl and Blackbeard in his 1995 investigation of Vaal Reefs).

This dissertation, therefore, seeks to assign to the middle management level specific activities or programme elements that will help it to identify latent conditions and active errors. The programme elements will focus primarily on the evaluation of required safety standards during task performance at the supervisor/worker level. For this purpose steering controls are utilised to ensure evaluation of task performance during operational processes. Middle managers in conjunction with supervisors will be required to measure compliance to existing safety control standards. They are further empowered to evaluate on a continuous basis the existence of latent conditions – resident accident pathogens – which can endanger the safety of operations.

4.1.2 Function of Steering Controls

The function of steering controls lies in the evaluation of safety programme effectiveness of the various middle management groups at Koeberg Nuclear Power Station. The intention is to provide middle managers with a mechanism for measuring operative compliance to existing task procedures and to evaluate task procedures/processes on an ongoing basis in order to identify possible latent conditions or active errors. It follows that these evaluatory processes are designed to assess the behavioural response of operational personnel.

The steering mechanism prescribed for the above process is a group safety committee with a specific structure to facilitate evaluation of the safety programme at both middle and supervisory management levels. Incorporated into this process is the provision of support programme elements which measure operative compliance to existing task procedures and continuously evaluate task procedures/processes for latent conditions or resident (accident) pathogens.

The group safety committee, in terms of staffing, will require the mandatory participation of the respective group manager, 'frontline' supervisors and worker-elected safety representatives. Group managers, via the committee agenda, are required to measure supervisor/operator compliance to safety programme requirements. Examples of these measurements of compliance are supervisory task observations, inspections and hazard assessments.

The above measurements of compliance are evaluated at group safety committee level. Where compromised behavioural response is indicated, corrective actions as appropriate are then assigned to committee members, i.e. supervisors, worker representatives or investigations are conducted to determine root causes. Where latent conditions are identified, the committee will attempt to resolve the problem 'in-house'. If, due to organisational constraints, this is not possible, the matter is deferred to the safety steering committee senior management level.

This chapter attempts, therefore, to assign specific safety programme elements to the middle managerial level to evaluate safety programme effectiveness. For this purpose a safety steering mechanism is utilised to evaluate compliance to existing safety programme standards. Measurements of compliance, provided by support programme elements, are evaluated by the group safety committee. Again, the role of steering controls and their impact on human behaviour is central to the discussion in this paper.

4.2 IDENTIFICATION: PROGRAMME ELEMENTS

4.2.1 Introduction

The middle manager, in a 3-tier organisational hierarchy, is normatively tasked with the actual co-ordination of the safety programme and required measurements of compliance. This entails programme implementation at the supervisory/worker level. In the past, the structures of the safety committees regrettably excluded supervisory staff with essential 'frontline' knowledge. This had effectively prevented middle managers from implementing the safety objective in the steering mechanism programme at supervisory level. To compound matters, safety committees were not structured to evaluate programme effectiveness at the 'rockface'.

4.2.2 Group Safety Committee

As discussed above, safety committees were not structured for programme co-ordination and evaluation. Consequently the steering mechanism, i.e. measurement and evaluation of safety programme effectiveness, could not be put in place. This dissertation therefore seeks to restructure both the human resource and safety programme functions at group committee level to promote the application of steering controls.

4.2.2.1 participation by supervisory management

Safety committees at Koeberg Nuclear Power Station were restructured to provide, under middle managerial chairmanship, participation by 'frontline' supervisors and worker elected safety representatives. Although Goodman in his 'Rushton Quality of Work Experiment' (1979:48) accepted supervisory participation on safety committees, measurements of compliance and evaluations of programme effectiveness were not carried out. Analysis of the 'Rushton' Accident Data revealed a static severity rate, with Goodman (1979:52) concluding that accident rates remained unchanged. Goodman's experiment clearly shows that the mere presence of supervisors on safety management committees does not enhance safety. Control mechanisms go hand-in-hand with this innovation.

The purpose of the new participatory approach at Koeberg, then, was to introduce a steering mechanism that would continuously evaluate programme effectiveness during operational processes. There are powerful arguments in favour of including supervisors in group safety committees. Supervisors are familiar with hazards affecting process safety; their presence would expedite joint middle manager/supervisor interaction during hazard evaluation and they would in any case be responsible for implementing controls for hazards identified. The role of the supervisor, in a safety context, is currently defined within narrow limits only (Bird & Germain, 1986:58); indeed current literature does not analyse the role of the supervisor in process safety. In the "Rushton Experiment", Goodman (1979:48-52) excluded the managerial – supervisory interaction at committee level. Significantly, Goodman concludes that the experiment did not reduce accident frequency rates over a four year period.

Similarly, Bird (1985:187-216) in his detailed description focuses almost primarily on supervisory communication but excludes evaluation of safety programme effectiveness. Nor does he consider the managerial relationships of the group safety meetings, i.e. middle manager – supervisor interactions.

Analysis of safety programme failure at Koeberg's middle managerial level identified that group safety committees lacked supervisory participation. Supervisors need to co-ordinate, however, the implementation of programme elements. Further, changes to the safety programme (whether a new programme element or adjustment to existing standards) require evaluation and feedback to assess effectiveness. Middle managers have to rely on supervisors for feedback from the operative/worker level with regard to key factors such as behavioural response and effectiveness of controls implemented. Quantitative analyses (safety audits) conducted in the time period 1990-1993 confirmed the lack of supervisory involvement in programme activities.

4.2.3 Developing Support Programme Elements

In order to facilitate the identification of latent conditions and active errors at the supervisory management level, specific safety programme elements are assigned to every middle manager in the organisation. It is again stressed that existing international safety programmes entirely exclude this aspect. Nor is the role of steering mechanisms defined for a specific management level. Accordingly, specific support programme elements are adapted to the middle level executive function.

4.2.4 Accident/incident investigations

Traditionally organisations display the required form of accident investigation but essentially without effective middle managerial input. Analysis of causal factors by the SA Department of Labour (1995), as well as the National Occupational Safety Association (NOSA) indicates that managers are not familiar with accident causative factors and that, as a result, incidents with a high loss severity potential are not investigated. Consequently, the root causes of accidents are not exhaustively identified.

Needless to say, middle managerial non-involvement in accident investigations had impacted on the informal organisation at the supervisory level – they withdrew from active accident investigations. This was established by conducting safety audits (quantitative assessments) during 1993.

Accident investigation was restructured to secure middle managerial input as follows: accidents/incidents exceeding a certain loss severity (quantifiable in terms of injury potential and cost) required managers to lead investigations. This notably included 'near-miss' type of incidents which required each event to be evaluated to determine the **potential** to cause major process losses. Further, middle managers are required to present causative factors for evaluation at the safety steering committee's meeting. These 'high profile' type of evaluations are to facilitate the identification of latent conditions and active errors. Accidents/incidents which do not exceed the required setpoint level in terms of severity potential and cost, are evaluated at safety committee level by the middle manager.

Analysis of current accident reports confirms that supervisors, due to the complex and multifaceted systems of today's high-risk technologies, cannot consistently identify resident accident pathogens (Reason, 1994:174). As a result, supervisors fail to distinguish between symptoms and root causes of accidents. This failure may derive from the fact that access to information is blocked by lack of 'hands on' contact with the process. Reason (1997:179) has consistently argued for the exposure of operational personnel to the potential hazards of high risk installations, and he cites the 'Piper Alpha' disaster (6 July 1988) to confirm his finding. In order to compensate for 'information blocks' encountered by supervisors during accident investigations, middle managers at Koeberg are required to analyse every incident/accident in order to identify contributory factors. Such data is evaluated in terms of trends identified and briefed to operational personnel. Hence again the imposition of a steering mechanism to evaluate accident causative data.

4.2.5 Risk assessments

Risk, in the context of this dissertation, refers primarily to: (i) the identification of hazards (latent conditions, active errors) and (ii) the measures identified to control the hazards. Control measures include certain adaptive strategies to either treat, tolerate, transfer or terminate the risk of the hazard identified.

Risk assessments are carried out to evaluate hazards in middle management's areas of accountability as well as to evaluate the threat posed by the hazard in terms of risk adaptive strategies. It follows that risk assessments provide a steering mechanism to assess the effectiveness of operational safety standards. Interestingly, mining giants – notably Vaal Reefs Exploration and Mining, Rustenburg Platinum Mines, (Anglo American Corporation) – have adopted a comprehensive risk management strategy.

Referring back to the lack of exposure of operational staff to potential hazards, middle managerial level executives need to actively participate in risk assessments. The implication of this finding is that middle managers need to participate in the assessment of major hazards to demonstrate that appropriate controls have been provided. Where high-risk (nuclear, gaseous, corrosive) technologies are used, activities are most likely to occur which require specific controls to prevent or ward off potential loss (Reason, 1994). A brief summary of the evaluation process is given below.

4.2.5.1 people

People need to be evaluated because they may lack the necessary skills, adequate training and motivation, or they may evince abnormal behaviour patterns. Programme support may be lacking. People are also responsible for inadequate policy and communication, inadequate programme standards and tasks not analysed in terms of process safety.

4.2.5.2 equipment

Equipment needs to be evaluated because it may be 'not fit for purpose', not maintained or lack essential safeguards. Hazards inherent in equipment, such as physical stresses or latent pathogens, may have been overlooked.

4.2.5.3 materials

Materials need to be evaluated because they may contain hazards, or they may be of poor quality, or not fit for purpose. There may be chemical or biological stresses.

4.2.5.4 environment

Ergonomic stresses such as noise, light, heat, contamination, dust and radiation, need to be evaluated for risk potential.

The primary function of risk assessments lies in the provision of an evaluatory mechanism. Some of the elements of this mechanism are outlined below.

4.2.6 New design/modifications

The latent error analyses represented in the works of Reason (1991), Rasmussen (1988), as well as engineering psychology contributions by Noyes and Stanton (1997), accurately reflect inadequate design as a major causative factor of accidents. Analyses of accidents in the South African context, such as : Vaal Reefs (1995), Kinross (1986) and Merriespruit Dam Disaster (1994) confirm this hypothesis. Further, numerous disabling injuries incurred by workers are the result of incompatibility between equipment design, procedures/training and achievable human performance (Noyes & Stanton, 1997:110). Approval of new design and modifications for plant and equipment are often not compatible with the users expectations and mental models. As Noyes and Stanton (1997:111) point out, the 'state of the system should always be unambiguously clear to the operator in order to reduce the occurrence of mode errors'.

In order to eliminate the margin of error, design principles require structures that evaluate the design from a standpoint which may be hostile to the user, i.e. user misinterpretation as to design function (Norman, 1988 and Reason, 1991). New structures must, moreover, be designed for error, i.e. assume the occurrence of error and plan for error recovery. Plant processes must be ecologically designed so that they simultaneously support the skill-based, rule-based and knowledge-based levels of worker/operative performance (Rasmussen & Vicente, 1987). Finally, an ergonomic audit of design criteria must establish physical, mental and chemical stresses. (The 'negative' response of the informal organisation amongst operational staff was induced *inter alia*, by persisting design problems.) In order to incorporate these four criteria in the review of existing, new and modification designs, a two-step approach is proposed by the author of this paper.

Firstly, there is an exigent need for design review at safety committee level with input from designer, middle manager, supervisors and worker elected safety representatives. **Important at this stage is the user presence for the evaluation of user expectations.** Certain facilities designed at Koeberg, for example materials handling in workshops (1993), were problematic to operate. (The problem is certainly not unique to Koeberg and evidence as to the lack of user requirements in general industry is available from the Cape Western National Occupational Safety Association.) Further, reviews from engineering and safety programme analysts are necessary to identify the potential for accident loss or risk factors. This is in line with Norman's 'The Psychology of Everyday Things' (1988) as it provides consistency of 'wrapping' between the designer's model, the system model and the user's model.

Secondly, after implementation of the design, an acceptance inspection by designer, manager, supervisor, programme analyst and worker representatives to measure compliance with the original design. Where possible, systems are to be tested to confirm design effectiveness. Reason and Norman both suggest the exploitation of natural 'wrappings' between intentions and possible actions.

4.2.7 Inspections

Managerial inspection programmes are, in current safety systems, primarily focused to measure compliance to plant maintenance standards, the operation of safe systems of work, cleaning and housekeeping. As Stranks (1994:86) points out, this technique tends to be a more general examination of safety performance at a particular juncture. The limitations of this inspection technique are ascribed to the exclusion of formal safety assessments of major hazards. A further problem is the lack of managerial participation which tends to downgrade the importance of these inspections. Although both Bird (1985:121) and Stranks (1994:86) propose specific inspection criteria, cognisance is not taken of specific process hazards or managerial participation. Yet the latter demonstrates managerial commitment to the safety effort through a somewhat limited controlling function. The author of this dissertation argues for a wider definition in terms of managerial safety measurements. Analysis of current inspection programmes indicate limited impact on worker safety motivation and evaluation of control systems. This viewpoint is confirmed by Stranks (1994:86) and indirectly by Goodman in 'The Rushton Quality of Work Experiment' (1979).

Accordingly, for the purpose of this paper, inspections have been re-structured to provide a meaningful evaluation of control systems critical to process safety. Three sub-elements are utilised: (i) inspection of high risk areas (ii) evaluation of controls implemented for high risk areas (iii) worker/operative compliance to controls governing high risk areas. The inspection function is not limited to the areas critical to process safety, but also extends to aspects such as cleanliness, housekeeping and maintenance of physical conditions. But the emphasis is redirected to assess factors critical to process safety, the aim primarily being the identification of latent conditions and active errors, which, as Reason has convincingly argued (1997:10) forms the basis of accident occurrence.

This revised inspection function is to facilitate the identification of latent errors in areas of plant, equipment and systems design as well as of failures in the managerial organisation such as operational problems, fallible board decisions and line management deficiencies. Identification of errors is again based on Reason's accident causation model (1997:17). The revision also allows for the identification of active errors such as procedural non-compliance (heuristics) and particularly utilisation of Rasmussen's adept knowledge-based framework (1983) as a way of measuring worker/operative error from changes that they have neither been prepared for nor anticipated. This point is also confirmed by Reason (1991:61).

4.2.8 Task hazard identification

Current task evaluations are limited to supervisory observations which measure the subjects compliance to the various steps dictated by a specific procedure. This approach is subscribed to by present day safety programmes such as the SA-based NOSA programme or U.S. International Safety Rating System. Although there is merit in measuring compliance to standards, this type of controlling function is beset with specific problems. Analysis of task observations clearly indicates that hazards/deviations are identified very infrequently and that the loss potential of the hazards/deviation identified is mostly of little consequence. These aspects were identified by the author at Koeberg during quantitative assessments (1994-1997), and generally confirmed by franchised operators of safety programmes such as International Risk Control Africa and Haslac. Supervisors largely resent this function of measuring compliance as it seems to imply 'spying' on subordinates or watching them during task activities, often regarded by both workers and supervisors as breaking mutual trust. The behavioural response to task observation is therefore largely negated by the factors outlined above. Indications are that generic training directed at hazard identification does not provide immunity the tendency to overlook hazards during task performance (JC Cotton, 1993).

Nevertheless, the necessity to identify hazards associated with process safety remains, and the author of this dissertation is advocating a 'pre-emptive' approach, in the first place to identify and evaluate hazards **before** commencement of task activities. This is best undertaken by supervisors, specific responsible persons or self-directed work teams. Secondly, worker/operative team-brief on hazards most likely to be encountered in the job situation is needed. This will entail a structured approach with practical definitions concerning risks encountered during task performance or the graphic usage of hazard identification charts. Where hazards are identified, risks are evaluated to determine (a) the need for short-term protective measures, and (b) medium to long term actions to control the potential of risk. This might entail replacing heuristics with task procedures or instituting changes to engineering design.

4.3 CONCEPTUAL FRAMEWORK DISCUSSED

The safety programme elements discussed so far (group safety committee, task hazard evaluation, new design/ modifications, accident/ incident investigation) define the activities required by the middle manager to evaluate programme effectiveness at the supervisory/ operational level.

The function of this framework is essentially threefold:

(i) measuring compliance to programme standards at the supervisory level;

(ii) evaluating the degree of compliance ;

(iii) evaluating hazards identified in terms of risk-adaptive strategies.

Essentially, therefore, the evaluation measurements of compliance exist to indicate the effectiveness of behavioural response.

The programme elements incorporate the organisational, engineering and personal models discussed in Chapters 2 and 3. The programme elements identified for the middle management level meet this requirement. The all-important organisational model views errors as symptoms that reveal the presence of latent conditions in the system at large. This model is represented by planned inspections and task hazard evaluations. Both programme elements facilitate the identification of latent conditions via their steering mechanisms. The engineering model is represented by the new design, risk assessment programme elements which are evaluated at group safety committee level. The personal model, with its focus on active errors and personal responsibility is represented by group safety committee meetings, accident/ incident investigations and inspections. Evidently, programme elements are multifunctional: they represent two or more safety management models.

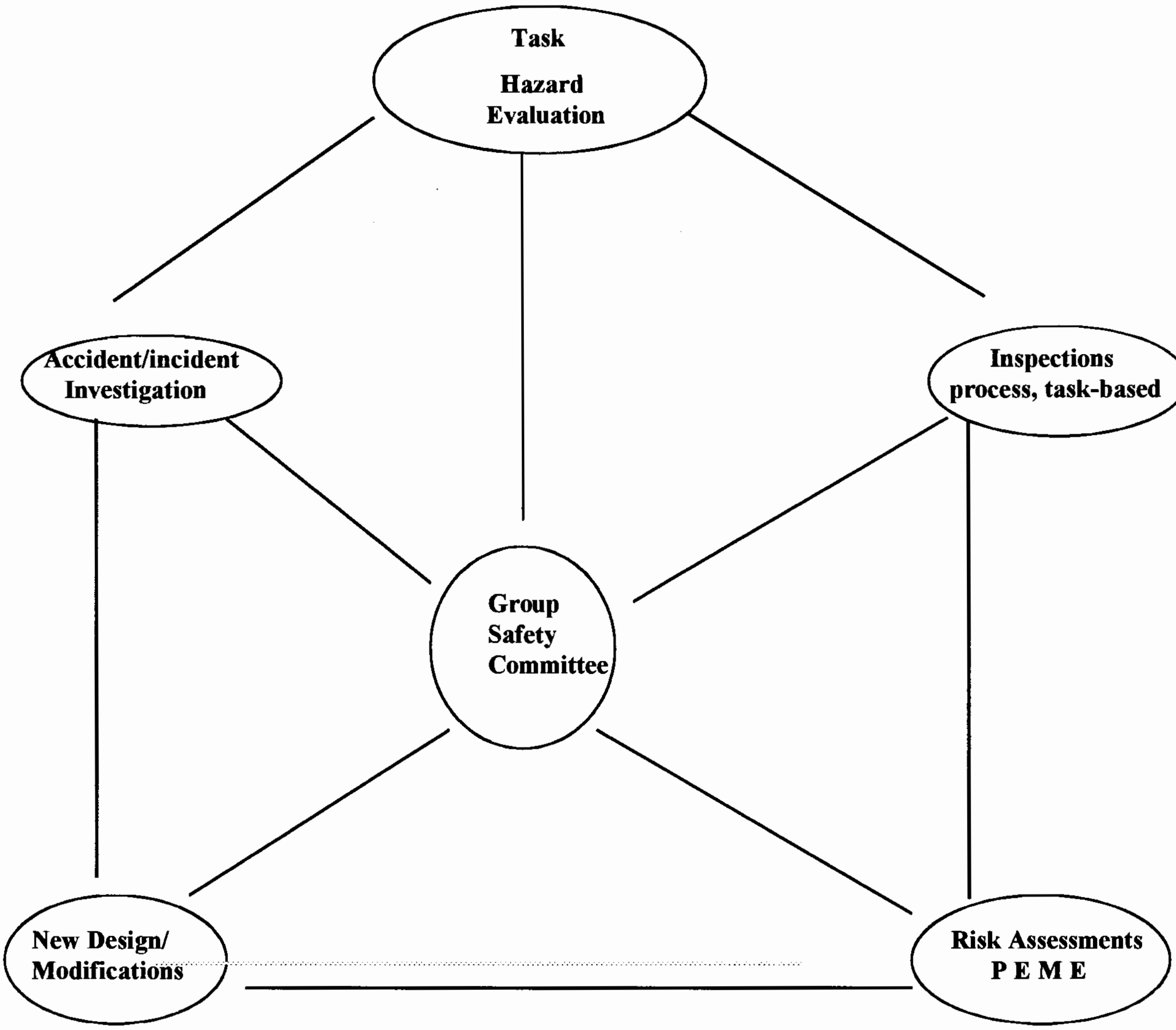

Figure 3. Exhibit 4A. Conceptual Framework of a Safety Risk Management System (middle managerial level).

4.3.1group safety committee

The purpose of this committee is threefold : (i) implementation of programme elements at the supervisory management level, (ii) measuring and evaluating compliance to programme standards, and (iii) correcting safety system deficiencies based on programme evaluations. In terms of organisational behaviour the steering mechanism of the group safety committee intends to expedite effective leadership for programme implementation and evaluation and to change, where necessary, the behavioural response of supervisors and workers by revising programme standards. The mechanism promotes lateral communication for decision-making, communication, and programme implementation. The Group Safety Committee also sustains the controlling function at subordinate management level by measuring and evaluating safety programme element effectiveness at supervisor and worker levels.

The agenda of the group safety committee requires middle level executives to exercise the controlling function of every support programme element whether it be task hazard evaluation or inspections. The primary function of the support programme elements lies in the evaluation of safety programme effectiveness at the supervisory management level. Supervisory feedback on the effectiveness of this function is evaluated via the group safety committee. A further aim of the steering mechanism lies in the creation of an 'open' safety-reporting culture, a culture disturbingly absent in many organisations.

4.4 BEHAVIOURAL RESPONSE: MEASURING CHANGE AGENTS

4.4.1 Introductory Remarks

Measurements of behavioural response at the middle managerial level comprise two types of assessments: (i) measuring the effect of steering mechanisms on the behavioural response of persons, and (ii) measuring the effect of specific programme elements adapted to influence behavioural response. The safety programme designed for middle management was implemented during the latter part of 1996, and has run continuously. Measurements in terms of behavioural response were conducted in 1996 and 1997. As a result, certain changes were effected to the safety programme during 1997 and 1998. The function of three support programme elements was altered; the strategic programme element (group safety committee) with its steering mechanism, however, was not. Both quantitative and qualitative assessments were conducted amongst middle managers to measure change in the various categories of human response

4.4.2 Leadership

The main structure of safety committees at group level evolved to provide middle managers with a mechanism to lead safety programme implementation and evaluation. Historically, safety committees were not utilised to evaluate programme effectiveness but relegated to simplistic measurements of compliance with regard to inspections conducted by safety representatives. Moreover, the absence of supervisors at safety committee level had made it impossible for managers to lead subordinates in terms of safety programme requirements (Koeberg Safety Audit Reports, 1990-1993.) Multiple choice, quantitative assessments were evaluated from eighteen responses with a 90% rate of return. The principle four factors which influenced middle management leadership are discussed below.

4.4.2.1 safety steering committee

As discussed in Chapter Three, middle managers had not been issued with safety programme guidelines by executive leadership. The introduction of the safety steering committee at that level cascaded safety policy down to middle level executives with a resultant breakdown into specific requirements. This enabled middle managers to plan, organise and lead the implementation of safety programme requirements, a practice not followed before.

4.4.2.2 group safety committee

The exclusion of frontline supervisors from safety programme involvement had been diagnosed as ineffective (see Koeberg Safety Audit Reports, 1990-1992; Stranks, 1994:6). In short, middle managers had previously not set in motion a 'process of influencing the activities of individuals or groups in efforts towards goal achievement' (Hersey & Blanchard, 1972:68). The revision of the safety committee, however, included both supervisory participation and evaluation of programme effectiveness.

Both these factors aided the leadership function. Middle managers could interact with supervisors, set the necessary safety standards and lead safety programme evaluation. The mandatory measurements of compliance conducted at the supervisory level were evaluated via the group safety committee, placing the middle manager in a position to lead corrective actions.

The structure of safety committees prior to 1993 excluded steering controls, i.e. safety programme effectiveness was not evaluated during committee meetings. The introduction of specific programme elements which measured safety system compliance - such as inspections, risk assessments and task hazard evaluation - provided the necessary steering mechanism. This facilitated choice of leadership styles as well as adapting the style of leader behaviour to the needs of situations and the followers. A typical example is the identification of near-miss accidents where, in order to encourage reporting of such events, a trust relationship is required between the manager and employee. (It is a well-known fact in general industry that managerial reprisals against those who report near-miss incidents effectively isolates management from accident causative factors.) Ron Westrum (1992:401-416) has distinguished organisational cultures according to the way they deal with safety-related information. The re-structuring of the group safety committee constitutes a major situational variable which in this particular instance, supported effective leadership (Hersey, 1972). This particular type of safety committee or task structure complies with Fiedler's (1967) adaptive strategy where situational variables determine whether a given situation is favourable or unfavourable to a leader. Fiedler defines the 'favourableness' of a situation as the degree to which the situation enables the leader to exert influence over his group.

4.4.2.3 support programme elements

The provision of safety programme elements, which supported the leadership function, are identified below.

Planned inspections and task hazard evaluations carried out by middle managers provided management with self-appraisal information to be communicated to members of the group safety committee. Again, this constituted a specific task structure (Fiedler, 1967) which provided favourable information to the middle manager with which to lead and control process safety. Further, the planned inspection function requires middle manager - subordinate interaction, which in terms of Hersey and Blanchard's model, initially necessitates a high task, high relationship leadership style. This leadership style was found to be essential when introducing evaluations of safety programme effectiveness.

4.4.3 Leadership style assessments

Multiple choice questionnaires were submitted to a sample of eight middle managers for evaluation with a one-hundred percent rate of return. Listed were four current leadership styles :

- Authoritarian
- Democratic
- *Laissez-faire*
- Counselling

Middle managers were asked which leadership style they considered to be the most effective to obtain commitment from supervisors with regard to the implementation of safety control standards. Results indicated that the 'situational leadership' style was utilised by middle managers to ensure compliance to programme standards. In a safety risk management context the reasons for this approach were primarily found in the forces of situations impacting on leadership styles. Nigro (1967:273) is correct in his assessment that often 'critical environmental pressures' surround the manager, necessitating particular leadership styles. 'Forces in the situation' refer to pressures bearing on the manager, stemming from, for example:

(a) a work group not adequately briefed as to safety standards;

(b) a specific problem posing a threat to the health and safety of workers.

The following case study supports Nigro's hypothesis in terms of 'out of normal' pressures that surround managers:

CASE STUDY 3

Workers carrying out a maintenance procedure are using equipment which has been rendered defective through abnormal application. There is immediate danger that complete equipment failure could occur, exposing workers to serious injury whilst simultaneously compromising process safety. In this particular instance, the middle manager halts the operation without recourse to supervisors and workers; ensuring termination of the task procedure. A potentially unsafe condition is rendered safe by the imposition of an authoritarian leadership style.

Subsequent to this incident, the manager convenes an investigation team, endeavouring to establish from supervisors and workers the reason for equipment failure. (Recourse to democratic leadership style). We can conclude from the above that the required imposition of an authoritarian leadership style, subsequently adapted to a democratic model, ensures effective remedial action. Further, this case study contains a considerable number of forces which will affect a manager's leadership style:

- work group - unable to resolve the problem
- nature of the problem - workers exposed to hazardous situation
- pressure of time - need for the manager to decide quickly

We can conclude, therefore, that authoritarian and democratic leadership styles were utilised by the respective middle manager to manage a situation which impacted on worker and process safety. The effect of the situational leadership approach resulted in high morale and high commitment to the safety programme. Supervisors and workers were essentially motivated by the following factors :

- authoritarian leadership style which resolved an urgent safety problem;
- democratic leadership style which enabled worker participation to resolve specific safety problems.

4.5 INFORMAL ORGANISATION

We recall here that the entire group of middle managers, over a time period of three years, displayed almost identical non-deliberate departures in terms of failures to carry out safety programme implementation. Simon, Smithburg and Thompson's criteria (1970:192) with regard to the incompleteness of the formal plan applies here - the lack of an effective safety programme which induced middle managers to bypass the required participation.

4.5.1 Measuring commitment before the safety steering committee

Multiple choice questionnaires were submitted to middle managers to measure their commitment to process safety. A one-hundred percent rate of return was received from a sample of eight middle managers. The above quantitative approach was also supplemented with a qualitative approach, which relied on anonymity of response and personal interviews. Evaluations identified a particular paradigm shift on the part of middle managers, details of which are discussed below.

Questionnaire evaluations indicated that middle managers had curtailed their involvement in the safety programme for the following reasons :

- lack of provision of a structured safety programme endorsed by senior management;
- lack of safety policy arising from the above;
- senior management failing to carry out any type of safety programme co-ordination with middle managerial levels.

Analysis of the three factors above indicate failure of the formal organisation which caused non-deliberate departures in terms of safety programme management on the part of middle managers. The non-deliberate failure by middle managers to carry out the formal plan, confirms Simon, Smithburg and Thompson's hypothesis that ineffective or over-elaborate administrative processes may 'be forgotten or ignored, even without deliberate intent'(1970:193). The authors are correct. Notably middle management programme activities were not acted on by senior management nor was a safety steering mechanism provided for this purpose, i.e. the organisation safety steering committee.

4.5.2 Measuring commitment after steering committee

The implementation of the safety steering committee marked a watershed in the organisation's safety management programme. For the first time, co-ordination of the safety programme by heads of department had not only become possible but constituted a requirement. Consequently heads of department were required to evaluate programme effectiveness with middle level executives.

Questionnaire evaluations identified a specific paradigm shift on the part of middle managers. The principal factors influencing the informal organisation at the middle managerial level are diagnosed below.

The safety steering committee required mandatory co-ordination of the safety programme; at the middle and supervisory management levels. Arising from the above implementation of a group safety committee at middle management level was required. As discussed above, middle managers, under the old dispensation, were not required to co-ordinate safety programmes at supervisory level. The lack of this requirement was also manifest in the results of quantitative analyses, for example safety audit reports, which consistently highlighted middle management's failure to co-ordinate the safety programme.

Group safety committee. Analysis of qualitative and quantitative assessments revealed that middle managers supported safety programme co-ordination at the supervisory level. The group safety committee provided the direction and control for the evaluation of programme effectiveness. Significantly, the agenda of the group safety committee provided programme elements with steering controls for programme evaluation. Newman (1975, p40) has consistently argued that since steering controls provide inputs early enough for operational staff concerned to use the data in their own decisions, their personal involvement in the control cycle is high. Moreover, this close involvement in the control process adds to the positive response of steering controls. It is of interest therefore, that the implementation of the organisation's safety steering committee confirmed Newman's hypothesis in favour of middle management involvement in the control cycle of safety programmes.

Training. Delays with regard to safety programme implementation were primarily experienced at the middle management level. This is directly attributed to lack of specific training. Indications are that programme requirements were not adequately understood. This still remains a point of concern as the quality of training provided did not alleviate this particular problem, despite the fact that programme acceptance at this level had considerably changed.

4.6 COMMUNICATION

4.6.1 Evaluation of primary communication channels

Primary communication typologies - lateral, upward and downward - had not been effectively practised in terms of safety programme co-ordination. The reason for this lack of primary communication is to be found in the inadequate structure of safety committees. Neglect of this function had precipitated safety programme failure at the supervisory level. The re-introduction of safety committees as a strategic programme element structured to provide effective primary communication was intended to rectify programme stagnation. The symptoms of programme failure were manifest in a lack of programme co-ordination by middle managers (see Safety Audit Reports, 1990-1992), and a lack of supervisory participation in safety committee structures.

The 'Tripod-Delta' technique, used to assess disruptive processes in terms of accident causation, was utilised by Reason (1977:135) to identify 'lack of effective communication' as one of eleven general failure types. Reason diagnosed three types of communication problems: (i) system failures in which the necessary channels of communication do not exist, (ii) message failures in which channels exist but information is not transmitted, and (iii) reception failures in which channels exist, but the right message is misinterpreted. Hence, the need at Koeberg to transform safety committees into evaluatory types, as existing committees failed to provide even the essentials of primary communication.

4.6.2 Lateral communication.

Evaluation of qualitative assessments with a one-hundred percent rate of return indicated supervisory participation. The inclusion of supervisors in safety committee structures facilitated safety programme co-ordination. This was reflected in the unanimous feedback of middle managers during questionnaire evaluation. Further, quantitative assessments in the form of safety audits were conducted, towards the latter part of 1997 and early 1998 which indicated that certain safety committees, although restructured, failed to utilise lateral communication effectively despite the inclusion of supervisors. Alternatively, safety committees with effective lateral communication structures demonstrated a rigorous compliance to safety standards.

Middle managers in some instances failed to remove the barriers that existed between supervisors and health and safety representatives. Supervisors displayed a tendency to abdicate from safety programme involvement which introduced tensions into the supervisor - safety representative relationship. These tensions were not reconciled in the committees concerned. In this instance, the group norm of supervisors constituted a carry-over behaviour from past situations i.e. their non-participation on previous committees. This point is also made by Robbins (1996:309) who argues that group members bring expectations with them from past experiences and backgrounds. The group norm would also remain important to the supervisors for reasons of predictability of group members behaviour. Robbins sketches further that groups can pressurise individuals to change their attitudes and behaviour to conform to the groups' standard. These attitudes unfortunately persisted among supervisors for reasons of historical exclusion from setting safety standards via committee meetings. The leadership style of middle managers determined however, the quality of lateral communication insofar as the respective manager permitted the supervisor to function within the limits defined. This point is also sketched by Nigro (1965:271). Evidence of the above emerged during safety audits of groups which had consistently displayed symptoms of non-compliance in terms of process safety.

In order to address the middle managerial failures related to programme co-ordination, a system detailing the required evaluation of programme effectiveness was launched during 1998. Group safety committee agendas were restructured to require mandatory evaluation of programme compliance at the supervisory level. Middle managers were required to measure and evaluate programme compliance during safety committee meetings with supervisors.

We can summarise therefore, that the structure of safety committees promoted lateral communication but required the effective leadership of the chairperson (middle manager) for ensuring supervisory participation.

4.6.3 Upward communication

The inclusion of supervisors and worker-elected health and safety representatives in the structure of group safety committee meetings made upward communication possible. Feedback from middle managers indicated the usage of safety committees as the primary function for upward communication. As discussed above, the structure of safety committees was adapted to facilitate upward communication by incorporating specific programme elements into the business agenda of these meetings. The following safety programme elements were included:

<u>Planned inspection programme</u>

Safety inspections were initially carried out in conjunction with heads of department to facilitate upward communication by middle managers. This programme failed however, as initially supervisors were not included in the inspection function. The programme was subsequently entirely restructured, with the focus on task observations and evaluation of safety programme compliance. The evaluation of areas critical to process safety achieved good acceptance amongst middle management. This was evidenced by the large number of maintenance and housekeeping issues identified during inspections.

<u>Supervisory participation</u>

Supervisors, by not participating in committee structures, were not able to communicate the root causes of accidents to middle managers and workers. Analysis of accident reports indicated that supervisors were not entirely proficient with basic or root cause analysis of accidents. Investigation of accidents was primarily left to safety representatives and, furthermore, training on accident investigation had not been given. This essentially implied that **middle managers received inadequately researched incident reports from supervisors. This factor created a barrier in terms of upward communication of accident causative data**. Analysis of this trend primarily indicated lack of supervisory training with regard to accident investigation, and middle managers' reluctance to ensure supervisory participation in accident investigation. Subsequently, measures were introduced to remedy the problems described above.

4.6.4 Downward communication

A one hundred percent rate of return confirmed middle manager's unanimous opinion that the revised structure of committees facilitated downward communication. There were indications however, that middle manager/supervisor communication remained ineffective in certain instances.

The determinants for both effective and ineffective types of downward communication are now identified.

Structure of safety committees

The participation of supervisors and health and safety representatives in group safety committee structures was diagnosed as the primary channel of effective downward communication. During meetings, safety programme standards were readily communicated by middle managers to subordinates. The effectiveness of this communication was reflected in the ratings attained by groups or sections during safety audits (see Koeberg's Safety Audit Reports 1996-1998). Limitations apply, however. Some groups failed to apply steering mechanisms to evaluate the effectiveness of process safety. These aspects of non-compliance were attributable to the permissive leadership style exercised by the chairman of safety committees. It is of interest to note that groups with compromised safety standards invariably resided under safety committee chairmen who had adopted a *laissez faire* - permissive leadership style. (Safety Audit Reports 1990 - 1992.)

A significant point is made by Newman (1975:159) in this regard. Since leadership style is intertwined with the application of control standards, there should be compatibility between leadership style and control design. Extrapolating this principle to the area of safety management, it follows that the coupling of a control system predicated on close observance of safety standards with a permissive leadership style may cause programme failure.

4.7 DECISION-MAKING

Essentially, middle managers could not effectively implement decisions as lateral clearances with supervisors due to their absence could not be established. Re-structuring of safety committee attendance provided the channel for lateral communication, essential for effective decision making. However, incorporation of frontline supervisors into the committee system did not entirely solve all problems encountered in terms of decision-making. Supervisors, historically excluded from safety programme involvement, were subject to a specific 'groupthink' discussed above – they had abdicated their involvement in programme activities and delegated their responsibilities to the worker-elected safety representative. Analysis of safety audit reports clearly indicated that this type of abdication imposed serious limits on the degree of programme compliance (see Koeberg's Safety Audit Reports 1990-1992 and 1994-1997). Put differently, the subordinate safety representatives could not make decisions on behalf of their superiors, the supervisors! This particular groupthink persisted for at least four years and is attributed to middle managerial inactivity on the subject. Supervisory groupthink surmised that delegation of programme standards would not impact on decision-making. Yet in fact it did impact, due to lateral clearances not being available for decisions during group committee meetings (see Lau & Jelinek, 1984:137).

Lau and Jelinek (1984) in their exposition on the development of norms in small group dynamics, attributed decisions leading up to Pearl Harbour, Bay of Pigs and Cuba missile crisis to groupthink. This reasoning can also be applied to present day disasters such as Zeebrugge (Belgium) and Vaal Reefs (South Africa) where groupthink deemed certain safety requirements as superfluous. A further problem associated with this type of groupthink is the rationale behind it - middle managers and supervisors ignored the warnings by collectively constructing rationalisations, i.e. there could be no threat to process safety (Janis, 1971).

In order to influence the group norm amongst supervisors so that they would participate meaningfully in safety programme decision-making, group safety committees were restructured to include mandatory participation by supervisors and steering mechanisms such as task hazard evaluations, inspections and accident recall. The changes effected to middle managerial safety committee agendas became operative during 1998. Indications are that the steering mechanisms incorporated in the structure of safety committees are particularly effective. This positive reaction to steering controls is confirmed by Newman (1975:40).

4.8 CONTROLLING

We recall that the controlling function lacked the structure to evaluate safety programme effectiveness. This was evident in the absence of steering controls essential for this purpose. This, in essence, had deprived the organisation of effective safety management, confirming Newman's (1975:22-23) analysis of system failures. For the purpose of this dissertation, specific controlling functions were incorporated in the safety programme at the middle management level. Again, emphasis was placed on steering mechanisms with their related evaluation techniques to monitor the effectiveness of the programme elements.

4.8.1 Restructured committees

Accordingly, the strategic element or group safety committee function was restructured to enable measurements and evaluations of compliance. Unlike previous agendas, programme elements with steering controls were included. These programme elements were specific to the needs of the middle management level and facilitated the evaluation of process safety. The three programme elements incorporated for this purpose exhibited the functions of task hazard evaluation, accident recall and critical task observation. This incorporation expedited the controlling function by measuring and evaluating compliance and risk factors, and regulating and improving methods and results. It is of interest that safety committees in the SA context are largely structured to exclude evaluation mechanisms; this raises an empirical observation: the existence of latent conditions and active errors are attributed to impaired controlling functions of safety programmes. The widespread practice to structure safety committees without steering controls, unfortunately contributes towards accident causation. Further, a correlation exists between the accident experience of a work group and its safety committee structure - this factor is borne out in the more favourable inquiry into group safety committees with steering mechanisms.

4.8.2 Inspection programme

The implementation of an inspection programme at the middle management level intended to provide self-appraisal information assessing (a) effectiveness of remedial actions taken with regard to accident prevention; (b) managerial commitment through visible activity for safety and health (Bird, 1986:12); and (c) identification of changes in processes or materials which may impact on process safety. Managerial non-compliance, however, remained high as middle level executives were not held accountable by senior management. A further limitation posed by the inspection programme was the lack of steering controls: inspections were limited to the investigation of physical conditions such as good housekeeping and cleanliness. As a result, the planned inspection programme was restructured to include both a condition (plant)- and task-based evaluation programme, both programme elements featuring steering controls. Interestingly, neither Bird (1986) nor Stranks (1994) advocate the integration of steering controls into planned inspection typologies. This is a particular point of concern: excluding the evaluatory function in inspection programmes fails to identify the causative factors of accidents, notably latent conditions and active errors.

4.8.3 Task hazard evaluation

Towards the end of the period of assessment set by this dissertation, a final controlling factor was introduced. This primarily dealt with task hazard evaluation and was based on hazard assessments conducted by supervisors. There were a good number of reasons for this particular approach. Supervisors, due to long term exposure to certain risks, were not able to assess the magnitude of the hazards. Major hazards identified during risk observation could not be fully resolved by supervisors, but required middle managerial input. Finally, the essential identification of latent conditions and active failures was facilitated.

4.9 CONCLUDING REMARKS

This chapter has argued that the application of steering controls is necessary for the evaluation of safety programme effectiveness at middle and supervisory management levels. Further, that the structure of support programme elements needs to support the function of the strategic element. Both these concepts were integrated into the framework of the safety management programme operating at this level. The evolution from a static safety programme to an evaluatory system, is reviewed below.

The structure of safety committees excluded steering controls which effectively implied that the safety programme at the supervisory level was not evaluated. Methods and models employed for evaluating programme effectiveness excluded measurements of compliance. As a result, accident causative factors were not identified and behavioural response at the middle management level failed to co-ordinate the safety programme at the supervisory level. Analysis of programme failure indicated that middle managers were not leading programme implementation/evaluation and that the structure of support programme elements did not facilitate safety programme evaluation. The inadequacy of the safety system framework affected middle management's commitment to support the programme. This lack of commitment constituted a non-deliberate departure from the formal organisation plan (Simon, Smithburg and Thompson, 1972:193). Further, as the committee framework conceptually excluded lateral communication due to supervisory exclusion, decision making and the primary channels of communication remained ineffective.

Based on the above analyses, a lateral safety system was implemented at the middle management level. The framework conceptually included steering controls at both the strategic and support programme element levels and the safety committee was restructured to include mandatory participation by supervisors, thus facilitating lateral clearances required for the co-ordination of the organisation's safety programme.

The support programme elements were structured to evaluate safety system effectiveness at the supervisory level, and provide feedback to the safety committee members. Also, support programme elements conceptually provided methods of measurement for programme evaluation. Again, functions and effectiveness of these elements are evaluated by the safety committee. The structure of the elements/variables makes identification of hazards and subsequent analysis of risk assessments easier. The methods of measurement embodied in support elements differ in scope and domain, i.e. inspections incident investigations carried out by middle managers measure compliance at the supervisor/worker level, whereas other variables/elements provide measurement criteria to supervisors to evaluate the safety of task performances, with a feedback mechanism to the safety committee. This safety management model therefore, provides measurements of compliance required for programme evaluation to both middle managers and supervisors.

The impact of programme elements on the behavioural response of middle managers was evaluated by a mix of quantitative and qualitative methods of assessment. Quantitative assessments were based on the descriptive analysis of statistics, i.e. safety audit compliance measurements. The concept of middle management leadership was strongly influenced by the steering controls incorporated in programme elements. It is of interest to note that groups without the structural support of these programme elements continued to display static paradigms in terms of behavioural response. The spill-over effect of inadequate leadership was also manifest in the categories of informal organisation and controlling. Exposure to the steering mechanism of the programme elements reversed the non-deliberate departures from the formal organisation plan, and middle managers in question displayed commitment towards programme requirements.

The 'lateral clearances' afforded by the safety committee through active supervisory participation restructured the primary communication channels. Support programme elements facilitated this process, i.e. incident investigation requiring supervisory participation. Correspondingly, decision-making was conceptually aided by the mandatory participation of supervisors. Supervisors were in a position to attain lateral clearances with one another, facilitating the decision making process.

The controlling function was restructured by adapting programme elements to measure compliance to programme standards on a continuous basis. The process of evaluating safety system effectiveness was aided by elements/variables with steering control functions, i.e. planned inspections and task hazard evaluations.

5. METHODS, MODELS FOR IDENTIFICATION AND MEASUREMENT AT SUPERVISORY MANAGEMENT LEVEL

5.1 IDENTIFICATION - INTRODUCTORY

Supervisors and workers are frequently implicated in accident scenarios and it is to them that the much-bandied about term 'human error' usually refers. Yet these frontline personnel are not equipped by line management to identify latent conditions and active errors. In fact, analyses of accident reports in the organisation identified repeat accidents, not only in the category of materials handling (where supervisors are responsible), but in categories such as design failures and training, which are not the responsibility of supervisors. Having said this, the analysis by Reason of the Boeing 737-400 (Daventry, 1995) and "Herald of Free Enterprise" incidents, and by Blackbeard of the Vaal Reefs Locomotive incident, would appear to indicate supervisory inability to formally identify and evaluate latent conditions. Reason (1991: 237; 1997:10) as well as Stanton & Noyes (1997: 110) have consistently drawn attention to cases where workers and supervisors were aware of accident causation factors which they neither addressed nor reported.

This dissertation, therefore, seeks to provide supervisory management with a safety programme that will assist in the identification of unsafe acts and conditions at the person-machine interface. Accordingly, the safety programme elements designated for this purpose will focus on the identification of errors committed during task performance and the recognition of resident pathogens or precursors of accidents.

To this end, programme elements are designed to provide procedures for critical task performance and to identify error in existing task procedures. Two further criteria incorporated in these programme elements are the identification and evaluation of hazards during task performance and of resident accident pathogens in equipment and materials.

Crucially, the function of the supervisory safety programme lies in the ongoing identification of latent conditions and active errors which may endanger the safety of operations. Where this process is compromised, for example where a pathological rather than a generative safety culture exists, supervisors may be actively discouraged from reporting accident causative factors.

The steering controls assigned to supervisors for the evaluation of process operations and task procedures form the subject of the next discussion.

5.2 FUNCTION OF STEERING CONTROLS

Steering controls, for the purpose of this chapter fall into two categories, namely measurements of compliance to existing task procedures and identification of operational hazards. The intention is to identify the all-important resident accident pathogens at the level where they matter most: in the operational theatre. The primary objective lies, therefore, in the timeous identification of possible accident sequences.

The steering mechanism to be utilised for the continuous identification of latent conditions and active errors comprises a number of programme elements with the following functions:

(i) **Task assessments**. These are scheduled observations to measure operative compliance to existing procedures. Measurements of compliance are evaluated during group safety committee meetings.

(ii) **Risk assessments**. These entail the identification of hazards during operational procedures. The risk posed by the hazard is evaluated during follow-up group safety committee meetings.

(iii) **Accident recall**. This means that operational parameters which have given rise to accidents during task performance are evaluated and operational staff are briefed appropriately.

This chapter attempts to assign specific programme elements to the supervisory management level, firstly to evaluate the effectiveness of operational procedures and, secondly, to enable supervisors to identify existing latent accident conditions and active failures prior to the occurrence of accidents.

The next section of the paper discusses the actual composition and required characteristics of the programme elements in more detail.

5.3 IDENTIFYING PROGRAMME ELEMENTS

5.3.1 Introduction

Supervisors, by virtue of their position in the organisational hierarchy, are closer to the 'point of control' than any other members of management. They know the people and conditions. They know what happens at the 'rock face' where people, equipment, materials and environment interface in order to produce goods and services. Their leadership will determine the emphasis that is to be placed on the various factors of production and safety. They are, therefore, in a position to know firsthand the occupational health and safety hazards that workers face in their daily task executions.

The foremost function of any health and safety programme is to identify the hazards that workers and society at large will face. **One of the imperatives of a health and safety programme is to place the supervisors in a position where they can manage the risks that workers face**. The identification of hazards and evaluation of risks in the workplace is, therefore, among management's first priorities. Risk management of the 'critical few' (the most significant hazards) removes the root cause effect which produces the majority of serious incidents. As Peter Drucker states, '*the first duty of business is to survive and the guiding principle of business economics is not the maximisation of profit – it is the avoidance of loss*'. Loss here constitutes, *inter alia*, downgrading incidents with regard to people, equipment, materials and environment. The first remedial step, therefore, is to provide the supervisor with a means to perform hazardous work safety. Among the control measures that can be offered to supervisors to govern their productive activities are operating or critical task procedures.

5.3.1 Critical Task Identification

In the complex interface of people, equipment, materials and environment, the identification of critical tasks can only succeed through a participative process. This implies drawing on the experience pool of supervisors and workers familiar with given work situations. Firstly, as experience has shown in actual participative sessions on the critical few, the perception of risk by supervisor and worker alike is strongly influenced by the time period they have carried out a particular critical task. **Workers exposed over the years to certain hazards have lost their perception of the magnitude of the hazard,** i.e. constant exposure to a hazard over a certain time period has seemingly reduced the risk of an accident occurring. This claim could not be verified by existing literature, but in the author's experience, based on the investigation and analysis of individual accidents over a ten-year time period. Indeed, actual observations carried out during critical task performances have often identified a lack of hazard perception on the part of workers and supervisors. Task observations carried out by the author in supervisor/worker hazard assessment have revealed a disturbing confusion as to what constitutes a hazard and what does not. This phenomenon is readily explained, however, through two key factors :

(i) **Time and exposure : the perception of risk by a person is strongly influenced by the time period he has been exposed to a certain hazard.**

(ii) **The organisation does not focus on the 'critical few', i.e. it focuses on 'nice to have' instead of 'must know' procedures.**

It is essential that a facilitator who is familiar with the given hazards of a work situation guides brainstorming sessions on the critical few. Such a facilitator could be the group's supervisor or manager, if adequately trained. Or, in the case of bigger organisations, a designated programme analyst could facilitate a participative process during which the critical few are identified.

Furthermore, it is imperative that the facilitator is familiar with the work process. If not, guidance of the process is constrained by inadequate process knowledge, significantly limiting hazard identification. Further, participative processes, in order to generate commitment for task identification, need to be supported by management.

5.3.1.1 methodology

The currently accepted 'two best methods' to identify critical task procedures are described by Bird (1986:147) in *Practical Loss Control Leadership*. Neither method, however, conceives of an evaluatory mechanism. Accordingly, a programme element for the measurement and evaluation of task criticality is included.

It is the author's contention, based on accident scenarios of the past few decades, that safety management has neglected effective critical task identification. Yet this concept is applicable to most of the disasters that have beset the latter part of the twentieth century.

Analysis of accidents such as those at Bophal (India), Vaal Reefs and Three Mile Island, indicates that safe operating procedures were in existence. However, Reason (1997:74) questions the effectiveness of these procedures, since they demonstrably do not prevent major organisational accidents. Reason argues that procedures focus on production processes rather than on factors influencing the response or behaviour of operating personnel. Hence the author's intention to guide behavioural response right from the start by introducing an evaluatory mechanism when operating procedures are drawn up.

In task-by-task observation, experienced personnel assess the probability of operator error when carrying out a critical task. Threads that may induce human error are evaluated and listed against the task step of a specific procedure. (Actual experience has shown that this need not be a laborious or lengthy process, in fact it seemed to shorten certain procedures. Actual knowledge of the hazards identified enabled operators to focus on aspects that were critical in terms of the operational process to be followed.

Some practical implications or spin-offs of the task-by-task observation method include:

- Identification of potential problems not anticipated during the design of a stage. Typical examples are the design problems encountered with the roll-on/roll-off ferries ('Herald of Free Enterprise') and mining locomotives (Vaal Reefs incident).

- Identification of equipment deficiencies. Ranking high amongst basic causes of accidents is the inadequacy of equipment design, particularly in the SA context. Poor ergonomic design of equipment causes a large number of disabling injuries, particularly in power generation (Bird , 1982:61).

- Identification of active errors. Observing task performance helps to assess the effectiveness of written procedures.

This concludes the hazardous task evaluation methodology. The existence of critical task procedures alone will not, however, provide continuous identification of latent conditions and active errors in the person-machine interface arena. How this may be done is the subject of the next discussion.

5.4 DEVELOPING SUPPORT PROGRAMME ELEMENTS

The function of support programme elements at the supervisory management level is of a critical nature. It is precisely here, at the person-machine interface, that the final phase of accident causation is initiated. The supervisory management level is, so to speak, the last barrier to be breached. For instance, frontline personnel may intentionally or unintentionally disable certain defences in order to achieve local operational objectives. Typically, production pressure may result in short cuts, i.e. not complying with precautionary measures. Alternatively, frontline operators may fail to diagnose an off-normal system state. The Three Mile Island nuclear incident is a typical example where operators failed to diagnose process parameters correctly, resulting in the release of small quantities of radioactive material.

The identification and measurement of latent conditions and active errors at the supervisory management level serves a dual function that is critical in nature: (i) timeous evaluation of hazards by the organisation management, and (ii) constant vigilance at the rock face by operational personnel. The programme elements developed for this dual purpose are discussed below.

5.4.1 Hazard identification

Supervisory staff, in conjunction with operatives, are required to assess the safety of task performances in order to facilitate the identification of resident accident pathogens. This principle, as the analysis of accident scenarios has shown, is of primary importance for the maintenance of process safety (Reason, 1994) despite the fact that Stranks (1994) and Bird (1986) conceptually limited its application when analysing safety programmes.

The identification of hazards during actual process activities must take into account that relatively complex, non-linear production systems – such as nuclear power and petrochemical plants – require specific analyses because certain information about the state of the system must be obtained indirectly or inferred and the possibility of isolating failed components is limited.

Furthermore, many common-mode connections (i.e. components whose failure can have multiple effects 'downstream') are present, and there is only limited understanding of some processes, particularly those involving transformation (Perrow, 1984).

5.4.2 Critical task observation

This element evaluates whether operatives/workers adhere to the operational standards set for specific tasks by the organisation. For example, supervisors will carry out observations to measure whether subordinates comply with a particularly hazardous task as per written standard. This activity provides insight into the effectiveness of operational procedures which may, *inter alia*, suggest the need to upgrade a specific standard or improve training manuals. Alternatively, it may simply confirm the effectiveness of the status quo.

One of the dictates of risk assessment is that compliance of task performance and certain critical activities can only be measured by actual observation. Examples in this context would be found in the maintenance arena, for example the critical activities of removing the reactor head to enable refuelling, purging systems with explosive or asphyxiating gases, or replacing turbine rotors. A considerable number of these tasks, because of critical interfaces created by the operational complexities, have to be physically observed to identify the potential hazards.

Although Reason never specifies the concept of task observation for the identification of active errors, his analysis of "Herald of Free Enterprise" in particular, indicates that the failure to close the bow doors of the ship constituted non-compliance with procedure. This non-compliance had been repeated (without mishap) many times prior to the incident. But on that fateful day, when the ship again left port with the bow doors open, water flooded in and the vessel capsized.

Accident scenarios in the nuclear, mining and manufacturing industries invariably indicate that managerial activities fail to identify and measure active errors. Accident analyses clearly indicate that in non-linear and tightly coupled industries the omission of task observations is an accident causative factor.

Typical examples are the Piper Alpha (6 July 1988), and Phillips 66 Company (23 October 1989).

The problem is compounded by the current structure of safety programmes, and to a large extent by the fact that supervisory management is not trained in hazard identification and critical task observation. Problems also arise due to supervisors' lack of involvement in the replay of accidents scenarios, for which specific observation skills are required. This problem is augmented by most supervisors' (possibly natural) reluctance to evaluate their subordinates in terms of procedural compliance with any rigour, fearing to be seen as on the side of management.

Conclusively, task observations facilitate the measurement of compliance to existing standards. They provide a basis for the identification of active errors which are useful to influence the cognitive knowledge structures of the observer. Observation and evaluation of deviations will assist in the correct recall of accident data and provide the added advantage of identifying latent conditions. This advantage was repeatedly verified in task observations. Hazardous conditions were actually more readily identified than deviation from procedure. Areas of assessment were primarily maintenance activities at the nuclear power plant.

5.4.3 Accident/incident recall

The introduction of accident recall has two main purposes, namely to familiarise supervisors and workers/operatives with accident causative factors and to compensate for schematic error tendencies on the part of supervisors and workers during task performances and accident/incident investigations. Systematic errors can arise from fitting incoming data to the wrong schema (Reason, 1991) or from relying too heavily upon active or salient schemata. Most of these schematic error tendencies can be explained by a single principle: a schema only contains evidence of how a particular recollection or sensory input *should* appear. It has no representation of what it *should not* look like (Reason, 1991).

The principles of accident recall (accident causation symptoms and root causes identified and related to task performance), possibly compensate for the variables of schemata with default values. Particularly at the supervisory/worker level, the same error in terms of accident causation is repeated frequently, explaining why certain industries are faced with static accident frequency rates despite safety awareness programmes and generic safety training. Analysis of industrial accidents shows repetition of error in the various categories of accident causation. This is in support of Rumelhart's (1977) theory that high-level knowledge structures (schemata) contain information slots or variables. Each slot will only accept a particular kind of information. If the current inputs in an industrial environment fail to supply specific data to fill those slots, they take on 'default assignments': stereotypical values derived from past interaction with the industrial environment. This habit may also explain Rumelhart and Orton's theory (1977) on the activation of schema: only instantiated schema are stored in memory. During the process of accident recall, generic information may be used to further interpret a particular memory from the instantiated schema record. The purpose of accident recall as a safety programme element therefore seeks to fill the schemata slots with the required kind of information which, in a supervisory and worker context, is utilised to prevent task error. By linking accident causative data to personal experiences with persons, equipment, materials, plant or environment, default assignments of the various slots of schemata are possibly limited.

The intention is, therefore, to assist the correct encoding of the representational function of schemata for purposes of lending structure to accident experience.

5.4.4 Accident pre-emptive task procedures

Task instructions at the supervisor and worker levels are primarily directed at providing a control system for the prevention of error during task execution. Task instructions are a mechanism for avoiding the more serious errors made by those in supervisory control of industrial installations, notably maintenance functions. Generally, all existing task procedures are written up as linear step-by-step appraisals to be followed. The structure of such procedures, however, essentially provides no mechanism to interpret and evaluate conditions which threaten the normative function of the procedure. The North Anna incident

(Pewietal, 1981) identified that operator-induced error had its origin in mandatory procedures which left no room for manoeuvring during an emergency. Duncan (1987:210) points out '*the intrinsic limitation that, by definition, an algorithm will only distinguish the set of occasions which could have been foreseen. If an unforeseen event occurs, the operator is to helped ...*' JT Reason demonstrates, in his analysis of potential measures for error reduction, that '*existing diagnostic rules did not increase the correct diagnosis rate in comparison to circumstances where rules/procedures were not readily available*' (1994:243).

The larger the number of discrete steps in an action sequence, the greater the probability that one or more will be omitted. Further, the greater the informational loading of a particular procedural step, the more likely that items within that step will be omitted. Also, procedural steps that do not follow a direct linear sequence are likely to be omitted (Reason, 1991:243).

Such observations prompt an analysis of the efficacy of current task procedures. It is the author's contention, therefore, that task procedures, when the normative function is threatened, can provide the user with a mechanism to evaluate how best to deal with changed circumstances. To meet this requirement, a particular task procedure must facilitate the interpretation and evaluation of off-normal parameters. Rasmussen and Jensen (1974), for example, have identified as part of contemporary schema, a '*knowledge-based level that is triggered in unusual situations for which actions must be planned on line*' – using conscious analytical processes and stored knowledge (Reason, 1994). **Rasmussen's stages of decision-making at the knowledge-based level include both interpretation and evaluation of a given set of data, which in effect constitutes the application of steering controls** (adapted by the author, 1998).

In order to facilitate the application of steering controls in task procedures (task procedures are essentially yes-no controls only), the author proposes a tripartite approach:

(i) **Steps which are critical to the effective execution of the procedure are identified.** Analysis of accidents indicates that supervisors and workers are seldom familiar with critical aspects of task performance. Accordingly, steps critical to task execution are highlighted to enable easy recognition by the taskmaster (supervisor and/or worker).

(ii) **Critical step failure scenario is introduced**. This entails 'one or two liners' describing the consequence of critical step failure. This built-in negative evaluation process has one purpose only: to trigger automatically the knowledge-based schema of the taskmaster (interpretation and evaluation) by a procedural signal. The intention is to equip the taskmaster with a steering mechanism with which to control the possible sequential error of a procedure to be followed and/or recognise impending error in other areas of task performance. Analysis of accident causative factors and the author's own research, strongly point to the current mismatch between the characteristics of technical systems, e.g. maintenance procedures and human information processing. Reason points out '*that system designers have unwittingly created a work situation in which many of the normally adaptive characteristics of human cognition (its natural heuristics and biases) are transformed into dangerous liabilities*' (1994:238).

(iii) **Supervisors and workers are regularly briefed on critical steps and their evaluation in failure mode**. For this purpose a participative process is envisaged to expose supervisors and workers to steering mechanisms, and with increasing expertise, the focus of control moves from the knowledge-based to the skill-based levels in terms of Rasmussen's framework.

5.4.5 Steering-based task instruction

Steering-based task instruction is not a formal training programme, but intends to reinforce, on a continuous basis, the evaluation of critical steps of task procedures with supervisors and workers. Most of the more serious injury-related accidents occur at the worker level, even though written work instructions are explicitly followed. Analyses of these accident scenarios have identified the limited application of critical step evaluation by technicians, supervisors and artisan-based staff.

Communication of critical step evaluation by supervisory/technical staff to operatives is based on a tripartite approach.

(i) **Critical step evaluation before the execution of task performance.**

The current method, whereby the task procedure to be followed is thrust unceremoniously into the operative's hand, does not make allowance for the evaluation of task criticality. In order to facilitate critical step evaluation with subordinates, supervisors need briefly to review task criticality with the workers concerned as part of normal routine job instruction. Bird and Germain (1986) developed a near identical principle called 'key point tipping', although it excludes the evaluation mechanism of critical steps. Rasmussen's two stages of decision-making (interpretation and evaluation) come into play here – with increasing expertise, operational errors are reduced. A further benefit of Rasmussen's approach to the pre-emption of accidents, is that staff are increasingly able to identify accident-producing sequences.

(ii) **Critical step evaluation by team talk**

The current method of raising the accident awareness level is achieved by so-called shop floor safety talks. Staff in a particular area/group are required to participate and topics of general interest with regard to safety are discussed. This mostly excludes, however, any interpretation or evaluation of accident causative data.

This type of safety communication has long been practised by NOSA, Chamber of Mines, but lacks the evaluatory process of a steering mechanism. The author has implemented, on a frequent basis, a critical task review by team talk. Critical steps are highlighted in the discussion.

(iii) **Evaluation of past accidents by team-talk**

Workers/operatives are briefed on the root causes of accidents utilising the structured approach outlined above, i.e. through a description of task performance, equipment utilised, material and environmental issues. Again the intention here is to provide diagnostic rules to operational staff so that they can recognise impending accident sequences.

5.5 CONCEPTUAL FRAMEWORK DISCUSSED

Steering controls were central to the discussion of safety programme element identification at the supervisory level. Significantly, these steering mechanisms provide three safety management models essential for spotting latent conditions and active errors. The management models discussed in Chapter 2 focus on essential safety programme requirements.

Firstly, the **organisational model** views human error as symptomatic of the presence of latent conditions. Hence the inclusion of programme elements such as critical task observation and hazard identification to measure and evaluate both latent conditions and active errors.

Secondly, the **engineering model** views human error as stemming from human-machine mismatches or poor 'human engineering'. The engineering model is reflected in programme elements such as task observations, accident recall and hazard identification. Importantly, programme elements with evaluatory or steering mechanisms may have two or more functions: for example, both the organisation and engineering models are characterised by the same elements.

Thirdly, the **person model** focuses on unsafe acts and personal injury accidents. Human error is seen as a result of psychological factors such as inattention, negligence, lack of knowledge or skills. This model is represented by task instruction, accident pre-empting task and critical task procedures. Neither of the latter two programme elements contains steering mechanisms.

Consequently, limitations apply to the function of critical task procedures as (conceptually) an evaluatory mechanism is excluded. This missing mechanism is provided by support programme elements such as critical task observation and accident recall, evaluating compliance to, and measuring effectiveness of, critical tasks on a continuous basis. Put differently, the missing steering mechanism of the strategic programme element (critical tasks) is provided by the support programme element structure. This is in support of Reason's hypothesis that '*existing diagnostic rules [i.e. critical task procedures] do not necessarily increase the correct diagnosis ...*'

(1994:243). The existing structure of task procedures generically excludes the extrapolation to accident-producing factors in its step-by-step approach.

In this light, additional programme elements are introduced which conceptually provide accident 'buffers' such as hazard identification, i.e. review of actual process/task activities in terms of safety. Similarly, critical task procedures are construed to reflect accident causative data.

A conceptual framework incorporating three safety management models with steering controls has not been tested before in strategic industries.

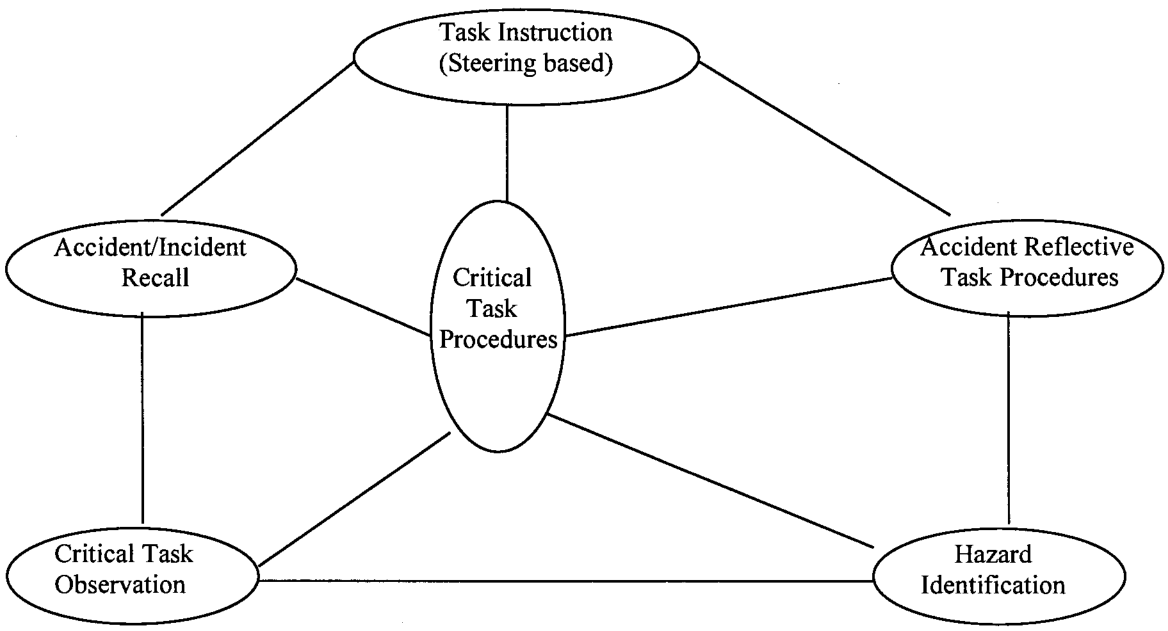

Figure 4 Exhibit 5A. Conceptual framework of a safety risk management system (supervisory management level).

5.6 BEHAVIOURAL RESPONSE : MEASURING CHANGE AGENTS

5.6.1 Introductory Remarks

A conceptual framework based on steering controls at the supervisory management level was evaluated over a time period of four years (1994-1998). The subsequent changes to behavioural response were measured by qualitative and quantitative assessments. Supervisors, technicians, artisans and artisan aides were tasked with the completion of questionnaires.

5.6.2 Leadership

Prior to analysing the changes in supervisory leadership it is appropriate briefly to recall that supervisors had been excluded, due to ill-defined participative structures at the middle management level, from safety committee activities. This had effectively isolated supervisors from information and data required for the co-ordination of the safety programme at the operative/worker level.

5.6.2.1 safety committee steering function

Supervisory participation in committee structures restored the leadership function required for programme implementation. This is a singular point of importance: analysis of the informal organisation amongst supervisors had clearly indicated an organisation-wide abdication in terms of safety leadership. Put differently, supervisors had kept their involvement in programme activities to a minimum as a result of middle management's failure to address their participation in committee structures. The reversal of this non-participatory approach revived the once discarded leadership function at the supervisory level. Analysis of this ready acceptance on the part of supervisors identified four contributory factors.

5.6.2.2 positive response to steering controls

The participation of supervisors in measurements and evaluation of safety programme elements provided essential hands-on, working knowledge with regard to process safety. Further, this mechanism empowered supervisors to make inputs regarding decisions affecting process safety. As a result, personal involvement in the control cycle was high (cf. Newman, 1975:40). This close involvement in the control process contributed to the positive response of goal acceptance. Consequently, the most important hurdle was crossed when supervisors accepted their accountability in leading the co-ordination of process safety at this level.

5.6.2.3 controls compatible with leadership styles

Since leadership style is intertwined with the application of control standards, the compatibility between leadership style and control design is essential (Newman, 1975:159). For instance, to couple a control system predicated on close observance of safety standards with a permissive leadership style can precipitate disaster (Reason, 1994:194). Typical examples are Zeebrugge (UK) and Vaal Reefs (SA). In an organisational context, the criticality of task procedures had not previously been analysed. Consequently, supervisors were not familiar with the criticality of task performance and did not know which tasks required dependability and close co-ordination. Put differently, supervisors simply did not know which task performances required tight control and those which did not. Not surprisingly, the supervisory leadership position was not engaged to participate and involve operatives/workers in activities concerning process safety. Consequently, a permissive leadership style characterised all areas of process safety, which, *inter alia*, did not provide workers with evaluations of process safety. Subsequently, a framework with revised control standards was incorporated in programme elements designed to ensure the safety of task performances. This included the principle of the 'critical few' or Pareto's Law whereby the majority (80%) of any group of effect is produced by a relatively small (20%) number of causes.

Critical process awareness was heightened and supervisors adapted their leadership style to task requirements. Significantly, supervisors adjusted leadership style in accordance with the steering mechanism. Analysis of leadership styles indicated that 80% of supervisors preferred the situational leadership style, i.e. a combination of authoritarian and democratic.

Fiedler (1965: Harvard Business Review) confirms that task structure or standards provided in terms of operating instruction facilitates leadership; the '*organisation is able to back-up the authority of the leader'*. This viewpoint is also expressed by Lau and Jelinek (1985:55) in their exposition of leadership styles.

Justification for both the authoritarian and democratic leadership style is sketched below.

Task observation by supervisory staff

This steering mechanism identified procedural non-compliance and subsequent autocratic intervention to terminate a hazardous procedure. The forces governing process safety may be 'critical environmental pressures' which surround the supervisor (Nigro, 1966:273). Similarly Lau and Jelinek (1984:54-55) assert that the consequences of certain actions or situations will require autocratic leadership styles, with beneficial results. Two case studies which support the above hypothesis are briefly evaluated for this purpose.

CASE STUDY 4

A rigger assistant (new employee) uses the wrong lifting procedure during a hoisting operation. This, unbeknown to him, is simultaneously endangering the safety of nuclear systems and personnel. A timeous supervisory intervention halts all hoisting operations (autocratic decision), until the safety of the task is restored. In this given situation, no other option was open to the supervisor. Where the task requires close observance of safety standards, a permissive leadership style will put workers and process at risk.

From the above we can conclude that lack of knowledge, skill, stress or improper attitude on the part of the operatives can precipitate autocratic decision-making by the supervisor. The second case study illustrates equipment failure of a critical nature.

CASE STUDY 5

During the removal of the primary linkages from a turbine/generator coupling, the hydraulic power tool starts to slip at 2000 psi pressure, distorting the path of applied power. This poses a serious risk in terms of operator injury and equipment damage. Again, this is an example of critical environmental pressure surrounding the supervisor for which immediate resolution is required. There will be thus a marked tendency by supervisory staff to resort to autocratic decision-making as dictated by the dynamics of a critical situation. Permissive leadership styles in situations such as these can pose a threat to process safety. A further case in point is that supervisory intervention in critical situations normally invokes tacit approval on the part of subordinates.

Alternatively, supervisors utilised democratic leadership styles in order to resolve process safety problems. The fact that 80% of supervisors preferred the situational leadership style implies that supervisors attempted, with the full participation of subordinates, to identify solutions to problem areas by group discussion and decision. The manifestation of a democratic leadership style was therefore evident in general problem solving.

Addressing the earlier statement that 20% of the supervisors questioned on leadership style used a democratic approach only during task performance, it needs to be pointed out that these supervisors were not faced with critical environmental pressures.

5.6.3 Informal organisation

We recall here that informal organisation at the supervisory level, prior to the implementation of the revised safety programme, was non-supportive in terms of the formal organisation plan. Analyses of causal data indicated that a steering mechanism was absent and that the safety programme was inadequate in that it caused non-deliberate departures on part of the supervisors. In their analyses of similar circumstantial evidence, Lau and Jelinek observe that *'the issue of involvement in assuming responsibility was avoided, not intentionally, and standards were permitted to deteriorate'* (1984). In the case of Koeberg, supervisors had also not been receiving middle management support for co-ordinating the safety programme.

Multiple choice questionnaires were submitted to supervisors to measure their commitment to process safety. A one-hundred percent rate of return was received from a sample of seventeen supervisors. The above qualitative approach was supplemented by a quantitative approach, which was based on safety audits.

The introduction of the revised safety programme did contribute towards changing the informal organisation. Due to compromised middle managerial support in certain areas, however, supervisory commitment had not changed as significantly as in others. The primary factors which influenced the informal organisation at the supervisory level are discussed below.

(i) Measuring supervisor's commitment before the implementation of middle management safety committees.

Questionnaire evaluation indicated that supervisors had curtailed their commitment to the safety programme because they had been excluded from participation in safety committee structures, because the existing safety programme was deficient in structure and because middle managers failed to co-ordinate with them.

Analysis of the above assessments indicates almost complete failure on the part of senior and middle management in the formal organisation. Deficient programme structures had induced a non-deliberate departure among supervisory management.

(ii) Measuring supervisory management's commitment after the implementation of the middle management safety committees.

The participation of supervisors in safety committee structures enabled co-ordination of the safety programme at the operative/worker level. Supervisors had previously not managed the various aspects of a safety programme. Questionnaire evaluation identified a paradigm shift in terms of safety management.

The structure of the safety committee now required mandatory participation by supervisors, enabling programme co-ordination with the middle manager. Arising from this, measurements of compliance at the operative/worker level became possible. Consequently, supervisors were in a position to evaluate programme effectiveness in conjunction with the middle manager.

Analyses of qualitative assessments indicated that supervisors supported the re-structured safety programme for reasons of focus on process safety. The steering mechanism incorporated in programme elements such as critical task observation and accident recall facilitated measurements of compliance, and subsequent evaluations of compliance factors.

The implementation of the safety programme experienced delays attributable to a lack of conceptual safety training at the supervisory management level. Consequently, programme acceptance by supervisors in certain areas was slower than in others.

Conclusively, the application of steering programme elements such as Accident Recall and Task Observation facilitated the evaluation of task performance. As a result, supervisors were effectively co-ordinating the safety programme, ensuring operational staff support for the programme. Hence a paradigm shift had occurred at the operative level, where support for operational safety requirements was manifest.

5.6.4 Communication

The primary channels of communication – lateral, downward and upward – were to a large extent not utilised before the introduction of the revised safety programme. This had constrained safety communication at the worker level. Critical safety-related issues were not communicated in a structured manner to the workers, who were not involved in safety programme activities, i.e. raising concerns that affected their safety. Supervisors were not providing safety information to workers on a regular basis.

The introduction of a structured safety programme at the supervisory management level facilitated safety communication as information from key programme elements could be made available.

5.6.4.1 assessing patterns of lateral communication

Evaluations of the multiple choice questionnaires with a 100% rate of return from a sample of seventeen supervisors indicated that supervisors were discussing safety issues on a lateral level (amongst peers) as often as once a week. It was evident that the previous demand-based, ad hoc, discussions on safety issues had been replaced with a structured programme. Implied here is also that safety enjoyed a higher priority with supervisors.

For example, safety audits measuring compliance to the safety programme showed almost without exception favourable results, i.e. a 94% compliance on average. Worker perception with regard to safety had changed. This was evident in positive contributions with regard to the identification of unsafe practices and conditions, and reporting them to supervisors.

Supervisory participation in committee structures promoted lateral communication in terms of programme co-ordination. Certain safety committees, although restructured, failed to utilise lateral communication, i.e. the inclusion of supervisors remained largely ineffective as a result of committee chairmen failing to involve supervisors in programme activities.

These tensions were not reconciled in the committees concerned and reflected a type of 'countervailing organisation' (Nigro 1966:199). Some of the committee chairmen did not endeavour to improve 'small group effectiveness' (Lau & Jelinek, 1984:102) and group norms continued to act as a constraint (Robbins, 1996:725). Lateral communication therefore, was rendered relatively ineffective in certain cases where the sub-groupings of supervisors resisted the integration in safety committee structures.

5.6.4.2 downward communication

Evaluation of feedback received via multiple choice questionnaires indicated that supervisors were utilising safety programme elements with steering mechanisms for downward communication. Feedback from the observation of critical task performance by the supervisor meant that supervisors briefed subordinates (workers) on any deviations noted during measurements of compliance.

Supervisors briefed workers on accident causal data, raising worker/operator awareness as to the 'trigger mechanism' of accident sequences. Safety talks were utilised by the supervisor to communicate accident causative information and critical task procedure content to subordinates. Briefing workers on critical steps of task procedures provided an effective means of focusing on the consequences of procedural failure. Supervisors also indicated that safety aspects were conveyed to workers through safety tips when assigning work; through daily interactions with workers/subordinates; and in specific group meetings intended to solve production problems.

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5.6.4.3 upward communication

The Group Safety Committee (chaired by middle managers) achieved upward communication with regard to safety matters. This implied that supervisors, required to attend safety committee meetings on a monthly basis, would communicate safety issues upwards to their middle manager. Conclusively, safety committee meetings had become supervisory management's channel for upward communication. Of significant importance was the role of the safety committee during programme co-ordination.

There were several reasons for this. The safety committee enabled supervisory feedback to middle management on the effectiveness of the health and safety programme. Supervisors raised problems resulting from safety programme element implementation with the group safety committee. This played a major part in solving 'teething problems' – typical problems like performance criteria for key programme elements and standardisation of safety documentation were solved with the aid of the committee. Middle managers and programme analysts used the committee forum to assist supervisors with programme co-ordination. **The Group Safety Committee had become the 'vehicle' for implementing the safety programme at the supervisory management level.**

Supervisors were therefore able to resolve safety issues with the next level of management in a structured manner. This contributed to the overall effectiveness of the programme.

There were other avenues of upward communication. Supervisors discussed safety issues with the senior manager of the department during safety inspections. This opportunity, however, was not always readily available to the supervisor. Subject matter discussed during these meetings in some instances unfortunately excluded issues such as critical task performance.

5.7 DECISION-MAKING

The nature of feedback from the operational level needs to be actively sought and analysed. Cognisance must be taken that often defensive filters are installed to protect the manager from bad news. The revised structure of the Group Safety Committee was seeking to address the above problem areas, by facilitating lateral communication amongst frontline supervisors and line managers (Nigro, 1965:176). The restructured agenda of safety committees required supervisors to report to middle managers aspects of safety programme co-ordination. As a result, supervisory involvement in operational safety processes provided middle managers with salient information in terms of decision-making. Progress was made in the following areas:

(i) evaluating new design from a safety standpoint;

(ii) evaluating non-machine interfaces to determine accident potential;

(iii) evaluating accident causative data to determine remedial actions.

A particular type of groupthink persisted amongst supervisors, despite the participation on safety committees. Supervisors, historically excluded from safety programme involvement, were specifically aligned in terms of the informal organisation. This phenomenon meant that supervisors continued to withhold effective participation in safety committee processes and tended to rationalise any resistance to the assumptions they had made. This aspect is confirmed by Robbins (1996:321-322). Supervisors, moreover, seemingly withheld participation from committee structures for reasons of risk taking in terms of safety solutions proposed. Admittedly, conceptual safety training had not been done at their level.

It needs to be pointed out however, that the safety committee chairman did not respond decisively or affirmatively in areas where a specific group think persisted.

5.8 CONTROLLING

5.8.1 Inspecting areas of accountability

Supervisors demonstrated their commitment to the safety programme through planned inspections. As supervisors were seen publicly to support the safety programme, workers themselves came to evince support. The inspection function particularly succeeded in improving substandard physical conditions, for example housekeeping and safeguarding of machinery. The self-appraisal information generated during inspections enabled supervisors to upgrade environmental and operational conditions. This demonstrated management commitment to workers and, as a result, changed the behavioural response of subordinates. Again, confirmation of a general improvement in physical conditions was obtained through safety audits.

The steering mechanism of the revised safety programme impacted on the behavioural response of supervisors and workers, leading to increased worker involvement in the new safety programme. This implied, in practical terms, that supervisors were briefing workers on critical issues in a structured manner. Alternatively, workers were briefing supervisors on risks they encountered during task performance. This, figuratively speaking, 'closed the loop', for example, feedback from the shop floor was evaluated by supervisors and corrective action, as appropriate, implemented.

Supervisor involvement in the new safety programme had increased. The required safety communication, now structured as part of the supervisory function, required supervisors to brief workers regularly. This implied that supervisors were communicating to workers the control standards of four key safety programme elements. This safety communication included supplying information on the root causes of accidents, critical aspects of task performance and briefing new employees on hazards in the job situation.

5.9 CONCLUDING REMARKS

Past exclusion of supervisors from safety committee structures prevented their involvement in programme co-ordination. Consequently, methods and models for evaluating programme effectiveness were not implemented, inducing programme failure at the worker/operative level. Significantly, support programme elements excluded the identification of hazards in industrial processes, hence the stagnation of critical task evaluation at the worker level. Lack of safety programme co-ordination negated the lateral communication function, causing the non-implementation of a strategic programme element or failure of support programme element typologies to identify human error and process hazards.

The revision of the safety programme framework at the supervisory management level conceptually included a strategic programme element (its primary focus on the maintenance of critical task performance) and support programme elements (conceptually evaluating critical task performance). Interestingly, the strategic programme element at the supervisory level does not incorporate a steering mechanism. This programme element is based on the identification of the critical few (Pareto's Law), providing standards and controls for critical task performances. The steering mechanism for the evaluation of programme effectiveness at the supervisory level has conceptually been structured into the framework of the support programme elements. Methods of measurement for programme evaluation are primarily based on the observation of industrial processes and task performances. Ninsky (1975) and Rumelhart's (1975) 'schemata' (the reconstruction rather than the reproduction of past accidents) were conceptually structured into support elements/variables.

The impact of the lateral safety system on the behavioural response of supervisors and workers was evaluated by a mix of quantitative and qualitative methods of measurements. Supervisory leadership was primarily influenced by the participation in safety programme co-ordination, which introduced strategic and support programme elements at the worker/operative level. The programme co-ordination afforded by the safety committee facilitated, *inter alia*, lateral communication, essential for evaluating safety programme effectiveness. The reporting structure of support elements/variables required feedback to and from safety committees. This effectively re-introduced the primary communication typologies, i.e. upward and downward communication, which had previously remained dysfunctional under the old dispensation. Significantly, the lateral dissemination of accident causative data amongst workers motivated a greater awareness in the area. There was a tangible achievement in this regard: the organisation's accident frequency rates had declined steadily during 1997 and 1998. This is attributed to the descriptive taxonomies of the activities stipulated for the identification of accident causative data at the worker level. The structure of programme elements facilitated worker/supervisor exposure to the root causes of accidents and incidents. It follows that the informal organisation at the supervisor/worker level reversed its non-deliberate departure from safety programme activities. It needs to be stressed however, that some of the supervisors serving on safety committees with inadequately maintained co-ordinating structures did not reverse their paradigm as other counterparts. They were effectively prejudiced by poor managers. Finally, the lack of effective controlling evident amongst supervisors under the old dispensation was rectified by: (a) measurement of compliance regularly carried out by both supervisors and workers, and (b) hazard identification (latent condition, active error) typologies structured into support programme elements.

6. CHAPTER SIX : A BEHAVIOURAL RESPONSE FRAMEWORK

6.1 INTRODUCTORY

At the heart of safety management analysis lie two problems:

(i) identifying and prioritising programme elements and their role in managerial levels;

(ii) measuring acts of compliance which serve as indicators of behavioural response.

As discussed in Chapters 3, 4 and 5 of this dissertation, a specific conceptual framework was developed for the identification and measurement of safety systems. We recall here that existing frameworks of safety management systems (ISRS, NOSA, and benchmark efforts such as ROSPA, Shell, Gulf Oil, Eskom) attempt to:

(a) identify and measure the accident-producing factors prior to their occurrence in industrial operations;

(b) ascertain the probability that accidents will be of limited occurrence and low risk potential.

Attempts to obtain these objectives have been constrained by required administrative systems ('excessive paperwork'), the wide variety of programme activities and a concomitant failure to identify key programme elements. The lack of dynamically integrated programme activities in management levels has also posed a restriction (Reason, 1997).

Consequently, although these programmes have improved existing accident frequency rates in general industry, the theoretical aspect of safety programme co-ordination has not as yet effectively reduced the margins of error in areas critical to process safety (Reason, 1994, 1997). Credit is given however, to existing safety programmes (NOSA, ISRS) for progress made regarding limited hazard identification and measurements of programme compliance. As discussed earlier, a formal programme that has taken cognisance of behavioural response factors via integrated management levels and process safety evaluation, does not exist.

Following a review of the dissertation's main hypotheses and conceptual foundations, this chapter's primary objectives are to analyse critically the integration of steering controls in programme elements and to discuss the efficiency of assigning specific programme elements to the various management levels. This chapter summarises the impact of these elements on behavioural response and assesses whether the steering mechanisms are consistent with the three safety management models discussed in previous chapters.

6.2 REVIEW OF THE MAIN HYPOTHESES

Central to the discussion presented in this paper are the hypotheses that : (a) safety programme elements can only be effectively identified and measured in relation to an organisation's management levels; and (b) steering controls, conceptually integrated in safety programme elements, can induce persons to respond appropriately to the needs of a safety system. Both hypotheses were tested empirically in Chapters 3, 4 and 5. Specific programme elements were assigned to senior, middle and supervisory management to test the behavioural response of persons to safety programme requirements. Further, distinctions were made between strategic and support programme elements assigned to each management level, in order to provide a framework capable of revealing interdependencies among variables. Current national, international safety programmes do not assign specific programme activities to managerial levels, nor is the controlling function, i.e. evaluation of programme effectiveness, adequately defined. As current international accident scenarios invariably display the symptoms of managerial failure, the author of this dissertation is seeking to link accident causal data to inadequate managerial structures, which consequently affect the behavioural response of persons.

6.3 REVIEW OF CONCEPTUAL FOUNDATIONS

6.3.1 Chapter 3 : Senior management level

The absence of a safety steering process in the organisation meant that specific guidelines with regard to safety programme co-ordination were not available to executive leadership. Since specific programme activities were neither defined nor required, senior managers were not in a position to lead safety programme mandates, thus exhibiting a lack of commitment to subordinate management levels. In terms of the informal organisation, senior managers had abdicated from the required involvement in the safety programme. This non-deliberate departure from the formal organisation plan is ascribed to executive leadership failure to provide safety programme structure. The three primary communication typologies, but particularly lateral communication, remained ineffective due to the absence of a steering committee, thereby disabling exchanges of safety product information required for decisions. The controlling function excluded the evaluation of safety programme effectiveness at steering committee level.

In order to compensate for the inadequate safety programme structure described above, a lateral safety measurement system was implemented to provide direction and control for the organisation's safety programme. This model includes strategic and support programme elements as operational and classifies the function of these elements into two broad descriptive categories, namely a **safety steering committee** to direct and control the organisation's safety programme at subordinate management levels, and **support programme elements** to assist in the evaluation of programme effectiveness. These elements involve: (i) accident/incident analysis, (ii) baseline risk analyses, (iii) planned inspections, (iv) co-ordination of the safety programme, and (v) management leadership. Both categories of programme elements are structured for the participation of executive leadership and senior management, with defined roles for the key players, and both specify the evaluation of programme element compliance at middle and supervisory management levels. Broadly speaking, both categories are of an analytical nature, causally associated with measurements of compliance to safety programme standards and performance evaluation. The structure of the programme elements is of an independent explanatory nature, i.e. senior level executives do not require the assistance of staff groups or programme analyst at the operational level of the programme elements.

Behavioural responses are classified into the five categories of leadership, informal organisation, communication, decision-making and controlling. Significantly, the safety steering committee was rated critical by executive leadership in terms of direction and control required for the organisation's safety policy. The definitional aspects of the steering committee and support programme elements, in terms of programme structures and standards, provided senior managers with systematic leadership. From an extrapolative standpoint, this aspect changed the structure of senior management's informal organisation. The previously recorded non-deliberate departures from safety programme management were reversed due to the paradigm shift in the senior managers' informal organisation. The participative approach afforded by the steering committee and support variables/elements provided the means to disseminate information to and from subordinate levels of management through lateral, upward and downward communication. The category of lateral communication at steering committee level assured co-ordination of organisational objectives whilst simultaneously providing the basis for decisions required in terms of safety programme management. A negative aspect was identified, however, in the area of controlling. Although the five support programme elements detailed the required activities, structural deficiencies were identified under 'planned inspections'. The remaining four support programme elements, notably 'safety programme co-ordination', supported the evaluation of programme effectiveness.

6.3.2 Chapter 4 : Middle management level

Middle level executives, without a steering mechanism at the senior management level, were not able to co-ordinate the organisation's safety programme. Consequently, the safety committees chaired by middle managers were not utilised to lead safety programme interventions. Since methods of operation, notably guidelines needed for programme implementation, were not specified to middle managers, the informal organisation at this level remained non-committed to the safety effort. This constituted a non-deliberate departure from the formal organisation plan (Simon, Smithburg and Thompson, 1970). The exclusion of supervisors from safety committee structures limited lateral communication required for the attainment of organisational objectives, notably programme co-ordination (Nigro, 1965). Absence of this communication typology meant that the steering mechanism of the safety committee could not be utilised, the identification of latent and active errors at the operative/worker level moreover remained static (Reason 1997). Exclusion of the supervisory function withheld information essential for effective decision-making, nor could the chairman 'laterally clear' safety issues with key subordinates. Consequently the organisation's safety policy could not be implemented. Finally, effective controlling was constrained through (a) lack of safety programme co-ordination due to lack of definitional guidelines, (b) middle managers not participating in safety inspections, and (c) new design not being evaluated from a safety standpoint.

The test model developed for the middle managerial level encompassed strategic and support programme elements as discussed in the preceding evaluation. Again, programme elements were chosen for their analytical/evaluatory capabilities and independent explanatory power. The structure of the strategic programme element (or safety committee) catered for the much-needed supervisory participation, whilst simultaneously evaluating key programme elements at the supervisory level, a concept not applied previously. The structure of five support programme elements provides evaluatory information to the safety committee for assessing programme effectiveness. The function of the support programme elements encompassed : (a) incident investigation, (b) issue-based risk assessments, (c) new design/modifications, (d) inspections, and (e) task hazard identification (an entirely new concept at this level). Both the strategic and support programme elements share a singular purpose : to measure compliance to safety programme standards at the supervisory level, evaluate performance as measured and introduce corrections if so required. The primary objective here is to identify resident accident pathogens already in place at the operational level, which can lead to latent and active failures in terms of accident causation (Reason, 1994).

The restructured strategic programme element (safety committee) provided effective leadership for two reasons, namely mandatory supervisory participation and steering controls to evaluate support programme elements at both middle and supervisory management levels. Upon the introduction of the lateral safety system, the informal organisation ceased its non-deliberate departure from safety programme activities. The raised structure of the safety committee re-introduced the primary communication typologies, notably lateral communication, which enabled supervisory participation in terms of programme evaluation, as well as receiving communication from and disseminating to, the worker level. Further, decisions concerning the co-ordination of the safety programme at the supervisory level were based on lateral communication. The participation in the committee structure significantly influenced groupthink amongst middle managers which, since the inception of the original ill-defined safety programme, had collectively rationalized that specific safety standards were superfluous. The various categories of controlling were primarily based on the evaluatory mechanism of the safety committee, planned inspections and task hazard evaluations (a new concept in terms of safety management).

6.3.5 Chapter 5 : Supervisory management level

The exclusion of supervisors from safety committees and the resultant inability of middle managers to co-ordinate the safety programme, disabled the capacity of supervisors to lead effective safety programme evaluation at the worker level. Workers/operatives perceived the non-involvement of supervisors in the safety effort as abdicatory. It follows that supervisors, without the structural guideline afforded by the steering mechanism (safety committee) remained, in terms of the informal organisation, non-committal about programme support. Similarly, the lack of participation on safety committee agendas implied failure of lateral communication and, by implication, of safety programme co-ordination at worker level. There was an outright failure of downward communication when supervisors did not brief workers on aspects of process safety, and of upward communication when supervisors did not convey to the safety committee issues raised at the worker level. The breakdown in the three primary communication typologies adversely affected decision-making required for programme co-ordination, ultimately preventing necessary procedural interventions. The structure of the safety committee with the exclusion of the supervisory function impeded the activities necessary to evaluate programme effectiveness, namely personal inspections and task observations. Neither of these elements was acted upon, nor were feedback requirements stipulated by middle management.

The test model developed for the supervisory management level encompassed both strategic and support programme elements (as discussed in the review of the preceding two chapters). However, one important proviso applies. Unlike the strategic programme elements at the senior and middle management levels, which were structured as a steering control mechanism (i.e. steering committee and safety committee respectively), the element of critical task procedures at supervisor level excludes an evaluatory mechanism. The decision for this particular type of structure is based on Pareto's Law as well as Reason's accident causation model discussed in Chapter 5. The analytical capability of the support programme elements incorporates the following functions:

committee, planned inspections and task hazard evaluations (a new concept in terms of safety management).

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(i) Accident recall, to compensate for default values (Rumelhart's schemata, 1977).

(ii) Accident anticipatory task procedures (conceptually new to safety programmes).

(iii) Hazard identification.

(iv) Steering-based task instruction.

(v) Critical task observation for measurements of operational compliance.

The analytical/evaluatory capability of the restructured safety programme aimed to change the behavioural paradigm at supervisory level, with the identification of latent conditions and active errors as a prime motivation.

Subsequent to the introduction of the revised programme, analyses in terms of organisational behaviour identified a particular weakness/non-conformance. Middle managers did not hold supervisors accountable for safety programme co-ordination, but continued to vest this authority in the worker-elected health and safety representatives. As a result, supervisors failed to co-ordinate the programme. The situation was redressed through the introduction of a specific process which evaluated safety programme compliance at worker level. Supervisory leadership benefited from measures of compliance. The structure afforded by the revised safety programme increased the commitment of supervisors, but not to the extent experienced at the middle and senior management levels. This slow shift within the informal organisation towards an affirmative response is attributed to middle level executives' failure to hold supervisors accountable. Hence the need to change the evaluation of support programme elements. Perceived groupthink at both the middle and supervisory management levels was identified as contributory. The three primary communication typologies were, due to limited supervisory involvement, not always effectively utilised, although downward communication was effectively deployed via task instructions. Middle managers neglected (in some areas) the supervisory accountability for programme co-ordination and this, given the dearth of lateral communication, led to organisational objectives being shelved. Evidence points to an avoidance of formal group diagnostic meetings by about 20% of the middle managers. As a result task accomplishments, including problem solving, were not discussed with supervisors (French & Bell, 1995: 171). In terms of broader applicability, the lateral safety system did, however, provide the necessary structure for changing the behavioural paradigm at the supervisory level.

6.4 HAZARD IDENTIFICATION: LINKING BEHAVIOURAL RESPONSE TO PROGRAMME ELEMENTS

Prior to proposing a conceptual model for the identification and measurement of safety management systems, the next section of this paper discusses the difficulties of establishing linkages between behavioural response and programme elements. Safety systems can only be identified and measured in relation to an organisation's management levels (as discussed in the preceding chapters). The focus of effort so far has been to establish the above hypothesis. This excludes however, certain factors beyond the normative control of managers and individuals.

Certain occurrences may induce failure in the various categories of behavioural response, and existing hazards are consequently not identified. Typical examples are psychological stresses induced by sources outside the organisation: these may include personal factors such as resource limitations, operational emergencies or improper motivation (Bird, 1986:28). It is feasible to imagine a scenario where a behavioural response occurs that directly or indirectly leads to a failure to identify a specific hazard in terms of the propagated lateral safety system proposed. For example, Rasmussen's model (skill-rule-knowledge framework) is primarily directed at critical errors made by those in supervisory control of industrial processes. Rasmussen as well as Reason recognise that the schematic processes which reconstruct past experiences may result from resource limitations ('bounded rationality') such as incorrect knowledge or misclassification of situations leading to the application of the wrong rule.

A number of significant incidents, for example Chernobyl, Piper Alpha, and Bophal (India) fall into the categories described above. Neither Bird et al. (1986) nor Stranks (1994) in their respective expositions on safety programme effectiveness address cognitive control mechanisms that are error-orientated. The inadequacy of safety control systems which ignore cognitive knowledge structures or schemata is reflected in the static accident frequency rates of industrial operations such as the general manufacturing industry (SA).

The author of this dissertation postulates, therefore, the evaluation of safety programme elements in terms of both effective behavioural response and the role played by schemata in past accidents. Contemporary schema theorists such as Rumelhart (1975), Schmidt (1995) and particularly Reason and Rasmussen, have provided successful frameworks to clarify the nature of interaction between incoming episodic information and generic information embodied in schemata, 'the relationships between new and old knowledge' (Reason). The objective, therefore, was to integrate a conceptual framework that would compensate for schemata-induced error as well as support the categories of organisational behaviour. Accordingly, a lateral safety system with emphasis on task hazard identification and accident recall was developed for the purposes of this dissertation. The system includes steering controls which evaluate programme effectiveness on an ongoing basis, particularly strategic programme elements such as critical task procedures.

The next section briefly reviews the frameworks of existing 'market' safety programmes, conceptually evaluating the basic controlling typologies, organisational (managerial) integration and structures governing behavioural response.

6.5 CONCEPTUAL FOUNDATIONS OF CURRENT SAFETY PROGRAMMES: A CRITIQUE

6.5.1 Introductory

This section of the paper discusses the structure of existing 'market' safety programmes and the concepts applied to assure process safety in general industry. The overall effectiveness of programme structures is evaluated.

6.5.2 Market leader : NOSA

The NOSA safety programme is presently grouped into six categories of programme elements. Measurement methodologies assess an organisation's compliance to statutory (legal) regulations, as well as the safety of industrial processes in terms of people, equipment, materials and environment. Physical conditions (plant, machinery) are required to meet certain operational safety standards.

The NOSA programme has been tested successfully for over nearly five decades. Implementation of this programme has resulted in the reduction of industrial accident frequency rates. A central critique of the NOSA programme is that managerial involvement is not specified. Consequently, lack of managerial commitment remains a primary factor in accident causation, in particular the managerial response to identified hazards. This is reflected in the punctuated occurrence of accidents and near-miss incidents with high loss potential. Significantly, the structure of managerial programme elements in the NOSA framework excludes performance standards for executive leadership. Lack of commitment to the safety programme was identified via quantitative assessments which implicated particularly leadership, informal organisation and controlling programme compliance. This is primarily attributed to managerial activities not being specified in the broader framework of the NOSA programme. The structure of programme elements is not specific in terms of managerial involvement, an aspect which this dissertation has sought to address. A feasibility study was conducted by the author for reasons of integrating the lateral safety system into the NOSA programme. This programme has run concurrently since 1994. Indications are that managerial safety programme specifications as espoused by the lateral safety system, effectively supplement the NOSA programme. This was established via quantitative assessments during the above time period.

6.6 LATERAL SAFETY SYSTEM CONCEPT: OVERALL IMPLICATIONS

6.6.1 Safety management systems conceptualised schematically

6.6.1.1 introductory

Lateral safety systems are defined, identified and measured in terms of three conceptual frameworks:

(i) Identification of specific programme elements for each management level.

(ii) Integration of three basic types of control into programme elements.

(iii) Rating the strategy function of programme elements.

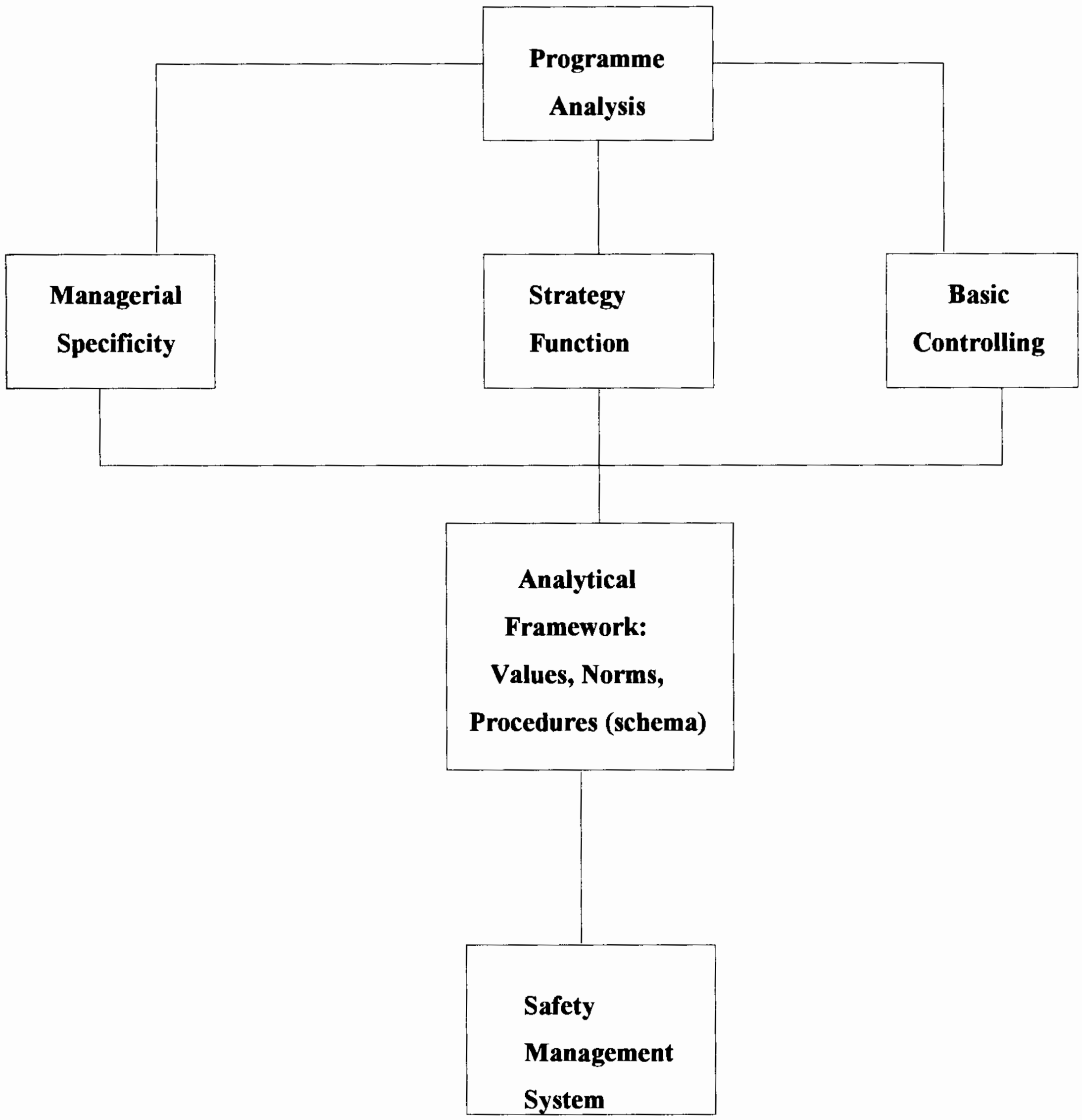
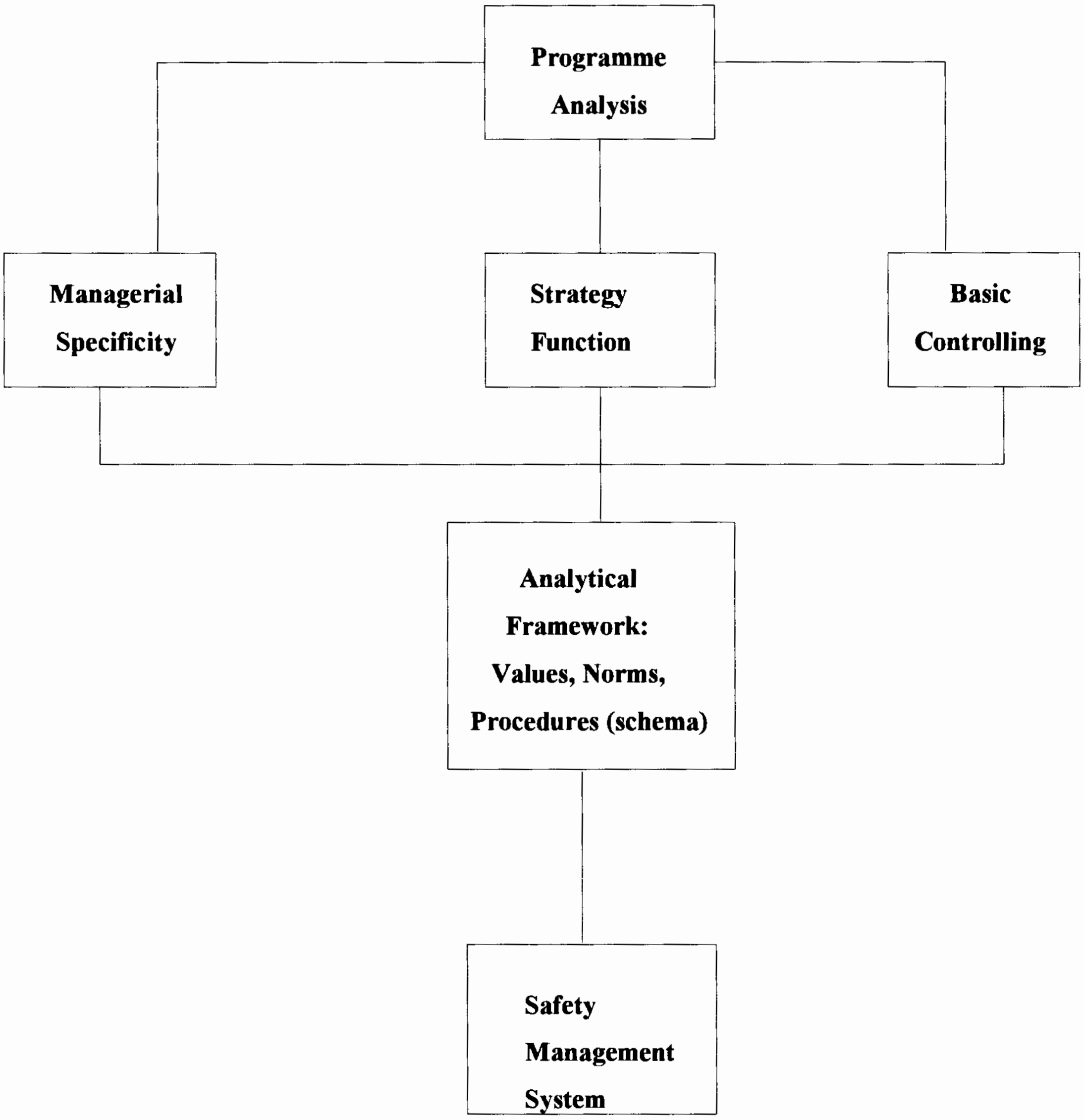


Figure 5. Exhibit 6A. Conceptual framework of a safety system.

The interaction of these elements constitutes a lateral safety system. It follows that a primary concern of the safety programme analyst is to identify the relevant programme elements that will govern a specific management level, as safety programme effectiveness is conceptually determined by managerial activities (Reason, 1994, 1997). Explicit conceptual frameworks such as the one discussed above are currently not available. Existing frameworks of safety programmes exclude the taxonomies of managerial specificity, strategic function and basic controlling. The above taxonomies



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6.6.1.2 integrating safety management system into current safety programmes

The adaptive potential of the lateral safety system, as well as the strategic predisposition of the programme elements in terms of behavioural response, enables one to link this model to current safety programmes. The process suggested by the author to restructure the concept of 'market' safety programmes encompasses a three step approach.

(i) Linking programme elements to managerial levels

Current safety system models are structured primarily as a bureaucratic checklist of risks. They have failed to produce a conceptual model orientated towards the identification and measurement of programme elements adapted to the organisational hierarchy. Further, current structures detail the operational requirements set by programme elements, but conceptually exclude interaction between programme elements. Since the information or historical record generated by a set of programme elements remains insular, i.e. the information is not used in conjunction with other elements or models for safety analyses and evaluations, managerial levels lack specific information required for effective forecasting of safety strategy. This is also in part comparable to the 'scalar' or pyramid hierarchical structures of organisations (Nigro:197), which fail to indicate the lateral interaction between instances/elements on the same level. It is not suggested, however, to restructure the current checklist-type of safety programmes entirely, but to regroup certain key programme elements in terms of the managerial function. (Current safety programmes vary in their number of programme elements from twenty to eighty, with sub-divisions ranging to roughly four hundred.)

As a first step, safety programme element structures should be identified in terms of evaluatory (steering mechanisms) and interactive processes. Conceptions of these vary, depending on the choice of the safety programme analyst. It is stressed, however, that programme elements are strategically chosen to enable managers to evaluate programme effectiveness. Further, the number of variables/elements chosen for a programme element structure is limited to six, as managers cannot seriously give attention to more than six different objectives (Newman, 1975). See Exhibit 6b below.

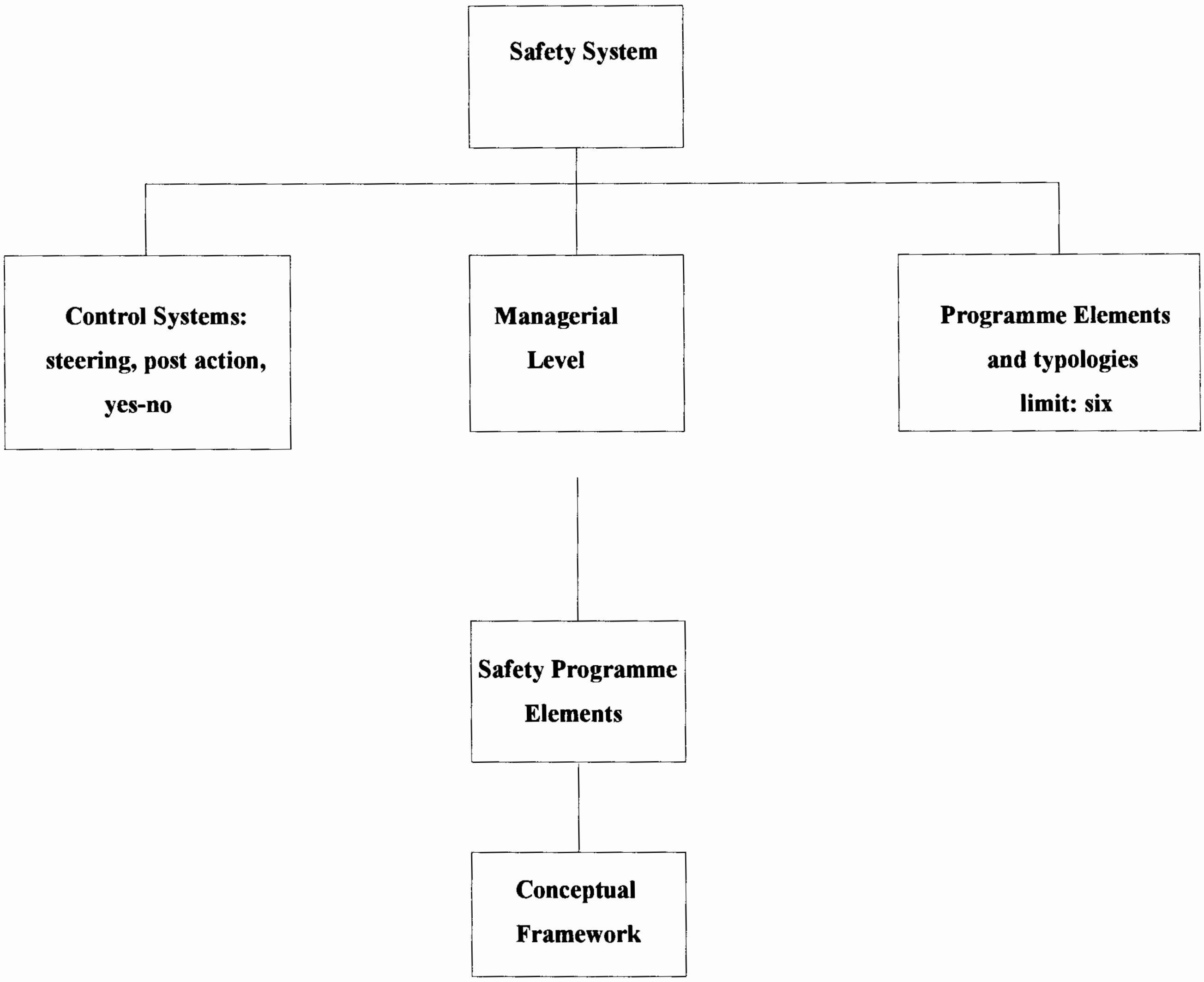

Figure 6. Exhibit 6b. Conceptual framework, for managerial levels.

Current-day safety programmes would need to be redesigned to include a lateral safety system. However, some of the checklist typologies, rules and procedures of market safety programmes need not be altered. Required however, is the introduction of programme elements which conceptually evaluate programme effectiveness. Secondly, programme elements must be reconceptualised according to the function required by the lateral safety system.

(ii) **Altering existing non-evaluatory frameworks**

As discussed above 6.6.1.2(i), programme elements with steering control - evaluation capability replace the 'yes-no' controlling structures of current programme elements. At the senior management level, the concept and/or function of safety programme evaluation is lacking in all major safety programmes. Accordingly, a steering mechanism is introduced at the executive leadership level (as part of the organisation's safety steering committee) to provide direction and control for the safety programme. This conceptual schematisation is repeated for the middle managerial level, where existing ordinary committee structures are changed to facilitate programme evaluation. Please note that the supervisory level is excluded from this as the programme evaluation process is maintained by the middle management safety committees. Evaluation of programme effectiveness at the operational interfaces is assured however, by the function of support programme elements at the supervisory level.

(iii) **Reconciling the distinction between individual and organisational accidents**

This dissertation has sought to address human performance in terms of the individual in an organisational setting, examining the differences between individual and organisational accidents. There is a belief held by many technical managers that the main threat to process safety is posed by the behavioural and motivational shortcomings of operatives/ workers at the 'rockface' (Reason, 1997:223). For these managers, the often-repeated statistic that 80-95% of all accidents/ incidents are due to human error means that human inadequacies and errant actions are perceived as the primary causes of accidents. This particular mindset chooses to ignore the conditions or systems under which people work. Furthermore, it ignores the evidence that most solutions to human performance are technical rather than behavioural (Reason, 1977: 224).

A particularly effective method of resolving these apparent conflicts is to recognise the three models for managing safety distinguished by Deborah Lucas. The following analysis reviews the structure of the lateral safety management system in terms of the three-model concept.

The person model

This model exemplifies the traditional occupational safety approach. As such, it includes awareness campaigns, safety audits and inspections, 'safe work' procedures and safety training. Progress is measured by a star-rating system, and by a record of disabling injuries incurred by the organisation. In relating this model conceptually to the steering mechanisms employed by this dissertation, it is apparent that the functions of awareness, audits and training are reflected in the programme elements, but with greater specificity in terms of hazard identification (which is critical to process safety). For example, the identification of hazards is repeated at all three management levels. At this point in time (1998), Koeberg has achieved its lowest disabling injury frequency rate since it started operating commercially in 1986. It needs to be pointed out, however, that a low disabling injury frequency rate is no guarantee, whatsoever, that the integrity of a particular installation is beyond question in terms of safety. On the contrary, a methane underground fire occurred in one of the SASOL coal collieries on the day they were awarded a 95% safety compliance rating, with a disabling frequency rate less than one (Star, 1977). Further, in contrast to the generic nature of training in current market programmes, the safety management system focuses on the specificity of critical tasks.

The engineering model

Human error, in the context of the engineering model, is regarded as a consequence of human-machine mismatches, in other words, failure on the part of system designers to take into account the *'cognitive strengths and weaknesses of human controllers'* (Reason, 1997:225). The engineering model focuses on how operatives are influenced by the informational properties of the human-machine interface. Practical applications include hazard operability studies, technical audits, cognitive task analyses and ergonomics, to name a few. The safety management model has sought to incorporate the engineering model by means of task/process observations by supervisory staff and workers, with a feedback mechanism to the middle management level safety committees. Further, the evaluation of new design or modification to existing processes is carried out at middle management level, with a feedback loop to the senior management level safety steering committee.

The organisational model

The organisational model views human error more as a consequence than a cause. Reason correctly states that *' errors are symptoms that reveal the presence of latent conditions/ resident accident pathogens in industrial systems under which people work'*. The organisational model emphasizes the need for proactive measures so that human error cannot adversely affect the integrity of existing defences. As such, the organisational model seeks constantly to evaluate the effectiveness of safety control systems for one purpose only: the identification of active and latent failures/conditions which might breach a system's defences. This will include, typically, evaluation of hazards due to extended exposure and accumulation of latent conditions that can occur in the managerial, maintenance and operational spheres. The organisational model therefore deals with the integrity of defences and broader systemic factors. A keypoint to note (constantly emphasized , firstly by Reason but also by Bird et al.): effective safety risk management requires continuous evaluation of factors that may breach a system's defences. For the purpose of this dissertation, typical examples of programme elements which conceptually evaluate safety system effectiveness have been:

- Supervisory level: measuring compliance to operational standards via task observations with a feedback loop to the middle management level.

- Middle management level: evaluating supervisory measurements of compliance to task procedures and hazard identification.

- Executive leadership : co-ordinating the safety programme with middle managers by evaluating feedback on key programme elements such as task hazard identification, accident/incident analyses and task observations.

6.7. CONCLUSION

The framework of the safety management system proposed by the author met the objective of this dissertation: a continuous evaluatory or steering process for the identification and measurement of latent conditions and active errors. The structure of programme elements is geared to identify hazards and measure compliance, with a feedback loop to and from super-ordinate management levels.

The framework of the safety system management demonstrably reconciles the three different approaches to safety management : (a) the person model, directed at reducing personal injury events, (b) the engineering model, focusing on the person-machine interface and system reliability, and (c) the organisational model, providing a conceptual evaluatory framework and broader systemic factors for effectively managing process safety.

As a postscript, the author would like to voice his concern that the concept of safety management is not currently taught in tertiary institutions in South Africa. In view of the magnitude of southern Africa's mining sector and the location of heavy, and manufacturing industries throughout the country, safety management should form part of the curriculum for engineering and the building environment, commerce and humanities.

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