The UNIVERSITY
of NEWCASTLE
Human Factors Group

Coal Industry Safety Culture

Final Report Project 1

Report: HFG-0804-1139-02

H. Peter Pfister & Rebecca J. Atkins

Human Factors Group
School of Behavioural Sciences
The University of Newcastle
University Drive
Callaghan, NSW, 2308
Australia

October 2005

Prepared for

Joint Coal Board
Health and Safety Trust
and
Coal Services Pty Limited

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SECTION 1:
Project and Report Overview

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1.1 Project Team

Project Supervisor:
Associate Professor H Peter Pfister PhD
Director
Human Factors Group
School of Behavioural Sciences
The University of Newcastle

Principal Research Officer:
Rebecca J. Atkins BA (Psych) Hons Assoc MAPS
Doctoral Candidate
Human Factors Group
School of Behavioural Sciences
The University of Newcastle

Research Officer:
Lisa Thomas PhD
School of Behavioural Sciences
The University of Newcastle

International Collaborator:
Mark Fleming PhD
School of Psychology
Saint Mary's University
Halifax, Nova Scotia, Canada

International Collaborator:
Steven Smith PhD
School of Psychology
Saint Mary's University
Halifax, Nova Scotia, Canada

Research Students:
Thomas R. Bellamy; Honours Student (2003)
N. Susan Fielding; Honours Student (2003)

Alexandra Adoni, Honours Student (2004)
Rachael Henry, Honours Student (2004)
Danielle McMahon, Honours Student (2004)
Alison White, Honours Student (2004)

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1.4 Abbreviations

ARC	Australian Research Council
CS	Coal Services
HF	Human Factors
HFG	Human Factors Group (The University of Newcastle)
HRI	High Reliability Industry
HRO	High Reliability Organisation
IHF	Industrial Human Factors
JCB	Joint Coal Board
JCB-HST	Joint Coal Board Health and Safety Trust
NS	Nova Scotia (Canada)
NSW	New South Wales (Australia)
SMQ	Safety Management Questionnaire
SPSS	Statistical Package for the Social Sciences
OC	Open-cut (Coal Mine)
UG	Underground (Coal Mine)
UK	United Kingdom
USA	United States of America

1.5 Foreword

This report was prompted by the Joint Coal Board Health and Safety Trust (JCB-HST) and Coal Services (CS) Pty Limited to identify critical factors contributing to safety culture within the Australian coal mining industry. The research involved participation by a number of Coal Mines from the Hunter Region, NSW: mostly underground and one open-cut. The information outlined in this report is of the first project of an extended research program aimed at developing a safety culture measurement tool for the Australian national coal mining industry. This report contains a detailed review of the scientific literature relevant to safety culture and safety climate within the Industrial Human Factors domains relating to critical safety factors pertinent to the Australian coal mining Industry and its workforce. Concentrated discussion is presented on the critical factors contributing to human error, safety culture, and safety climate together with the results and recommendations from the first phase of the initial research project, which was commenced in 2003. The project to date has been funded by the JCB Health & Safety Trust with supplementary funding from the University of Newcastle. The project was conducted under National Ethical Guidelines approval number H-578-0503 Human Research Ethics Committee, The University of Newcastle. The views expressed herein do not necessarily represent official CS Pty Limited or JCB-HST positions. The project team wishes to acknowledge Mr Ken Cram, CS Pty Limited, who has acted as the Project Liaison Officer. We express our further appreciation to the Safety Training Coordinators from the mines involved in the research project for arranging site tours and providing much assistance with access and the administration and facilitation of this project. Finally, we would like to acknowledge

the research staff and students involved in this project during the period 2003 to 2005.

Newcastle October 2005

H. Peter Pfister
Project Director
Human Factors Group
The University of Newcastle

Rebecca J. Atkins
Principal Research Officer
Human Factors Group
The University of Newcastle

1.6 Scope

The scope of this project was to provide a report containing a review of the current research literature available within the IHF field relating to safety culture and safety climate within the Australian coal mining industry. During the life of the project this was extended to also include both attitudes and behaviour of the workforce. The first stage of the supporting research project further extends to the identification of critical factors contributing to safety culture and safety climate within a sample of coal mines, and a determination of the degree of generalisability to the wider Australian coal industry. Project 1 of the extended research program was conducted 2003 to 2005 at several mining operations within the Hunter Region, NSW: underground (UG) and one open-cut (OC) mine were utilised. Further scope of this project was to develop an extended research program based on the results of the first project. A proposal for the latter stages of the research program are outlined in Section 6 of this report, detailing project extension to incorporate broader state samples followed by an Australian national sample. Opportunities to further extend this project to enable international comparison are currently being explored by the project team.

1.7 Report Overview

This report is presented in five sections. Section 1 (this segment of the report) contains introductory materials to the report and project (including full report index). At the request of JCB-HST and CS Pty Limited, Sections are detachable. The executive summary of the project including the theoretical underpinnings and data report is contained in section 2. A disclaimer has also been included for contextual reference and statement qualification. Section 3 includes an extensive theoretical and empirical review of safety culture and safety climate within high reliability teams, organisations, and industries sourced from the coal mining industry, allied industries and the wider Industrial Human Factors fields. Section 4 contains a broad bibliography essentially providing a detachable reference database for future research, theory, and other information. Section 5 contains a thorough report of the 2003 to 2005 Project involving a sample of mines from the Hunter Region, NSW, Australia. Data analysis and interpretation of the project is also included in Section 5 together with a discussion of the findings and recommendations based on the project results. We are planning to provide a plan forward but only after consultations with key personnel of the funding body and industry.

The research team is available to discuss any aspects of this report, the current research, and/or the proposed research expansion. Please contact:

Associate Professor H. Peter Pfister

Director – Human Factors Group – The University of Newcastle

Phone: (02) 49215760 – Fax: (02) 49216906

Email: Peter.Pfister@newcastle.edu.au

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Coal Industry Safety Culture
Final Report Project 1, 2005

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SECTION 2:
Executive Summary

H. Peter Pfister & Rebecca J. Atkins

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Section 2: Executive Summary

2.0 Executive Summary

2.1 Overview

The project team was funded to develop a valid safety measure for the Australian Coal Industry. Specifically the team was expected to conduct the following research:

1. Literature search to identify appropriate criteria for examination and to serve as a test bed;
2. Focus groups with miners, supervisors, and managers to test criteria identified in the literature review;
3. Development and testing of a safety culture questionnaire;
4. Evaluation and refinement of questionnaire; and
5. Second testing of questionnaire in another mine to validate questionnaire.

Overall, we can report that we have completed all five steps outlined above. Furthermore, additional funding provided by the University of Newcastle allowed us to extend the project by testing the questionnaire for a third time having significantly advanced the original objectives outlined above. We are conducting this third round of testing as this report is being prepared. We expect that the updated version of the questionnaire and data tables will be available as an addendum to this report in early 2006. After this we will provide the Board with the final SMQ version for public release.

In the following sections we report in short format structure what we have achieved in each of these five steps of project 1. Other sections within the extended report contain the details which form the basis of this executive report.

These other sections also contain the technical information and evidence that underpin the development of the Safety Management Questionnaire (SMQ).

2.2 Literature Search

The details of the literature search are contained in two sections of the extended report; section 3 which analyses what the scientific literature has to offer and section 4 which contains a reference bibliography with just under 1100 entries. Both serve as a foundation for further work.

In essence the safety literature addresses a number of global issues and also provides some specific information on critical safety factors.

The psychological, behavioural, and situational elements of safety culture hold a combined critical role in accident causation and error prevention within high reliability industries (HRIs) such coal mining. Safe, effective, and efficient HRI operations are dependent upon a positive safety culture across the entire workforce including both mine workers and management. Identification and analysis of the critical factors contributing to safety culture enables the development of innovative error prevention strategies at both the individual and also the organisational levels. This approach is also critically important when developing cost-effective interventions, targeted at specific areas of identified need. The purpose of this report and the supplementary research program was to identify those factors critical to safe performance and efficient operations across the Australian coal mining industry. The information presented throughout the report has been sourced from the wider Industrial Human Factors (IHF) field and examined in terms of applicability to the Australian coal mining context. A summary of the key elements of each section of the extended report are presented below.

2.2.1. Safety Culture: Definition and Distinction from Safety Climate

While a universal definition does not exist, safety culture is widely accepted as the product of individual and group attitudes, values, and behaviours that influence safety (both safety behaviours and safety management). Safety culture is commonly used interchangeably with safety climate. Safety climate relates to the psychological aspects of safety culture and provides an indication of the safety attitudes and perceptions of an organisation at a given time: thus providing an indication of the underlying safety culture present in the organisation. The two concepts are not isolated: climate is in fact ‘culture in the making’.

2.2.2. The Effective Measurement of Safety Culture

Questionnaires have been identified as a valid measurement tool for both safety climate (assessing attitudes and perceptions) and safety culture (evaluating attitudes, perceptions, *and* behaviours). Effective measurement of safety culture is a complex process requiring multiple techniques including but not limited to: questionnaires, observation, behavioural checklists, focus groups, safety audits, and site inspections. Identified critical factors of safety culture may be an artefact of questionnaire design: the inclusion of multiple assessment techniques is essential for the validation of findings and the evaluation and refinement of measurement tools.

2.2.3. Critical Factors Contributing to Safety Culture: Core Set for HRIs

Safety culture is a multi-dimensional concept determined by a number of critical factors. Identification of the factors contributing to safety culture enables areas for advancement to be targeted and resourceful safety initiatives to be developed. A core set of 10 critical factors of safety culture have been identified from the scientific literature across a variety of HRIs (see also section 3 for a detailed report). The core set of critical factors from the scientific literature is as follows:

(1) management commitment to safety

(2) individual responsibility to safety

(3) perceived level of risk,

(4) training,

(5) safety systems and procedures,

(6) the prioritisation of safety and production,

(7) communication,

(8) importance of safety,

(9) risk-taking/safety behaviour, and

(10) environmental risk

The factor sub-components of these ten factors are summarised in Table 5.4 of the Section 5 report.

We expected that this order will vary across organisations. This expectation was based on the clear view expressed by the workforce in each of the mines that their operation is unique and quite different from all others. Each of these 'factor categories' further contain a number of underlying sub-components – for example, employee perceptions of management commitment to safety may be influenced by such forces as communication, management style, role modelling, production pressure, safety focus, and so forth – sub-components will also vary across organisations. Critical factors feedback into the overall safety system and shape the safety attitudes and actions of the individual worker, management, and the organisation. As such, the critical factors hold significant influence over safety performance and safety culture.

2.3 Focus Groups

The extent to which the above stated core set of critical factors of safety culture are applicable to the Australian coal mining industry was examined in the current research. That part of the project was conducted using a total of three mines (two underground and one open-cut) in the Hunter Region. Focus groups were held with representatives from all levels of the workforce (mine workers, supervisors, and management) at each of the participating mines. After extensive open discussion, focus group participants were asked two complete two written tasks, (a) 'what they felt were the five most important safety issues at their mine' and (b) 'whom they believed held the top 3 levels of responsibility for safety in terms of job function at their mine'. The first task helped us to consolidate the analysis of critical safety factors.

A factor structure was revealed which remained largely invariant from the above stated 'core set'. The top 6 factors identified from the focus groups (in ranked frequency order), on average across all participating mines, were:

(1) the prioritisation of safety and production,

(2) management commitment to safety

(3) risk-taking/safety behaviour,

(4) safety systems and procedures,

(5) training, and

(6) individual responsibility for safety

Additional factors such as safety equipment and job security were further identified and communication was found to be a sub-component of management commitment. As evident some variation of ranking/order was identified in this sample from the core set. We also found some differences between work groups for specific mines. However, the emphasis of this task was to search for factors in common rather that seeking differences. This task supported the primary suggested provided by the literature in that the Australian Coal Industry is not likely to diverge much from well established critical safety factors.

In relation to responsibility for safety at their mine, the data is contained in Tables 5.7, 5.10 and 5.13 in section 5. The data is not additive but overall one can conclude that the participants within the focus groups do understand that they are personally responsible for their own safety. However, there is some minor degree of confusion where some workers suggest that management has that primary responsibility. We planned to address this issue in more detail during the questionnaire phase of the project.

2.4 SMQ - 1 (Original Version)

The safety Management Questionnaire (SMQ) was provided to all workers and staff at the same three mines used in the focus groups involving a total sample of

601. Participation was on a voluntary basis. 158 (27%) questionnaires were returned.

The details of the results for the three mines are contained in 5.9.2 (section 5) of the extended report. For the purposes of this executive report we were able to identify a 6 factor model which served as the basis for further development.

The factor structure revealed repetition of the core set of critical factors of safety culture with some order variation. The top 6 factors identified from the SMQ, on average across all participating mines, were: (1) management commitment, (2) individual responsibility, (3) the prioritisation of safety and production, (4) safety systems and procedures, (5) communication, and (6) risk-taking/safety behaviour. Such a finding reveals further support for the emerging core set of critical factors and also the validity of the measurement tool.

Statistical analysis of the collective data set has revealed a factor structure of 6 factor categories (with various sub-components) contributing to safety culture within the specific context of Australian coal mining. The additional information obtained during the first data run was then incorporated into the revised SMQ (version 2) for subsequent testing.

2.5 SMQ-2 (Version 2)

Significant changes were made to the questionnaire as a consequence of the data obtained in version 1. The most important advancement that was possible was to examine independently the responses within two dimensions (a) safety attitudes and (b) safety behaviour. Accordingly the questionnaire was restructured to explore that avenue in more detail during round two.

Based on the feedback provided to the three mines other mines as well as individuals were willing to participate. For SMQ-2 we had a total of 6 participating mines. 3 of these were from the original group and three new underground mines joined the project. The mine that dropped out for version 2 was doing so because of internal difficulties at the mine site. Thus eventually SMQ-2 was conducted with one open cut and 4 underground mines.

Response Rates by Mine for the SMQ-2 Study

Mine	**Total Workforce Numbers**	**Number of Responses**	**Response Rate (%)**
Mine A	249	99	39.8%
Mine B	-	-	-
Mine C	199	120	60.3%
Mine D	159	50	31.4%
Mine E	141	56	39.7%
Mine F	64	28	43.8%
TOTAL	812	353	43.5%

In summary, during round two of the project the number of mines increased from three to five with a total of capacity of 812 participants of whom 353 responded to the questionnaire. This represents a participation rate of 43.5% a significant increase from round one where the rate was below 30%.

SMQ-2 is a significant improvement on the previous questionnaire developed while maintaining the six factor model and introducing a behavioural and an attitudinal scale.

The table below contains the reference data for both scales and the 6 factors. It is noted that no items loaded on factor 6 on the behavioural scale thus resulting in a zero value. This will be addressed in SMQ-3 together with other issues raised in the preceding sections.

Results of the SMQ-2 Factor Scores for both Behaviour and Attitude

Factor	Behaviour Scale (FB)	Attitude Scale (FA)	Total (FG)	Standard Deviation	Reliability Coefficient
F1	3.94	3.51	3.72	.68	.92
F2	3.66	3.41	3.54	.59	.86
F3	2.30	3.11	2.70	.78	.78
F4	3.41	4.49	3.95	.74	.82
F5	3.83	4.03	3.93	.68	.54
F6	0.00	4.66	4.66	.47	.55
Total	3.44	3.86	3.75	.43	.93

Finally, the statistical analysis has shown that both validity and reliability of SMQ-2 improved significantly from the previous version.

In conclusion, SMQ-2 is an improved instrument over SMQ-1 however a number of minor issues needed to be addressed including the issue of non-loading questions and the veracity of factor 6. These and other questions will be addressed in SMQ-3 currently under data collection. For a copy of the three SMQ versions see the appendix in the section 5 report.

2.6 SMQ-3 (Version 3)

SMQ-3 testing is being undertaken as this report is being prepared. It is expected that a final version of the SMQ together with reference data (see SMQ-2 reference data in the table above) will be available in early 2006 for general release.

Furthermore, at the end of version 2 we conducted a major revision of all the factors and options open to participating mines (usually the Mine Safety

Committee) after we discussed the findings with them. One of their major requests was to provide them with identifiable components for both the attitude and behaviour dimensions to allow for focused training programs in the future.

Additionally, from a mathematical / statistical modelling perspective we thought it prudent to contract the 6 factor model to a 5 factor model for both attitudes and behaviour. We have found that a 5 factor model for both the attitude and behaviour dimension will in the end deliver better information (statistically more valid) to companies and organisations when deciding where to strategically focus their safety training effort. Running version 3 also allows us to make some minor editorial changes to the questionnaire.

2.7 Financial & Legal

The major funding from the Joint Coal Board Health and Safety Trust to this project is acknowledged. A special supplementary grant of $ 12,000 was provided by the University of Newcastle which allowed for the funding of a Doctoral student and 6 Honours Project students, all working on this project. From both funding agencies this was a most efficient and cost effective way to proceed.

Under the National Ethics Guidelines the Human Research Ethics Committee of the University of Newcastle had overall responsibility for the approval of the project under the Ethics guidelines. Such approval was initially obtained in 2003 approval number H-578-0503 and subsequent variations of documents, questionnaires and participating students were approved under the same number.

2.8 Disclaimer

Any opinions, findings, or recommendations expressed in this executive summary are those of the project team as scientifically derived from the research literature and the findings of the research project and do not necessarily reflect the views of Coal Services Pty Limited, the Joint Coal Board Health and Safety Trust, The University of Newcastle, or any other body or mining installation and / or organisation.

This executive summary forms part of an extensive report prepared for Coal Services Pty Limited and the Joint Coal Board Health and Safety Trust by The University of Newcastle Human Factors Group. The report relates to the 2003 to 2005 project of an ongoing research program. The first project (that which is contained in the extensive report) was conducted in order to identify critical factors contributing to safety culture within the Australian coal mining industry from a sample of Hunter Region, NSW, coal mines: both underground and open-cut. This executive summary relates only to the initial project and the underlying theory of the extended research program.

For further information on this report or to discuss access to the extended report, please contact Coal Services Pty Limited.

For further information about the current research project please contact the Human Factors Group from The University of Newcastle, Australia:

Associate Professor H. Peter Pfister
Director – Human Factors Group – The University of Newcastle
Aviation Building, School of Behavioural Sciences,
University Drive, Callaghan, NSW, 2308
Phone: (02) 49215760 – Fax: (02) 49216906
Email: Peter.Pfister@newcastle.edu.au

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3.1 Overview

The role of safety culture in the causation of accidents within High Reliability Industries (HRIs) such as aviation, transport, off-shore oil platforms, and coal mining continues to be a source of investigation on an international scale. On a national level, large amounts of resources are dedicated to improving safe work practices and policies within the Australian coal mining industry on an annual basis. Investigation reveals this commitment has not yet produced a consistent reduction in the annual number of accidents, injuries, and fatalities. Research has shown the psychological, behavioural, and situational elements of safety culture to hold a critical role in maintaining the safety and efficiency of HRI operations. Such outcomes are dependent upon a positive safety culture across the entire workforce. Safety culture is a multi-faceted concept comprised of the safety attitudes and behaviours of an organisation's individuals contributing to its safe operations. Identification of the critical factors contributing to safety culture enables the development of innovative error prevention strategies at both the individual and organisational level. These factors such as employee perceptions of management commitment to safety, individual responsibility, the balance between production and safety, training, risk-taking, and communication may be specific to individual organisations or common across industries and nations or a combination of both. This section of the report focuses on identifying critical factors contributing to safety culture across a variety of HRIs and assessing their relevance to the Australian coal mining industry, through a comprehensive review of scientific (both theoretical and empirical) literature. This represents the first stage of an extended research program ultimately aiming to establish a national measure of safety culture.

3.2 Introduction

Despite the large amount of resources dedicated to the improvement of safety and safety culture within the Australian coal mining industry, a respectively consistent reduction in the number of annual fatalities has not coincided (Stephan, 2001). For this reason, the coal mining industry is among the High Reliability Industries (HRIs) in Australia with the highest number of annual injures. As such, the development and implementation of Human Factors research into identification of the factors contributing to accidents in coal mining and wider HRI operations is essential. The psychological, behavioural, and situational elements of safety culture hold a combined critical role in accident causation within HRIs such as aviation, offshore oil platforms, and coal mining. Safe, effective, and efficient HRI operations are dependent upon a positive safety culture across the entire workforce. Identification and analysis of the critical factors contributing to safety culture enables the development of innovative error prevention strategies at both the individual and organisational levels. The purpose of this report and the supplementary research program is to identify those factors critical to safe performance and safe operations across the wider Industrial Human Factors (IHF) field and to examine the extent of their generalisability to the Australian coal mining industry. This report will further clearly define the concept of safety culture, as distinctive to safety climate (an issue which has generated much empirical debate), and as applicable to the Australian coal mining industry in accordance with the development of an extended research program by The University of Newcastle Human Factors Group examining safety culture across Australian coal mines.

3.2.1 Safety Culture and Accidents: An Overview

Over the past decade within the NSW coal mining industry 7,000 injuries were registered across a workforce of 16,789 individuals in a single 12 month period: 62 percent of which resulted in one or more days of lost working time (Hull, Leigh, Driscoll, & Mandryk, 1996). November 1996 saw the drowning of 4 miners while working in an Upper Hunter mine near Gretley, NSW: increasing the number of deaths that year to 25, compared to the 7 fatal injuries during 1995 (McKenzie, 1997). In addition, across a single weekend in June 2003, during the interim processing of this report, two NSW coal miners were hospitalised, one requiring neural surgery after a rock fall; the cutting off his own arm with a Stanley knife after an underground vehicle rolled. These findings, among several other examples presented over the course of this report, indicate the significant safety related issues within the Australian coal mining industry and their impact across the workforce.

The major motivations behind safety culture and safety related investigations are two-fold: (1) the health and safety of mine employees; and (2) productivity. Annual workers compensation payout figures highlight concerns not only for the expenditure of the industry, but the alarmingly high accident and injury rates. Additional costs are further incurred resulting from accident inquiries such as training and re-training, developing new policies and procedures, and production losses (Leigh, Mulder, Want, Farnsworth, & Morgan, 1990). In addition there are intangible costs associated with potential deterioration of company reputation, worker moral, and losses to the injured worker's family, friends, and co-workers (Leigh et al., 1990). The extent to which this is reflected in safety culture within the Australian coal mining industry and across the wider IHF field is yet to be comprehensively determined.

In a survey of 165 managers/supervisors and 400 mine workers, Pitzer (1998) conducted a comparative investigation between several NSW coal mines and pre-existing survey data collected from other states within the national industry, such as Western Australia. The survey identified NSW as having a less positively people-based approach to safety, further indicating a less flexible system with little or no input from the workforce in relation to safety advancement programs. The primary indicators of safety being management driven and the poor level of safety culture at the time of the Pitzer (1998) survey were:

1. External companies or separate company supervisors were not concerned with the mining process, audited adherence to specific safety procedures;
2. There were no incentives for adherence to safety, only punishment for non-compliance;
3. Safety was entirely management driven with little or no worker involvement in the safety training procedures; and
4. Any safety programs implemented concentrated on engineering solutions, rather than people solutions, to solve safety concerns.

Such findings highlight the wider concern of poor safety culture within the NSW coal mining industry and the ability of survey-based research to identify key factors contributing to safety culture and wider safety concerns in Australian coal mines.

Improving safety culture is an investment. The need for ‘efficient safety cultures’ is dramatically present, where safety improvements (and accident reduction) are possible without extreme costing. This study is taking steps towards building a platform from which this can be undertaken from a Human Factors perspective.

Safety culture and safety climate are concepts thought to encompass the organisational and human factors that influence organisational safety. Stephan (2001) states a poor safety culture is often linked to a poor accident record in the mining industry. The magnitude of its importance is recognised as McKenzie (1997, p. 25) quotes Dick Wells, Director of the Minerals Council of Australia in 1997, in saying: safety performance is “90% culture and management leadership and 10% technology and mine design”. Such recognition supports the increasing Human Factors research focus currently emerging in HRIs such as mining on an international scale.

Investigations into a number of major industrial disasters, including the Chernobyl disaster in the Ukraine (Sorenson, 2002), the Piper Alpha oil platform explosion in the British North Sea (Stephan, 2001), and the Moura Number 2 mining disaster in Queensland (Hopkins, 1999), and the Clapham Junction rail disaster in London (Clarke, 1998) determined the cause of each of these disasters to be poor safety cultures within the organisation at the time of the disaster. These findings have led researchers to conclude the quality of an organisations’ safety culture to be a major determinant of safety performance (Cox & Flin, 1998; Pidgeon, 1998). Signifying the need for research into improving safety culture in order to increase safety performance and reduce the occurrence of accidents. The continuing debate surrounding the definition of safety and organisational culture and climate must underlie any research and intervention/prevention strategy.

Archetypal research conducted by Zohar (1980) established a distinct separation of organisational climate and safety climate, signifying safety climate as a sub-section of organisational climate. Zohar (1980) was also the first researcher to propose means by which a 'perfect safety' culture may present itself. The researcher considered the active involvement of management in safety management through which management creates a general administrative control climate in which production is to be achieved. This ideal climate would result in increased performance reliability of workers, good 'house keeping', and high design and maintenance standards for the work environment. Well-developed personnel-selection training and development programs of which safe conduct is an integral part have been developed and are currently operational on an international scale. Such programs emphasise the importance of open communication links between the workforce and management (and also between management and the workforce), enabling a flow of information regarding production as well as safety matters. A further implication of the research is that management should be trained to develop and promote balanced attitudes in relation to production and people, and guided in supporting these attitudes through revised policies (Zohar, 1980).

Unfortunately, this proposed 'perfect' system of safety culture is more idealistic than realistic as no human is without fault, no industry relying on human operation without error (Reason, 1998). Accidents in the coal mining industry (and other HRIs) will inevitably occur. This inevitability must be incorporated into intervention strategies for improving safety. A more realistic view of the situation has coal mines attempting to deliver a result that reduces the number of accidents to a minimum within the resources available, and to create an 'efficient safety culture'. However as safety culture compared with costs is represented by a cubic curve, meaning that as safety culture arrives near to 100 percent the costs increase dramatically. The asymptote of the curve also means that in order to achieve 100 percent an infinite amount of money would be needed (Stephen, 2001). Such a statement further acknowledges the inevitability of human error in safety systems.

In accordance with the above and combined with the major exporting responsibility and authority of the Australian coal industry, it is vital to establish the contributing factors to accidents and injuries across the national workforce. Furthermore, it is of importance to extend this investigation to incorporate the critical factors of safety culture across a variety of HRIs noting the identified factors, improvement techniques, and industry responses. In addition, the extent to which these factors are also true for the national mining industries and the ability to generalise the responses and techniques across nations and industries to the benefit of the workforce and the industry at large needs to be examined (Flin, Mearns, O'Connor, & Bryden, 2000; Mearns, Flin, Gordon, & Fleming, 2001; Sorensen, 2002; Zohar, 1980). This report serves to investigate contemporary IHF researchers in order to identify the critical factors contributing to organisational and industrial safety culture in the Australian coal mining industry. In addition supplementary variables such as hierarchical issues and human error will be addressed and related to overall safety culture and safety climate. This review paper further serves to distinguish the critical factors of safety culture and climate within the coal mining industry, differentiates the concepts of culture and climate, and discusses their role in organisational outcomes.

3.3 Human Error

Research has revealed organisational safety to be directly related to the level of technological advancement within an organisation (Hine, Lewko, & Blanco, 1999). Technology will continue to be considered a determinant of safety performance in organisations into the future. However, technological advancement and its corresponding increase in safety performance have reached a plateau (Lee, 1998). It was this recognition that lead researchers to conclude human and organisational factors hold an additional influence over safety performance. According to Lee and Harrison (2000) organisational factors and human errors are now generally accepted to be responsible for the majority of industrial accidents.

Human error typically implies some form of unsafe act performed by a system operator, regardless of severity. Errors may be categorised into *active errors* or *latent errors* (Pidgeon, 1991). Active errors are those that have an immediate effect and appear to be spontaneous: these are characteristically issues with the systems operator and occur most frequently in industries such as aviation. In contrast, latent errors are those errors that are not noticed immediately. Latent errors can lie dormant in a system for some time before the effects are realised: they are normally created by those removed from industry such as design and construction staff. Latent errors are fundamentally a 'time bomb' only taking a triggering active error to release the potential error that has accumulated (Sorenson, 2002). This build up of errors over time is usually at odds with the way the organisation's culture develops in terms of safety, and is often termed the 'disaster incubation period' (Pidgeon & O'Leary, 2000).

The majority of large-scale disasters occur as a result of latent errors; a build up of technical problems and human errors create a dormant problem, which is contrary to the organisation's safety beliefs and climate. It only needs a critical error (trigger event) for the latent error to erupt and the 'disaster' to occur (Pidgeon, 1991). It can therefore be speculated from consistent reports across a variety of HRIs that safety concerns are rarely a result solely of technological failures, rather they are most likely attributed to human failures which may not be immediately apparent but may manifest themselves in the from of 'latent' errors. Further indicating any investigation into organisational safety needs to commence with a behavioural analysis of the workers, such as a study into safety culture and safety climate, assessing safety attitudes, safety perceptions, and safety behaviours.

3.4 Safety Culture: Definitions and Characteristics

Safety Culture is perceived as an enduring concept, operating independently of those currently employed within an organisation and continuing to exist beyond their period of employment. It is thought to be a modelled concept, through which new employees learn the values and behaviours of the organisation's culture through observation, feed back, and trial and error systems (Fleming, 2003). The concept of safety culture was introduced when researchers postulated that if all technical aspects of an industry were made to be perfect and faultless (if this is indeed possible), why then did accident rates remain so high. Research has demonstrated the need to look at the accidents in a broader social context (Donald, 1993, 1999 as cited in Hine et al., 1999). The concept of safety culture has allowed us to view accidents not in narrow technical terms but in broader socio-technical terms, where problems are more likely to be socially based or a combination of social and technical factors: which implies accidents occur as a result of human error (Pidgeon, 1991).

The link between accident frequency and severity and safety culture has been evident for some time, research illustrating that an increasing frequency/ severity of accidents is often caused by a poor safety culture (Arboleda, Morrow, Crum, & Shelley, 2003; Gillen, Baltz, Gassel, Kirsch, & Vaccaro, 2002; Zohar, 1980). This was earlier indicated by Zohar's (1980) ground breaking research into climate, which outlined those organisations with a weak safety climate, had a high frequency of accidents and injuries, while the opposite was true for those with a relatively strong safety climate (Zohar, 1980).

The International Nuclear Safety Advisory Group (INSAG, 1991) first devised the term *safety culture* in the aftermath of the Chernobyl accident in the United States of the Soviet Republic (USSR), as a subdivision contributing to organisational culture (Cox & Flin, 1998; Sorenson, 2002). INSAG-4 (Version 4; 1991) defines safety culture as "…that assembly of characteristics and attitudes in organisations and individuals that establishes, as an overriding priority… safety issues receive the attention warranted by their significance" (p. 190). It is a structural and attitudinal concept (involving both individuals and the organisation), which is a result of the shared attitudes, beliefs, and values of the workforce regarding safety (Arboleda et al., 2003; Cooper, 2000; Cox & Cox, 1991; O'Toole, 2002; Pidgeon, 1991; Weigmann, Zhang, von Thaden, Sharma, & Mitchell, 2002; Williamson, Feyer, Cairns, & Biancotti, 1997). An essential component of safety culture is worker behaviours and, across all levels, the availability of knowledge together with a sense of accountability, for both individuals and the organisation (Sorenson, 2002). Safety culture is perceived as a subset of organisational culture, where the individuals' beliefs and values relate exclusively to health and safety (Clarke, 1999 as cited in O'Toole, 2002; SAFEmap, 1999; Weigmann et al., 2002).

There are numerous definitions of safety culture. The most popular working definition according to Cheyne, Cox, Oliver, and Tomas (1998) is that given by the Advisory Committee on the Safety of Nuclear Installations (ACSNI, 1993). The ACSNI definition states "safety culture is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determines the commitment to, and the style and proficiency of, an organisation's health and safety management". Most definitions incorporate some if not all components of the ACSNI definition.

Table 3.1 provides an overview of the definitions of safety culture: examination of which provides a clearer interpretation of the overall consensus on safety culture. Essentially, safety culture is the product of the attitudes, beliefs, and values shared across the workforce in relation to health and safety. This concept appears to be both structural and attitudinal, therefore involving both the individual and the organisation (Sorenson, 2002).

Safety culture has been studied since the 1980's yet many researchers disagree on what is meant by the term 'safety culture' (Fleming, 2003) as indicated in Table 3.1 following. In the review presented by Guldenmund (2000), 18 different safety culture definitions are outlined. However, support is growing for the comprehensive definition devised by ACSNI as stated above (Cheyne et al., 1998; Cox & Flin, 1998; Fleming, 2003; Lee, 1998). Cooper (2000) presents an adapted version of Bandura's (1977, 1986 as cited in Cooper, 2000) model of reciprocal determinism in a model of safety culture, which incorporates the three components

Table 3.1

Definitions of Safety Culture from Review of Literature

Definitions of Safety Culture	
Author	**Definition**
Cox & Cox (1991)	Attitudes, perceptions, beliefs, and values that employees share in relation to safety.
Pidgeon (1991) O'Toole (2002)	Safety Culture is perceived as a subset of organisational culture, where the individuals' beliefs and values relate exclusively to health and safety.
Williamson et al. (1997) Cooper (2000)	Safety culture involves the shared beliefs, behaviours, attitudes and values, which are instilled by the organisation.
Hine et al. (1999)	Shared attitudes, beliefs, intentions, norms, and practices related to the minimisation and/or control of hazards within an industry or organisation.
Sorenson (2002)	Safety culture is that assembly of characteristics and attitudes in organisations and individuals that establishes that, as an overriding priority…. safety issues receive the attention warranted by their significance. Furthermore, the concept is both structural and attitudinal, concerning the roles of both individuals and the organisation, and monitors behaviours as well as actions. Together with this is a need for all levels to have all the available knowledge and a sense of accountability, for both individuals and organisation.
Weigmann et al. (2002)	1. Safety culture is a concept defined at the group level or higher, which refers to the shared values among all the group or organisation members. 2. Safety culture is concerned with formal safety issues in an organisation, and closely related to, but not restricted to, the management and supervisory systems. 3. Safety culture recognises the contribution from everyone at every level of an organisation. 4. The safety culture of an organisation has an impact on its members' behaviour at work. 5. Safety culture is usually reflected in the contingency between reward systems and safety performance. 6. Safety culture is reflected in an organisation's willingness to develop and learn from errors, incidents, and accidents. 7. Safety culture is relatively enduring, stable, and resistant to change.
Arboleda et al. (2003)	Beliefs and values that stress the importance of health and safety.
Fleming (2003)	The product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine commitment to, and the style and proficiency of, an organisation's health and safety management.

of safety culture implicated in the ACSNI definition: personal, behavioural, and situational components. The personal component refers to psychological factors of the workforce, the behavioural component refers to the work behaviour of employees, and the situational component refers to the safety management system, rules and procedures of the organisation.

The personal component of safety culture is considered by many researchers to be the primary component of safety culture (Cheyne, Oliver, Tomas, & Cox, 2002; Cox & Cox, 1991: Lee & Harrison, 2000; Pidgeon, 1998). Some researchers actually refer to the personal component as the only component of safety culture (Arboleda et al., 2003; Cox & Cox, 1991), which is often termed *safety climate* (Brown & Holmes, 1986; Coyle, Sleeman, & Adams, 1995; Zohar, 1980). Since the personal component is considered to be the most important component of safety culture, and questionnaires are considered to reliably assess attitudes and perceptions, most researchers support the measurement of safety culture by questionnaire. Others argue that multiple methods should be used to measure the components of safety culture independently (Cooper, 2000; Cox & Cheyne, 2000). However, behavioural and situational components in addition to the personal component can be incorporated into a questionnaire, enabling all three components to be measured in a single tool (Hale, 2000). Lee and Harrison (2000) suggest that the elements interact so closely it is a difficult task to separate them. A single questionnaire measure is advantageous for organisations as safety culture can be measured internally, without the assistance and therefore cost of external consultants (Fleming, 2003).

Often because of the nature of culture, the ‘deeper structure’ is not immediately available to those involved in its study. What is required are ethnographic approaches, which encompasses intensive observations and worker interviews (Weigmann et al., 2002). This approach enables the determination of beliefs and culture within the organisation, if surveys were solely used it would be a measure of climate, as indicated in section 3.5 following. The empirical exploration of safety culture since the 1980s, has not yet produced a unanimous decision on its definition, its distinction from safety climate, nor its measurement techniques. These issues continue to be debated in a scientific forum.

Safety culture according to Williamson et al. (1997) and Cooper (2000) involves the shared beliefs, behaviours, attitudes, and values, which are instilled by the organisation. Conversely McDonald, Corrigan, Daly, and Cromie (2000) indicated that different organisations could have shared safety cultures, implying safety culture can extend beyond the single organisation, for example differing airline companies may have similar cultural beliefs. The disparity usually occurs between the levels of the organisation where ‘professional sub-cultures’ are formed, which differentiate between different hierarchical levels of employees (McDonald et al., 2000). However, this can differ between levels of the organisation, and in turn create sub-cultures, which may not be aligned with the ‘primary’ culture of the organisation, so that, for example, deputies working for different companies have a similar safety culture.

One of the critical factors, which contribute to an organisations safety culture, is the level of risk(s) employees believe to be acceptable. Pidgeon (1991) defines safety culture in terms of risk and danger: “Safety culture [refers to] constructed systems of meanings through which a given group or people understand the hazards of the world. …[It is] created and recreated as members behave in ways that seem to them to be natural, obvious, and unquestionable ways of acting, and as such will serve to construct a particular version of risk, danger, and safety” (p. 135). In this way Pidgeon (1991) defines safety culture as an indicator of which levels of risk are acceptable in the operations of the organisation, through which employees contemplate, in principle, whether a hazardous action is appropriate.

If a poor safety culture is indicative of a poor organisational safety performance, logic suggests a good safety culture would be indicative of good organisational safety performance. It is this suggestion that has lead researchers to define and operationalise the concept of safety culture and to determine the characteristics of a 'good' or 'poor' safety culture (Pidgeon, 1998). This concept will be further explored throughout this report.

A fundamental assumption of safety culture research is that the concept can be described by a limited number of dimensions or critical factors. As such researchers are currently attempting to identify the critical factors of specific organisations or industries in order to target areas for safety improvements. It seems clear within the scope of a definition of safety culture that there is little room for the idea of human error. If it was possible to change the actual safety climate and the values and beliefs of an individual then there would be no reason for human error as all possible safety issues a person has would be dealt with i.e., training, appropriate working hours and so forth. The following section presents the defining characteristics of safety climate as distinct from safety culture.

3.5 Safety Climate: Definitions and Characteristics

In past research, the terms safety culture and safety climate have been often been used interchangeably, mistakenly. Safety climate has been defined as a ‘snap shot’ of a workforce’s attitudes and perceptions at a given time, providing an indication of the underlying safety culture present in the organisation (Mearns, Flin, Fleming, & Gordon, 1997 as cited in Fleming, 2003). This is a summary concept describing the safety ethics in a workplace, which indicates beliefs about safety through which employee's safety behaviour can be predicted (Williamson et al., 1997). Climate is the overt and temporal manifestation of culture (Guldenmund, 2000), it is 'culture in the making' (Guldenmund, 2000). Therefore it is actually the employee's climate perceptions that are being measured with any safety questionnaire distributed, which can give an indication of the underlying safety culture present in the Australian coal mining industry.

Safety climate is described as being restricted either in the time scale, the depth, the breadth, and/or the context of safety culture that it encompasses and each of these distinctions will be highlighted throughout this critical review. In regard to context, it is generally acknowledged by the majority of researchers that safety climate relates to the psychological aspects of safety culture (Brown & Holme, 1986; Cox & Flin, 1998; Coyle et al., 1995; Zohar, 1980). However there is disagreement as to which psychological aspects of safety culture that safety climate refers to: attitudes, perceptions, or both (Williamson et al., 1997). Zohar (1980) and Brown and Holmes (1986) considered safety climate to be based on employee perceptions of safety in the workplace. In contrast, Cox and Cox (1991), Cox and Flin (1998), and Williamson et al. (1997) consider safety climate to be composed of both attitudes and perceptions. In a review by Guldenmund (2000) perceptions were found to be more closely associated with climate studies while attitudes were more closely associated with culture studies.

Zohar (1980) conducted one of the major studies into safety climate in 20 Israeli industrial organisations. Climate is consequently defined as the molar perceptions individuals share about their working environment. Based on environmental cues, the workers form expectations of behaviour contingencies and behave accordingly. The implication of this is that workers may not behave according to the guidelines and procedures put into place by management systems, but rather role model inappropriate behaviours from senior workers or even management, who in some cases expect workers to adopt a 'do as I say, not as I do' mentality. Furthermore it is seen that management systems are a major critical factor for safety culture and climate; a factor needing to be addressed in the formation of a positive safety culture.

Table 3.2 provides an encompassing view of safety climate. Safety climate is the objective measure of attitudes and perceptions of employees regarding safety at one specific point in time (Glendon & Stanton, 2000). This 'snapshot' of workers attitudes can be regarded as the underlying structure of safety culture within that organisation. Furthermore climate is thought to be predictive of workers actual behaviour.

Through review of current literature, there is an apparent trend to move away from retrospective measures, such as for accidents, lost-time injuries, and safety performance, towards a measure of safety climate. This enables the researcher to identify areas of weaknesses prior to the commencement of consequential serious safety concerns. Flin et al. (2000) describes this as a switch from 'feedback' to 'feed forward' information, in an attempt to pre-empt any accident. The current research extends a methodology previously used and validated by the Flin et al. (2000) study into safety climate. Firstly sets of themes (critical factors) are derived from a thorough literature review. These factors are then customised to the particular industrial setting by the use of interviews and focus groups; an essential element in this field of research given the empirically

Table 3.2

Definitions of Safety Climate from Review of Literature

Definitions of Safety Climate	
Author	**Definition**
Zohar (1980)	Climate is defined as the molar perceptions that individuals share about their working environment. Based on environmental cues, the workers form expectations of behaviour contingencies and behave according to these.
Coyle et al. (1995)	The objective measure of attitudes and perceptions towards Occupational Health and Safety issues.
Williamson et al. (1997)	Summary concept describing the safety ethic in an organisation or workplace which is reflected in employee's beliefs about safety and is thought to predict the way employees behave with respect to safety in the workplace.
Flin et al. (2000)	Safety climate can be regarded as the surface features of the safety culture discerned from the workforce's attitudes and perceptions at a given point in time. It provides an indicator of the underlying safety culture of a work group, plant or organisation.
Griffin & Neal (2000)	All types of climate are based on individuals' perceptions of the practices, procedures and rewards in the organisation.
Neal, Griffin, & Hart (2000)	Describes individuals' perceptions of the value of safety within the working environment.
Fleming (2003)	The workforce's attitudes and perceptions at a given place and time. It is a snapshot of the state of safety providing an indicator of the underlying safety culture of an organisation.

derived knowledge that critical factors significantly vary across different organisations (Flin et al., 2000).However, critical factors identified in other industries and countries may be used as a guide to determine those that are relevant to the Australian coal mining industry.

3.6 Distinction of Safety Culture from Safety Climate

The very existence of safety climate and its relationship to safety culture is the cause of the conceptual confusion surrounding safety culture (Guldenmund, 2000). Safety culture and safety climate are highly related concepts, contributing to their interchangeable use in past research (Cox & Flin, 1998; Glendon & Stanton, 2000). More recently however, researchers suggest that the two concepts are distinctly different (Mearns et al., 1998; Mearns & Flin, 1999). Mearns and Flin (1999) suggest that treating them as such increases there scientific utility. Safety culture is broadly considered to be a concept that encompasses the more specific concept of safety climate (Cooper, 2000; Cox & Cheyne, 2000; Glendon & Stanton, 2000; Guldenmund, 2000). Safety climate is therefore a component of safety culture, making the past confusion explicable.

It becomes increasingly clear, from the definitions and characteristics of safety culture and safety climate as independent concepts, that climate is the overt and temporal manifestation of culture. Where climate is a measure of the behaviours, attitudes, and indicators of safety at one point in time that is influenced by the beliefs and values (culture) employees share within an organisation (Guldenmund, 2000). There is a separation here of the affective (culture) and evaluative (climate) nature of safety attitudes. Mearns et al. (1998) have also indicated that culture and climate differ in the direction the act on the workforce. Climate acts on how the individual actually feels about the safety of the organisation, while culture involves the beliefs that the individual has regarding safety.

The way in which each of the entities is measured is also found to be significantly different where climate is typically measured quantitatively with surveys; culture is measured qualitatively with such methods as focus groups. Furthermore, through these measurement differences climate can be seen as a state-like concept unchanging in its composition (Cheyne et al., 1998). In contrast, culture is constantly changing and is influenced by the characteristics of the organisation (Guldenmund, 2000). These differences have, however, indicate that culture and climate are not isolated concepts, that climate is in fact ‘culture in the making’ (Guldenmund, 2000; Schein, 1992 as cited in Clarke, 1999). Further, the development of both culture and climate occurs in succession rather than in parallel (Guldenmund, 2000). The theoretical backgrounds encompassing these two terms are also extremely different: climate evolved from social psychology: the study of attitudes; where as culture evolved from anthropology (Lee, 1998): the study of human nature, including beliefs and values (Glick, 1985 as cited in Guldenmund, 2000; Pidgeon, 1998). The distinction between the two concepts is further outlined in section 3.7 below.

3.7 Models of Safety Culture and Safety Climate

Guldenmund (2000) proposes climate is composed not only of the psychological aspects of safety culture (attitudes/perceptions), but also safety behaviours. Guldenmund (2000) presents a version of Schein’s (1992 as cited in Clarke, 1999) model of organisational culture, adapted for safety culture, refer to Figure 3.1 following. The model illustrates the proposed relationship between safety culture and safety climate. Safety culture refers to the core layer, termed basic assumptions, and safety climate refers to the two outer layers, termed espoused values and artefacts respectively.

Guldenmund (2000) explains that the basic assumptions are general unconscious organisational assumptions, not specifically related to safety. Fleming (2003) suggests that organisational and national cultures influence these basic assumptions. Espoused values are operationalised as attitudes to hardware (e.g., mine design), software (e.g., safety systems), people (e.g., management), and behaviour (e.g., risk-taking). Artefacts are considered manifestations of the basic assumptions and espoused values; artefacts include behaviours (the wearing of protective clothing and inspections), safety performance (accidents and incidents), and physical signs such as posters. Guldenmund (2000, p. 251) further redefines safety culture from this model to be “the aspects of organisational culture which will impact on attitudes and behaviour (climate) related to increasing or decreasing risk”.

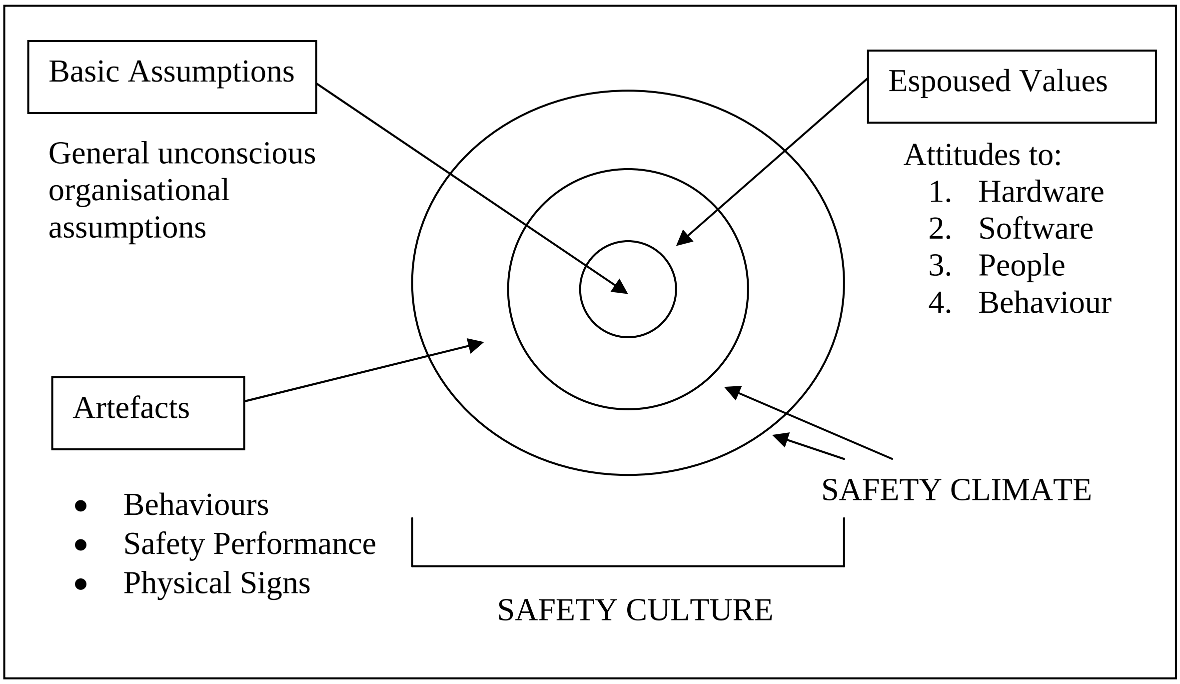

Figure 3.1. Safety culture model (adapted from Guldenmund, 2000).

In Guldenmund's (2000) model, it is proposed that safety culture manifests itself in safety climate. A fitting analogy given by Cox and Cox (1991) in relation to organisational culture and climate, explains culture as the organisation's personality, while climate is a transient mood state. Consistent with this view, culture is thought to be an enduring aspect of the organisation and climate is an indication of the underlying culture at a particular point in time (Cheyne et al., 1998; Cheyne et al., 2002). Hence, one recurrent view of researchers is that safety climate is a temporal indicator of an organisation's safety culture.

In Guldenmund's (2000) model culture presents itself in attitudes, which are manifested into behaviours. According to Weiten (1995) it is widely accepted that attitudes predispose individuals to certain behaviours. However the relationship between attitudes and behaviours is complicated, as Ajzen (1985, 1991, as cited in Weiten, 1995) explains, situational norms interact with attitudes to shape peoples intentions, which then determine their behaviour. Illustrating this point, discrepancies between management ideals and management behaviours have been found within the mining industry (Hine et al., 1999). However, regardless of these suggestions, attitudes are still considered reliable predictors of behaviour. Lee and Harrison (2000) suggest accidents can also shape attitudes: there is a 'feedback loop' from behaviours to attitudes. However, Lee and Harrsion (2000) expected to find an increase in perceived risk following an adverse event, however this was not supported. The possible effect of behaviours on attitudes is not taken into account in Guldenmund's (2000) model.

A typical model – as understood from a review of the literature – would involve initially determining the organisational characteristics (Guldenmund, 2000), which comprises such factors as safety systems, the workforce, and the risks associated with the organisation. These characteristics are consequently broken down into individual critical factors and perceptions, which represent the actual climate of the organisation as seen from the individual worker perspective. The organisational climate is further translated in terms of safety; safety climate is manifested at this stage. Safety behaviour is determined from the aforementioned, which then links back, and impacts on, the organisational characteristics (Guldenmund, 2000).

Glendon and Stanton (2000) propose that climate, as a measure of culture, is not only limited in its time frame, as suggested by Cox and Cox (1991), but in the depth and breadth of the culture it examines, refer to Figure 3.2. The depth aspect has been highlighted by the Guldenmund (2000) model of safety culture, based on Shein's (1992 as cited in Clarke, 1999) model of organisational culture. The breadth aspect however, is a dimension not incorporated into other safety culture models. This dimension relates to the extent to which cultural elements are

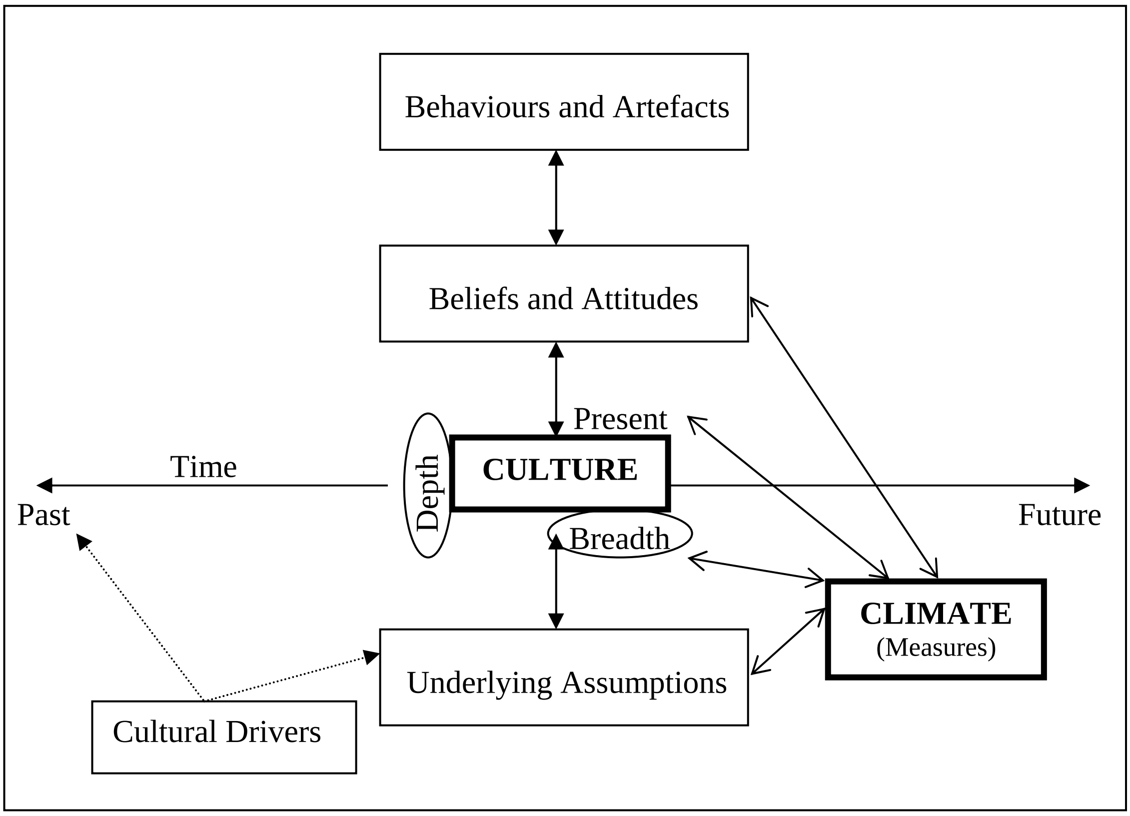

Figure 3.2. Organisational culture and climate (adapted from Glendon & Stanton, 2000).

shared across the workforce. Although the breadth dimension has not been incorporated into subsequent models of safety culture, several researchers have found safety sub-cultures within organisations. These sub-cultures have found to be based on hierarchy (Arboleda et al., 2003; Coyle et al., 1995; Harvey et al., 2002) and occupational groups (Cox & Cheyne, 2000).

One of the necessary features of any model of safety culture or climate is the cyclic nature of the industrial safety process. Whatever outcomes are reached as prescribed by the model, these will ultimately have an impact on the organisational characteristics, which are the starting point of any model. In this way it can be seen that safety culture is an ever-changing paradigm within an organisation, while climate changes with time between measurements as a result of the changing culture. Cooper's (2000) Reciprocal Model of Safety Culture (refer to Figure 3.3 below) exemplifies this idea by creating an interacting relationship between 'safety situation' (management system), 'person' (safety climate), and

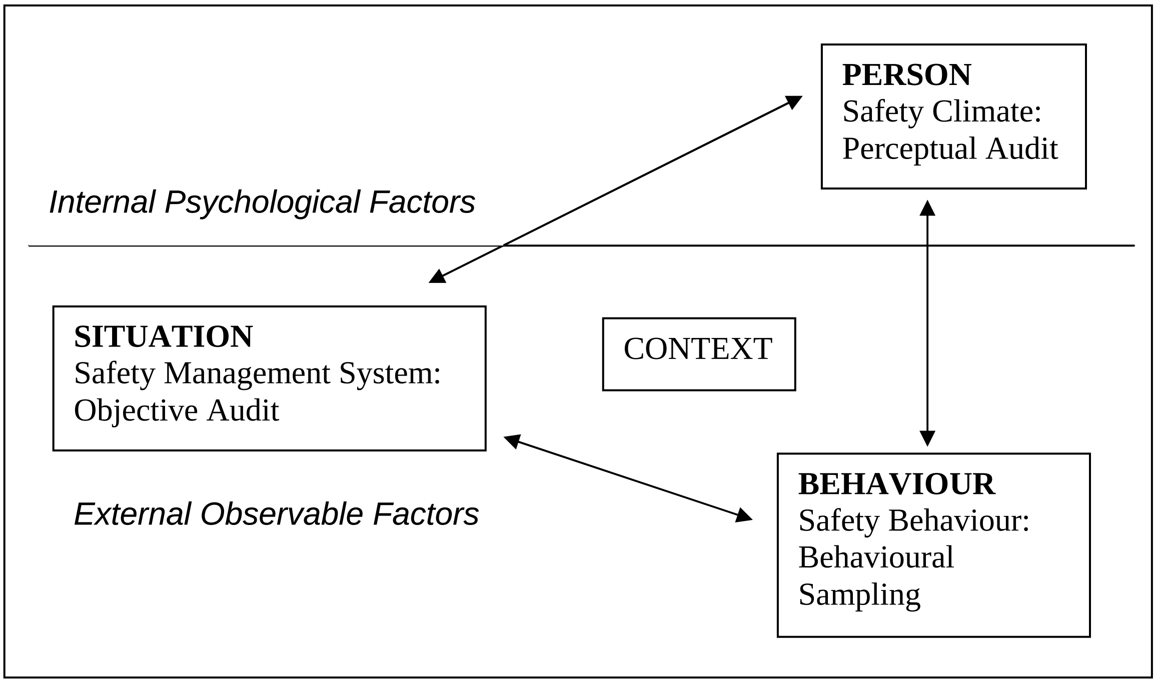

Figure 3.3. Reciprocal safety culture model (adapted from Cooper, 2000).

‘behaviour’ (safety behaviour). Cooper (2000) illustrates these factors have causal interactions which result in dynamic changes between each as well as responses to changes in the other.

The safety culture model presented by Cooper (2000) is essentially an adapted version of Bandura's (1977, 1986 as cited in Cooper, 2000) model of reciprocal determinism presenting the two-way interaction between attitude (person component) and behaviour together with an additional third variable, situation. The behavioural component refers to work related behaviour, the situational component relates to safety systems employed by management, and the personal component relates to psychological factors. The behavioural and situational components are external and thus observable, while the personal component is internal and hence not directly observable.

A common element to the Guldenmund (2000) and Cooper (2000) models is that they both incorporate behavioural, situational, and personal variables into safety culture. According to Cooper (2000) the incorporation of these three variables is the common link between existing safety culture models. Cooper (2000) further suggests the majority of safety culture models can be reinterpreted through these three factors. As such they should be used as a comparative model, enabling a meta-analysis of safety culture. To date this has not yet been achieved.

In Cooper’s (2000) reciprocal model of safety culture, each component is not of equal strength. Cheyne et al. (2002), Cox and Cox (1991), Lee and Harrison (2000), and Pidgeon (1998) among others argue attitudes to be the most important aspect of culture. The literature reveals no difference of this opinion. Those whom additionally believe that safety climate incorporates attitudes as well as perception consider safety climate to be the most important predictor of the effectiveness of a safety culture.

Hale (2000) suggests management factors (the situational component of Cooper [2000] reciprocal safety culture model) can be separated into structural and cultural components. Hale (2000) further suggests the structural components, such as rules and regulations should be measured by audit and the cultural components, such as management commitment, should be measured by questionnaire. Further, factors able to be studied objectively, such as safety systems, should be studied objectively for increased reliability. It is necessary to measure both the structural and cultural components of management systems, to ensure the management systems are not only put in place, rather actually working. Thus incorporating top-down and bottom-up perspectives to safety inspections, respectively (Lee & Harrison, 2000).

Models of safety culture/climate, as outlined above, often disregard the actual behaviour shown by the employees, they are limited to concern with the antecedents of the behaviour. However, since the behaviour has an impact on the ever-changing culture of the organisation, a comprehensive model should indicate some of the outcomes of the cues and what effects are created. Neal et al. (2000) indicate that in terms of safety performance there are two prevailing factors: ‘safety compliance’ and ‘safety participation’. Safety compliance is the active adherence to safety procedures while also operating in a safe manner, while safety participation is the active promotion of the safety program within the work place, showing safety initiative and helping to improve safety within the work place (Neal et al., 2000). It is this breakdown of safety behaviour which allows the measurement and analysis of safety initiatives within an organisation, and for the cyclic nature of culture to be understood.

Cox and Cheyne (2000) support the use of multiple methods in the assessment of safety culture, see Figure 3.4 below. However, Cox and Cheyne (2000) suggest interviews are additionally necessary in safety culture assessment,

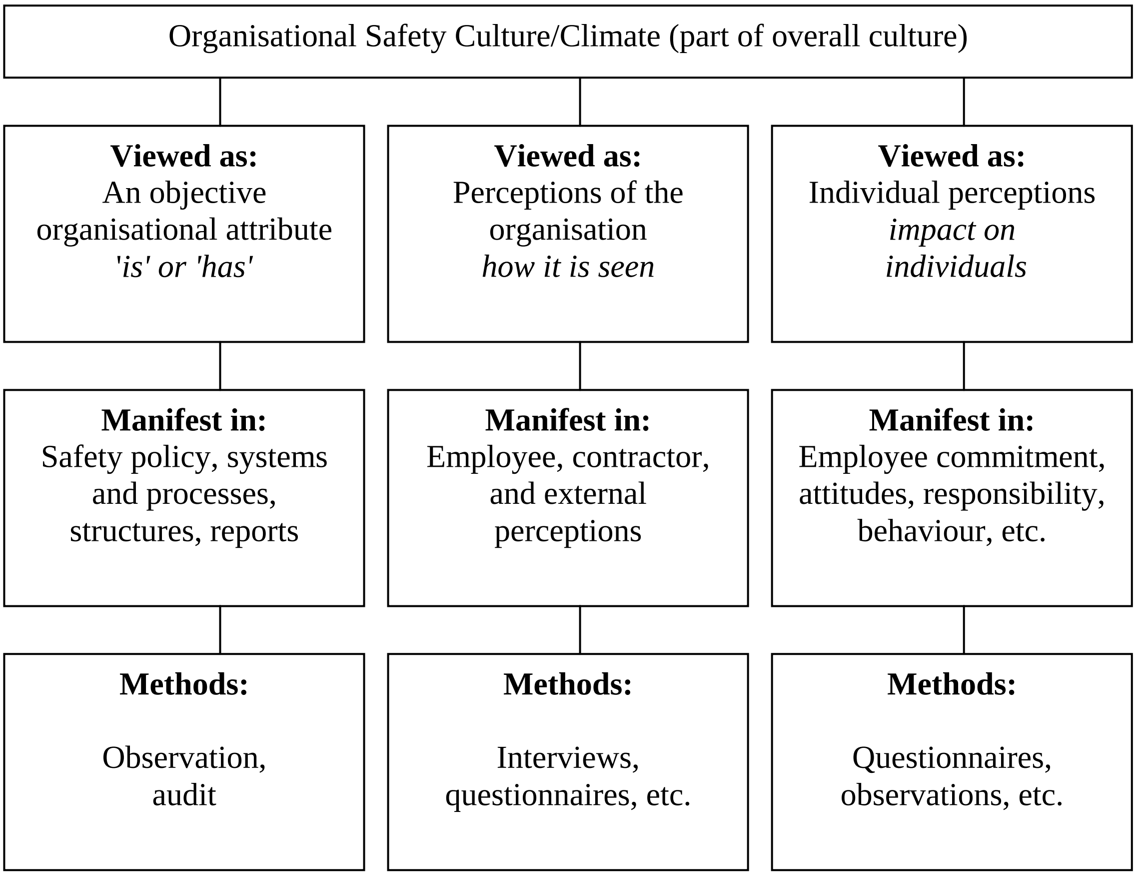

Figure 3.4. Multiple perspective model of safety culture (adapted from Cox & Cheyne, 2000).

in order to measure the perceptions of employees as distinct from their attitudes. Williamson et al. (1997) suggests attitudes reflect more general beliefs while perceptions reflect more specific workplace beliefs. Focus groups are a form of group interview process that are being utilised by a number of researchers working in the safety culture field including Cox and Cheyne (2000), Lee (1998), Lee and Harrison (2000), and Mearns et al, (2001). The use of focus groups in the creation of a safety culture/climate questionnaire ensures both specific workplace perceptions and general attitudes can be identified and incorporated into the questionnaire design.

Coyle et al. (1995) suggest that researcher's preconceptions of what questions are important in the design of a safety culture/climate questionnaire can bias questionnaire results. The underlying purpose of the focus group is to gain reliable information about the shared views of the workforce (Gibbs, 1997). Focus groups provide an accurate indication of specific workforce perceptions rather than relying on the subjective views of researchers concerning what is important for the inclusion of survey questions. However, researcher's views are generally supported by research in the area and hence are fairly reasonable indicator of the general critical factors of safety culture.

3.8 Measurement of Safety Culture and Safety Climate

Measurement is generally dependent upon a concepts definition. In accordance with the numerous definitions of safety culture and safety climate, various measurement techniques are recommended by researchers in the field including: questionnaires, observations, behavioural sampling, audits, inspections, and interviews/focus groups.

Those who considerer safety climate a temporal indicator of the underlying safety culture believe questionnaires assessing safety climate also assess the underlying safety culture at that specific point in time. As such questionnaires are a sufficient measurement device for safety culture (Cheyne et al., 1998). However, certain safety climate questionnaires assess perceptions only while attitudes are considered to be the central component of safety culture. Safety climate questionnaires that measure attitudes, however, are considered to provide a substantial indication of safety culture (Cox & Cox, 1991; Lee & Harrison, 2000). If safety climate is a subset of safety culture, then safety culture measures must incorporate safety climate measures. Therefore, to more accurately measure culture, perception questions as well as attitude questions should be incorporated into any safety culture measurement design.

Safety climate is generally measured by questionnaires. Safety climate is broadly recognised as relating to current safety attitudes and/or perceptions of the workforce and questionnaires are considered reliable measures of attitudes and perceptions (Fleming, 2003; Flin et al., 2000; Griffin & Neal, 2000; Zohar, 1980). Questionnaires are beneficial as they are anonymous and can be quantitatively analysed.

Alternately, researchers whom give climate a context distinction within the definition of safety culture, suggest safety climate questionnaires are not sufficient in the measurement of safety culture. Further suggesting additional measurements are required. Cooper (2000) makes a context distinction of safety climate rather than a time sampling distinction and suggests a triad of measurement devices are preferred for the measurement of safety culture. He proposes safety climate questionnaires are used for the personal component of safety culture, safety management audits/inspections for the situational component of safety culture, and observations/behavioural checklists for the behavioural component of safety culture.

Clearly a triangular approach would increase reliability, yet it is costly and time-consuming. Alternately, a safety culture questionnaire could be developed that incorporates not only psychological, but behavioural and situational factors of safety culture as well, to give a more comprehensive measure of safety culture. Lee and Harrison (2000) suggest that the elements interact so closely that it is difficult to separate them. Behavioural factors can be added to a safety culture questionnaire however, self presentation bias is associated with self-reported behaviours. Yet if one considers behaviours to be directly related to attitudes, then attitude measurements should accurately assess behaviour. However, as previously noted, attitudes do not always determine behaviour.

Arising from accidents such as Chernobyl (Sorenson, 2002), a number of safety culture questionnaires have been created in various industries to proactively measure organisational safety levels (Lee, 1998). The Australian coal mining industry have recognised that their "traditional safety measure, Lost-Time Injury Frequency Rate (LTIFR) has a number of deficiencies" (Farrar, 2000, p. 5) and aims to create a safety culture questionnaire to more accurately assess the level of safety in the industry and to target areas for safety improvements.

3.9 Critical Factors of Safety Culture and Safety Climate

Safety culture is considered to be a multi-dimensional concept; determined by a small number of critical factors (Guldenmund, 2000). Many recent studies are attempting to identify these critical factors (Arboleda et al., 2003; Brown & Holmes, 1986; Coyle et al., 1995; Cox & Cheyne, 2000; Cox & Cox, 1991; Glendon & Litherland, 2001; Harvey et al., 2002; Lee, 1998; Lee & Harrison, 2000; Williamson et al., 1997; Zohar, 1980) as they will inform management and training officers of the target areas for safety improvement (Mearns, Whitaker, & Flin, 2003). The question is whether the critical factors of safety culture are consistent across organisations within a national industry and across international industries.

Guldenmund (2000) explains different organisations have different objects for worker attitudes, hence one would expect to find different critical factors across organisations, regardless of industry. Cheyne et al. (2002) term this proposal, the context-dependency of safety culture. Rather, Cox and Flin (1998), suggest critical factors may be specific to the industry of the organisation e.g., nuclear, manufacturing, mining, and so forth. Alternately, Flin et al. (2000) conducted a literature review which identified management/supervision, safety systems, risk, work pressure, and competence as the five fundamental factors common to many organisations' safety cultures, irrespective of the organisation or industry.

Previous studies, conducted across a variety of industries, have found varying numbers of factors representing safety culture (Arboleda et al., 2003; Brown & Holmes, 1986; Coyle et al., 1995; Cox & Cheyne, 2000; Cox & Cox, 1991; Glendon & Litherland, 2001; Harvey et al., 2002; Lee, 1998; Lee & Harrison, 2000; Williamson et al. 1997; Zohar, 1980), refer to Table 3.3. Some studies reported as low as three factors (Arboleda et al., 2003; Brown & Holmes, 1986) while one study reported up to 19 factors (Lee, 1998). While this implies there may not be a core set of critical factors underlying safety culture, it is important to realise that few studies have utilised similar methodology. Flin et al. (2000) point out that safety culture questionnaires differ in content, style, statistical analysis, sample size, sample composition, and the industry or country of origin.

Few studies have utilised the same measurement devices (e.g., the same questionnaire and since the results of any questionnaire is influenced by the type of questions one asks, different resulting factor structures would be anticipated (Williamson et al., 1997). Therefore, the number of factors found in safety culture surveys may be an artefact of the questionnaire design. However, Zohar (1980) and Brown and Holmes (1986) conducted studies using the same questionnaire and different factor structures were derived (Table 3.3). The different critical factors found in these studies cannot be attributed to questionnaire design, which suggests that critical factors of safety culture may be industry or organisation specific. Each study was conducted in a variety of production companies, in different countries: Israeli and the United States of America (USA) respectively.

The results suggest that national culture may be responsible for the differing factor structures found. However, questions used in these studies were based only on perceptions and did not include questions relating to attitudes. Therefore the questionnaire may not have reliably measured safety culture.

Coyle et al. (1995) also used the same questionnaire in two similar organisations in the same country (both constituents of a single organisation, involved in health care services to the elderly, similar in size, and located in Sydney, Australia, with infrastructure extending beyond that area). This study also found differing factor structures within these organisations, see Table 3.3. Since the organisations studied were from the same industry (health care), this study implies that critical factors of safety culture may be organisation specific rather than industry specific. Again, it is evident factor structures are not due to questionnaire design alone, however three out of the 30 questions were reworded in the different organisations and four questions were added for one organisation. This may suggest that questionnaire results are highly sensitive to questionnaire design. Conversely the study may imply that critical factors of safety culture are organisation specific rather than nation or industry specific. Again the Coyle et al. (1995) questions were based only on perceptions and did not include questions relating to attitudes hence have measured only one component of culture.

The subjective nature of factor analysis also causes variability in the reported factor structures of safety culture. Guldenmund (2000) suggests discrepancies in factors could be accounted for by individual interpretation of which critical factors particular questions are probing. Differences extenuated by language and cultural differences (Cox & Flin, 1998). Glendon and Litherland (2001) note that many critical factor reviews are based only on superficial comparisons, i.e., similarity in the naming of the dimension. Hence, in Table 3.3 the individual questions relating to each factor were examined and renamed where considered appropriate, thus providing a consistent, however subjective comparison across studies. Some studies rather than including the individual items on the questionnaire included a sample of the questions (Cox & Cox, 1991; Lee & Harrison, 2000). In contrast some studies provided descriptions of the critical factors as an indication of what the individual items were probing (Arboelda et al., 2003; Flin et al., 2000; Lee, 1998; Lee & Harrison, 2000), refer to Table 3.3. Where individual questions or descriptions were absent, interpretations were based on the name of the factor (Brown & Holmes, 1986; Zohar, 1980).

Regardless of the discrepancies, in the number and type of factors found in the literature reviewed, there are certain factors that keep reoccurring in safety culture analysis. Of the 12 studies compared in the literature review presented in Table 3.3 several themes emerged in relation to critical factors of safety culture. In descending order of frequency, they are: management commitment, individual responsibility, risk perception, safety systems, training, priority for production or

Table 3.3

The Critical Factors of Safety Culture Identified in Individual Studies

Study	**Industry and Country**	**Critical factors**	**Are specific questions supplied y/n**	**Renaming of factor**
Zohar (1980)	Variety of industries Israel	importance of safety training programs management attitudes to safety effects of safe conduct on promotion level of risk at the workplace effects of required work pace on safety status of safety officer effects of safe conduct on social status status of safety committee	NO	training management commitment management commitment (rewards) perceived risk safety/production status of safety personnel status of safety personnel status of safety personnel
Brown and Holmes (1986)	Manufacturing and produce America	employee perceptions of how concerned-management is with wellbeing employee perception of how active-management is in responding employee physical risk perception	NO	management commitment management commitment risk perception
Cox and Cox (1991)	Production and distribution of gases Europe	personal scepticism individual responsibility safeness of work environment effectiveness for arrangements for safety personal immunity	YES (sample)	individual responsibility and safety/production individual responsibility risk perception Importance individual responsibility
Coyle et al. (1995)	Elderly health care Australia	Organisation 1…. maintenance and management issues company policy accountability training and management issues work environment policy and procedures personal authority Organisation 2…… work environment	YES YES	 management commitment and s.s and environment safety systems and management commitment individual responsibility and training and communication training and management commitment Environment safety systems individual responsibility Environment

		personal authority training and enforcement policy		individual responsibility training and safety systems
Williamson et al. (1997)	Various industries Australia	personal motivation for safety positive safety-practice risk justification optimism fatalism	YES	management commitment and training safety systems and training and safety/production training and safety/production and safety systems importance and risk perception safety/production, individual responsibility and risk taking
Lee (1998)	Nuclear Processing Plant UK	confidence in safety procedures workers cautious about risk perception of risk trust in workforce efficient permit to work (PTW) system workers in favour of PTW system PTW necessary workers interested in their job workers content in their job good working relationship workers receive praise safety rules are understood safety rules are clear training staff selection safety suggestions safety actions taken by management individuals have control over safety good plant design	YES descriptions given	management commitment and safety systems importance and risk taking risk perception individual responsibility safety systems safety systems safety systems job satisfaction job satisfaction Relationships management commitment (rewards) safety systems safety systems Training staff selection management commitment management commitment (rewards) individual responsibility and communication Environment
Cox and Cheyne (2000)	Offshore oil UK	management commitment priority of safety communication safety rules supportive environment involvement personal priorities and need for safety personal appreciation of risk	YES	management commitment safety/production Communication safety systems management Commitment and individual responsibility individual responsibility Importance risk perception

		work environment		Environment
Flin et al. (200)	literature review	management safety systems risk competence work pressure	YES Description	management commitment safety systems risk perception training safety/production
Lee and Harrison (2000)	Nuclear UK	confidence in safety contractors job satisfaction participation risk safety rules stress training/selection	YES descriptions and some questions	n/s (safety systems) n/s ---- job satisfaction individual responsibility and management commitment risk perception and risk taking safety systems management commitment and safety/production Training
Glendon and Litherland (2001)	Road construction Australia	communication and support adequacy of procedures work pressure personal protective equipment relationships safety rules	YES	management commitment and communication management commitment and safety systems safety/production safety systems Relationships safety systems and safety/production
Harvey et al. (2002)	Nuclear UK	management style and communication responsibility and commitment risk taking job satisfaction complacency risk awareness	YES	management commitment and communication individual responsibility and importance importance and risk taking job satisfaction Importance individual responsibility and importance
Arboleda et al (2003)	11 Trucking industries USA	driver fatigue training driver opportunity for safety input management commitment to safety	YES description	Training individual responsibility and communication management commitment

safety, communication, importance of safety, environment, risk-taking, job satisfaction, relationships, staff selection, stability, and status of safety personnel.

Comparison of Australian studies (Coyle et al., 1995, Glendon & Litherland, 2001; Williamson et al., 1997) identified similar critical factors of safety culture to the overall literature review. Management commitment, individual responsibility, safety systems, training, and safety/production were identified in 3 out of 4 studies reviewed, communication was identified in 2 out of 4 studies reviewed, and risk perception, relationships, and environment in 1 out of 4 studies reviewed. The main difference was that risk perception was not a dominant critical factor in the Australian sample.

Alternately, a literature review by Flin et al. (2000) identified management/supervision, safety systems, risk, work pressure, and competence as the five fundamental factors common to many organisations' safety cultures, irrespective of the organisation or industry. Suggesting a core set of critical factors for safety culture. It is possible that discrepancies between organisational factor structures found in the different organisations are due simply to methodological issues rather than context dependency. For example, few safety culture studies have utilised the same questionnaire and since the type of questions one asks influences the results, different resulting factor structures would not be uncommon when studies use different questionnaires (Williamson et al., 1997). In other words, the critical factors found in safety culture surveys may among other things also be an artefact of the questionnaire design.

A further methodological consideration is the subjective nature of factor analysis, which causes variability in reported factor structures of safety culture. Guldenmund (2000) suggests discrepancies in factors could be accounted for by individual interpretation of which critical factors particular questions are probing. Differences, that according to Cox and Flin (1998) are extenuated by language and cultural differences. Glendon and Litherland (2001) note that many critical factor reviews are based only on superficial comparisons i.e., similarity in the naming of the dimension. Therefore individual questions relating to each factor were examined in the reviewed studies in Table 3.3. Factors were renamed where considered appropriate, providing a consistent, however subjective comparison across studies. Some studies rather than including the individual items on the questionnaire included a sample of the questions (Cox & Cox, 1991; Lee & Harrison, 2000). In contrast, some other studies provided descriptions of the critical factors as an indication of what the individual items were probing (Arboleda et al., 2003; Flin et al., 2000; Lee, 1998; Lee & Harrison, 2000). Where individual questions or descriptions were absent, interpretations were based on the name of the factor (Brown & Holmes, 1986; Zohar, 1980).

Regardless of the discrepancies in the number and the type of factors found in the literature reviewed, there were critical factors that emerged in several studies, as presented in Table 3.3. Of the 12 studies reviewed 10 studies identified management commitment as a critical factor of safety culture, 9 studies identified individual responsibility and 9 studies identified risk. Seven studies identified safety systems, 7 studies identified training, 6 studies identified the priority of production or safety, and 6 studies identified communication. Four studies identified risk-taking, 3 studies identified job satisfaction, 2 studies identified relationships, and only 1 study identified staff selection, stability, and status of safety personnel as critical factors of safety culture. Figure 3.5 following illustrates the proposed relationship between the core critical factors of safety culture.

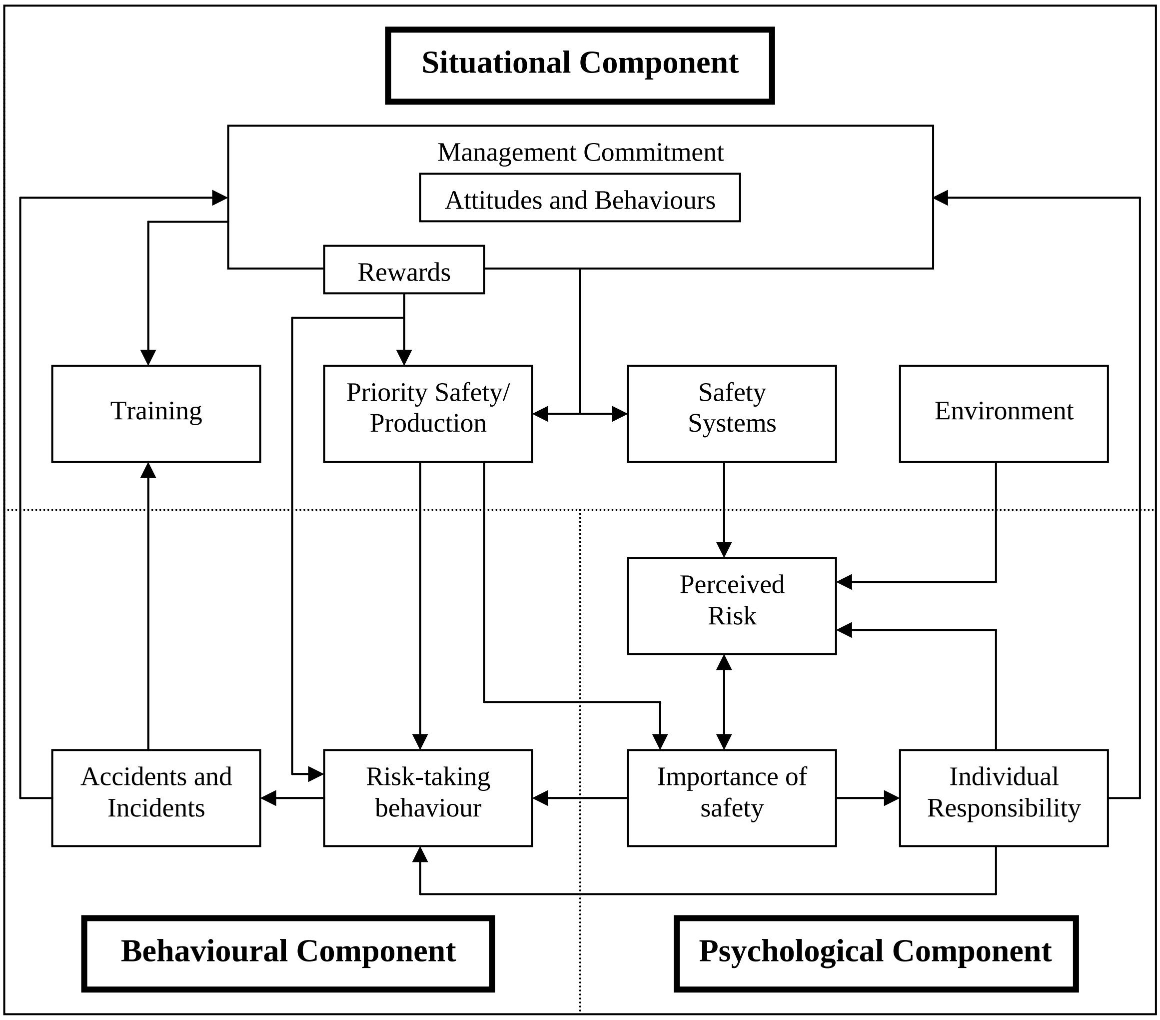

Figure 3.5. Relationship between critical factors of safety culture.

In the following sections, each critical factor is discussed in detail. Each factor is defined followed by an examination of the effect on the other factors.

3.9.1 Management Commitment

Management commitment is a critical factor that has emerged from research into the safety culture of a wide variety of organisations. It is the critical factor that is most consistent across studies, appearing in 10 out of 12 of the reviewed studies (Arboleda et al., 2003; Brown & Holmes, 1986; Coyle et al., 1995; Cox & Cheyne, 2000; Glendon & Litherland, 2001; Harvey et al., 2002; Lee, 1998; Lee & Harrison, 2000; Williamson, 1997; Zohar, 1980) and in a literature review by Flin et al. (2000).

The reoccurrence of management commitment as a critical factor of safety culture is foreseen as Schein (1992, as cited in Clarke, 1999) suggests the way "managers instruct, reward, allocate their attention, and behave under pressure, will be particularly salient in shaping organisational culture" (p. 185). Additionally, many organisational theorists and safety experts suggest management is ultimately responsible for organisational safety (Hine et al., 1999).

Morgan (1996) states that what is critical for a good safety record is the ability of management to demonstrate they care for and value their workforce. Furthermore Jeans (2000) points out that management must lead by example. Correspondingly, the critical factor 'management commitment' relates to employees' perception of management attitudes and behaviours in regard to safety. Each study reviewed which identified management commitment as a factor, incorporated both the attitudes and behaviours of management (Arboleda et al., 2003; Brown & Holmes, 1986; Coyle et al., 1995; Cox & Cheyne, 2000; Flin et al., 2000; Glendon & Litherland, 2001; Harvey et al., 2002; Lee, 1998; Lee & Harrison, 2000; Williamson, 1997; Zohar, 1980).

Due to management issues overriding frequency in similar studies of safety culture, it has been considered an important critical factor. Research has revealed a greater level of management commitment in those companies with a decreased injury frequency, when compared with those of high injury frequency (Shafai-Shafai, 1973 as cited in Cox, & Cox, 1991); this was also the case for those industries with a low accident rate (Zohar, 1980).

Within the rock mining industry, evidence was sourced that management (who develop most organisations' safety procedures) attitudes were more aligned to the organisations safety principles when compared to the safety attitudes of the workforce (Hine et al., 1999). This supports the findings that the higher the rank of the safety officer, the more positive the safety culture (Sorenson, 2002; Zohar, 1980). However there is evidence to suggest that management behaviour does not consistently match these positive safety attitudes (Hine et al., 1999). This appears to be an area of concern, how can the workforce be influenced to behave in a safe manner if the management do not display their own commitment? Past research has highlighted the need for management to show that they put safety before production if the situation is appropriate, in this way providing positive role modelling (Sorenson, 2002). Research conducted by Pitzer (1998) established 80 percent of NSW coal miners stated management 'could not be trusted' and were 'lacking in leadership skills'. Such perceptions indicate deficiencies within management systems such as poor role modelling for safety behaviours for the workforce in the coal mining industry.

An additional element incorporated into the management commitment factor is rewards given by management for safety behaviour (Lee, 1998; Zohar, 1980). Neal et al. (2000) suggest motivation is an important determinant of individual compliance and participation in safety. Rewarding safe behaviour is a motivator for safe behaviour however; it can also have negative effects. Lee and Harrison (2000) note that rewards may lead to stress, the underreporting of incident and accidents, and premature return to work among sick or injured staff. In line with Neal et al. (2000) suggestion, Figure 3.5 illustrates that management creates reward systems that directly affect the risk taking/safety behaviour of the workforce.

The notion that management commitment creates a heightened level of positive attitudes and behaviours towards safety amongst the workforce is supported by several studies (Cox & Cox, 1991; Morgan, 1996; Zohar, 1980). It has been indicated that through studies of two companies, one with high injury frequency and one with low injury frequency, the lower injury company had greater top-level commitment (Shafai-Shafai, 1973 as cited in Cox & Cox, 1991).

Similarly, in a literature review conducted by Zohar (1980), it was found those industries with a low accident rate had a much higher management commitment to safety issues when compared with others with a high accident rate.

The definition of safety climate implies that workers at the ‘coal face’ need to have shared cognitions regarding their organisations safety guidelines. These perceptions and behaviour outcome expectations can direct an individual’s actual work place safety behaviour. However, the major factor in workers perceptions is how organisations management are committed to implementing a safe working environment (Zohar, 1980).

Management commitment is a critical factor that impacts heavily on various other critical factors of safety culture identified for this literature review. Figure 3.5 demonstrates that management commitment impacts on the prioritisation of safety/production, training, and safety systems as these are the responsibility of management. Management commitment also affects individual responsibility via communication channels, which will be discussed in more detail below. Two further areas of management commitment; responsibility in accident prevention, and positive role modelling are outlined in details below.

3.9.1.1 Management Responsibility for Preventing Industrial Accidents

Hine et al. (1999) postulated that because the majority of North American organisations' safety procedures are developed and overseen by management, management would be more aligned with the safety principles of the organisation than the frontline workers. This hypothesis was supported in that the research revealed the workforce to be much less aligned to the safety principles than the senior management. However, the Hine et al. (1999) study further revealed evidence which found manager's behaviour did not always match their indicated attitudes. The extent to which this inconsistency is true for occupational groups not limited to management within the Australian coal mining industry is yet to be comprehensively investigated.

Investigation into the effects of the Chernobyl disaster by Sorenson (2000) showed it was extremely important to have the senior member of the operational staff in control and responsible for safety of the industry. The rank of the safety officer has been found to be a determining factor for a positive safety culture, where those organisations with a high-ranking safety officer had a much more positive safety culture than those that did not (Zohar, 1980).

Since the 1980s when safety culture became a prominent area of development for the Australian coal mining industry, large amounts of resources and funding have been invested in order to improve safety culture. Despite this investment, the number of fatalities during the period has not decreased consistently, there still exists years of many deaths. Figure 3.6 indicates that the number of fatalities has continued to rise and fall over the presented 25-year period; sustained improvement has not occurred.

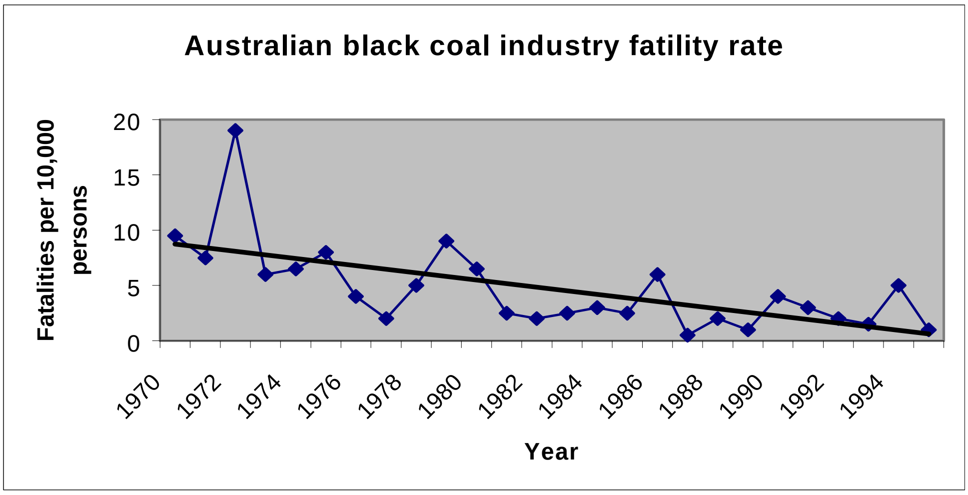

Figure 3.6. Australian coal industry fatality rates (Adapted from Stephan, 2001).

Stephan (2001) indicated the planned use of resources in a step-by-step, year-by-year process aims to improve safety culture gradually. However, it is the unplanned organisational factors mediated by the management that lead to small improvements, which decay quickly over time; steps up are reduced to a static plateau, as shown in Figure 3.7. Such unplanned factors include employee

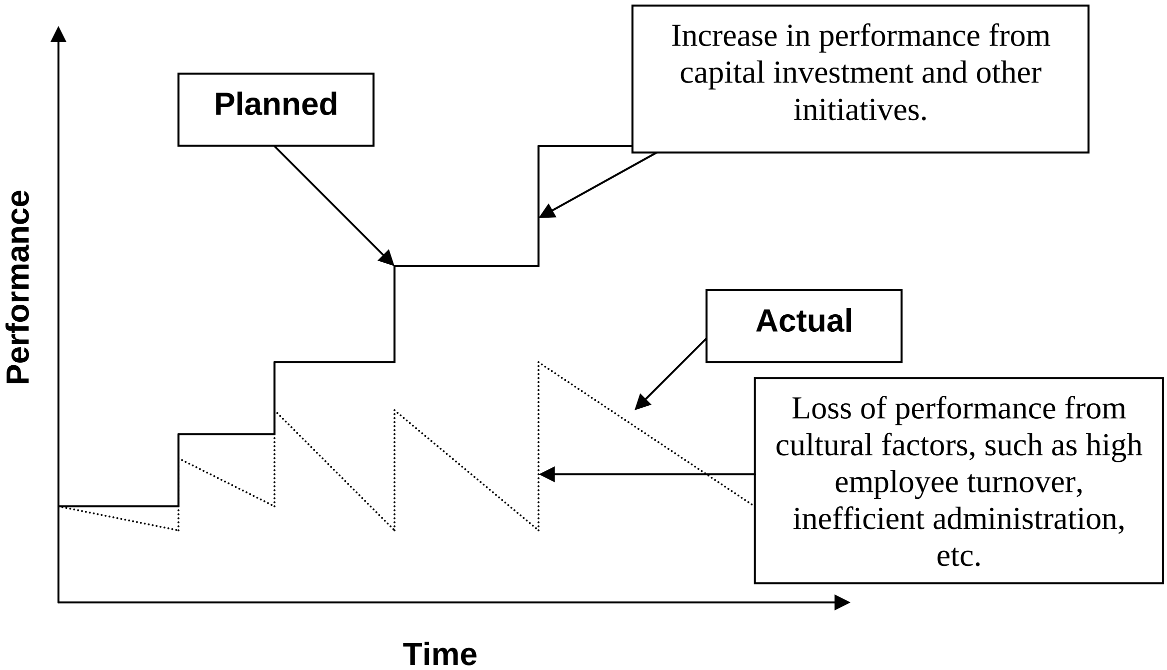

Figure 3.7. The impact of an ineffective management system (adapted from Stephan, 2001).

turnover, competition within the organisation for scarce resources, timing, and incentive issues (Stephan, 2001). This has also been established in the food processing industry (Probst & Brubaker, 2001), where employees with high levels of job insecurity have a significantly decreased level of safety motivation; safety motivation is the ‘drive’ to participate in safety training and adhere to safety procedures.

3.9.1.2 Positive Role Modelling by Management

As previously noted, research conducted by Pitzer (1998) established 80 percent of NSW coal miners stated management ‘could not be trusted’ and were ‘lacking in leadership skills’. Such perceptions indicate deficiencies within management systems such as poor role modelling for safety behaviours for the workforce in the coal mining industry.

Cox and Cox (1991) support the notion that role modelling of safety by management is an important component of a positive safety culture. When working with ‘people’ it was found most programs attempted to define individual employee roles within the organisation and to provide high-level role models who instilled in the employees positive feelings towards safety (Cox & Cox, 1991). Sorenson (2002) notes that management should show they put safety before production in the industry if the situation is appropriate. Thereby illustrating the need for management to demonstrate their personal positive attitudes towards safety. Such facets of management commitment being a critical factor of safety culture are not isolated concepts. The roles and responsibilities of management, while independently important in safety, do not override factors such as individual responsibility in safety critical environments and industrial workplace systems.

3.9.2 Individual Responsibility

The second most cited critical factor emerging from the literature is 'individual responsibility', it was a critical factor identified in 9 out of 12 studies (Arboleda et al., 2003; Coyle et al., 1995; Cox & Cheyne, 2000; Cox & Cox, 1991; Harvey et al., 2002; Lee, 1998; Lee & Harrison, 2000; Williamson et al., 1997). It is important to note two of the three studies that did not include individual responsibility as a factor (Brown & Holmes, 1986; Zohar, 1980) used questionnaires based on perception questions only excluding attitudinal questions. It is possible the inclusion of individual responsibility as a critical factor of safety culture is dependant on the inclusion of attitudinal items in questionnaire design.

Individual responsibility relates to the individuals perception of their role in safety, whether they think they should personally be involved in promoting and ensuring safety. This factor however does not only relate to the individual, but others in the organisation, since asking individual questions may reflect a self-serving response (Lee & Harrison, 2000). Therefore the factor more accurately reflects the statement, safety is not only the role of management but also every person in the organisation. Flin et al. (2000) suggest that responsibility for safety affects safety behaviour. Hence the link between responsibility for safety and risk-taking behaviour in Figure 3.5.

3.9.3 Risk

Flin et al. (2000) note that what is meant by risk in many studies is fairly ambiguous, i.e., does it relate to risk-taking, perceptions of risk in the workplace or attitudes towards risk? Risk was therefore separated into two factors for discussion: perceived risk and risk-taking behaviour.

3.9.3.1 Perceived Level of Risk

'Perceived risk' is a critical factor that appeared in 7 out of 12 studies reviewed (Brown & Holmes, 1986; Cox & Cheyne, 2000; Cox & Cox, 1991; Lee, 1998; Lee & Harrison, 2000; Williamson et al. 1997; Zohar, 1980) as well as a literature review by Flin et al. (2000).

What is the deciding factor for an individual to determine whether a risk is acceptable in light of danger awareness, prior warnings, and the knowledge that to take risks is wrong? A majority of those involved in risk management have acknowledged the association between risk perception and safety attitudes (Rundmo, 2000). It has been established that 75 percent of surveyed workers in NSW coal mines have the perception that there are times when they feel they have to take risks in order to reach productivity levels (Pitzer, 1998). It has been acknowledged that workers often behave according to these risk-taking norms, despite the fact that their personal views do not concur to these norms (Pitzer, 1998). Therefore knowledge alone cannot be viewed as an overall effective way to reduce risk since the individual's motivation will govern whether a particular behaviour is appropriate. This concept appears to be irrespective of whether the taking of a risk will enable goals to be reached more quickly and with less effort (van Vuuren, 2000). Furthermore such risks taken by employees take are usually not 'one offs' but rather they are engrained in their everyday work, so as to meet their targets with the least effort (Pidgeon, 1991). This indicates risk assessment of a mining site cannot be completed in a one-time measurement nor by assessments on a continual temporal scale. Rather the workers must possess some form of control over the technologies available to them so that the 'acceptable risk becomes sufficient control'. In this way the workers are able to monitor the given risks instead of relying on prediction (Vlek & Cvetkovich, 1989 as cited in Pidgeon, 1991). In this manner, these practices have ceased to become risks, so the employees need some form of new motivation to change the current culture that allows and accepts these risks.

According to Flin et al. (2000) risk-taking behaviour is not explained by risk perception, therefore Figure 3.5 does not show a direct link from risk perception to risk-taking behaviour. Rather, perceptions of risk are thought to influence the importance one places on safety and individual responsibility, which in turn affect risk-taking behaviour. Donald and Canter (1994, p. 204) support the effects of risk perception on importance of safety and individual responsibility as they state "attitudes to accidents partly derive from the extent to which processes or events are perceived as hazardous".

3.9.3.2 Risk-Taking Behaviour

Risk-taking behaviour has also been referred to as safety behaviour throughout this critical review. Risk-taking/safety behaviour was identified as a critical factor in 4 out of 12 studies reviewed (Harvey et al., 2002; Lee, 1998; Lee & Harrison, 2000; Williamson et al, 1997). Risk-taking behaviour may not have been identified as a critical factor in 8 of the 12 studies as behaviour is not considered an aspect of safety culture/climate by some researchers. Additionally risk-taking behaviour may have been exclusively measured by observation. Hence, risk-taking behaviour may not have been incorporated into these questionnaires.

Mearns et al. (2001) found through regression analysis, that unsafe behaviours (i.e., risk-taking behaviour) was the best predictors of accident/near-misses in their analysis of safety culture. Supporting the link between risk-taking behaviour and accident/incidents in Figure 3.5. The results of the Mearns et al. (2001) study were however, based upon self-reported data.

A further characteristic which impacts on a person's risk taking is their past accident history and severity of the accident. Molitor and Mosinger (1967 as cited in Cox & Cox, 1991) identified the 'fear of accidents occurring' as another variable contributing to employees' safety behaviours. It was further noted this fear is directly related to accident experience. The study found, that in relation to fire, those who were 'accident repeaters' had low fear scores, while 'accident-free' workers had either very high fear or very low fear scores. Naturally anxious individuals were identified as extremely safety conscious (accident-free) while others demonstrated extreme confidence in the safety of their environment leading to a very low fear score (accident-free) [Cox & Cox, 1991].

Brown and Holmes (1986) established that there were differences in climate perceptions between injured and uninjured workers. The study into safety climate indicated that those with a no-injury history were likely to act according to the perceived risk, if the risk was high there was a distinctly low correlation with the workers actions, the opposite was also found to be true. Employees who had suffered an injury in the past were found to be in a sense immune to risk, in that they displayed a moderate probability of action regardless of the level of risk. These injured workers indicated that saving time and work pressure for deadlines were the most important factors for perceived risk-takers and risk-avoiders (Gillen et al., 2002). This data supports the Browne and Holmes (1986) findings in that individuals with accident histories have a form of ambivalence to the levels of risk they face in the workplace; it is as if they have faced the worst so now do not fear the dangers associated with working. This safety climate feature is associated with 'danger culture' that involves the employee's forming their own levels of appropriate risk in carrying out their tasks. This factor can be influenced by such things as the 'invincibility mentality' highlighted by the worker believing they are beyond harm (Pidgeon, 1991). The reason why this type of behaviour can be engrained within an organisation is because the bonus schemes and financial incentives generated by the management are geared towards productivity and production levels, instead of safe behaviour (Lee & Harrison, 2000; Vredenburgh, 2002). Knowledge of the elevation of risk-taking due to management system(s) must be incorporated into appropriate methods for safety advancements geared at producing cultural change. An effective mechanism for producing change is through the use of training: technology, skills, and Human Factors focussed.

3.9.4 Training

'Training' was identified as a critical factor of safety culture in 7 out of the 12 studies reviewed (Arboleda et al., 2003; Coyle et al., 1995; Lee, 1998; Lee & Harrison, 2000; Williamson et al., 1997; Zohar, 1980) and also in a literature review by Flin et al. (2000). Training was identified as the key factor in a study by Arboleda et al. (2003) whom subsequently suggested training as a primary target for safety improvements within the trucking industry. According to Flin et al. (2000) training must be properly applied and resourced to work effectively, especially in the case of multi-skilling which is common in the mining industry, increasingly at open-cut mines.

Guldenmund (2000) indicated the importance of training in the creation of a positive safety culture in his review of safety climate and culture. The need for appropriate training and education was further identified. The need for effective evaluation is also paramount. O'Toole (2002) found that 'workforce input' is an invaluable creation component of safety training programs due to the practical knowledge of industrial and organisational operations and recognition of potential problems – together with the acknowledgement of personal consequences.

Training increases individual knowledge, skills, competence, and experience. Neal et al. (2000) suggests both knowledge/skills are important determinants of individual compliance and participation in safety. Following this suggestion, Figure 3.5 shows that training affects ones risk-taking behaviour. Two sub-divisions of training in the extended context of safety culture, safety specific training and motivation, are outlined in further detail below.

3.9.4.1 Safety Training

Guldenmund (2000) indicated the importance of training in the creation of a positive safety culture in his 'onion' model of safety culture (see Figure 3.1). The outer layer of his model is referred to as artefacts, which entails the outward behaviours of the employees, such as the appropriate use of safety equipment. Artefacts are typically the base components in training programs (Fleming, 2003).

The working environment ideally includes defined safety responsibilities and detailed practices at all levels. Effective training and education should ensure staffs have knowledge about possible errors in each individual's area of activity. Safety concerns ideally would be given a high level of attention by site inspectors, audits, visits by senior officers, and safety seminars. Satisfactory facilities, including tools, equipment, and information, should also be provided to the staff (Sorenson, 2002). Staff strengths and weaknesses can be examined by observing significant events. These reviews and the resulting efforts to correct the problems are important indicators of an industry's safety (Sorenson, 2002).

3.9.4.2 Safety Knowledge verses Safety Motivation

Motivation to be a safe employee is mediated heavily by the organisational climate, as is the knowledge (skills) one possesses regarding safety (Griffin & Neal, 2000; Neal et al., 2000). Motivation does however, appear to be linked more closely with safety participation as opposed to safety compliance, since participation is a voluntary process based on a person's drives to secure goals. Safety knowledge is described by Neal et al. (2000) as compliance behaviour since often skills and knowledge are prescribed as concrete requirements of the organisation. In order for an organisations safety culture to be improved it can be postulated that a focal point change is the individual workers' safety motivation, as opposed to the worker's knowledge. Training programs provide the opportunity to improve employee safety knowledge; a strategy, which has shown great improvement in recent history (Stephan, 2001). Such training is ineffective and ensuing knowledge inconsequential if however, the employee is not motivated to participate in the safety program: presenting another issue for management in developing training programs and promoting a self-motivated workforce in terms of training participation in the context of improving safety. Awareness of such factors produces the need for development of training strategies that may result in changes in safety systems as well as individual workers behaviours and attitudes in order to produce lasting cultural change.

3.9.5 Safety Systems

Seven out of 12 studies (Coyle et al., 1995; Cox & Cheyne, 2000; Glendon & Litherland, 2001; Lee, 1998; Lee & Harrison, 2000; Williamson et al., 1997) and in a literature review by Flin et al. (2000) identified 'safety systems' as a critical factor of safety culture. Safety systems commonly refer to the rules and procedures made by management in regard to safety. Figure 3.5 shows that safety systems affects perceived risk.

Safety systems may have been absent in 5 of the12 studies reviewed, since safety systems can alternately be measured by a safety management audit and hence may not be incorporated into specific safety culture questionnaires (Hale, 2000). Additionally, the lack of identification of safety systems as a critical factor in the Arboleda et al. (2003) study may have been contributed to by the low technical nature of the trucking industry.

Safety systems or safety rules and procedures is the official way in which safety is monitored and controlled in an organisation (Mearns et al., 1998). The Mearns et al. (1998) research further established through the use of focus groups, that ‘safety systems’ was a critical factor for safety in the high risk industry of offshore oil drilling. The key role of safety systems in safety culture extends beyond isolated procedures. The balance between safety and production related issues and policies with safety and employee perceptions of this prioritisation is also a critical factor contributing to safety culture.

3.9.6 Prioritisation of Safety/Production

Perceptions of the workforce regarding whether safety or production has the most importance in their organisation, is a critical factor that has emerged in 6 out of 12 studies reviewed (Cox & Cheyne, 2000; Cox & Cox, 1991; Glendon & Litherland, 2000; Lee & Harrison, 2000; Williamson et al. 1997; Zohar, 1980) and in a literature review conducted by Flin et al. (2000). The fact that the prioritisation of safety/production occurred as a critical factor in half the studies reviewed, suggests that in line with Guldenmund (2000) model, general organisational assumptions affect safety culture.

Mearns et al. (2001) found that unsafe behaviours were driven by perceptions of production pressures and that this factor accounted for 57 percent of the variance in self reported safety behaviour. Hence, the link between the prioritisation of safety/production and risk-taking behaviour shown in Figure 3.5. It also within reason to expect the prioritisation of safety/production would affect the importance of safety for the individual, see Figure 3.5, a key concern according to McKenzie (1997, p. 25) stating " safety is now the number one priority for the mining sector". The issues surrounding the balance between safety and production are further manifested in sub-sections risk and production mentality as outlined below.

3.9.6.1 Risk and Production Mentality

It has been established that 75 percent of workers in a sample of NSW coal mines perceive that there are times when they feel obligated to take risks in order to reach productivity levels (Pitzer, 1998). It has been acknowledged that workers often behave according to these ‘risk-taking norms’, despite their personal views not being concurrent to these norms (Pitzer, 1998). Therefore, knowledge alone cannot be viewed as an overall effective way to reduce risk since the individual’s motivation will govern whether a particular behaviour is appropriate. This concept appears to be irrespective of whether the taking of a risk will enable goals to be reached more quickly and/or with less effort (van Vuuren, 2000). This was further explored previously in section 3.9.3.1.

Research further shows employees who have suffered an injury in the past are, in a sense, immune to risk: they displayed a moderate probability of action regardless of the level of risk (Browne & Holmes, 1986). This safety climate feature is associated with 'danger culture' that involves the employee's forming their own levels of appropriate risk in carrying out their tasks. This factor can be influenced by such things as the 'invincibility mentality' highlighted by the worker believing they are beyond harm (Pidgeon, 1991). The reason why this type of behaviour can be engrained within an organisation is because the bonus schemes and financial incentives generated by the management are geared towards productivity and production levels, instead of safe behaviour (Lee & Harrison, 2000; Vredenburgh, 2002). The overriding theme of management commitment continues in section 3.9.7 below.

3.9.7 Communication

A critical factor that relates directly to both management commitment and individual responsibility is 'communication', which was found in 6 out of the 12 studies reviewed (Arboleda et al., 2003; [one study in] Coyle et al., 1995; Cox & Cheyne, 2000; Glendon & Litherland, 2001; Harvey et al., 2002; Lee, 1998). Harvey, Bolam, and Gregory (1999) further found communication was the highest weighted factor in their analysis of safety culture and they further suggest that communication is of vital importance if there are sub-cultures within the organisation.

While half of the studies reviewed identified communication as a critical factor, the other half did not (Brown & Holmes, 1986; [one study in] Coyle et al., 1995; Cox & Cox, 1991; Lee & Harrison, 2000; Williamson, 1997; Zohar, 1980). Furthermore communication was not identified in a literature review by Flin et al. (2000). The absence of communication as a critical factor in these studies suggests that communication (as an isolated concept) may not be a critical factor of safety culture. It is proposed that communication is a process whereby the critical factors, management commitment and individual responsibility interact. Items on a safety culture questionnaire that relate to communication can be typically separated into management commitment or individual responsibility depending on the direction of the communication. As such management commitment to communication may be more a critical factor of safety culture than communication alone: highlighting the complexity of communication within safety critical domains.

Morgan (1996) suggests that leadership is a very important contributing factor towards improving the safety culture in the mining industry. However, communication must be carefully considered in leadership style and actual delivery. The communication must "flow through to every level of the organisation" (Morgan, 1996, p. 369). Stressing another area of consideration and responsibility for management: and giving context to the link between management commitment and individual responsibility presented in Figure 3.5. Carroll (1998) identified problems in safety culture related to ineffective communication, not only from management to the workforce, but also from the workforce to management (feedback). Responsibility here stands with the individual. Hence, Figure 3.5 shows the link from individual responsibility to management. However, feedback is governed by the openness of management to this feedback (Carroll, 1998). Therefore, management commitment is proposed to have a greater effect on individual responsibility than individual responsibility has on management commitment.

Zohar (1980) identified the need for open communication links and frequent contacts between the workforce and management (Mearns et al., 2003; Zohar, 1980). An expression of this free flow of information was found to be the execution of frequent safety inspections by appropriate personnel. Similarly Cheyne and colleagues' (1998) study into a model of safety behaviour found that communication between the management and the workforce was a key factor in their individual responsibility, so that the workforce monitored their own safety and others. In this way Cheyne et al. (1998) stressed the importance of open communication channels in those industries perceived to possess a poor safety history.

Rundmo's (1994) research indicated that, with the Offshore Safety Questionnaire (OSQ: developed in the oil platform industry over a two year period), communication was found to be a single critical factor in the make up of safety climate (Mearns et al., 2003). Communication has also shown to be predictive of dangerous occurrences (Mearns et al., 2003), and as such is important for discussion between hierarchical levels on the topics of near misses, safety audits, and safety initiatives (Jeans, 2000; Mearns et al., 2003).

Communication can also be thought of as information processing difficulties, where organisations attempt to deal with highly uncertain and unstructured problems. Organisations attempt to find solutions without all possible information, on the misguided assumption that a possible solution can be found

(Pidgeon & O’Leary, 2000). A problem may not be adequately solved due to its dynamic and ever changing nature; therefore one solution will never suffice (Pidgeon & O’Leary, 2000).

According to Jeans (2000), management commitment to communication is an important facet of safety within the coal mining industry. It is the belief of workers that management should consult with the workforce on initiating a change in safety policy, implementation, and discussions on subsequent outcomes on the safety process within the mine. According to Jeans (2000) commonly held beliefs within the coal mining industry for the purpose of management initiating communication can be summarised as follows:

1. Initiating change in safety policy;
2. Identifying the objectives for the change in policy;
3. Discussing the problems and lessons learned as a result of the safety policy changes; and
4. To indicate how the changes in policy have improved or affected the progress of the organisation.

While other studies have not noted any significance for ‘communication’, as a critical factor, it is possible this is a result of the type of questions asked during the measurement process and is heavily dependent on the design of the experiment. Communication has been investigated in past research conducted in the manufacturing industry, producing evidence of an association between communication and a positive safety culture (Cheyne et al., 1998). Such a finding, combined with the results of similar research conducted in the oil industry (Cox &

Cheyne, 2000), necessitates further investigation into the role of communication in safety culture within other HRIs, for example coal mining.

Many of the above stated identified critical factors of safety culture relate to employee perceptions and wider organisational attitudes that are of vital importance to safety behaviour and the attitudes and perceptions involved in safety culture. Another critical factor of safety culture relating to employee perceptions is the sheer importance of safety: outlined in section 3.9.8 below.

3.9.8 Importance of Safety

The importance of safety is a factor label that does not occur explicitly in any of the studies however it is implied in 5 out of the 12 studies reviewed (Cox & Cheyne, 2000; Cox & Cox, 1991; Harvey et al., 2002; Lee, 1998; Williamson, 1997). While the importance of safety was identified in less than half of the studies reported in this review, such a results may be subject to sampling bias rather than signifying it as an issue of less importance. Rather, some perspective is provided into the apparent order of importance or prevalence of the critical factors.

The importance of safety refers to the individuals' opinion on the importance of safety, typically influenced by the degree to which the individual considers safety as their responsibility. Figure 3.5 highlights the proposed effect of importance of safety on individual responsibility. Presumably individuals who consider safety to be important will perceive situations as more risky than those whom do not consider safety to be important. This factor may also feed the attitude of those who do not consider risk before taking a short-cut or performing an unsafe act: hence the link between the importance of safety and perceived risk in Figure 3.5. The more importance one places on safety, presumably the less risk-taking behaviour. The scope of this factor is also yet to be comprehensively determined in terms of perceived importance of personal safety; workmate/team safety; environmental safety; and/or safety in general. The environmental aspect of safety is outlined in section 3.9.9 below.

3.9.9 Environment

Environment appeared as a critical factor of safety culture in 4 out of 12 studies reviewed (Coyle et al., 1995; Cox & Cheyne, 2000; Lee, 1998). Reason (1998) suggests that in the mining industry, risks are more evident than in 'high-tech' industries. Essentially noting that many apparent risks are due to the environment rather than the organisation. Figure 3.5 shows the link between environment and perceived risk. Farrar, Chairman of the Joint Coal Board in 2001 suggested many risks are related to the machinery used in the coal mining industry, as they are large and powerful and are operated in confined spaces. The environment in which equipment is operated contributes to overall risk. Additionally, miners are repeatedly exposed to dust and coal particles and other environmental factors. The role of the environment in safety and safety culture may be context-specific in that it may only be a critical factor for specific industries, such as mining industry, more so than other industries highlighting the need for further research into this factor in the specific context of coal mining.

3.9.10 Additional Factors

The extent to which critical factors contributing to safety culture are specific to the coal mining industry or are generalisable to other safety critical domains continues to be investigated. It is reasonable to anticipate some difference between the

Australian coal mining industry and off-shore oil platforms in the North Sea will exist. This literature review identified several additional factors which, while not mentioned with the same frequency of say, management commitment, are still valuable to mention and essential for further investigation not only into those additional factors for the Australian coal mining industry but for individual mines. Factors that occurred in three on less studies included, job satisfaction, relationships, staff selection, status of safety personnel and stability of workforce.

The supplementary research project (refer to section 5 of this extended report) serves to identify those critical factors of safety culture within the Australian coal mining industry. Factors such as those 'additional factors' stated above are frequently revealed albeit at a lower level of reporting. These factors, while not necessarily generalisable across the entire industry highlight the individuality of each mine. For example, while an issue such as job security may be a critical concern (and contributing factor to safety culture) for one particular mine, it may not be an issue at several other like mines. It is therefore important to present these lower order critical factors, especially within the context of individual operations.

3.10 A Comparative Critical Factor Model

The complexity of the identification and interaction of critical factors of safety culture is evident from the information presented in section 3.9 of this report and also the factor relationships presented in Figure 3.5. The following section of the report presents a model of common critical factors of safety culture developed from HRIs. The results of research conducted by Cox and Cheyne (1998) lead Cheyne et al. (1998) to develop a model illustrating the relationship between several critical factors of safety culture, refer to Figure 3.8. The Cheyne et al. (1998) model was developed in the manufacturing industry in both the United Kingdom (UK) and France and was validated by Structural Equation Modelling (SEM). The value of examining a variety of industries across numerous nations in terms of their applicability to the Australian coal mining industry is further evident from the Cheyne et al. (1998) model, given its origins and the similarity of the critical factors included.

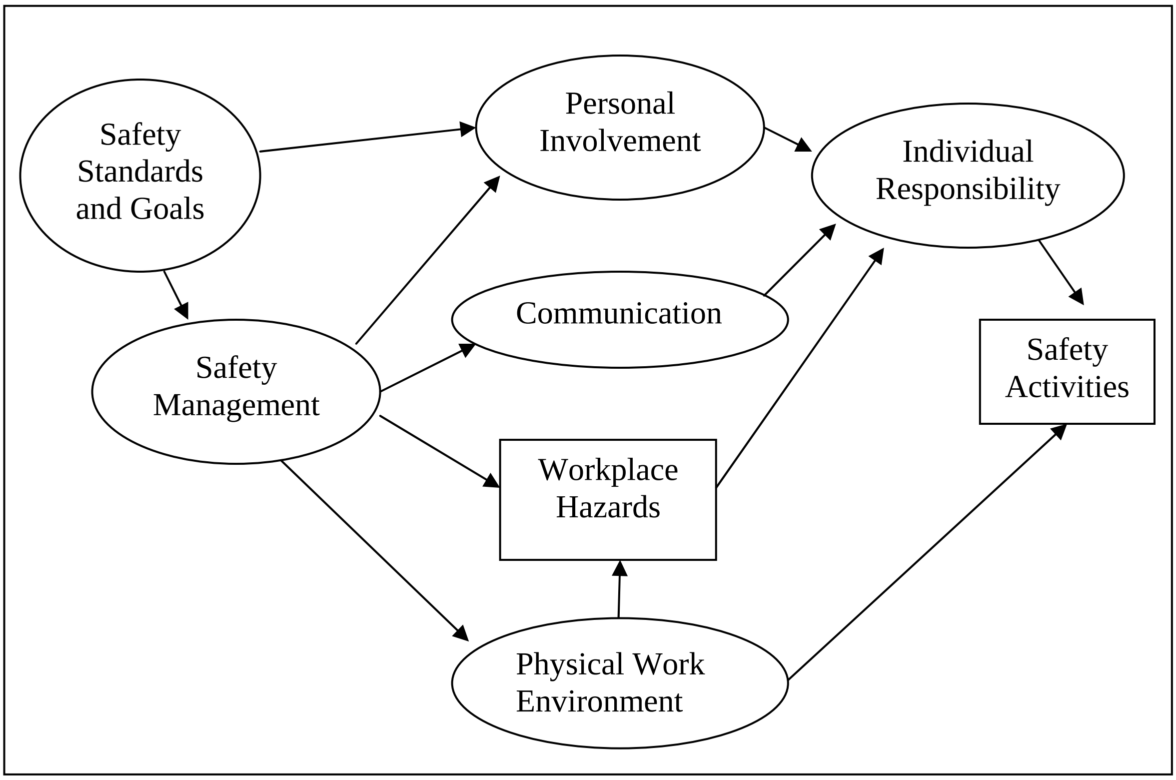

Figure 3.8. Safety culture critical factor model (Cheyne et al., 1998).

The Cheyne et al. (1998) model incorporates many of the same factors outline in this literature review, such as management commitment (safety management), environment (physical work environment), perceived risk (workplace hazards), communication, safety systems (safety standards and goals), individual responsibility (individual responsibility and personal involvement), and risk/safety behaviour (safety activities). The terms listed immediately previously in parentheses correspond with the re-naming of the factors as presented in the model as compared to the factor labels presented in the literature review.

The Cheyne et al. (1998) model is uni-directional with management/situational factors affecting attitudinal/psychological factors that affect behavioural factors. Therefore the Cheyne et al. (1998) model of the critical factors of safety culture fits into the Guldenmund (2000) model of safety culture. The working model proposed from this literature review is more inline with Coopers (2000) model of safety culture, incorporating a bi-directional influence between the situational, psychological, and behavioural components of safety culture.

Further additional influences affect and contribute to an organisation's safety culture. The following section presents summary information on the role of hierarchical differences in safety culture as well as safety sub-cultures. Comparison of prevailing safety issues for underground and open-cut mines are also outlined as discussion points for further inquiry.

3.11 Hierarchical Differences

One of the areas not closely examined in studies of safety culture and safety climate is how climate perceptions vary between the hierarchical levels of an organisation; i.e., whether management, supervisors, and miners have similar or different perceptions of the safety of the coal organisation. The supplementary research program (see section 5 of this report) has this field of investigation included into the methodology. The Arboleda et al. (2003) study into safety culture in the United States (US) trucking industry indicated the factors that are predictive of safety culture include: driver safety training, driver autonomy regarding safety, opportunities for safety input, and first-rate management commitment. This, combined with the information presented throughout this review, illustrates the full range of occupational groups are involved in safety culture, its maintenance, and its change. Research has further shown that different positions within the company can have differing views on safety culture and its make up, and also on the perceived level of responsibility for safety (Chesher & Smith, 1995).

Differences in hierarchy can lead to differences in individuals' cultural experience. Differences can also occur because culture is being constantly 'reconstructed' (Martin, 2002 as cited in Arboleda et al., 2003). Previous research has indicated that the rate of underground injures are almost four times higher than those of open-cut workers (Leigh et al., 1990). A review of past Studies has further indicated that when employees take greater control of the safety-training program they are more likely to be positive about the changes that are initiated. This indicates when individuals are permitted active involvement in training (e.g., input into development and delivery, also opportunities for feedback), not only does the positive experience of the program increase, the likelihood of individuals putting new skills into practice also increases.

In a study conducted by McDonald et al. (2000) into several differing airlines it was found that while there were significant differences between the safety cultures of the overall structural levels of the organisations, there were similarities between the cultures of equivalent levels between companies, particularly within the technical sector. It was established that a 'professional sub culture' had formed for these aircraft technicians in different companies where they believed that they were solely responsible for the safety of the aircraft. This was in contrast to the management who believed the technicians' role was to adhere explicitly to the managerial developed guidelines. Such differences between hierarchical levels creates a difference between the 'actual' procedure and the 'official' procedure (McDonald et al., 2000), ultimately leading to potential difficulties in times of crisis, as an effective procedure (actual) could be abolished to make way for an official procedure. This indicates that communication between the levels is significant so that synchronised safety arrangements can be created in order to avoid disputes in terms of safety procedure, following any negative outcomes (McDonald et al., 2000).

3.11.1 Safety Sub-Cultures

Several researchers have found safety sub-cultures within organisations differentiated either by organisational hierarchy (Arboleda et al., 2003; Coyle et al., 1995; Harvey et al., 2002) or occupational group (Cox & Cheyne, 2000). Arboleda et al. (2003) conducted a study in the US trucking industry and found there were significant differences between drivers, dispatchers, and safety directors' perceptions of the main critical factor identified in the study (management commitment to safety). Cox and Cheyne (2000) also found that drilling teams in the offshore industry had different perceptions towards the critical factors of safety culture to other groups within the organisation. A possible explanation given was that these drilling teams were employed by another company and hence were outside the company's internal communication channels. The issue of safety sub-cultures requires further investigation specifically within the Australian coal mining industry. The extended research program in support of this review aims to examine the deeper issues of safety culture including sub-cultures and hierarchical differences.

In examining the extent to which the information presented in this review is generalisable to coal mining in Australia, it is also essential to examine applicability to both underground and open-cut coal mines. The following section (3.12) provides a summary of the differences between underground and open-cut coal mining operations.

3.12 Differences Between Open-Cut and Underground Mining Installations

The key difference evident between open-cut and underground mining installations is the environmental differences and associated risk of personal injury. Research conducted by Leigh et al. (1990) has revealed the rate of underground injuries to be approximately four times higher than those of open-cut workers. This is not to say safety concerns are of greater importance in the underground mining industry than the open-cut mining industry. Rather, the distinction between these elements of the industry in terms of environmental and other differences must be examined in detail. It is also predictable that many critical factors of safety culture would exist in both settings: as well as the expectation of some differences. As such any recommendation for implementation of innovation strategies aimed at improving safety culture, must take into account the context of the operation and the applicability to both open-cut and underground industries within our national structure.

3.13 Discussion

This section of the extended report has presented a review of scientific literature (both theoretical and empirical) for research conducted in a variety of HRIs across a number of differing nations relating to safety and safety culture. The individual studies and the collaborative review have defined the concepts of safety culture and safety climate and identified their key contributory factors from both the organisation and personnel. The information has been presented within a context of applicability to the Australian coal mining industry in the development of an Australian national measure of safety culture.

As discussed, considerable debate surrounds the definition of safety culture: debate that has not yet been resolved. While numerous definitions of safety culture exist, the majority include (at least in part) elements of the definition put forward by the Advisory Committee on the Safety of Nuclear Installations (ACSNI, 1993). The ACSNI definition describes safety culture as the end result, the ‘product’, of all the individual and group values, attitudes, perceptions, skills, and behaviours from within an organisation relating to safety. Implicated in the ACSNI definition is the existence of three main components of safety culture: personal, behavioural, and situational elements (which relate to the psychological factors of the workforce, work behaviour of employees, and safety systems and procedures respectively). The personal component has been described as the primary component of safety culture (Cheyne et al., 2002; Cox & Cox, 1991; Lee & Harrison, 2000; Pidgeon, 1998) and further identified as representing the ‘safety climate’ of an organisation (Arboleda et al., 2003; Cox & Cox, 1991).

Safety climate has long been used interchangeably (mistakenly) with safety culture. Research has shown safety climate to be distinct to, but not isolated from, safety culture (Mearns et al., 1998; Mearns & Flin, 1999). In fact, safety climate is a part of safety culture, having been described as a snap shot of a workforce's attitudes to and perceptions of safety at a particular point in time, providing an indication of the underlying safety culture present in the organisation (Mearns, Flin, Fleming, & Gordon, 1997 as cited in Fleming, 2003). Safety climate can be seen as 'culture in the making' (Guldenmund, 2000).

The scientific debate surrounding the conceptual elements of safety culture and safety climate (and the distinction of their defining characteristics) has produced several theoretical models by numerous researchers in the field. Such models provide clear representation of the theoretical aspects of the concepts, the interaction of the sub-components, the critical factors contributing to safety culture, the relationship between the factors, and the complex nature of the concepts.

Proposed models of safety culture typically address aspects of the personal, behavioural, and situational elements of safety culture. The Guldenmund (2000) model presents a diagrammatic representation of safety culture as an 'onion' with many layers. The layers (sub-components) consist of a core set of basic assumptions held by a workforce which operationalise the values and attitudes held across the organisation, manifested in actual safe working behaviours and practices. Under the Guldenmund (2000) model safety climate is produced by attitudes and behaviours ultimately resulting in safety culture, the outer layer of the onion. The Glendon and Stanton model (2000) presents the concepts outlined in the Guldenmund (2000) model in a historical time-frame. The model accounts for the existence of safety sub-cultures by identifying not only the depth of culture, but also its breadth. Cultural drivers such as hierarchy and occupational groups have been further identified as unique inclusions in a safety culture model (Arboleda et al., 2003; Cox & Cheyne, 2000; Coyle et al., 1995; Harvey et al., 2002).

The reciprocal model of safety culture proposed by Cooper (2000) clearly presents the three components of safety culture: classifying the personal component as internal psychological factors and both the behavioural and situational elements of safety culture as external observable factors. The model presents the connectivity between the elements emphasising the cyclical and dynamic influence of change. The fourth model outlined in this review is the Cox and Cheyne (2000) model which presents a range of elements of safety culture, their manifestations, and associated measurement techniques. The model supports the use of multiple methods of measurement in the assessment of safety culture.

Cooper (2000) proposes the three elements of safety culture are common to the majority of safety culture models. Therefore, it is considered necessary to measure each of these components either separately or within a single design to achieve a reliable measure of an organisations safety culture. Separate measures would include a questionnaire for the psychological component, observation, or checklists for the behavioural component, and an audit or inspections for the situational component. The only way to measure all three components of safety culture in the one measurement is to use a questionnaire. This method would include items relating to attitudes, perceptions, behaviours, and situational components to adequately measure safety culture.

Questionnaires have been identified as tools by which critical factors of safety culture may be identifying, allowing organisations to target areas for safety improvements. Research has however shown that the critical factors identified through questionnaires, may be an artefact of questionnaire design itself. As such careful scientific development of an appropriate safety culture measurement tool incorporates many step, taken as required over a number of years. Critical factors identified from literature reviews were traditionally used as an aid for direction in the design of safety culture questionnaires. More recently however, researchers are incorporating an intermediate step in the research process: focus groups. Focus groups are beneficial as they indicate the context-specific critical factors of safety culture. Focus groups however, cannot take place without initially conducting a literature review. As literature reviews identify the non-specific critical factors of safety culture for discussion topics in the focus groups. Typically a questionnaire follows the focus groups in safety culture research.

Studies using the same questionnaires have not always found identical results. Such research has produced differing factor structures across nations and organisations within the same industry. While evidence suggests critical factors are context-dependant, core critical factors of safety culture of across a wide variety of industries were identified in this review. The critical factors identified in at least 50 percent of studies were management commitment, individual responsibility, risk perception, safety systems, training, priority for safety or production, and communication. Additional factors found in less than 50 percent of studies reviewed included the importance of safety, environment, risk-taking, job satisfaction, relationships, staff selection, stability, and status of safety personnel.

This review gives further insight into the nature of critical factors in national and international investigations of safety culture. Critical factors are not thought to be nation specific since several factors were identified in more than one nation (also in varying industries). The critical factors of safety culture identified in the

Australian studies (4 out of 12 reviewed) were similar to those identified in the entire sample. Further investigation is required to determine the extent to which national culture plays a role in organisational safety culture. National culture may also play a role in questionnaire design, raising the further issue of critical factors being an artefact of questionnaire design. An internationally validated measurement tool is not currently operational.

Further to the Australian research, Coyle et al. (1995) used the same questionnaire in a research project conducted in two similar organisations in Sydney, Australia (both constituents of a single organisation, involved in health care services to the elderly, similar in size, with infrastructure extending beyond Sydney). This study found differing factor structures within these organisations, see Table 3.3. As Such it is again evident factor structures are not due to questionnaire design alone. This may suggest that questionnaire results are highly sensitive to questionnaire design. Conversely the study may imply that critical factors of safety culture are organisation specific rather than nation or industry specific. It is important to note the Coyle et al. (1995) questions were based only on perceptions and did not include questions relating to attitudes hence have measured only one component of culture.

The subjective nature of factor analysis also causes variability in the reported factor structures of safety culture. Guldenmund (2000) suggests discrepancies in factors could be accounted for by individual interpretation of which critical factors particular questions are probing. Differences extenuated by language and cultural differences (Cox & Flin, 1998). Glendon and Litherland (2001) note that many critical factor reviews are based only on superficial comparisons, i.e., similarity in the naming of the dimension. Hence, in this review the individual questions relating to each factor were examined and renamed where considered appropriate, thus providing a consistent, however subjective comparison across studies. Some studies rather than including the individual items on the questionnaire included a sample of the questions (Cox & Cox, 1991; Lee & Harrison, 2000). In contrast some studies provided descriptions of the critical factors as an indication of what the individual items were probing (Arboleda et al., 2003; Flin et al., 2000; Lee, 1998; Lee & Harrison, 2000), refer to Table 3.3. Where individual questions or descriptions were absent, interpretations were based on the name of the factor (Brown & Holmes, 1986; Zohar, 1980).

Regardless of the discrepancies, in the number and type of factors found in the literature reviewed, there are certain factors that keep reoccurring in safety culture analysis. Of the 12 studies compared in the literature review several themes emerged, see Table 3.3. In descending order of frequency, they are: management commitment, individual responsibility, perceived level of risk, training, safety systems, the prioritisation of safety and production, communication, importance of safety, risk-taking/safety behaviour, and environmental risk.

Comparison of Australia studies (Coyle et al., 1995, Glendon & Litherland, 2001; Williamson et al., 1997) identified similar critical factors of safety culture to the overall literature review. Management commitment, individual responsibility, safety systems, training and safety/production were identified in 3 out of 4 studies reviewed, communication was identified in 2 out of 4 studies reviewed and risk perception, relationships and environment in 1 out of 4 studies reviewed. The main difference was that risk perception was not a dominant critical factor in the Australian sample.

The identification of critical factors of safety culture provides direction not only for the design of measurement tools, also safety advancements and change. A summary of the key factors identified in this review is provided below.

Management is cited widely in the literature as a key component of safety climate and culture. The areas of management indicated as relevant to climate and culture were ‘management commitment’ (the degree to which those in managerial positions indicated that they were committed to a safe working environment), and ‘positive role modelling by management’ (the degree to which management actually displayed safe behaviours).

Training as a critical factor refers to the extent to which the training of new employees and retraining of current employees affects the safety culture of an organisation. Specifically it is the imparting of safety knowledge to the workers and an increase in safety motivation that will allow the workers to behave more safely, thus creating a positive safety culture.

It has become apparent that risk-taking in order to achieve production results more quickly and with decreased effort, is a possible cause of poor safety culture within industry. The perception that sometimes workers act in risky ways, against their actual beliefs and values is interesting for implications of safety culture improvement, how can one deal with risk taking by changing safety culture if the employees ignore the culture of that organisation? For this reason risk is considered a critical factor of safety culture by this review paper.

Communication is also a vital factor considered here, and also serves as a facilitator for change and the dialect between the managers and the workforce for the discussion of areas for improvement and the implementation of initiatives. Communication also dictates the understanding between the workforce and management, if the management attempts to solve problems without full technical input from the workers, adequate solutions may not be found.

Collectively, the research suggests that safety culture is an important determinant of organisational safety performance. Individual and group behavioural outcomes involve both positive and negative (human error; risk-taking) behaviours. Such performance significantly impacts on the safety outcomes of the organisation, and thus on the organisational culture and safety culture. In order to improve safety behaviours and safety systems within the coal mining industry, the critical features of safety culture and climate must be uncovered, and targeted improvement in the specific areas must be advanced. This review of safety culture was undertaken to investigate the factors within the context of the Australian mining industry. The derived knowledge will act as a test-bed for the creation of a national direct measure of safety culture within the coal industry. Further information on the supplementary research project is contained in section 5 of the extended report.

3.14 Summary

The underlying elements of safety culture including psychological, behavioural, and situational influences hold a critical role in both the causation and prevention of error. A positive safety culture significantly impacts the safety, effectiveness, and efficiency of both performance and system operations. Identification of the critical factors contributing to safety culture is a crucial component of safety and error management. Furthermore critical factor analysis provides directed guidance for the development of resourceful and cost-effective safety improvements and training initiatives. The empirical and theoretical review of scientific literature presented in this section of extended report has outlined the defining characteristics of safety culture (as distinctive to safety climate) and has provided an overview of effective measurement tools and techniques. The empirical review has further identified an emerging core set of 10 critical factors of safety culture which includes: (1) management commitment, (2) individual responsibility, (3) perceived level of risk, (4) training, (5) safety systems and procedures, (6) the prioritisation of safety and production, (7) communication, (8) importance of safety, (9) risk-taking/safety behaviour, and (10) environmental risk. These 10 factor categories are core contributing factors to safety culture across a range of HRIs (further contributed to by an array of [varying] sub-components). The extent to which this set of core factors is applicable to the Australian coal mining industry is yet to be comprehensively determined. The supplementary research project (detailed in section 5 of the extended report) aims to investigate the critical factors of safety culture within a sample of Australian coal mines (both underground and open-cut), in accordance with the core set.

3.15 References

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3.16 Disclaimer

Any opinions, findings, or recommendations expressed in this report are those of the project team as scientifically derived from the research literature and do not necessarily reflect the views of Coal Services Pty Limited, the Joint Coal Board Health and Safety Trust, The University of Newcastle or any other body or mining installation.

This literature review forms part of an extensive report prepared for Coal Services Pty Limited and the Joint Coal Board Health and Safety Trust by The University of Newcastle Human Factors Group. The report relates to the first phase of a multi-year research program. The first project (that which is contained in the extensive report) was conducted in order to identify critical factors contributing to safety culture within the Australian coal mining industry from a sample of Hunter Region, NSW, coal mines: both underground and open-cut. This review relates to the underlying theory of the extended research program.

For further information on this report or to discuss access to the extended report, please contact Coal Services Pty Limited.

For further information about the current research project please contact the Human Factors Group from The University of Newcastle, Australia:

Associate Professor H. Peter Pfister

Director – Human Factors Group – The University of Newcastle

Aviation Building, School of Behavioural Sciences,

University Drive, Callaghan, NSW, 2308

Phone: (02) 49215760 – Fax: (02) 49216906

Email: Peter.Pfister@newcastle.edu.au

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H. Peter Pfister
Director
Human Factors Group
The University of Newcastle

Rebecca J. Atkins
Principal Research Officer
Human Factors Group
The University of Newcastle

The UNIVERSITY of NEWCASTLE
Human Factors Group

Human Factors Group

School of Behavioural Sciences
The University of Newcastle
University Drive
Callaghan, NSW, 2308
Australia

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SECTION 4:
Bibliography

H. Peter Pfister & Rebecca J. Atkins

Human Factors Group
School of Behavioural Sciences
The University of Newcastle

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Health and Safety Trust
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4.1 Overview

This section of the report contains an extended bibliography in addition to the references contained in Sections 3 and 5 of this report. The purpose of the bibliography is for use as a reference database for future research, theory, hypothesis formation, and other information. This select bibliography has been compiled on safety and safety culture from a range of sources specific to the Coal Industry and related fields with supporting references drawn from organisational theory derived from psychological, scientific, industrial, and engineering databases accessible by the project team. In total we have complied just under 1100 references as a data source.

All bibliographies have a limited shelf-life. This one was compiled in January 2005.

4.2 Acknowledgements

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H. Peter Pfister
Project Director
Human Factors Group
The University of Newcastle

Rebecca J. Atkins
Principal Research Officer
Human Factors Group
The University of Newcastle

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The UNIVERSITY of NEWCASTLE
Human Factors Group

Human Factors Group

School of Behavioural Sciences
The University of Newcastle
University Drive
Callaghan, NSW, 2308
Australia

Coal Industry Safety Culture
Final Report Project 1

Report: HFG-0804-1139-02
SECTION 5
Project Analysis & Report

H. Peter Pfister & Rebecca J. Atkins

Human Factors Group
School of Behavioural Sciences
The University of Newcastle

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and
Coal Services Pty Limited

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5.0 Declaration

The project described in this report was primarily funded by the JCB Health & Safety Trust with supplementary funding from the University of Newcastle. The project was conducted under National Ethical Guidelines approval number H-578-0503 Human Research Ethics Committee, The University of Newcastle.

H. Peter Pfister
Director
Human Factors Group
The University of Newcastle
7/11/2005

5.1 Background

This project has been commissioned by Coal Services (CS) Pty Limited and the Joint Coal Board Health and Safety Trust (JCB-HST) in response to the continuing high annual lost-time injuries for workers in the Australian coal mining industry. This appears to be despite the vast amount of resources dedicated to the improvement of safety (behaviours, systems, and management) and safety culture within the Australian coal mining industry. In Tables 5.1 and 5.2 below are some summary tables amended from Table 17 (p. 29) and Table 20 (p. 33) respectively from Lost-time Injuries and Fatalities NSW coal Mines 2001-02 document produced by CS Pty Limited (2002). Table 5.1 recounts some of the common 'hardware' causes for accidents and injuries resulting in lost-time injuries within the coal mining industry.

Table 5.1

Lost-time Injuries NSW Coal Mines 2001-02

Agency	Agency of Accident (number)	Agency of Injury (number)
Machinery & (mainly) fixed plant	60	53
Mobile/portable plant & transport	184	177
Non-powered tools/equipment	65	73
Chemicals	10	6
Materials/Substances	49	90
Environmental agencies	177	145
Other agency and note stated	16	17
TOTAL	**561**	**561**

Table 5.2 following indicates common 'software' issues in lost-time accidents for the NSW coal mining workforce. The software issues are described as actual activities at the time of the injury.

Table 5.2

Employee Activity, Lost-time Accidents NSW Coal Mines 2001-02

Activity	Open Cut	Underground	TOTAL
Roof bolting-drilling	--	16	16
Cable handling	2	23	25
Operating dump truck	12	--	23
Equip repair/maintenance	12	21	33
Servicing plant/equip	6	10	16
Handling supplies/materials	2	16	18
Handling items	1	41	42
Getting on/off transport/equip	9	15	24
Inspections	--	36	36
…	…	…	…
TOTAL	**111**	**377**	**488**

The process of assessing hardware and software issues relating to accident and injury causation within the Australian national coal mining industry has been a typical system of evaluation for many years. This process does not however cover all aspects of accident and injury causation: namely Human Factors issues. Attitudes, perceptions, and behaviours relating to safety are key areas of Human Factors investigations into safety critical domains. These areas relate specifically to safety culture: a concept that has shown direct association with safe working behaviours and performance outcomes. Such information is driving the current CS Pty Limited focus on improving safety attitudes and actual safety behaviours as well as safety systems at the organisational level together with overall safety management and safety training. This approach follows an all-encompassing Human Factors perspective. This extended research program will serve to identify key area for advancement in safety training and safety related behaviour, ultimately delivering a nation-specific measurement tool for safety culture and strategic recommendations for related training initiatives.

5.2 Overview of the Research Program

The extended research program consists of three distinct projects:

Project 1. A primary investigation whereby a safety culture measure will be developed.

Project 2. Assessment of current standards and practice as well as an identification of best practice.

Project 3. Development and testing of a best practices training program.

The development of Projects 2 and 3 is dependent upon the outcomes of Project 1. Projects 2 and 3 are subject to additional funding and will thus not be considered in this report. This section of the report presents the findings for Project 1, as outlined below.

5.2.1 Overview of Project 1

The objective of Project 1 was to identify behaviours in the coal and similar industries that are associated with positive safety culture from which one can develop a questionnaire based measurement tool to assess the prevailing safety culture in Australian coal mines. We expect this tool will be validated as a measure that is predictive of safety behaviour in Australian coal mines and for this tool to be an effective and efficient measurement instrument that can be easily used across the coal industry in Australia to assess safety culture. Future application of this tool could include its use to identify areas for advancement in safety behaviour and to assess the effectiveness of any intervention.

There are five components to Project 1:

1. Literature search to identify appropriate criteria for examination and to serve as a test bed;
2. Focus groups with miners, supervisors, and managers to test criteria identified in the literature review;
3. Development and testing of a safety attitude questionnaire;
4. Evaluation and refinement of questionnaire; and
5. Second testing of questionnaire in another mine to validate questionnaire.

2003 saw the commencement of Project 1 which was conducted in two segments. Stage 1 of Project 1 (completed in the 2003 program) relates to components 1, 2, and 3 as outlined above. Stage 2 of Project 1 (forming the first phase of the ongoing research program which has commenced in 2004) relates to components 4 and 5 as identified above. The following sections of this report relate only to Stage 1 of Project 1. The first component of this stage of the research (the theoretical stage [literature review]) has been documented in section 3 of this report. This section of the report details the two experimental stages of the research program (components 2 and 3 as identified above). The experimental stages have been divided into their separate components and referred to as Phase 1 (focus groups) and Phase 2 (questionnaire administration) of Project 1: Stage 1. This structure and sub-division of Project 1 is clearly illustrated in Figure 5.1 following. Section 6 of the report outlines the remaining components of Project 1 (Stage 2) of the extended research program, together with the methodology and projected budget for Project 2 and Project 3.

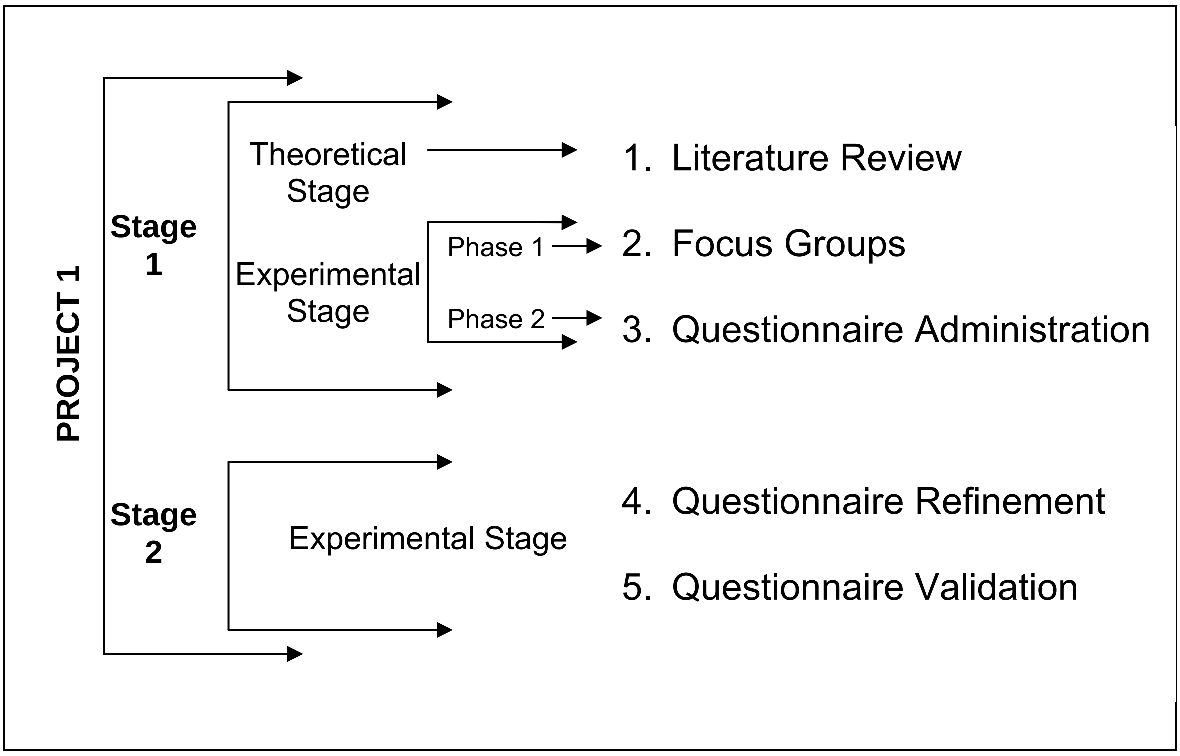

Figure 5.1. Structure and sub-division of project 1 of the extended research program.

5.2.2 Project 1: Stage 1

Stage 1 commenced with a theoretical stage comprising of a search of the scientific literature (theoretical and empirical) conducted to identify appropriate criteria for examination (critical factors of safety culture) and to serve as a test bed. From the literature review, behaviours in the coal and similar industries were identified that are associated with a positive safety culture. This stage of the research was followed by the experimental stage involving focus groups (Phase 1) and the distribution/completion of a safety management questionnaire (Phase 2) in order to test criteria identified in the literature review and to capture employee perceptions of effective safety management behaviours.

5.2.2.1 Project 1: Stage 1: Phase 1

Focus groups were conducted with a sample of participating company employees across all levels of the workforce (miners, supervisors, and management). Each focus group contained a small number of participants (i.e., 6-10 individuals) from a range of occupational groups. To encourage open discussion each group only contained employees at the same level of seniority. The focus groups lasted approximately two hours and were facilitated by the research team. Focus group participants were asked to discuss a number of topics surrounding the central theme of safety and safety culture, such as:

1. What are the requirements for a positive safety culture;
2. What behaviours should managers display to demonstrate they are committed to safety;
3. What do you believe the critical factors contributing to safety are; and
4. Who is responsible for safety (e.g., the individual, management, etc.).

The results of the literature review (contained in section 3 of this extended report) and the focus groups were collated in order to identify critical factors that contribute to safety culture. This information will be used to revise the questionnaire (ongoing process) for distribution to all levels of the workforce across a wider industry sample.

5.2.2.2 Project 1: Stage 1: Phase 2

Phase 2 commenced with the administration of a safety management questionnaire (SMQ). The SMQ was an existing ‘safety culture’ questionnaire originally developed in the offshore oil platform industry: adapted and revised for the Australian coal industry based on the findings the literature review and the focus groups. The questionnaire gathers demographic information (such as occupational group and years of experience) and employee perceptions of safety culture, safety behaviour, safety management, and perceived level control over safety environment. Questionnaire packs were distributed across the entire workforce including mine workers, supervisors, and management. The questionnaire took approximately 20-25 minutes to complete. It was emphasised that participation was voluntary and that individual responses would remain confidential to the University research team. All data was de-identified: individuals could not be identified by their participation or their responses. There was no need for individuals to be identified. The responses on the returned questionnaires were statistically analysed to test the relationship between safety culture factors and the employee and management behaviours. The psychometric properties of the questionnaire will also be further tested throughout the future research program, the results of which will be used to refine the measure and enhance the psychometric properties of the instrument.

Appendix A contains the activity timeline compiled by The University of Newcastle Human Factors Group indicating the research activities undertaken for the completion of Project 1: Stage 1.

5.3 Introductory Materials

The literature review (section 3 of the report) was conducted as the first phase of an extended research project aiming to customise a safety culture survey for the Australian coal mining industry. Firstly, various definitions and conceptual models of safety culture were discussed in the review to justify the use of a questionnaire device when examining safety culture. Several definitions consistently described safety culture as consisting of three elements: psychological, behavioural, and situational. Assessment of each element is considered necessary to gain a reliable measure of safety culture. A questionnaire is the only scientific measurement tool able to incorporate all three elements.

The literature review identified factor structures reported in a number of studies from a variety of organisations to be used as a topic guide/discussion points in subsequent focus group sessions. Focus groups are an intermediate step in safety culture questionnaire development, which are able to identify context-specific critical factors of safety culture (i.e., those key contributing factors for each individual mine). The section 3 review further revealed empirical evidence to suggest the critical factors of safety culture may be context-specific and/or an artefact of questionnaire design. Hence, focus groups are considered an essential element of safety culture questionnaire development (and content verification).

Although critical factors in the literature review were found to be context-specific, common critical factors were also identified in the literature review. Identified in at least half of the studies reviewed were the following safety issues: management commitment, individual responsibility, risk perception, safety systems, training, the prioritisation of safety/production, and communication. This report (and the extended research project) examines the extent to which these critical factors and additional factors (specific to the coal mining industry [as identified in the focus groups held at a sample of open-cut and underground coal mining installations in the Hunter Region]), can be generalised to the wider coal mining industry.

In order to establish the reasons for the perceived shortcomings of safety cultures within the Australian coal mining industry it is necessary to determine which factors are important for safety culture: as has been done in other industries for the workforce and management (Flin, Mearns, O'Connor, & Bryden, 2000; Mearns, Flin, Gordon, & Fleming, 2001; Sorensen, 2002; Zohar, 1980). This study aimed to establish that critical factors of safety culture can be elucidated through a literature review and through the use of focus groups with all levels of employment within the relevant pilot mines. Once the factors were established a pre-existing questionnaire can be modified based on these factors (and terminology suiting the national coal industry) to assess which areas of the worker and management safety culture are affecting overall safety behaviours. This study was the first step in the process of developing a safety culture questionnaire tailored to the Australian coal mining industry.

The ultimate goal of this research was to incorporate the critical factors identified in the literature review and focus groups into the development of a safety culture survey, customised for the Australian coal mining industry. The results of the experimental stage of Stage 1 of Project 1 (Phase 1: focus groups; Phase 2: SMQ-1) are detailed in this section of the report.

5.4 Aim of Project 1

The overall aim of the extended research program was to scientifically assess and improve safety culture within the Australian coal mining industry. Furthermore, we expect to be able to quantify (in the long term) how improved safety results in improved productivity in terms of reduced missed work time and increased tonnage produced. As outlined in section 5.2, the research program consists of three distinct projects, each comprising of a number of components. This section of the research report relates to Stage 1 of Project 1.

The aim of Project 1: Stage 1 was to identify critical factors of safety culture in the Australian coal mining industry. A further aim was to explore for possible differences in the critical factors of safety culture in underground and an open-cut coal mines and also according to hierarchal level or occupational group. The broader objective of Project 1: Stage 1 was to identify behaviours in the coal and similar industries that are associated with positive safety culture from which we can develop/revise a questionnaire based measurement tool to assess the prevailing safety culture in Australian coal mines.

The aim of Project 1: Stage 2 was to further revise the questionnaire utilised in Project 1: Stage 1 and to evaluate the ability of this questionnaire (adapted from the UK offshore oil industry) to assess the safety culture of the Australian coal mining industry.

The wider outcomes of Project 1 are further aimed at producing recommendations for expansion of the research into latter project stages of the extended research program. The research objectives for the latter stages of the research program are outlined in section 6 of the extended report.

5.5 Hypothesis

Several hypotheses have been developed from the empirical and theoretical review completed as part of Project 1: Stage 1 (refer to section 3 of the extended report for detailed information). These research expectations are stated below:

Hypothesis 1

The first hypothesis to be examined was that management commitment, individual responsibility, risk, safety systems and procedures, training, the prioritisation of safety and production, and communication will be identified as critical safety issues in focus groups conducted at a sample of underground and open-cut coal mines in Australia. Flin et al. (2000) suggests there may be a core set of critical factors of safety culture, and the literature review conducted as part of this study supports this suggestion. The critical factors identified in over half the studies reviewed were those stated above.

Hypothesis 2

A second hypothesis was that management commitment, individual responsibility, risk, safety systems and procedures, training, the prioritisation of safety and production, and communication will be identified as the critical issues of safety in Task 1 of the focus groups. In Task 1 individuals were asked to record their personal perceptions of the top five safety issues. Again, we would expect the same safety issues identified in the focus groups to be identified as a result of Task 1, as these safety issues correspond with the critical factors identified in over half the studies reviewed. Task 1 was included in the study to control for the possible over representation of opinions in focus groups by dominant individuals, a problem noted by Cox and Cheyne (2000). As we expect focus group data to accurately represent participant's views, we therefore expect identical safety issues to be presented in the focus groups as in Task 1.

Hypothesis 3

The third hypothesis postulates that differences will be identified in the frequency of specific safety issues between management and workers in the focus group sessions and in Task 1 of the focus groups, since Pitzer (1998) found differing perceptions between leadership levels and operator levels (miners) in the minerals industry as a whole 'especially the coal sector'. A further research question explored possible differences in perceptions of safety issues at the supervisor (deputy) level, as differences at the supervisor level have been identified in a number of studies (Harvey, Bolam, & Gregory, 1999; Clarke, 1999; Arboleda, Morrow, Crum, & Shelley, 2003). Differences in the importance placed on each critical safety issue for trade's people (fitters and mechanics) and miners were also explored. Cox and Cheyne (2000) have found differences in the critical factors of safety culture for different occupational groups and perceived level of responsibility, according to job function. This aspect was also explored for possible differences between mines and between occupational groups in the underground and open-cut mines.

Hypothesis 4

The fourth hypothesis extends on the third hypothesis exploring possible differences in perceptions of safety issues at the supervisor (deputy) level (Harvey et al., 1999; Clarke, 1999; Arboleda et al., 2003) and other occupational groups

(Cox & Cheyne, 2000) in the context of perceived responsibility for safety. Task 2 of the focus groups asks participants to make comment on whom they believe is responsible for safety. Possible differences between open-cut and underground mines were explored.

Hypothesis 5

A fifth hypothesis postulated that management commitment, individual responsibility, safety systems and procedures, communication, and the prioritisation of safety and production were identified as critical factors of safety culture from questionnaires administered across a sample of underground and open-cut coal mines in Australia, providing that these safety issues were identified in the focus groups. We expect that if the questionnaire reliably assesses the safety culture of the Australian coal mining industry then the critical safety issues found in the focus groups would be identified as critical factors in the questionnaire. However, critical factors identified by questionnaire measurement are partly an artefact of questionnaire design (Williamson, Feyer, Cairns, & Biancotti, 1997). As such, one would only expect to derive factors from the questionnaire that are adequately assessed. Since the questionnaire used in this study has only one question relating to training and one question for environmental risk, it is suggested that these factors will not be found as critical factors of safety culture by the questionnaire. They may however be identified as sub-components of other factors. Management commitment, individual responsibility, safety systems and procedures, communication, and the prioritisation of safety and production are incorporated (to differing degrees) into the questionnaire used in this study and therefore are expected to be identified as critical factors of safety culture. Again no differences were expected between the critical safety issues in the underground and open-cut coal mines, as Pitzer (1998) found only slight differences in safety culture of underground and open-cut mines in the minerals industry as a whole.

Hypothesis 6

Due to the context-specific nature of safety culture, it is additionally possible that factors not identified in the literature review may be identified in the focus groups as critical factor of safety culture in the mining industry.

Hypothesis 7

It is further hypothesised that no difference will be identified between the frequency of critical safety issues (in the focus groups, task 1 of the focus groups, and the questionnaire) in the underground and open-cut coal mines. Supporting this hypothesis is the findings of Pitzer (1998) where only slight differences in safety culture were identified between underground and open-cut mines in the minerals industry as a whole. Further supportive of this hypothesis is that the mines involved in this study are situated in the same region.

5.6 Overview

The role of safety culture in the causation of accidents within High Reliability Industries (HRIs) such as aviation, transport, off-shore oil platforms, and coal mining continues to be a source of investigation on an international scale. On a national level, large amounts of resources are dedicated to improving safe work practices and policies within the Australian coal mining industry on an annual basis. Investigation reveals this commitment has not yet produced a consistent reduction in the annual number of accidents, injuries, and fatalities. Research has identified safety culture to be comprised of three subcomponents: the psychological, behavioural, and situational elements of safety culture hold a critical role in maintaining the safety and efficiency of HRI operations. Safe outcomes are dependent upon a positive safety culture across the entire workforce. Identification of the critical factors contributing to safety culture (at individual mines, on a national level, and on an international scale) enables the development of innovative error prevention strategies at both the individual and organisational level. These factors such as employee perceptions of management commitment to safety, individual responsibility, the balance between production and safety, training, risk-taking, and communication may be specific to individual organisations, or common across industries and nations, or a combination of both. Mine worker's perceptions regarding safety and responsibility have become vitally important in the drive to consistently lower the number of accidents and deaths that occur in the coal industry each year. This section of the report extends the comprehensive review of scientific literature contained in section 3 of the extended report (focussed on identifying critical factors contributing to safety culture across a variety of HRIs and assessing their relevance to the Australian coal mining industry) and represents the first stage of an extended research program ultimately aiming to establish a national measure of safety culture for the Australian coal mining industry.

The research (supplementary to the literature review) was conducted in two parts: Phase 1 (focus groups) and Phase 2 (questionnaire). The literature review identified a core set of critical safety factors across a variety of HRIs. Discussion of these factors and wider issues relating to safety and safety culture were incorporated into the schedule for focus groups held with a representative sample of the organisation (including all levels of the workforce: miners, supervisors, and managers) at two underground coal mines and one open cut coal mine in the Hunter Region. The focus groups served to assess the applicability of the core set of critical factors to the Australian coal mining industry. Each of the core factors identified in the literature review (management commitment, individual responsibility, environmental risk, safety systems and procedures, the prioritisation of safety and production, communication, and training) were identified in focus groups as were additional issues for each mine. Differences were further found for the frequency of safety issues across hierarchical and occupational groups (miners, deputies, managers, night miners, and trades).

Phase 2 of the research involved administration of a Safety Management Questionnaire (SMQ-1). Questionnaire packs were distributed across all levels of the workforce (including miners, supervisors, and management) at the same three mines. The response rate averaged 25.6% across the three mines involved in the research. It was hypothesised that the critical factors identified in the literature review and the focus groups would additionally be identified in the questionnaire.

Essentially this hypothesis was supported with some variation between each mine and in terms of sequence.

The study recommends, as anticipated, revision of SMQ-1 according to a forced 6-factor model as identified through statistical analysis of the questionnaire data for the three participating mines. It is further recommended questionnaire revision be considered through incorporation of the issues identified in the focus groups as a further means of creating a questionnaire that is tailored to the Australian coal mining industry. Critical factors of safety culture have been identified in Project 1: Stage 1. Further research is required to conclude Project 1 and to meet the objectives of the extended research program.

5.7 Introduction

Positive safety culture has been identified as an important determinant of organisational safety performance. Considerable debate does however surround the actual definition of safety culture and also the critical factors that contribute to a positive (or negative) safety culture. Further debate has been generated through the conceptual definition of safety climate and its differentiation to safety culture. A widely accepted definition of safety culture is that proposed by the Advisory Committee on the Safety of Nuclear Installations (ACSNI, 1993). The ACSNI definition describes safety culture as the product of values, attitudes, perceptions, skills, and behaviours from all individuals and groups within an organisation in relation to safety. The ACSNI definition purports the existence of three main components of safety culture: personal, behavioural, and situational elements, further supported by Cooper (2000). The personal element relates to the psychological factors of the workforce. The behavioural component refers to the work behaviour of employees. The situational element relates specifically to safety systems and procedures in existence within the organisation. The personal component has been described as the primary component of safety culture (Cheyne, Oliver, Tomas, & Cox, 2002; Cox & Cox, 1991; Lee & Harrison, 2000; Pidgeon, 1998) and further identified as representing the ‘safety climate’ of an organisation (Arboleda et al., 2003; Cox & Cox, 1991).

Safety climate has long been used interchangeably and mistakenly with safety culture. Research has shown safety climate to be distinct to, but not isolated from, safety culture (Mearns, Flin, Gordon, & Fleming, 1998; Mearns & Flin, 1999). Safety climate has been shown to be a part of safety culture, having been described as a snap shot of a workforce’s attitudes to and perceptions of safety at a particular point in time, providing an indication of the underlying safety culture present in the organisation (Mearns, Flin, Fleming, & Gordon, 1997 as cited in Fleming, 2003). Safety climate can be seen as ‘culture in the making’ (Guldenmund, 2000). As such identification of critical factors relating to safety culture, will also capture safety climate issues.

In light of the acknowledgement of three main components of safety culture, it is considered necessary to measure each of these components either separately or within a single design to achieve a reliable measure of an organisation’s safety culture. Separate measures would include the use of a questionnaire for the psychological component, observation or checklists for the behavioural component, and audit or inspections for the situational component of safety culture. The only scientific means by which all three components of safety culture may be examined in the one measurement is to use a questionnaire. This method would include items relating to attitudes, perceptions, behaviours, and systems/procedures components to adequately measure safety culture.

Identification of critical factors of safety culture (through scientific measurement such as questionnaires) allows organisations to target areas for safety improvements. Critical factors identified from literature reviews have traditionally been used as direction in the design of safety culture questionnaires. More recently however, researchers are incorporating an intermediate step: focus groups. Focus groups are beneficial as they indicate the context-specific critical factors of safety culture (i.e., for a particular industry or an individual mine). Focus groups however, cannot take place without initially conducting a literature review as literature reviews identify the non-specific critical factors of safety culture for discussion guides in the focus groups. The information collected from focus groups as well as that gathered in the review of empirical and theoretical literature provide substantive guidance for development of a questionnaire. Research has shown identified critical factors of safety culture may be an artefact of questionnaire design. As such the process of literature reviews and focus groups is a vital component of questionnaire design.

This research has followed the above stated steps in the development of a national measure of safety culture: (1) literature review, (2) focus groups conducted at three coal mines in the Hunter Region, and (3) adaptation of a safety management questionnaire for the Australian coal industry. This section of the extended report presents the findings from the focus groups conducted and the questionnaire administered at three Hunter Region coal mines (including both open-cut and underground) in 2003. The research has been conducted in supplementary reference to the literature review (contained in section 3 of the extended report): the findings of which are presented below.

5.7.1 Critical Factors of Safety Culture Identified in the Literature Review

A review of scientific literature, both theoretical and empirical, from a number of HRIs across a variety of nations was conducted in order to identify a set of core critical factors of safety culture. The identified factors serve as a test-bed for criteria inclusions in both the focus group discussions and the questionnaire as incorporated into the methodology of this research project. While some discrepancy was revealed in terms of factors and the ranked order of importance across the various studies reviewed, a core set of critical factors was determined (through repeated identification) as holding significant influence over and impact on safety culture in terms of development, maintenance, and change. The critical factors of safety culture identified in the literature review are presented in Table 5.3 below in order of importance (determined through frequency of identification).

Table 5.3

Critical Factors of Safety Culture Identified in the Literature Review

Ranked Order of Influence over Safety	**Critical Factor of Safety Culture**
1	Management commitment
2	Individual responsibility
3	Perceived level of risk
4	Training
5	Safety systems and procedures
6	The prioritisation of safety and production
7	Communication
8	Importance of safety
9	Risk-taking/safety behaviour
10	Environmental risk

The critical factors included in the table above are considered the ‘core set’ of factors to which comparisons and reference will be made throughout this report. The above factors relate to safety issues that contribute to safety culture. Each factor is made up of and driven by a number of sub-component issues. The sub-components will typically vary for each mine as will the ranked order of influence over safety. Expansion of the factors identified in Table 5.3 together with typical examples of their component issues is contained in Table 5.4 following.

The literature review was conducted as the theoretical stage of Project 1: Stage 1. This segment of the research was followed by the experimental stage of Project 1: Stage 1, comprised of Phase 1 (focus groups) and Phase 2 (questionnaire) conducted at three mines in the Hunter Region. The methodology

Table 5.4

Critical Factors of Safety Culture and Typical Safety Sub-component Issues

Critical Factors of Safety Culture	Sub-component Issues
Management commitment	Care and concern shown by management; safety focus; covering their backs; punishment; role modelling
Individual responsibility	Individual responsibility for safety; safety and hazard education; general awareness; responsibility for others
Perceived level of risk	Awareness of safety; hazard awareness; decision-making; pressure (production/workmates); habitual performance
Training	Training; re-training; funds allocated to training; learning outcomes; multi-skilling; experience of the instructors
Safety systems	Standard operating procedures; rules; general procedures; risk assessments; compensation systems
The prioritisation of safety/production	The balance between safety and production; work pressure; pressure to take risks; manning; fatigue; the cost of safety
Communication	Communication pathways; the delivery of messages; flow of communication; open channels for feedback
Importance of safety	Knowledge of safety related issues; decision-making; personal prioritisation; experience; past safety incidents
Risk-taking/safety behaviour	Risk-taking; short-cuts; pressure to take short-cuts; team dynamics; personal protective equipment; age; experience
Environmental risk	Environmental hazards; working with machinery; uneven ground; working conditions; roadways; noise; fumes; dust

and results for the experimental stage Project 1: Stage 1 is presented below. The mines are not identified during the course of this report. Rather, coded reference is made to ‘Mine A’; ‘Mine B’; and ‘Mine C’. Mines A and B are underground coal mines (UG Mine A; UG Mine B), while Mine C is an open-cut mine (OC Mine C).

5.8 Phase 1: Focus Groups

The critical factors probed for in safety culture questionnaires have typically been based solely on literature reviews, however a number of researchers in recent studies have utilised focus group sessions as an intermediate step in questionnaire development (Cox & Cheyne, 2000; Lee, 1998; Lee & Harrison, 2000; Mearns et al., 2001). Focus groups are used in addition to literature reviews to ensure the critical safety issues specific to the organisation are identified (and included in the questionnaire). Focus groups are also considered to be beneficial as they involve the workforce in the creation of a questionnaire, creating a sense of ownership for the measurement tool among employees (Cox & Flin, 1998). This research involved focus groups being conducted on-site by The University research team at each of the participating mines: the details of which are outlined below. Note: where present, the miscellaneous category was comprised of minor issue that were mentioned less than 5% of the time which further did not related to a larger (or more common) factor category.

5.8.1 Phase 1: Method

5.8.1.1 Participants

Focus groups were held at each of the three Hunter Region coal mines participating in the study: six focus groups were held at UG Mine A with 36 participants; five focus groups were held at UG Mine B with 28 participants; a single focus group was conducted at OC Mine C with 5 participants. This combined sample typically included representation from mine workers (day, afternoon, and night shift) on-site, injured workers, tradesmen, maintenance staff, deputies, under-managers, middle and executive management. Participants were recruited internally through expressions of interest. Participation was voluntary, anonymous, and all information was treated as confidential by the research team: participants were further asked not to discuss the session, individual comments, or arising general issues with others. Groups were collated with the assistance of the safety training coordinator following the guidance of Cox and Cheyne (2000) where each group consisted of individuals within the same occupation category in order to promote open discussion.

5.8.1.2 Materials

Information statements were distributed and discussed with participants prior to formal commencement of the session, which included information on the aims and objectives of the project together with ethical information such as privacy, use of the data, and feedback. The focus group sessions were audio-tape recorded for transcription purposes which supplemented written notes taken throughout each session. Pens and paper were also given to each participant for completion of two written tasks near the end of the session.

5.8.1.3 Procedure

Each focus group contained a small number of participants (approximately 6-10 individuals per group). Groups were limited to a small number to enable greater ease of conversation within the allocated time. Only those individuals at a similar level of seniority (occupational group) were assigned to the same focus group, in order to further enable (and encourage) open discussion (Cox & Cheyne, 2000). Initially, participants were introduced to the research team and an overview of the project and session procedures was discussed. Participants were informed of their ethical rights such as the right to withdraw from participation in the focus group ay any stage without giving a reason and free from consequence. Further details were contained in the information statement of which participants retained a copy. Each focus group lasted approximately 90 minutes where the discussion was audio-tape recorded to supplement written-notes for transcription purposes. The quality control and transcription purpose of the audio-taping and note-taking was explained to participants. Further, it was explained that no identifying information would be recorded or transcribed into the results, and that once the tapes had been transcribed they would be erased.

Each focus group was facilitated by the University research team. Participants were asked to discuss a number of topics surrounding the central theme of safety and safety culture. An example of discussed topics include:

1. What are the requirements for a positive safety culture?
2. What behaviours should managers display to demonstrate they are committed to safety?
3. What do you believe the critical factors contributing to safety are?
4. How can safety be effectively managed?
5. What are some positive safety initiatives at your location?

Participants were lead into discuss by some thought provoking statements relating to the above and typically a request for someone to make a comment to start the discussion. The focus group discussion was primarily self-run with the facilitator interjecting only to clarify an issue, end discussion of a well-addressed topic in order to move onto another topic, to ask for consensus or disagreement on an issue, and to include the more passive members of the group.

Nearing completion of the focus group session, participants were asked to complete two written tasks: each task took up to 5 minutes to complete. For Task 1, participants were asked to write down on a piece of paper what they personally perceived as the top 5 most important safety issues at their mine. For Task 2, participants were asked to write down who they believed held the top 3 levels of responsibility for safety in terms of job function.

Each focus group concluded with a summary of the key issues discussed during the session and information was provided on the continuing research program. Participants were thanked for their involvement and advised of feedback time availability and processes. Participants were further informed that participation in this phase of the research did not obligate them to participate in supplementary phases of the research: however participation was not limited or restricted to one phase of the project.

5.8.2 Phase 1: Results

Focus group discussions were transcribed (from written notes and audio-tape recordings) categorically in order to identify frequency of certain topics and those critical factors of safety culture identified in the literature review. The topics were further ranked order of importance according to the frequency distribution. Similarly, the data obtained from Task 1 and Task 2 in the focus groups was analysed according to frequency. The findings for each mine are presented in the following sections.

5.8.2.1 Critical Factors Identified for UG Mine A

The following section presents the findings of the focus group discussions and the two written tasks held at UG Mine A with 36 participants from a range of occupational groups.

5.8.2.1.1 Focus Group Discussions

Table 5.5 below presents a summary table of the safety issues discussed during the focus groups conducted at UG Mine A. The table indicates the ranked order of importance of factor categories in terms of frequency of discussion. Please refer to Table 5.4 for typical examples of the sub-components of the factor categories included in Table 5.5.

Table 5.5

Critical Factors of Safety Culture Identified from Focus Group Discussions Held at UG Mine A

Factor Category	Frequency	Percentage
Safety/production	108	25%
Management commitment	65	15%
Safety systems & procedures	56	13%
Communication	53	12%
Training	49	11%
Individual responsibility	39	9%
Risk-taking/safety behaviour	36	8%
Environmental risk	26	6%

5.8.2.1.2 Focus Group Task 1

Task 1 of the focus group asked participants to identify the top 5 critical issues of safety and safety culture at their mine. Following (Table 5.6) is a summary table of the findings for this task at UG Mine A. The table presents the identified critical factors in the ranked order of importance (as determined by participant written responses). Contained in Table 5.4 are sub-component expansions of the factor categories included in Table 5.6 for further reference.

Table 5.6

The Top 5 Critical Factors of Safety Identified from Focus Group Task 1 at UG Mine A

Factor Category	Frequency	Percentage
Safety/production	22	17%
Environmental risk	22	17%
Individual responsibility	20	16%
Training	17	13%
Management Commitment	13	10%
Communication	12	9%
Safety systems/procedures	9	7%
Risk-taking/safety behaviour	4	3%

5.8.2.1.3 Focus Group Task 2

Table 5.7 following presents the summary findings of Task 2 of the focus groups held at UG Mine A. Task 2 relates to participant perceptions of who is responsible for safety in terms of job function. The data has been divided into responses according to occupational group.

Table 5.7

The Top 3 Levels of Responsibility for Safety Identified from Focus Group Task 2 at UG Mine A

Responsibility Level	Miners	Trades	Staff	Deputies
1	Management	Individual	Individual	Management
2	Individual	Management	Middle Management	Everybody
3	Middle Management	Miscellaneous	Management	Individual

5.8.2.2 Critical Factors Identified for UG Mine B

The following section presents the findings of the focus group discussions and the two written tasks held at UG Mine B with 28 participants from a range of occupational groups.

5.8.2.2.1 Focus Group Discussions

The safety issues discussed during the focus groups held at Mine B have been collated in terms of frequency as presented in Table 5.8 following. The factor categories are essentially ranked in order of perceived importance: weighted from the discussion. Refer to Table 5.4 for typical factor category expansions. Note the vast majority of safety issues (factor categories) revealed in focus group discussions at UG Mine A (Table 5.5) have also been identified as critically important from focus group discussions at UG Mine B: while some variance is evident for ranked order.

Table 5.8

Critical Factors of Safety Culture Identified from Focus Group Discussions Held at UG Mine B

Factor Category	Frequency	Percentage
Safety/production	58	12%
Safety systems & procedures	55	11.5%
Training	51	10.5%
Management commitment	50	10%
Litigation	41	8.5%
Risk	40	8%
Shift issues	36	7.5%
Personal limitations	34	7%
Communication	32	6.5%
Reduction of the workforce	27	5.5%
Environment	27	5.5%
Safety equipment	26	5%

5.8.2.2.2 Focus Group Task 1

Identification of the top 5 critical issues of safety was the focus of the first written task of the focus groups conducted at UG Mine B. Table 5.9 following presents a summary of those safety factors identified as critically important by participants, ranked in order of importance according to a frequency analysis of the data. Factor category expansions are contained in Table 5.4 for guiding reference. Note the similarity between the responses for UG Mine B (Table 5.9) and the responses for UG Mine A (Table 5.6). Additional factors have also been identified for UG Mine B not included in the original core set of critical factors identified from the literature review (contained in Table 5.3) indicating preliminary context-dependent variables have been identified for UG Mine B.

Table 5.9

The Top 5 Critical Factors of Safety Identified from Focus Group Task 1 at UG Mine B

Factor Category	Frequency	Percentage
Training	90	25%
Safety attitudes	40	11%
Safety systems/procedures	38	10.5%
Management commitment Reduction of workforce / Job security	32 32	9% 9%
Safety equipment	30	8%
Personal limitations	21	6%
Safety/production	20	5.5%
Communication Shift (length/type)	16 16	4.5% 4.5%
Environmental Risk	14	4%
Risk	6	2%
Litigation	4	1%
New mining procedures	2	0.5%

5.8.2.2.3 Focus Group Task 2

Data was gathered from focus group participants at UG Mine B in a second written task where perceptions of the top 3 levels of responsibility for safety were recorded. Table 5.10 following presents the summary findings of focus group task 2, divided into responses according to occupational group. Where more than one position is listed in the same row of the table, this indicates even weighting was given, for example under-managers in this sample held the perception that the individual and management equally hold the first level of responsibility for safety. The similarity of responses is evident between UG Mine A and UG Mine B for this task as is the prevalence of the role of the individual in safety management.

Table 5.10

The Top 3 Levels of Responsibility for Safety Identified from Focus Group Task 2 at Mine B

Level of Respon-sibility	Under-managers	Production (Day)	Eng. Team Leader (day)	Production & Trades (Afternoon)	Deputies
1	Individual / Management	Individual	Management	Individual	Individual
2	Supervisors	Under-manager	Individual	Management	Under-manager / Deputies
3	--	Management	Other	Under-manager	--

5.8.2.3 Critical Factors Identified for OC Mine C

The following section presents the findings of discussions held OC Mine C with 5 participants as part of a single focus group. The findings from the two associated written tasks are also presented.

5.8.2.3.1 Focus Group Discussions

Table 5.11 following presents a summary of the safety related issues discussed during the focus group held at OC Mine C. The discussed factor categories have been collated in terms of frequency, as such they are presented in order of importance as determined by weightings from participant discussion. For reference, expansions of typical sub-components of the factor categories are presented in Table 5.4. Note this sample did not include representation from management. Similarity between OC Mine C and UG Mines A and B are again evident in the focus group discussions and the core set of critical factors of safety culture identified in the literature review (Table 5.3). Similarity also exists between the additional factors (outside the core set) identified for OC Mine C and those context-dependent factors identified at UG Mine B: suggesting these additional factors may not necessarily be domain (OC and/or UG) specific and highlighting an area for further investigation.

Table 5.11

Critical Factors of Safety Culture Identified from Focus Group Discussions Held at OC Mine C

Factor Category	Frequency	Percentage
Management commitment	18	14%
Safety systems/procedures	14	11%
Shift type	13	10%
Safety equipment	13	10%
Safety attitudes	13	10%
Safety/production	12	9%
Personal limitations	11	8.5%
Communication	11	8.5%
Training	6	4.5%
Contractors	6	4.5%
Risk	6	4.5%
Individual responsibility	5	4%

5.8.2.3.2 Focus Group Task 1

The first written task of the single focus group held at OC Mine C asked participants to record their perceptions of the top 5 critical issues of safety at their mine. The following table (Table 5.12) presents a summary of the critical factors identified in Task 1, listed in order of importance according to a frequency analysis of the data. Factor category expansions are contained in Table 5.4 for guiding reference. The similarity between the factors identified in focus group task 1 for OC Mine C and the core set of critical factors identified in the literature review (contained in Table 5.3) is highly evident. Similarity also exists for the findings of this task at OC Mine C with the akin results from UG Mines A and B. Again it is important to note this focus group was conducted with only 5 participants from a sample which did not contain representation from individuals in managerial positions.

Table 5.12

The Top 5 Critical Factors of Safety Identified from Focus Group Task 1 at OC Mine C

Factor Category	Frequency	Percentage
Production/Safety	16	21%
Individual Responsibility	14	18%
Management Commitment	12	16%
Communication	10	13%
Training Systems/Procedures	9 9	12% 12%
Risk-taking/Safety Behaviour	4	5%
Environmental Risk	2	3%

5.8.2.3.3 Focus Group Task 2

The second written task of the focus group held at OC Mine C asked participants to record their perceptions of the top 3 levels of responsibility for safety, according to job function. Table 5.13 below presents the summary findings. Results for this task were not classified according to occupational group as the sample included only 5 members of the workforce. Representation was not provided from management for this particular mine in the focus group. Once again however, the prevalence of the individual as holding first order of responsibility for safety is evident.

Table 5.13

The Top 3 Levels of Responsibility for Safety Identified from Focus Group Task 2 at OC Mine C

Level of responsibility	Job Function	Frequency	Percentage
1	Individual	15	48%
2	Management	8	26%
3	Workmates	7	23%

5.8.2.4 Phase 1: Comparative Analysis

Further statistical analysis was investigated for the above data obtained from the focus group discussions, focus group task 1, and focus group task 2, for each of the three mines involved in the study to examine any differences between occupational groups. As a result of the small sample size for OC Mine C (5 participants), it was determined further comparative analysis could not be executed within the scope of the selected statistical measures. Furthermore, focus groups conducted at OC Mine C did not contain representation from managerial positions. As such the data from OC Mine C was removed from the combined data set for this particular analysis. Comparative analysis was therefore conducted only between UG Mine A and UG Mine B. Essentially, the analysis was conducted to establish whether there were differences between the levels of employment (position) and perceptions of safety issues and levels responsibility in the underground environment.

Chi square analysis (specifically the Monte Carlo exact test) was conducted on the collective Phase 1 data from UG Mine A and UG Mine B using Statistical Package for the Social Sciences (SPSS) for Windows, Version 11.5. Chi square was considered significant at the $p < .05$ level as were individual chi square contributions. The $p = .05$ level for individual chi square contributions with 1*df* equates to a value 3.84, therefore values >3.84 were considered significant and are highlighted (*) in individual component tables.

For all chi squared tests the null hypothesis was that there would be no significant difference between either position verses level of responsibility and critical factors, or the two different mines verses level of responsibility and critical factors. In each case the null was rejected. It is important to note the focus groups were a small representative sample from each mine: UG Mine A 36 participants; UG Mine B 28 participants – approximately 4-6 individuals from each occupational group. As such the following results are to be considered a guide and indicative of areas for further research.

5.8.2.4.1 Focus Group Discussions: Occupational Differences

Chi square analysis was performed on the data obtained from the transcribed, categorised focus group discussions held at UG Mine A and UG Mine B according to occupational groups.

The frequency of safety issues raised in focus groups at UG Mine A were further analysed according to different occupational groups. As there were two day/afternoon focus group sessions at UG Mine A, the scores and percentages shown for the day/afternoon group are the average of the two groups. Chi square analysis showed significant differences in frequency of safety issues across occupational groups χ^2 (32, N = 483) = 125.32, p = .00.The outcome resulted in differences in frequencies across occupational groups for the safety issues: communication, management commitment, miscellaneous, the prioritisation of safety and production, risk-taking/safety behaviour, and safety systems and procedures. Compared to other occupational groups the day/afternoon shift (from the focus group discussions) has a significantly higher than average frequency for communication and a significantly lower than average frequency for the prioritisation of safety and production as well as safety systems and procedures. Deputies had a significantly higher than average frequency for the miscellaneous category. Managers had a significantly higher than average frequency for safety systems and procedures. The night shift group had a significantly higher than average frequency for the prioritisation of safety and production as well as risk-taking/safety behaviour and a significantly lower than average frequency for safety systems and procedures. The trades group had a significantly higher than average frequency for management commitment and a significantly lower than average frequency for risk and safety behaviour. The frequency of the environmental risk, individual responsibility, and training safety issues were not significantly different across occupational groups for UG Mine A.

The critical factors identified in the focus group discussions were also analysed for UG Mine B using chi square to ascertain whether there was a significant effect of position on perceived critical factors. Once again the point of significance was 3.84. The chi square test was significant $\chi^2(76, N = 578) = 216.69$, $p = .000$. There were 17 points that reached significance indicating some form of difference caused by the interaction of position on perceived critical factors. These factors included: reduction of the workforce, risk, safety equipment, individual responsibility, management commitment, safety attitudes, training, and communication among others. Compared to other occupational groups the under-managers involved in the focus groups at UG Mine B had a significantly higher than average frequency for reduction of the workforce, risk, individual responsibility, general site issues, and those issues arising from and relating to fatality. Production workers on the day shift had a significantly higher than average frequency for reduction of the workforce, risk, safety equipment, safety systems and procedures, as well as environmental issues. Engineering staff/team leaders did not significantly differ to any other occupational group in terms of frequency of discussion of particular safety issues. The production and trades workers on afternoon shift had a significantly higher than average frequency for management, new mining methods, reduction of workforce, safety attitudes, safety equipment, and training. Deputies had a significantly higher than average frequency for the communication category. The frequency of the safety issues bonus structure, litigation, personal limitations, and shift length/type were not significantly different across occupational groups for UG Mine B.

5.8.2.4.2 Focus Group Task 1: Occupational Differences

For the focus group task 1, chi square analysis revealed several critical factors identified in the written task reached a level of significance at the .05 level for both UG mines, further revealing several differences between occupational groups on responses for this task.

Chi square analysis of the focus group task 1 data for UG Mine A showed a significant difference in frequency of safety issues across occupational groups $\chi^2(32, N = 128) = 54.40$, $p = .00$. The analysis shows that compared to other occupational groups, the day/afternoon shift group had a significantly higher than average frequency for the miscellaneous category. Management had a significantly higher frequency for safety systems and procedures and the night shift group had a significantly higher than average frequency for risk-taking/safety behaviour. There were no significant differences in frequency of communication, environmental risk, individual responsibility, management commitment, the prioritisation of safety and production, and training safety issues across occupational groups at UG Mine A.

The written critical factor data obtained from task 1 of the focus group for UG Mine B was also analysed using chi square to ascertain whether there was any significant effect of position. The chi square test was significant $\chi^2(52, N = 363) = 283.36$, $p = .000$. There were 25 individual chi square cells that reached or exceeded the significance point of 3.84. These factors included safety equipment, shift length/type, safety systems and procedures, training, and the reduction of the workforce among others. Compared to other occupational groups the under-managers involved in the focus groups at UG Mine B for task 1 had a significantly higher than average frequency for environmental issues, risk, safety attitudes, and safety systems and procedures. Production workers on the day shift had a significantly higher than average frequency for communication, safety attitudes, safety equipment, as well as safety systems and procedures. Engineering staff/team leaders had a significantly higher than average frequency for litigation, reduction of the workforce, safety equipment, shift length and type, as well as safety systems and procedures. The production and trades workers on afternoon shift had a significantly higher than average frequency for management commitment, safety equipment, shift length/type, and training. Deputies had a significantly higher than average frequency for new mining methods, personal limitations, the prioritisation of safety and production, as well as safety equipment and a significantly lower than average frequency for the safety issue of training.

5.8.2.4.3 Focus Group Task 2: Occupational Differences

For task 2 of the focus group, written responses for perceived level of responsibility for safety were scored as follows: 3 for the first recorded level of responsibility, 2 for the second recorded level, and 1 for the third recorded level of responsibility. In situations where the individual wrote four levels of responsibility; last two responses were scored 0.5. The main categories of responses were typically recorded and individual, management, middle management, workmates, everybody, and an ‘other’ category. The other category was made up of those responses recorded less than 5% of the time including such positions as the safety training co-ordinator, engineers, and shareholders. The collective responses were again analysed with the chi square method according to occupational groups.

Responsibility for safety according to job function was separated according to occupational group for UG Mine A. Chi square analysis on the responsibility of safety according to job function across occupational groups was significant χ^2 (20, *N* = 215) = 32.66, *p* = .02. Individual chi square contributions appear in Table D1 (contained in Appendix D) and show that compared to other occupational groups deputies had a significantly higher than average frequency for the 'everybody' job function and trades had a significantly higher than average frequency for the 'other' job function. No other response reached significance at the 3.84 level for other occupational groups.

The data obtained from focus group task 2 at UG Mine B was also analysed using chi square, to test whether position had a bearing on perceived levels of responsibility. Chi square analysis revealed a significant effect of position verses levels of responsibility χ^2(28, N = 169) = 36.86, p = .049. Individual chi square contributions appear in Table D2 (contained in Appendix D) and show that compared to other occupational groups engineering team leaders had a significantly higher than average frequency for the 'other' job function and deputies had a significantly lower than average frequency for the 'management' job function. No other response reached significance at the 3.84 level for other occupational groups.

5.8.3 Phase 1: Discussion

Examination of the combined focus group data from UG Mine A, UG Mine B, and OC Mine C reveals the following safety critical issues common to all mines involved in this phase of the research: management commitment, the prioritisation of safety and production, training, safety systems/procedures, communication, and environmental risk. In addition for at least two of the sample mines individual responsibility and risk-taking/safety behaviour also rated highly in frequency analysis of the combine focus group data set. The following issues were also drawn out of the focus groups at one mine: safety attitudes, reduction of workforce/job security, safety equipment, personal limitations, and shift issues.

As evident a core set of critical factors of safety culture is emerging from the focus groups and the review of the literature relevant to the Australian coal mining industry. This core set has remained largely invariant from Table 5.3, however it is of importance to note that the ordering/ranking of each factor category within that set may vary between mines. The identification of safety issues outside of this core set such as safety attitudes, job security, and so forth highlights the existence of context-dependent variables. Just as it is reasonable to expect variance surrounding the order of importance of the core set of critical factors, it is reasonable to anticipate relevant additional factors will be identified for each mine: divergence may be the result of differing safety systems and procedures, managerial strategies, workforces, safety incidents, and at an underlying level, differing climate and culture issues. For example restructuring may necessarily result in reductions in the workforce (as evident at UG Mine B at the time of the focus groups) signifying job insecurity would understandably be an issue of concern at that period in time.

The first hypothesis, that management commitment, individual responsibility, environmental risk, safety systems and procedures, training, the prioritisation of safety and production, and communication would be identified as critical safety issues in the focus groups sessions at the underground mines (UG Mine A and UG Mine B) and the open-cut mine (OC Mine C) involved in this research was supported. Additional critical factors contributing to safety and safety culture were further identified as presented above. The second hypothesis that management commitment, individual responsibility, environmental risk, safety systems and procedures, training, the prioritisation of safety and production, and communication would be identified as critical safety issues in focus group task 1 at UG Mine A, UG Mine B, and UG Mine C was also supported. This suggests that the core critical factors of safety culture identified in several other industries (as presented in Table 5.3) are applicable to both underground and open-cut domains within the Australian coal mining industry. Due to the small sample sizes involved in the focus groups (and the pilot nature of Project 1: Stage 1) this generalisability is not to be considered a certainty at this stage of the research. It does however provide clear direction for extension of the research program, preliminary support for research objectives, and support for the factor structure of the safety management questionnaire (SMQ) employed during Project 1: Stage 1: Phase 2. Furthermore, analysis of the critical factors of safety and safety culture identified in both the focus group discussions and task 1 of the focus group revealed several context dependent critical safety issues, specific and limited to each individual mine. While this was anticipated, further research is required to examine the extent of influence and generalisability of these context-dependent variables. The latter part of hypothesis 2 was only supported in part. It was anticipated identical safety issues would be identified from the focus group discussion and focus group task 1. While the safety issues were essentially repeated in the discussion and the task 1, some variation did occur in terms of frequency according to each factor category.

Similar to the debate that critical factors identified through questionnaire measurement may be an artefact of questionnaire design (Williamson et al., 1997), critical factors identified through focus group discussions may reflect the perceptions of dominant group members (Cox & Cheyne, 2000). For this reason, Task 1 was incorporated into the focus group as a quality control mechanism and it is recommended for subsequent focus group studies. As presented, high levels of similarity of frequency of discussion and identification of certain critical 'factor categories' of safety culture occurred for each of the three mines. Task 1 has also been included as an open-ended question in the SMQ. Further quality control and correlation assessment of this will be conducted during Project 1: Stage 2 with analysis of the data collected from the revised SMQ: SMQ – 2 (Safety Management Questionnaire Revised Version 2). Although the critical factors of safety identified through task 1 of the focus groups were highly similar for each of the three mines participating in the research, differences did exist between the frequency of safety issues between mines, supporting both hypothesis 3 and the findings of the Pitzer (1998) study.

Past research has further revealed individuals holding supervisory level positions differ in their perceptions of safety issues to the wider workforce. Comparisons of this nature were not permissible for the OC Mine C due to the small sample size (5 participants) and the lack of supervisory/managerial personnel participating in the focus group. Comparison based on not only supervisory distinction but across all occupational groups was able to be conducted between UG Mine A and UG Mine B. As presented, the findings did indicate some differences between safety attitudes and perceptions amongst occupational groups. For UG Mine A differences in frequency between the focus group discussions and task 1 were found between all occupational groups (as presented in Tables B1 and C1). The same is true for all occupational groups in the UG Mine B sample (as presented in Tables B2 and C2). Further investigation of this will be carried out in the continuing stages of the research: larger sample sizes will assist with greater reliability of such analysis. While differences were noted between occupational groups, great similarity also existed, as presented, between the UG mines. Furthermore, identified safety issues continued to reflect the core set (Table 5.3) of critical factors identified in the literature review for each of the mines.

Differences in responsibility for safety according to job function also differed between the mines providing support for the fourth hypothesis. Comparative power (between the three mines) was reduced due to the low sample size (and limited representation) of OC Mine C. Irrespectively, the prevalence of the critical role of the individual in safety management and the frequent identification of the individual as the first level of responsibility for safety was evident.

The structure in the open cut industry was under represented: one focus group with no management inclusion. Future stages of the research program will endeavour to involve more representative samples from each of the mines involves from both domains of the Australian coal mining industry.

The final undertaking for Project 1: Stage 1: Phase 1 was to ensure all critical factors of safety and safety culture identified during the collective focus group process were represented in the SMQ. It was determined the majority of those context-dependent variables identified for the individual mines which did not fit within the existing factor structure of the questionnaire would not be specifically included in the SMQ at this stage of development. The small nature of their inclusion (< 5%) did not statistically warrant inclusion. It was determined (prior to the commencement of extensive SMQ modification) to include an open-ended section in the questionnaire including a section seeking additional comments as a continuing quality control process. Should the context-dependent additional factors arise again in the SMQ, there is scope for inclusion in future iterations of the questionnaire. In order to provide further guidance for the future development of this research program it is essential the main elements of safety culture (behaviours, attitudes, values, and perceptions) are examined. As previously stated focus groups provide strong indication of such forces and associated factors. It is essential additional research examines safety specific behaviours, attitudes, and perceptions of the workforce and management of the mines involved in this research across an extended sample of the workforce as the next stage after the focus groups. This will also occurs in the current research through administration of a safety management questionnaire.

5.8.4 Phase 1: Summary

In summary, the focus groups collectively confirmed the core set (see Table 5.3) of critical factors identified in the literature review for each of the mines. Although individual work groups within specific mines may differ strongly on the emphasis for each of the factors identified. The purpose of the focus group was to search for commonalities rather than for difference, in that this process has been successful in confirming what the literature suggests.

The second point dealt with the issue of structure of responsibility for safety within a mine. In relation to responsibility for safety at their mine, the data is contained in Tables 5.7, 5.10 and 5.13 for each of the mines. The data is not additive but overall one can conclude that the participants within the focus groups do understand that they are personally responsible for their own safety. However, there is some minor degree of confusion where some workers suggest that management has that primary responsibility.

5.9 Phase 2: Safety Management Questionnaire

Identification of critical factors contributing to safety culture through the methodological process of reviewing the scientific literature followed by focus groups and the administration of a questionnaire is common of recent researchers in this field (Cox & Cheyne, 2000; Lee, 1998; Lee & Harrison, 2000; Mearns et al., 2001). This research (Project 1: Stage 1: Phase 2) serves to develop an Australian national measure of safety culture: a process of scientifically revising and refining an existing questionnaire based on the factor categories identified in the literature and the focus groups (held at a sample of coal mines within Australia) and the emerging factor structure. This research involved the administration of a Safety Management Questionnaire (SMQ) to all levels of the workforce at three participating coal mines in the Hunter Region, NSW: the details of which are outlined and discussed in the following sections.

5.9.1 Phase 2: Method

5.9.1.1 Participants

The SMQ was distributed across the entire work force at each of the three mines participating in the study. All levels of the workforce were invited to participate by completing the questionnaire including mine workers (covering all shifts/crews), supervisors, and management. Of the 266 employees at UG Mine A, 50 questionnaires were returned indicating a response rate of 18.8%. Participants from UG Mine A held an average age of 48.04 years. At UG Mine B, 35 questionnaires were returned from the 165 employees, indicating a response rate of 21.2%. The average age of participants from UG Mine B was 46.25 years. Of the 170 employees at OC Mine C, 63 questionnaires were completed and returned indicating a response rate of 37%. Respondents from OC Mine C had an average age of 42.75 years. Demographic information according to gender was not recorded as the collective sample was entirely male with the exception of approximately 5 females at OC Mine C. Recording gender would therefore have potentially risked identification of females. Furthermore due to such an overwhelming majority of males in the sample, analysis according to gender would not have contributed any additional information of value due to the skewed sample.

5.9.1.2 Materials

The Safety Management Questionnaire (SMQ) was originally developed in the off-shore oil platform industry in Scotland by international project collaborator Dr Mark Fleming and colleagues at Aberdeen University, Scotland (see Mearns et al., 2001 for full details). This measurement tool was developed to assess safety related behaviours, attitudes, and perceptions across all levels of the workforce in a safety critical domain. The SMQ was originally developed on a 9-factor model measuring the following factors of safety and safety culture: (1) management commitment, (2) risk-taking/safety behaviour, (3) production/safety, (4) systems/procedures, (5) individual responsibility, (6) communication, (7) training, (8) environmental risk, and (9) general safety. The University of Newcastle Human

Factors Group modified the SMQ for the Australian coal mining industry (particularly certain terminology), retaining the above stated 9-factor model structure. Furthermore a total of 16 questions were added to the original SMQ due to the findings of the focus group sessions: this number was determined as reasonably sufficient so as to not interfere with the reliability of the tool. Further variation will occur as the tool is refined throughout Project 1: Stage 2.

The SMQ utilised in this research contained 65-items asking participants to respond according to a 5-point Likert scale (such as Fully Agree, Partially Agree, Neither Agree nor Disagree, Partially Agree, and Fully Agree). The SMQ contains four sections: (1) 'Demographics' – requesting general information such as regular shift, age, job category, and years of experience; (2) 'Your Job' - comprised of 18 questions relating to safety behaviours; (3) 'Safety Culture' - comprised of 47 questions relating to various aspect of safety culture including attitudes, values, and perceptions; and (4) 'Open-ended' – providing an opportunity for respondents to provide qualitative information such as improvement suggestions, personal perceptions of the top 5 critical factors of safety, and make any desired additional comments.

5.9.1.3 Procedure

Notification of the administration of the questionnaire occurred over a two-week period prior to distribution: information flyers were placed on-site; notices were included in company newsletters and/or internal memos (where available); pre-shift on-site briefings were held with the workforce; briefings were held with management, employee reps, and members of the relevant safety committees. The anonymous and confidential nature of the research was emphasised and the invitation to participate was extended to all levels of the workforce (mine workers, supervisors, and management). Questionnaire packs were distributed (primarily through internal mailing systems/pigeon-holes) across the entire workforce that contained a questionnaire pack summary sheet, a project information statement (providing information such as research ethics, use of the data, privacy, and feedback), the safety management questionnaire (SMQ), and a reply-paid envelope addressed to the research team. Collection boxes were also placed on-site as an alternate means of returning completed questionnaires to the University research team.

Individuals who participated in the focus groups were not obligated to participate in the questionnaire phase of the research: however, there was no restriction for participation. All members of the workforce were invited to complete the questionnaire. Personal identifiers (such as name or employee number) were not sought from respondents for the anonymous written questionnaire. The SMQ took approximately 20-25 minutes to complete. Response rates for each mine are as outlined in section 5.9.1.1.

Questionnaire responses occurred mainly within the first 3 weeks from the time the questionnaire packs were distributed at each of the 3 participating mines. The bulk of responses were returned to the University research team within the first 7-10 days. Questionnaire responses were coded and the data entered into a database in SPSS for Windows Version 11.5. The responses and the psychometric properties of the test were analysed through Factor Analysis, primarily Principle Component Analysis. Factor structures were identified and the forced factor models produced identify not only a preliminary indication of the critical factors contributing to the safety culture of the mine but also provide scientific guidance for further refinement and variation of the SMQ measurement tool.

At the completion of statistical analysis of the results and identification of the outcomes, de-briefing packs were compiled containing summary information of the project and the findings of the literature review as well as summary information for the results of each phase of the research for each individual mine. De-briefing sessions were held on a number of occasions presenting the information packs to management, relevant safety committees, and employee reps. On-site de-briefing sessions were also held with the workforce (where requested) and summary information drawn from the de-brief packs were distributed through company newsletters and internal memos (where available). Large posters of this summary information detailing the results of the study were further placed on-site in communal areas. The results from each particular mine were only disclosed and discussed with personnel from or associated with that particular mine. All information was treated as confidential. More widely publicised information was de-identified: neither individuals nor participating mines are identifiable. The University research team remains available to discuss the project with participants and other interested parties.

5.9.2 Phase 2: Results

Some variance of the critical factors of safety culture (in terms of the core set identified from the literature review and the focus groups) was anticipated for each mine completing the SMQ. It was further expected that not all of the factors found within the focus groups would contribute significantly to the safety culture of that mine as determined through the SMQ.

The SMQ data was analysed according to Factor Analysis, specifically Principle Component Analysis (PCA). The response rate obtained from both mines was sufficient to examine the psychometric properties of the questionnaire using PCA for this pilot study. Only those questions in the SMQ regarding safety perceptions, attitudes, and behaviours were analysed. As previously mentioned, the items are based on a Likert scale, with answers on a scale of one to five. Once the analysis was complete the factor categories of significance for each mine in relation to safety culture were evident in a preliminary form.

The factor analysis was primarily used in this pilot study to confirm the critical factors identified in the literature review and the focus groups and to illustrate how the wider factors (greater than 20) found in the focus group may load together forming sub-factors in larger factor categories (this may or may not reflect the core set of critical factors identifiable from the literature review as presented in Table 5.3). This will enable any safety initiative programs to target several specific areas of improvement and guide effective resource allocation. Continued investigation and analysis is required for the SMQ to be considered reliable and valid for an Australian coal mining industry sample (the aim of Project 1: Stage 2 and beyond). Sample sizes for each of the three mines was insufficient for full factor analysis (typically a minimum of 100 data sets is required) however, for the purpose of this pilot study, exploratory factor analysis was conducted. Data were analysed using SPSS for Windows, Version 11.5. Any missing values for the 65 variables were replaced by the mean. The findings of the statistical analysis for the SMQ (from this phase of the research) for each of the three mines involved in the research are outlined in the following sections.

5.9.2.1 Critical Factors Identified for UG Mine A

The following section presents the findings of the SMQ administered at UG Mine A with 50 participants from a range of occupational groups. Descriptive information was collected for UG Mine A as part of the analysis. The average age of SMQ respondents was 48.04 years. Average years working for employer, at site location, and in industry was 14.65, 17.57, and 24.85 years respectively. The majority of respondents were mine workers 53.2% of which 56% were morning shift workers, 17% were afternoon shift workers, and 27% were night shift workers. Trades workers further contributed 17% of responses, supervisors 17%, managers 6.4%, and miscellaneous category 6.4% (including those who failed to respond to this item). There were no contractors among respondents: all were company employees. The proportion of respondents that were not supervisors was 66%, 14.9% indicated they did hold a supervisory position but provided no details, 12.8% were deputies, and 6.4% were managers. Of the participant group, 78.7% of respondents indicated they had a past lost-time injury and 21.3% had not. Average number of lost-time injuries in the last two years was 0.13 per worker and average number of injuries while working for the company was 2.11. When asked who initiated the most serious personal accident, 42.6% of participants indicated they were personally responsible, for 29.8% of participants the question was not applicable, 10.6% stated a crewmember was responsible, 10.6% noted environment responsibility, and a respective 2.1% replied either system, supervisor, or work group member caused the accident. For the seriousness of the injury measured in days off work the question was not applicable to 38.3% of participants, 29.8% had 1-10 days off work, 17% had 10-30 days off work, and 13.9% had greater than30 days off work due to the injury. The main causes of the accidents noted were: working conditions 27.7%, equipment 17%, individuals 12.8%, rushing 6.4%, bad luck 4.3%, manning 2.1%, and multiple reasons 2.1%. This question was not applicable to 27.7% of questionnaire respondents from UG Mine A.

Principle component analysis (PCA) was conducted on the SMQ data for UG Mine A. This analysis enabled preliminary identification of the critical factors of safety culture (as identified from SMQ responses) for that particular mine. PCA for the 65 variables in the UG Mine A (section 2 'Your Job' and section 3 'Safety Culture' of the questionnaire) revealed 18 factors with eigenvalues of over 1.00 which described 82.88% of the variance. These 18 factors were further reduced to a forced six-factor category model which explained 53.22% of the variance. The rotated component matrix for the six-factor model is shown in Table E1 (contained in Appendix E). Individual questions were categorised according to the safety issues found in the focus groups and the literature review. Each question/item in the SMQ was designed (and modified where necessary) to probe for specific factors. Note that some questions were thought to probe more than one factor. It is recommended these questions be removed for the second iteration of the questionnaire.

The questions that loaded on to factor 1 were primarily questions relating to risk and safety behaviour (5 out of 6 questions that loaded only on factor 1 and 10 out of 16 questions that loaded onto factor 1 and others). The questions that loaded onto factor 2 were primarily questions relating to management commitment (3 out of 4 questions that load only onto factor 2 and 8 out of 15 questions that loaded onto factor 2 and others). The questions loading onto factor 3 were again questions relating to management commitment, but more specifically supervisor commitment (6 out of 6 questions that load only onto that factor and 9 out of 13 questions that loaded onto factor 3 and others). The questions that loaded onto factor 4 were questions mainly relating to individual responsibility (3 out of 4 questions that load only onto that factor and 4 out of 9 questions that loaded onto factor 4 and others). The questions that loaded onto factor 5 were questions mainly relating to communication (2 out of 4 questions that loaded only onto that factor and 3 out of 6 questions that loaded onto factor 5 and others). The questions that loaded onto factor 6 were questions mainly relating again to risk/safety behaviour (3 out of 4 questions that load only onto factor 5 and 4 out of 5 questions that load onto factor 6 and others).

Statistical revision of the forced six-factor model (in terms of questions which loaded on one factor only) revealed three main factor categories (management commitment, individual responsibility, and communication) to be the statistically significant critical factors of safety culture at UG Mine A as presented in Table 5.14 below.

Table 5.14

Critical Factors of Safety Culture Identified from Pilot SMQ Administration at UG Mine A

Factor Category	**Ranking**
Management commitment	1
Individual Responsibility	2
Communication	3

5.9.2.2 Critical Factors Identified for UG Mine B

The following section presents the findings of the SMQ administered at UG Mine B with 35 participants from a range of occupational groups. Descriptive information was collected for UG Mine B as part of the analysis. The average age of SMQ respondents was 46.25 years, 12.1% were aged below 40, 54.6% were aged between 40 and 50, while 33.3% were aged over 50. The average number of years working for employer was 8.73, at the site location was 15.08, and in the industry was 22.53 years. The majority of respondents were mine workers 41.7% of which 50% were morning shift workers, 16.7% were afternoon shift workers, and 30.6% were night shift workers. Management further contributed 13.9% of responses, fitters 11.1%, trainees/apprentices, supervisors, and electricians each further contributing a respective 5.6%, and engineering, employee services, purchasing officers, mine surveyors, trades, and maintenance each further contributing 2.8% respectively of the responses. There were no contractors among respondents as all were company employees. The proportion of respondents that were not supervisors was 63.9% 36.1% stated they held a supervisory position. Of the participant group, 88.9% of respondents indicated they had a past lost-time injury and 11.1% had not. The average number of lost-time injuries in the last two years was 0.11 per worker and average number of injuries while working for the company was 1.23. When asked who initiated the most serious accident associated with a lost-time injury, 38.9% of respondents indicated production issues such as manning and rushing was the cause, 30.6% indicated machinery and other workplace hazards, 22.8% indicated not following procedures personally, 5.6% indicated a workmate not following procedures, and 2.8% failed to respond. In relation to general accidents (not necessarily lost-time injuries)

55.6% of respondents stated they were personally responsible, 38.9% did not respond, and 5.6% said crewmember was responsible for the accident. For the severity of the accident 38.9% of respondents recorded no injury, 38.9% indicated the accident was moderate, 11.1% severe, 5.6% lingering, and 5.6% permanent for respondents at UG Mine B.

Principle component analysis (PCA) was conducted on the SMQ data for UG Mine B. This analysis enabled preliminary identification of the critical factors of safety (as identified from SMQ responses) for that particular mine. PCA for the 65 variables in the UG Mine B (section 2 'Your Job' and section 3 'Safety Culture' of the questionnaire) revealed a 12-factor structure. These 12 factors were further reduced to a forced seven-factor category model which explained 78.901% of the variance. The rotated component matrix for the 12-factor model is shown in Table E2 (contained in two parts [Table E2A and Table E2B] within Appendix E) and a summary of the rotated component matrix for the seven-factors model is shown in Table E3 (also contained in appendix E).

In reducing the factor model from 12 factors to 7, risk-taking/safety behaviour was identified as the most loaded factor from the SMQ: it contained the entire of factor 1 from the 12-factor model. Management commitment (containing factors 2, 3, and 8 from the 12-factor structure), including a communication sub-group, was the second most loaded factor followed by the safety/production balance (factor 4 of the 12-factor model), incident reporting (factor 5 of the 12-factor model), safety systems (factor 6, 7, and 10 of the 12-factor model), communication (factor 9 of the 12-factor model), and individual responsibility (factor 12 of the 12-factor model), giving seven factors in total for the underground mine. These factors together contributed 78.901% of variance.

In summary, each of the seven factors identified for UG Mine B were found to be of statistical significance in terms of their contribution to safety culture for that particular mine. These factors, as presented in Table 5.15 following, were: risk-taking/safety behaviour, management commitment, the prioritisation of safety and production, incident reporting, safety systems, communication, and individual responsibility. Further revision of the underlying factor structure of the SMQ (operational during Project 1: Stage 2) will enable the connection between such factors to be examined. For example it may be that incident reporting is not considered a factor category of its own for the wider sample, but a sub-component of safety systems and procedures or other such category (incident reporting was not identified as a critical factor of safety culture at any other mine involved in this study). As such the pilot nature of this phase of the research is emphasised while preliminary insight is obtained into the critical factors of safety and safety culture for each of the three mines.

Table 5.15

Critical Factors of Safety Culture Identified from Pilot SMQ Administration at UG Mine B

Factor Category	**Ranking**
Risk-taking/safety behaviour	1
Management commitment	2
Safety/production	3
Incident Reporting	4
Safety systems/procedures	5
Communication	6
Individual responsibility	7

5.9.2.3 Critical Factors Identified for OC Mine C

The following section presents the findings of the SMQ administered at OC Mine C with 63 participants from a range of occupational groups. Descriptive statistic information was gathered from OC Mine C as part of the analysis. The average age of respondents was 42.71 years, average years working for employer, at location, and in industry was 7.38, 7.45 and 16.95 years respectively. A total of 68.5% of respondents were rotating shift workers, 16.7% were morning shift workers, 11.1% specified other shift, 1.9% were afternoon shift workers, 1.9% were night shift workers, and the remaining respondents did not provide further detail of shift or crew. The majority of respondents were miners 64.8% followed by trades people 16.7%, managers 7.4%, supervisors 5.6%, and a further 5.6% did not respond to this item contributing to a miscellaneous group. Sub-contractors represented 1.9% of the participant group while 98.1% were company employees. The proportion of respondents that were not supervisors was 85.1%, 13% indicated they were supervisors, and 1.9% were managers. Of the 63 participants, 66.7% had not had a lost-time injury and 33.3% reported they had. The average number of lost-time injuries in the last two years was 0.02 and average number of injuries while working for the company was 0.13. When asked who initiated the most serious accident, for 51.9% of participants the question was not applicable, 33.3% of participants indicated they were personally responsible, 9.3% replied other crew member, 2.1% work group member, and 1.9% indicated system responsibility. For the seriousness of the injury measured in days off work the question was not applicable to 81.5% of participants, 13% had 1-10 days off work, 1.9% had 10-30 days off work, and 3.7% had greater than 30 days off work due to the injury. The main cause of the accident was not applicable to 75.9% of participants, however for the remainder, 7.4% of respondents indicated the working conditions, equipment 3.7%, rushing 6.4%, tiredness/fatigue 3.7%, experience (or lack there of) 1.9%, the individual 1.9%, and manning 1.9% for SMQ respondents at OC Mine C.

Principle component analysis for the 65 variables in the OC Mine C revealed 17 factors with eigenvalues of over 1.0 that described 80.69% of the variance. This was reduced to a forced six-factor model which described 53.21% of the variance. Table E4 (contained in Appendix E) shows the rotated component matrix for the six-factor model. The questions that loaded on to factor 1 were primarily questions relating to management commitment (5 out of 10 questions loaded onto only factor 1 and 9 out of 18 questions that loaded onto factors 1 and others). The questions that loaded onto factor 2 were primarily questions relating to production and safety (3 out of 6 questions that load only onto factor 2 and 8 out of 16 questions that load onto factor 2 and others). The questions loading onto factor 3 were questions relating to systems and procedures (2 out of 3 questions that load only onto factor 3 and 4 out of 11 questions that loaded onto factors 3 and other). The questions that loaded onto factor 4 were questions mainly relating to risk and safety behaviour (3 out of 3 questions that load only onto factor 4 and 5 out of 9 questions that load onto factor 4 and others). The questions that loaded onto factor 5 were questions mainly relating to individual responsibility (0 out of 1 questions that load only onto factor 5 and 3 out of 7 questions that load onto factor 5 and others). The questions that loaded onto factor 6 were questions that related to various ‘miscellaneous’ critical factors. Risk and safety behaviour was the most represented (1 out of 2 questions that load only onto factor 6 and 3 out of 7 questions that load onto multiple factors).

As presented in Table 5.16 following, it was statistically determined from analysis of the forced 6 factors model, 5 key factor categories were of significance for safety and safety culture within OC Mine C (not including the miscellaneous category). These were: management commitment, production/safety, systems/procedures, risk-taking/safety behaviour, and individual responsibility.

Table 5.16

Critical Factors of Safety Culture Identified from Pilot SMQ Administration at OC Mine C

Factor Category	Ranking
Management commitment	1
Production/safety	2
Safety systems/procedures	3
Risk-taking/safety behaviour	4
Individual responsibility	5

5.9.2.3 Critical Factors Identified for all Mines

The safety Management Questionnaire was provided to all workers and staff at the same three mines involving a total of 601. Participation was on a voluntary basis. 158 (27%) questionnaires were returned which is fractionally below industry standard.

Data gathered at this stage of research was analysed using Exploratory Factor Analysis. Responses to the SMQ were explained through a six factor model of mine safety culture, and had a reported Cronbach's α coefficient of .757. The six factors were labelled:

1. Production/Safety.
2. Management Commitment/Communication.
3. Safety Systems.
4. Procedures.
5. Individual Responsibility.
6. Risk-taking Behaviour.

These six factors collectively explained 46.05 percent of the total variance in the data collected. In other words, the first attempt at this has worked relatively well.

5.9.3 Phase 2: Discussion

The aim of this phase of the research was met with the initial identification of factor categories critically contributing to safety culture at each of the three mines using the pilot Safety Management Questionnaire (SMQ). While this instrument is in its early stages of development and refinement for the state and wider Australian coal mining industry, the power of the tool, and applicability to the Australian sample, is instantly evident. Analysis of the combined SMQ data set from each of the 3 mines involved in the research (UG Mine A, UG Mine B, and OC Mine C) further reveals evidence for the emerging core set of critical factors of safety culture. Management commitment and individual responsibility were identified as statistically significant factor categories at all participating mines. The prioritisation of safety and production, safety systems/procedures, as well as communication were further identified as statistically significant factors for at-least two of the mines involved in the research project. As such, support is found for the hypothesis that management commitment, individual responsibility, systems and procedures, communication, and the priority of production/safety would be identified as the critical factors of safety culture. While each of the above stated factors were not identified at every mine and in repetitious order, these factors can be considered core to the combined sample.

The SMQ is in its infant stages of development for use within the Australian coal mining industry. As such, the identified factor categories (at this stage of the research) are to be considered as representative or indicative of the factors contributing to safety culture within individual participating mines and across the combined sample. Further refinement of the instrument will enable the determination of a baseline measure of safety culture for each mine from which interventions and other improvement-oriented strategies may be evaluated in order to assess change on or influence over existing and developing safety culture. Questions that probed for each of the particular factor categories in the SMQ did not always load onto a single factor, such items are not considered pure questions. As such it is important that further statistical evaluation of these particular questions be included into Project 1: Stage 2 as part of the refinement process of the SMQ (this evaluation may conclude 'non-pure' questions be removed from the revised version of SMQ). This will further enable assessment of which factor categories emerging in the core set are single-loaded factors or they may be sub-components of other factor categories. For example in OC Mine C it was found that questions which probed for communication loaded equally between the first three factors suggesting that communication may not be a factor on its own, but a component of the management commitment, production/safety, and/or systems/procedures factor categories for this particular mine. Further research (and a larger sample of mines) is also required to determine whether this is only an issues in the OC industry or whether this is also generalisable to the UG domain.

As previously noted, the limited sample sizes for the SMQ (50 for UG Mine A, 35 for UG Mine B, and 63 for OC Mine C) did not permit full execution of factor analytic statistical tests. Greater sample sizes for the individual mines involved in the research and extending the sample to include additional mines in the Hunter Region and wider Australian industry will enable further examination of the psychometric properties of the tool and comparison of the results. Furthermore, the limited sample has not permitted statistical analysis to be performed comparing responses according to occupational groups, age, accident history, and the like, nor between mines. Expansion of the responding sample will enable this in future administration of the SMQ. From the preliminary analysis conducted, as presented in this section of the extended report, similarity is evident between the emerging factor structures of significance between each of the three mines. Furthermore, similarity is evident via comparison with the results of the focus group discussions and the associated tasks run at each of the participating mines and the core set of critical factors of safety culture identified in the literature review.

In light of the emerging set of core factors and the similarity of findings between the UG and OC coal mines involved in the study partial support is found for the final hypothesis. Slight differences were revealed between the mines and across the industries for those identified factors in terms of order of ranked importance. The factors are however, essentially similar and applicable to each mine. Essentially, the core set of critical factors of safety culture revealed in the SMQ are: management commitment, production/safety, systems/procedures, risk-taking/safety behaviour, individual responsibility, and communication. Further investigation of these factors will be permissible throughout the continuing research program. Refinement of the SMQ and the underlying factor structure combined with increased participation rates from the individuals mines involved in the research and increasing the sample of participating UG and OC mines will further enable more in-depth analysis of the data according to such variables as age, shift/crew, occupational group, years of industry experience, and so forth. Domain comparison will also be possible as will further analysis of the psychometric properties of the SMQ to guide future refinement of the measurement tool for an Australian coal mining sample.

5.9.3 Phase 2: Summary

In summary, the initial questionnaire (SMQ-1) has produced and confirmed a six-factor model of critical safety factors. The data largely supported the general finding from the focus group and information already concluded from the literature review.

In addition, this study has found very little significant difference between mines, although again there are some small changes. Generally both open and underground mines have similar outcomes. This is not surprising given the age and experience profile of the mine workers.

Finally, the relative small sample obtained in the first round does not allow for definite conclusions to be drawn. However, the data obtained is of sufficient merit to allow for the revision of the instrument and the development of SMQ-2 for further testing.

5.10 Phase 2: Safety Management Questionnaire Version 2 (SMQ-2)

Although the SMQ was found to be statistically reliable, the Safety Management Questionnaire Version 2 (SMQ-2) was developed with the aim of further validating and refining this six factor structure. The current research is necessary in order to further assess the suitability of this tool for eventual use within a wider population of Australian coal miners, and hence the external validity of the SMQ-2 (Howell, 2002).

The Safety Management Questionnaire Version Two. The current research presents version 2 of a developing tool for safety measurement. The SMQ-2 was developed at the commencement of 2004. Following EFA (exploratory factor analysis) carried out on data from the 2003 project, several SMQ items with multiple factor loadings were excluded or reworded. These exclusions were made with the aim of improving the item-content validity of the SMQ-2 (Piland, Motl, Ferrara, & Peterson, 2003). Items relating to lost time injuries (LTIs) and specific job descriptions were also withdrawn following debriefings and focus groups held at the participating mines. These items were considered to be 'too political', hence negatively influencing return rates (Eachus, 2004).

The SMQ-2 was constructed to consist of two scales: safety attitudes and behaviours. This change reflects a distinction between the constructs in the 2003 data, and also supports the current literature on the structure of safety culture, as discussed previously. In addition, the designation between these scales has contributed positively towards the ease of interpreting questionnaire responses. This attribute is of significance concerning the eventual utility of this tool within the marketplace. Considering the changes that have taken place between the SMQ and SMQ-2, there are several issues relating to the reliability and validity of the most recent tool that were of prime interest in the current study.

The reliability of the SMQ-2 relates to its demonstrated level of measurement consistency (Weiten, 2001). Literature on the subject of data collection instruments recommends three methods for establishing questionnaire reliability including parallel form, test-retest, and the demonstration of internal consistency (Gainford, 1999; Petri & Czarl, 2003).

Parallel form was not conducted at this stage of the project. Although it may be considered in future years as a means of avoiding negative affect amongst participants. The test-retest method of determining questionnaire reliability was also not applicable within the current research. Although the present study was aimed at establishing the reliability of the questionnaire within the same participant group over time, it does not meet the requirements of a test-retest reliability method due to the fact that the questionnaire tool has been altered since the 2003 study (Gainford, 1999; *Standards*, 2004). For this reason, the reliability of the SMQ-2 was primarily assessed concerning its demonstrated internal consistency.

The internal consistency of a psychometric instrument refers to sampling errors and temporary fluctuations within a single occasion (Dong-Chul et al., 2004; Smithson, 2000). It is most appropriate as a method of establishing reliability when a tool is proposed to measure a single principal construct. Considering this, Alderson and Banerjee (1996; cited in Petri & Czarl, 2003) point out that internal consistency may not be an adequate measure of questionnaire reliability due to the fact that questionnaires (unlike tests) are usually not intended to measure one thing. For this reason, the present study will run separate analyses on the behaviour and attitude scales of the SMQ-2 in order to establish the internal consistency of each scale. In addition, if a six factor model of safety culture is again supported through the current research, the inter-reliability of items loading on each factor will also be determined. In so doing, the reliability of the SMQ-2 may be understood considering the interrelationship of questionnaire items and the constructs under measure.

The validity of the SMQ-2 must also be established in order to demonstrate its ability to measure safety culture (Weiten, 2001). In this present study, the most pertinent types of validity are item content, construct, and response validity (Howell, 2002; Petri & Czarl, 2003; Stevens, 2002; Trochim, 2002). Predictive, criterion, and concurrent validity are not discussed as they are beyond the capacity of this study (Gregory, 2004).

Response validity concerns issues such as the readability and wording of SMQ-2 items and other pragmatic features that may have affected participant's completion of the questionnaire (Slater & Gibson, 2004). In assessing the response validity of the SMQ-2, the present study interpreted the frequency of non-responses to questionnaire items.

Content validity concerns the degree to which SMQ-2 items represented the domain of safety culture within the coal mining community of the Hunter Region (Gregory, 2004; Smithson, 2000; Weiten, 2001). Content validity checks were carried out during development of the SMQ-2 through the elimination of irrelevant SMQ items, collapsing of related statements, and re-wording of politically-loaded phrases (Petri & Czarl, 2003). The SMQ-2 was also presented to experts working within the coal mining industry as a means of further assessing this validity (Vogt et al., 2004).

Construct validity concerns the degree to which legitimate inferences were made from the findings of the present study to the theoretical construct of safety culture within the coal mining community of the Hunter Region (Trochim, 2002). This was investigated using EFA procedures. The multitrait-multimethod matrix (MTMM) has been used in similar studies (Petri & Czarl, 2003; Trochim, 2002) however, the literature indicates that this method is a complicated assessment of construct validity, and is particularly problematic when used in applied research (Trochim, 2002). For this reason the present study focused on the use of EFA techniques, which have a demonstrated ability to group variables (questionnaire items) into clusters according to common underlying themes or factors, thus depicting the construct behind the instrument (O'Connor, Colder, & Hawk, 2004; Petri & Czarl, 2003). The resulting factor loadings were examined in order to assess the construct validity of the SMQ-2.

5.9.1 Phase 2: Method

5.10.1.1 Participants

A total of 353 workers from five local Hunter Region coal mines participated in the current study. This sample represented a 43.5 percent response rate (see Table 1). Participating mines were recruited through expressions of interest put forward following a series of coal mining seminars held by the Joint Coal Board Health and Safety Trust (project funding body) in early 2003. Initially six mines were involved from the Hunter Region (mines A, B, C, D, E, and F), however mine B withdrew from the study in mid 2004 due to workplace issues unrelated to the current study. Mines A, B, and C were previously involved in the 2003 study of the SMQ.

Table 5.17

Response Rates by Mine for the 2004 SMQ-2 Study

Mine	**Total Workforce Numbers**	**Number of Responses**	**Response Rate (%)**
Mine A	249	99	39.8%
Mine B	-	-	-
Mine C	199	120	60.3%
Mine D	159	50	31.4%
Mine E	141	56	39.7%
Mine F	64	28	43.8%
TOTAL	812	353	43.5%

Participants were employed in both open-cut (N=120) and underground coalmines (N=233), with a mean age range of 41-50 years (SD = .941). Participants had an average number of 21 years experience in this industry (SD = 8.92 years) and were represented at all organisational levels (management, supervisors, and mineworkers [see Appendix G]).

5.10.1.2 Material

The SMQ-2 is the second iteration of a developing tool, and is based upon the previously mentioned six factor structure of safety culture that emerged from the 2003 analysis of the SMQ. The SMQ-2 has 71 items and is divided into four sections (A, B, C, and D). Section A consists of five items referring to demographic information (shift worked/crew, age, job category, employment status, and years in industry [see Appendix G]). Section B of the SMQ-2 contains 30 items. This section concerns safety *behaviour* and is responded to using a 5-point Likert scale: 1 = never; 2 = seldom; 3 = sometimes; 4 = often; and 5 = very often. Section C contains a further 33 items which refer to safety *attitudes* and *perceptions*, and is also answered using a 5-point Likert scale: 1 = fully disagree; 2 = partially disagree; 3 = neither agree nor disagree; 4 = partially agree; and 5 = fully agree. Within sections B and C, 38 items refer to safety using negative terminology, while the remaining 25 items refer to safety using positively phrased statements. Section D of the SMQ-2 consists of three open-ended items. These items invite respondents to elaborate on their workplace safety priorities and concerns (‘How can safety be improved at this site?’, ‘What do you personally believe are the top 5 critical factors relating to safety?’, and ‘Any other comments’). Responses within this section were not analysed in the current study however, due to time restraints and the nature of the project.

5.10.1.3 Procedure

Initially, extensive pre-distribution meetings with mine safety co-ordinators, union representatives, executive management, and relevant safety committees were held, informing them that the second phase of safety research was due to commence at their site. At these meetings, mine personnel who were involved in the first phase of research were reminded of the findings relevant to their mine, while newly recruited personnel were informed of the potential benefits of being involved in the project for the first time. At these meetings, all those present were encouraged to inform workmates and colleagues of the pending research, and were assured that all information gained from the project would be readily available to participant’s at all hierarchical levels. Potential respondents were also reminded that their anonymity was paramount within this research, and that management would not be privy to any individual responses.

Members of the research team from The University of Newcastle Human Factors Group personally delivered the SMQ-2 to each of the mine locations. A member of the research team briefed mine personnel during pre-shift meetings concerning the nature of the study and questionnaire. All interested personnel were encouraged to complete the SMQ-2 in their own time, and without consulting other mineworkers.

Questionnaires were distributed in sealed questionnaire packs (see Appendix H). Included in the envelopes were also a questionnaire pack summary sheet, information statement, and postage paid return envelope addressed to the University research team. Drop off boxes were provided on site as a convenient alternative for participants to return mail. Records were made of the time taken for each questionnaire to be returned, as well as the mine from which it came.

Section A of the SMQ-2 was analysed using standard descriptive statistics to gain demographic information on the population involved in the study. Sections B and C were evaluated using numerical responses (1-5). Responses made to negatively phrased items (e.g., 'I don't assess or consider risk, I generally act out of habit', and 'I am reluctant to report accidents') were reversed prior to data analysis. Following this score reversal, a score of five represented a high or 'good' safety culture, while a score of one showed a weaker safety culture. This was consistent for responses to both section B and C.

Upon completion of data entry, two participants were excluded due to their continuous response of '3' throughout the questionnaire. In addition, a further one participant was excluded due to the incompletion of more than 20% of items from sections B and C. Missing item responses from participants who completed more than 80% of sections B and C were excluded listwise in order to assess only valid responses. The final sample under analysis therefore consisted of 350 responses.

Statistical analysis was carried out using Statistical Package for Social Sciences (SPSS) version 12.00 for Windows. EFA was conducted on this data in order to again explore the suitability of a six factor model explaining safety culture within the coal mining industry. A comparative analysis was conducted following re-analysis of data gathered through the 2003 study of the SMQ. The outcomes of this comparison were viewed concerning any changes that have taken place in relation to the reliability and validity of the current tool.

5.10.2 Phase 2: Results – SMQ 2

In order to investigate H1, EFA was conducted on data from both the SMQ and SMQ-2. Results from re-analysis of data from the SMQ pilot study revealed that a six factor model of safety culture explained 46.05 percent of the total variance within the 2003 study, with F1 explaining 23.75 percent (see Appendix E). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for this sample was .80, hence indicating that the sample was sufficient, and that a factor analytic approach was acceptable (Paolini, 2003; Garson, 2004). Consistent with the procedures of the 2003 pilot study, the present research subjected item responses in sections B and C of the SMQ-2 to EFA techniques, namely Principal Component Analysis (PCA). The KMO score for this analysis was .89, indicating that the pattern of correlations within the current sample was also adequate for FA techniques to be utilised (Garson, 2004). Through this process, groups of items were established to form factors within the data set, and also within each of the two scales (behaviour and attitude). Varimax rotation was employed to assist in the interpretability of the factor loadings (Paolini, 2003). The results of this analysis can be viewed through the scree plot in Figure 2, which graphically represents the eigenvalues of each factor within the current study (Paolini, 2003). It is evident here that the greatest number of SMQ-2 items were explained by the first three factors, however these three factors only accounted for 32.28% of the total variance within the 2004 sample. Although EFA revealed 17 factors with eigenvalues greater than 1.00, a six factor model of safety culture was explored in accordance with the model proposed through the 2003 pilot study (Pfister & Atkins, 2004).

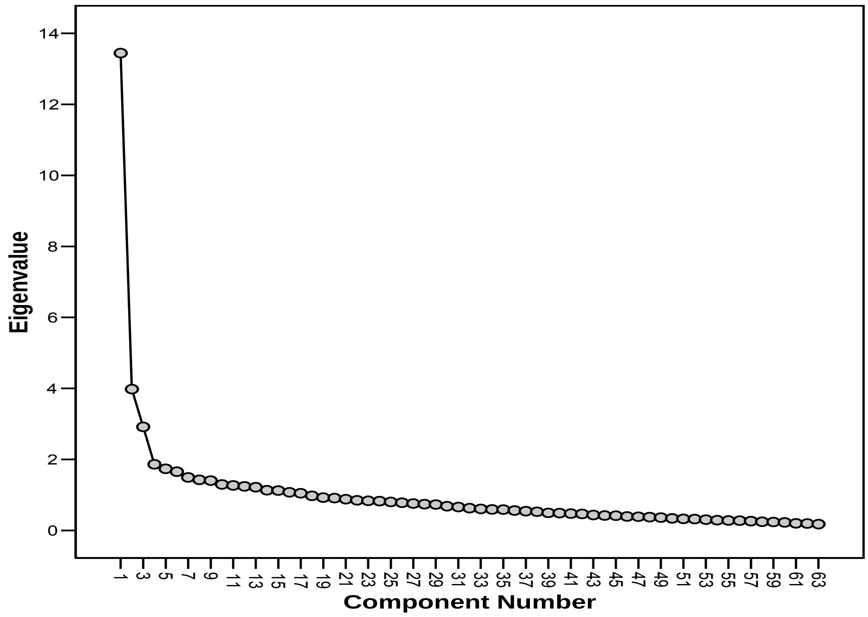

Figure 5.2.

Scree plot representing the distribution of eigenvalues within the 2004 SMQ-2 data.

Through the scree plot displayed in Figure 5.2, a slight 'elbow' can be seen between F6 and F7, hence lending support for this six factor model. The characteristics of this model are further outlined in Table 5.18 following.

Through this analysis it can be seen that H1 is not supported in the current study. Separate EFAs were conducted for each scale (attitude and behaviour) in the SMQ-2 in order to investigate H2. Analysis of the attitude scale within the

Table 5.18

Variance Explained Using a Six Factor Model of Safety Culture within the 2004 SMQ-2 Study

Factor	**Eigenvalue**	**% of Variance**	**% of Cumulative Variance**	**Number of Loading Items**
1	13.44	21.34	21.34	27
2	3.98	6.32	27.66	16
3	2.92	4.63	32.28	16
4	1.86	2.95	35.24	7
5	1.73	2.75	37.99	8
6	1.65	2.62	40.61	3

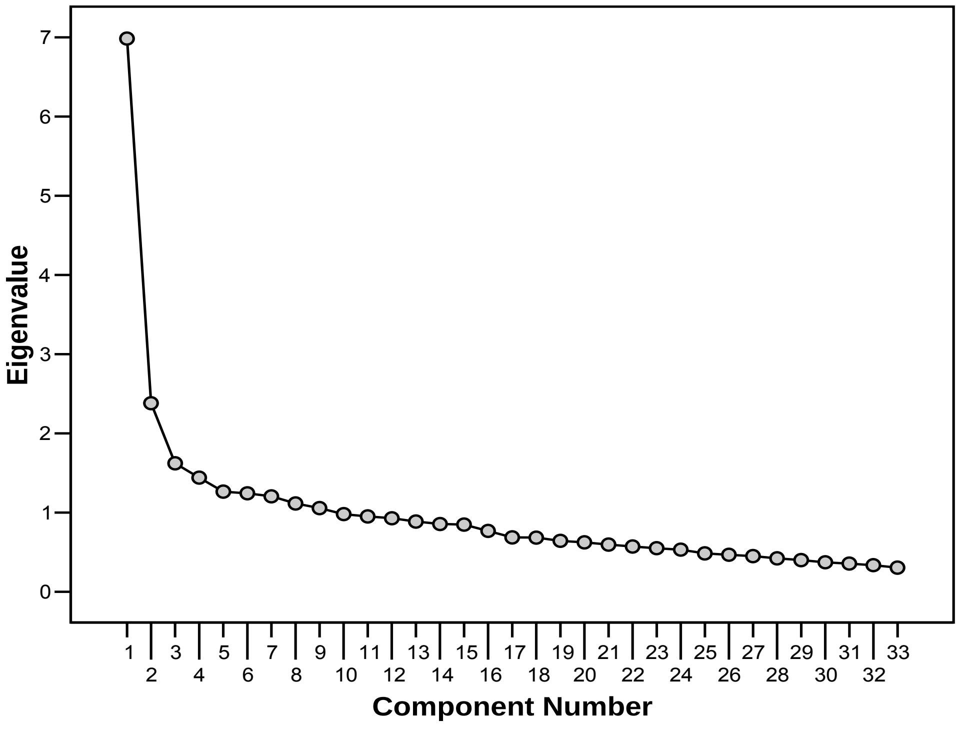

Figure 5.3.

Scree plot of eigenvalues following EFA on the 2004 data from the SMQ-2 attitude scale.

SMQ-2 revealed a KMO score of .869 (Garson, 2004). The results of EFA techniques employed in the analysis of this scale can be viewed in Figure 5.3.

The scree plot in Figure 3 shows that F1 is the strongest underlying factor of safety attitudes within the present sample, however the following five factors within this scale also contribute appreciably to the cumulative explained variance. Nine factors were found through this analysis with eigenvalues greater than 1.0, however a small distinction can be drawn between F6 and F7 on this plot (Figure 5.3), hence lending support to the exploration of a six factor model. These six factors, as they exist within the attitude scale of the SMQ-2, are explained in further detail in Table 5.19.

Table 5.19

Variance Explained Using a Six Factor Model of Safety Culture within the Attitude Scale of the 2004 SMQ-2 Study

Factor	**Eigenvalue**	**% of Variance**	**% of Cumulative Variance**	**Number of Loading Items**
1	6.99	21.17	21.17	14
2	2.38	7.22	28.38	14
3	1.62	4.92	33.30	4
4	1.44	4.37	37.66	5
5	1.26	3.83	41.49	4
6	1.24	3.77	45.26	2

Through Table 3 it can be seen that the six factor model of mine safety culture within the attitude scale of the SMQ-2 explains a greater amount of cumulative variance in the present data than was explained by the total SMQ-2 tool. The variance explained by this scale however did not surpass that demonstrated by the SMQ within the 2003 study. EFA techniques were used similarly on the behaviour scale of the SMQ-2 (KMO = .892). Findings of this analysis are depicted in Figure 5.4 following. Figure 5.4 again shows that F1 is the strongest underlying factor of safety behaviour within the present study, however the following five factors also contribute substantially towards the cumulative variance explained. Seven factors with eigenvalues greater than 1.0 were found through this analysis, however a small

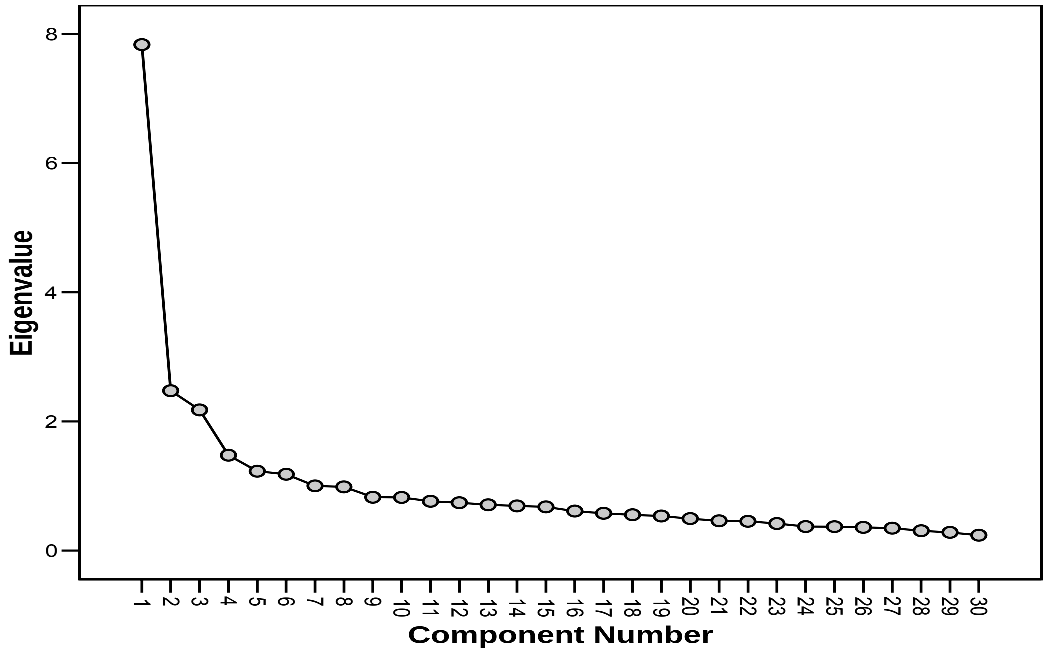

Figure 5.4.

Scree plot of eigenvalues following EFA on the 2004 data of the SMQ-2 behaviour scale.

distinction can again be drawn between F6 and F7. Support for a six factor model of safety culture within the behaviour scale of the SMQ-2 is explored further in Table 5.20.

Table 5.20

Variance Explained Using a Six Factor Model of Safety Culture within the Behaviour Scale of the 2004 SMQ-2 Study

Factor	Eigenvalue	% of Variance	% of Cumulative Variance	Number of Loading Items
1	7.84	26.12	26.12	12
2	2.48	8.25	34.37	8
3	2.18	7.27	41.64	7
4	1.48	4.93	46.56	7
5	1.23	4.10	50.66	5
6	1.18	3.94	54.60	5

Table 5.20 shows that the behaviour scale of the SMQ-2 also explains a greater amount of variance through the six factor model of safety culture than was demonstrated by the total SMQ-2 tool. In addition, the behaviour scale of the SMQ-2 explains a greater amount of variance than the collective SMQ tool did in the 2003 study.

Internal Consistency Reliability

In order to investigate H3, internal consistency was measured for both the 2003 SMQ and 2004 SMQ-2 data using Cronbach's α. These reliability coefficients were .76 and .93 respectively, both of which are acceptable. A Cronbach's α of .70 is accepted as the minimum desired value for this coefficient, however .80 is considered ideal as this α indicates a high degree of integrity within the sample (Nunnally, 1978; cited in Hayes, et al., 1998; Santos, 1999). Cronbach's α scores calculated for the behaviour (α = .89) and attitude (α = .85) scales within the SMQ-2 also revealed suitable levels of internal consistency. Cronbach's α scores computed for each of the six factors of both the SMQ and SMQ-2 can be viewed in Figure 5.5.

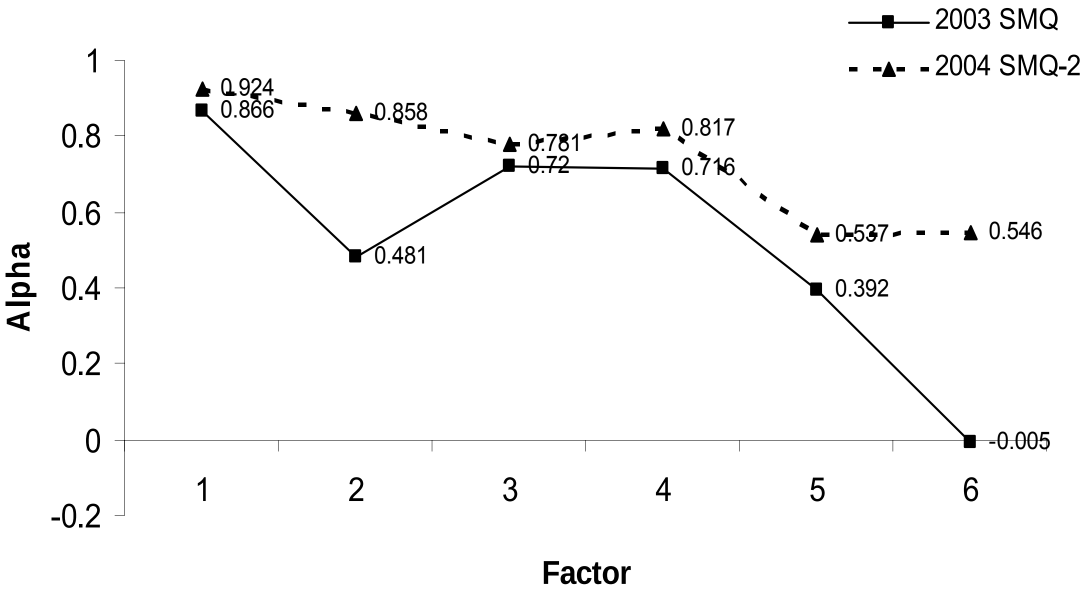

Figure 5.5

Cronbach's α scores by factor for the 2003 SMQ and 2004 SMQ-2.

As can be seen from Figure 5.5, F1, F3, and F4 from the 2003 study reached acceptable degrees of internal consistency. F2, F5, and F6 however, were not found to be reliable. F6 is of particular interest within the 2003 study as its negative value indicates a violation of the reliability model assumptions. Conversely, only F5 and F6 from the 2004 SMQ-2 data were found to have unacceptable levels of diffusion amongst their loading items. Scores of this range suggest that the data contributing towards these factors is multidimensional and requiring further attention. F1, F2, F3, and F4 from the current study however, are all acceptable measures of the latent constructs underlying them (*How to Perform and Interpret Factor Analysis using SPSS*, 2004).

Response Validity

Throughout the development of the SMQ-2, problematic items within the 2003 SMQ study were identified and either adjusted or replaced accordingly. In consideration of H4 and the future development of an improved SMQ-3 tool, analyses of items that elicited a non-response (or ‘0’) were used to demonstrate which questionnaire items were problematical (Sjostrom, Holst, & Lind, 1999). Figures 5.6 and 5.7 illustrate these frequencies as they occurred in the 2003 SMQ and 2004 SMQ-2 data respectively. Recommendations for the further development of the SMQ-3 will be made in consideration of these findings (Vogt et al., 2004).

Figure 5.6 shows that a wide range of items within the 2003 SMQ elicited a non-response in the 2003 pilot study (25 items & 30 non-responses). Figure 5.7 shows that the 2004 SMQ-2 data had fewer items eliciting a non-response (18 items), however each item had a greater frequency of non-responses than was found in the 2003 pilot study (53 non-responses).

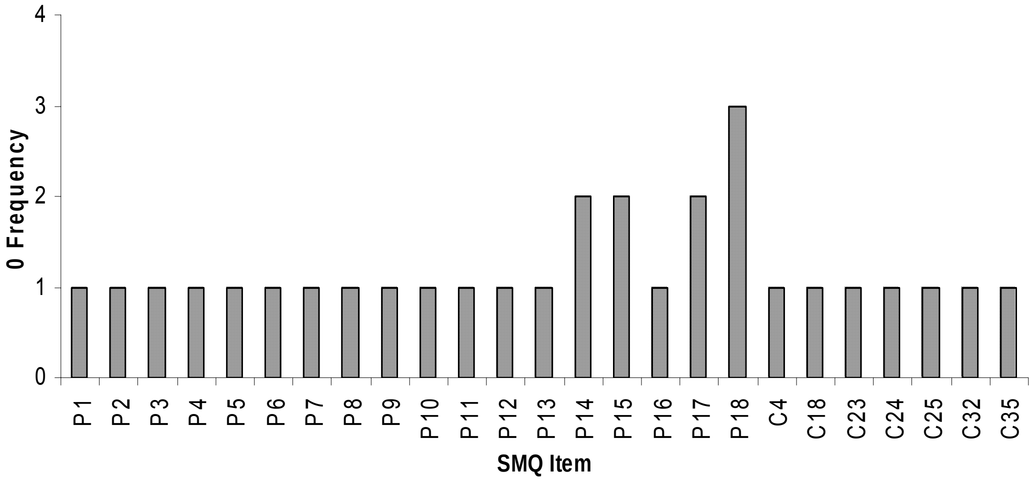

Figure 5.6

Frequency of non-responses to items within the 2003 SMQ pilot study.

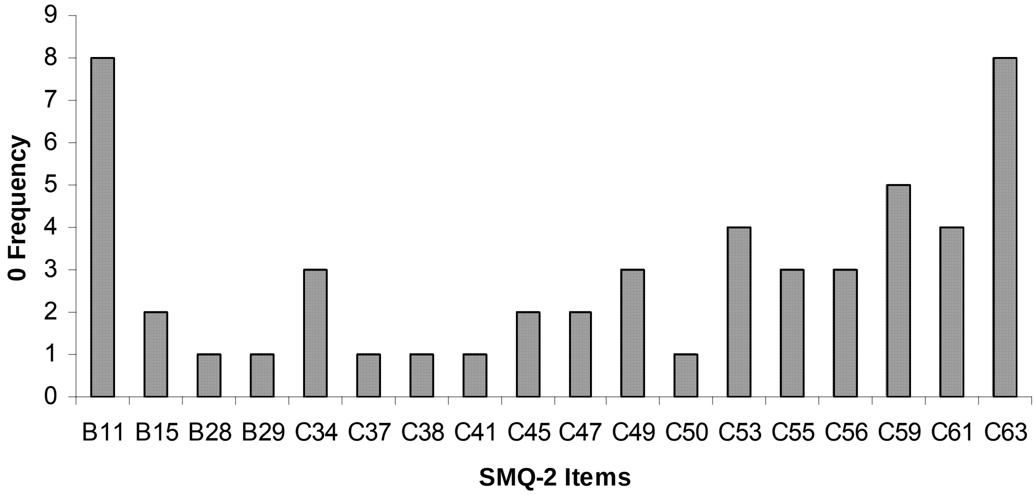

Figure 5.7

Frequency of non-responses to items within the 2004 SMQ-2 study.

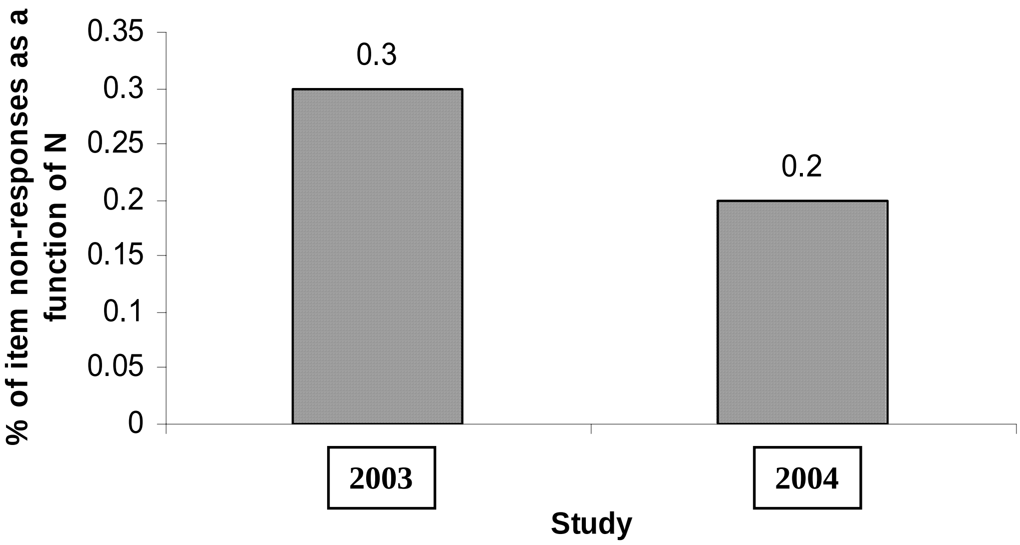

Figure 5.8

Frequency of non-response to items within the 2003 SMQ and 2004 SMQ-2 studies as a function of sample size.

It would appear from this analysis that the 2003SMQ had better response validity due to the fact that fewer non-responses were recorded, however this advantage is diminished when the differing sample sizes of the two studies are taken into account (2003 SMQ N = 150; 2004 SMQ-2 N = 350). This comparison can be viewed in Figure 5.8 below.

Figure 5.8 demonstrates that the 2004 SMQ-2 study elicited proportionally fewer non-responses than were found in the previous 2003 SMQ study. This finding contributes towards a better understanding of the trends in response validity within the SMQ tools.

Content Validity

Content validity is not tested through the present study, as it can be seen that the requirements of content validity have been met through the continuous analysis of item material by experts within the mining industry. A further understanding of the six factor model of safety culture within the 2004 SMQ-2 is explored however, in order to assess how well this tool represents the domain of safety culture. This is done through analysis of item factor loadings. By inspecting the ways in which specific SMQ-2 items group together to form factors, insight concerning the underlying constructs beneath each factor may be gained. Item loadings from within the SMQ-2 study can be viewed in Table 5.21.

Table 5.21

Factor Loadings of Items within the 2004 SMQ-2 Study

	Component					
	1	**2**	**3**	**4**	**5**	**6**
B5r	.808					
B21r	.747					

B6r	.736				
B13r	.734				
B9r	.701				
C40r	.673				
B14r	.672				
B26r	.662				
C31r	.650				
C46r	.646				
B25r	.635				
C35r	.609		.307		
C62r	.603				
B19r	.497			.338	
C48r	.446		.355	.316	
C32r	.389	.319	.351		
B4	.380				
B8r	.370				
C50r	.355				
C44r	.322		.312		
C36r	.308				
C60r					
B15		.738			
B3		.640			
C37		.609			
B11		.572			
C41		.563			
C54r		.555	.326		
B12		.547			
C61		.546			
C34		.529			
B28	.305	.461			
B2		.458			
C52r		.430			
C57r		.428	.344		
B24r		.326			
C42r					
C43r			.584		
B30r	.328		.518		
C39r			.516		
C33r			.355		
C56			-.337		
C63			.308		
C49			-.302		
B18r				.779	
C51r				.680	
B7r				.528	
B10r		.444	.301	.507	
B23r	.381		.318	.480	
C58r	.383			.460	
B29					.543
B20	.354				.534

B1r					.518	
B17	.330				.516	
B22					.512	
B27					.486	
B16r			.302		-.403	
C53					.332	
C45						.660
C38						.639
C47						.627
C59						
C55						

Note. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation. B = Section B, Behaviour items. C = Section C, Attitude items. r = Reversed items.

Table 5.21 shows that items C42r, C55, C59, and C60r within the current study do not load on any of the six factors established through this analysis. These items will be of particular interest concerning the further development of content validity within the SMQ-3.

Construct Validity

Correlation coefficients were compared both within and between the SMQ and SMQ-2 in order to further assess H4. Testing of the relationships between SMQ items and the complete SMQ tool. Shows that each of the 65 items within sections 2 and 3 of the SMQ (except for the 11 highlighted items) showed significant (p<.001), positive correlations with the total SMQ (.01 to .52), however these correlations were very weak. This shows that each item does not differentiate significantly in the same direction as the total SMQ.

Similar results were found concerning the correlation between SMQ-2 items, each of the two scales (behaviour and attitude) and the total SMQ-2 tool. It can be seen that each of the 63 items within sections B and C of the SMQ-2 (except for item 56) showed a significant (p<.001), positive correlation with the scales (.02 to .77) and with the total SMQ-2 (.05 to .65), however these correlations were again very weak. This shows that each item does not differentiate significantly in the same direction as either the scale it belongs to or the total SMQ-2.

Exploration of the relationship between individual factor scores and the global factor score (FG) for safety culture can be used to further analyse construct validity. Correlation coefficients between factor scores and the corresponding FG were examined for both the 2003 pilot study and the current data (Table 5.22 and Table 5.23). As can be seen in Table 5.22 below, only F2 within the 2003 SMQ reached a high level of correlation with the global score, while the remaining factors (1, 3, 4, 5, and 6) were moderately correlated with the global score (Weiten, 2001).

Table 5.22

Correlation of each SMQ factor score with the 2003 global score

Factor	Score	Correlation coefficient with FG
		r
1	2.39	.61
2	3.32	.81
3	3.52	.19
4	2.75	.67
5	3.84	.51
6	3.08	.72
FG	3.16	

From Table 5.22 it can be seen that the SMQ met the required conditions of construct validity within the 2003 study. Concerning the 2004 SMQ-2, construct validity is also demonstrated in this way, as can be seen in Table 5.23, which shows that F1, F2, and F4 were all highly correlated with the global score. While F3 and F5 were only moderately correlated, F6 was the only factor within the current study had a moderate to low correlation with the global score (Smithson, 2000; Weiten, 2001).

Table 5.23

Correlation of the 2004 SMQ-2 Factor Scores with Global Score

Factor	Behaviour Scale	Attitude Scale	Total	Correlation coefficient with FG
				r
1	3.94	3.51	3.72	.80
2	3.66	3.41	3.54	.74
3	2.30	3.11	2.70	.69
4	3.41	4.49	3.95	.74
5	3.83	4.03	3.93	.54
6	0	4.66	4.66	.35
FG	3.44	3.86	3.75	

5.10.3 Phase 2: Discussion SMQ -2

The objective of the current study was to investigate the comparative reliability and validity of the 2003 SMQ and 2004 SMQ-2 tools concerning their utility as measures of safety culture within the coal mining industry of the Hunter Region. A six factor model of mine safety culture was developed from the 2003 study (SMQ-1). This model was developed in accordance with issues raised through focus groups held at participating mines, theories within the current literature (Mearns et al., 2001; Alexander, Cox, & Cheyne, 1995), and EFA run on responses within the 2003 SMQ pilot study. The present study has further explored the utility of this six factor model through the revised version of the SMQ-2. In addition, a larger sample from within the coal mining community of the Hunter Region was used, and hence results were found to be more relevant to those obtained through the 2003 study of SMQ.

Hypothesis 1

A six factor model of mine safety culture explained a greater amount of variance in the 2003 SMQ study than in the present research. This finding demonstrates that H1 was not supported within the current study. It would appear therefore, that the original SMQ was a reasonably adequate measure of safety culture within the coal mining industry. As the SMQ-2 has been revised to contain two scales however, rather than one overall measure of safety culture, the total variance explained by the present study may be misleading. For this reason, the variance explained by the two scales in relation to the six factor model may be more relevant in determining the strengths of the SMQ-2.

Hypothesis 2

The second hypothesis within the current research stated that the behaviour and attitude scales within the SMQ-2 would explain a greater amount of variance than was demonstrated by the SMQ. H2 was supported concerning the behaviour scale of the SMQ-2, however it was not supported concerning the attitude scale. The attitude scale explained a similar level of variance using a six factor model, however it did not surpass that explained by the 2003 SMQ. Although H2 was not supported through this analysis, further support was shown for the distinction between the behaviour and attitude scales within the SMQ-2, as both were shown to explain more variance than the total SMQ-2. This finding, along with the theoretical distinction made between the concepts of behaviour and attitude in the literature, shows support for the maintenance of two scales within future iterations of the SMQ-3.

Hypothesis 3

H3 was supported through the current study as it was found that the SMQ-2 reached acceptable levels of Cronbach's α on more occasions than the SMQ did. It was also found that the SMQ-2 gained greater reliability coefficients (α) than the SMQ at all levels of analysis. This development in the number of factors demonstrating internal consistency is an indication that the SMQ-2 has taken considerable steps towards an improved standard of reliability (Gainford, 1999).

Hypothesis 4

H4 was also supported through the current study concerning all three forms of validity investigated. Support for the improved response validity of the SMQ-2 was shown through the smaller percentage of non-responses that were recorded as a function of the complete data set (N = 350) within the SMQ-2 when compared to the 2003 SMQ responses (N = 150). Non-responses (or '0s') demonstrate which questionnaire items are problematic. Such items may concern sensitive issues, or be too confusing due to poor wording (Sjostrom et al., 1999). In addition, non-responses may indicate fatigue in the participant, hence providing valuable information concerning the length of the questionnaire (Sjostrom et al., 1999). Recommendations for the development of the SMQ-3 have been made in light of this analysis.

The SMQ-2 satisfied the requirements of content validity through the use of literature reviews and expert opinions. Further support was shown for H4 however, through the exploration of factor loadings as they occurred in the current SMQ-2 study. Through EFA it was shown that four items within the SMQ-2 did not load onto any of the six factors within the model. These four items, in addition to those found to load onto multiple factors, are of particular interest concerning the further development of content validity within the SMQ-3 (see appendix L [Dong-Chul et al., 2004; Gregory, 2004). These four items should be assessed and either removed or reworded for inclusion in the SMQ-3. Future implementation of this tool should take interest in any coinciding fluctuations taking place

Construct validity was determined through the correlation of items with the total SMQ or SMQ-2 tool they belonged to. Insignificant or negative correlation coefficients indicate the absence of construct validity, while significant and positive correlation coefficients show that the proposed scale meets the required conditions of construct validity (Dong-Chul et al., 2004). It was show that the SMQ-2 took steps towards achieving construct validity over the SMQ as three factors were found to be strongly correlated with the global score in the SMQ-2, as compared to only one factor within the SMQ. Through this analysis however, it was demonstrated that items within these tools do not form two homogenous scales. This finding demonstrates a lack of internal consistency and construct validity within both the SMQ and SMQ-2 (Gregory, 2004). Although it was found that items within these tools did not reach acceptable levels of correlation (and hence construct validity), it was shown that the SMQ-2 has taken considerable steps towards an improved level of validity, hence again supporting H4. This was demonstrated through a reduction in the number of items within the SMQ-2 eliciting negative correlations with the scales and tool (1 item) than were found through the SMQ (11 items).

Within the SMQ-2, poor construct validity was also evident concerning the further analysis of the attitude and behaviour scales. The lack of correlation between SMQ-2 items and these scales indicates that questionnaire items have not reached appropriate levels of discriminative power (Dong-Chul et al., 2004).

These findings concerning construct validity within the SMQ-2 may be seen to contradict earlier support for H2, which preserved the distinction of the behaviour and attitude scales. Hence, here it can be seen that although the SMQ-2 demonstrates improved reliability and validity, contradictory evidence has been found for the continued partitioning of the attitude and behaviour scales within this tool.

In relation to the onion analogy presented (Hofstede, 1980), the concepts of safety behaviours and attitudes represent the practices of the coal mining industry, depicting the more peripheral safety attributes of the Hunter Regions coal community. For this reason, the SMQ-2 can be seen as an indirect measure of OC, as it measures the quantifiable features of behaviour and attitude as means of accessing the abstract concept of safety culture. A more accurate representation of the cultural core of safety within this industry may be achieved however, through further research into the prolonged findings of this tool. As safety culture has been cited as an enduring entity (Guldenmund, 2000), a longitudinal, ongoing approach to the research of safety culture through the SMQ tools may provide continuous enlightenment concerning the exact nature of the cultural core of the Hunter Region mining community (Basen-Engquist et al., 1998). For this reason, the current research suggests that the distinction between the attitude and behaviour scales of the SMQ-2 be maintained throughout the further development of the SMQ-3. In so doing, future versions of the SMQ tools will be aimed at further penetrating the cultural core of the mining community through ongoing measurement of the observable/reportable attitudes and behaviours of participants.

The SMQ-2: A Self-Report Measure

Within applied research, multiple concerns have been raised in relation to self-report measures of safety culture. It has been argued that a reliance on such measures risks monomethod bias (Cree & Kelloway, 1995; Petri & Czarl, 2003; Oh et al., 2004). It is for this reason that the current research took into account information from focus groups and on site meetings concerning the development of the SMQ-2. Future research into the development of this tool may also benefit by utilising a variety of research methods. It should be noted however, that the final version of the SMQ tool will best be employed in conjunction with a wide variety of other safety measures (for example, ongoing review of accident data, behavioural markers developed through observation, and safety audits). The SMQ-2 hence represents one tool in the developing toolbox of safety measures for the Hunter Region coal mining community.

Self-report measures are also limited in that they are unable to account for any incomplete understanding participants may have of the topic under inquiry. As Converse and Presser (1986) highlight, “participants transform obscure questions into ones that seem sensible from their standpoint as they strain for meaning” (p. 57; cited in Petri & Czarl, 2003). Accordingly, the inherent danger concerning any self-report measure is that participants may manipulate items through the process of interpreting them. Hence, participants may respond to their own ‘version’ of a question, which could differ somewhat from the categories and concepts deliberated by the researcher (Oh et al., 2004). In the current research, reports of poor literacy and extreme levels of fatigue among some participants may have complicated this issue. Attempts were made to alleviate the influence of these issues by encouraging participants to openly analyse questionnaire items during on site meetings, and also by offering private assistance to participants upon request. Despite these attempts, it cannot be said that the SMQ-2 is unaffected by respondent's misinterpretation of questionnaire items. Concerning the future development of the SMQ-3, attempts to improve the content validity of this tool may also be seen as a means to minimise the influence of this issue.

Further Limitations

It can be seen that selection bias may be introduced into the present design due to the fact that participants are not randomly selected. The SMQ-2 was made available to all mining personnel at participating mines, however participation was voluntary, thus raising concern that the current research is based on a sample of miners who are most passionate about both the positive and negative safety issues they perceive within their mines. This issue may be further explored through analysis of the polarisation of participant responses, and hence the consistent finding of factor scores of approximately three (an average of extreme responses of 1 & 5) within the 2003 SMQ and current SMQ-2 studies. The extent of this bias, as well as possible statistical analyses that may account for non-randomised samples (e.g., Barrios, 2004) should be further explored in conjunction with methods for increasing the rate of participation within this industry. By gaining a greater participation rate, responses may be more evenly distributed, hence providing a more accurate picture of safety culture within the coal mining community of the Hunter Region.

Future Research

Researchers involved in the current project were acutely aware of negative affect felt by some mineworkers concerning the SMQ-2. Although only a few of the participants from the present study were involved in the 2003 SMQ study, the mining population of the Hunter Region has been recently involved in several projects being run by research teams external to the University of Newcastle. Several mineworkers expressed their apathy towards questionnaire-based research, and also their resentment of previous researchers who had not made their findings openly available to participants across all levels of the workforce. Although the researchers involved in the current study went to great lengths to build rapport with participants, their negative experience of previous research may have influenced the current findings. As the involvement of participants in other research designs is not controlled by the current project (and cannot be), future research may seek to alleviate negative affect amongst participants by consistently providing feedback to all participants, and also through the use of alternate forms of the questionnaire. Alternate forms may be used within future test-retest analyses in order to avoid learned responses and boredom in participants throughout the further development of the current tool (Petri & Czarl, 2003; Reiman, & Oedewald, 2004). Alternate forms may be problematic as the process of determining that two forms of an item have the same underlying meaning is laborious and challenging. Such a challenge may be outweighed however, by the benefits of accessing a more accurate portrait of safety culture within this industry through the avoidance of negative affect.

Recommendations

It is evident that several problematic items still exist within the SMQ-2 instrument. It was found that four items did not load on any of the six factors within the model, which may be an indication that the four issues raised through these questions represent the most emotive safety concerns within the coal mining industry. The four items relate to the reporting of near misses, worker involvement in the development of procedures, individual responsibilities for safety, and safety rules. The lack of fit within the six factor model may indicate that there were as many diffused responses to these items as there were individual participants within the current study. Such items would normally be discarded, in accordance with the traditional assumptions of factor analysis, however in the present study these items are considered valuable as they coincide with innumerable situational reports from mineworkers siting these four issues as their prime safety concerns. Hence, the current research suggests that in fact these items are of most relevance, and should rather be broken down to form multiple related items in future iterations of the SMQ-3. In so doing, the concepts underlying these items may be revealed, hence warranting further analysis concerning their relationship within the proposed six factor model of mine safety.

Further analysis of the factor loadings within the SMQ-2 reveals that ten items loaded on two factors, and four items loaded on three items. Some of these multiple loadings may be explained through poor wording of items, for example, the use of ‘sometimes’ (6 cases) and ‘always’ (1 case) in questions where these same terms are used as verbal anchors within the Likert scale. The current research recommends that SMQ-3 items be amended to exclude these words from questions. It is also recommended that items that were rephrased after showing multiple factor loadings within the 2003 SMQ study and have again loaded on multiple factors in the current study should be dropped from the future SMQ-3 tool.

One item with a poor response rate was discovered to express a double negative, hence explaining any possible confusion participants may have encountered in relation to this question. Other phrases including ‘no blame culture’ and ‘legal liability’ were also met with non-responses, hence representing confusion or apprehension on the part of participants to commit responses to these items. Through the development of the SMQ-3, it is recommended that further consultation with mineworkers be undertaken in order to determine how such items may be suitably reworded.

Implications

Despite the limitations still evident concerning the reliability and validity of the SMQ-2, the present study has demonstrated that the current tool is an improved measure of safety culture for the Hunter Region coal mining industry. These findings have future implications, as the ongoing improvement of measurement techniques represent an integral step in the improvement of safety at these sites. In the absence of adequate measures of safety culture, mines within the Hunter Region lack a framework from which to guide any proactive attempts to improve safety standards, decrease the incidence of LTIs, and avoid workplace fatalities. By gaining a more accurate picture of the core safety issues within this industrial setting, future iterations of the SMQ-2 will contribute significantly towards a progressive understanding of the cultural issues faced by all levels of the mining workforce, and hence form a basis from which effective interventions can be propelled. Effective measurement of safety culture and the development of related safety interventions will also act to advance efforts towards a greater appreciation of the non-technical aspects of mining and parallel safety efforts from applied psychology with those of other technical fields.

5.10.3 Phase 2: Summary SMQ - 2

In summary, during round two of the project the number of mines increased from three to fivce with a total of capacity of 812 participants of whom 353 responded to the questionnaire. This represents a participation rate of 43.5% a significant increase from round one where the rate was below 30%.

SMQ-2 is a significant improvement on the previous questionnaire developed while maintaining the six factor model and introducing a behavioural and an attitudinal scale (see copy in the appendix section).

Table 5.23 contains the reference data for both scales and the 6 factors. It is noted that no items loaded on factor 6 on the behavioural scale thus resulting in a zero value. This will be addressed in SMQ-3 together with other issues raised in the preceding sections.

Finally, the statistical analysis has shown that both validity and reliability of SMQ-2 improved significantly from the previous version.

In conclusion, SMQ-2 is an improved instrument over smq-1, however a number of minor issues need to addressed including the issue of non loading questions and the veracity of factor 6. These and other questions will be addressed in SMQ-3 currently under investigation. For a copy of SMO-3 see the appendix section.

5.11 General Discussion

This report is focussed on the phases and stages outlined in the introduction of the report, namely the literature review, the focus groups and the two rounds of SMQs.

The data obtained from the review of the scientific literature, focus groups, and the SMQs have been presented in this section of the extended report and collated to identify determinants of the critical factors of safety culture within the Australian coal mining industry. The core factors found to contribute to safety culture are: management commitment, the prioritisation of safety and production, safety systems and procedures, risk-taking/safety behaviour, individual responsibility, and communication.

As the research progressed many of the issues were clarified in elucidating the underlying factor structure of each of these safety critical issues in order to comprehensively determine the finalised core set with the developing safety management questionnaire. Several additional factors such as training and environmental risk have also been identified over the course of Project 1: Stage 1 as potential contributors to safety culture within the Australian coal mining industry.

Many of the findings presented throughout this section of the extended report are not explicitly explained within the literature specifically derived from the coal mining industry. As noted in section 3 of the extended report, the scientific literature was reviewed from a wide array of safety critical industries (HRIs) such as aviation, nuclear power-stations, and off-shore oil platforms. Measurement of safety culture within HRIs is increasingly following Human Factors principles, while remaining reliant on traditional scientific measurement tools and techniques. However, in the coal mining industry within Australia and several other nations, safety is commonly measured and assessed in terms of outcome measures such as lost-time injuries. Review of the literature, although extremely helpful in pointing us in the right direction, did not produce conclusive evidence of the appropriateness of this measure. For this reason research such as that currently being undertaken by The University of Newcastle Human Factors Group is being commissioned to develop scientifically appropriate measurement tools for safety outcomes through the underlying issues surrounding safety culture. In addition to revision of the theoretical and empirical literature, discussions with all levels of the workforce at select coal mines within the Hunter Region, NSW proved invaluable for understanding and identifying the safety critical issues facing management and the workforce as well as direction for the development of the safety measurement tool.

The results of Project 1: Stage 1 suggested a core set of critical factors of safety culture identified in the literature review were applicable to the Australian coal mining industry (as a result of the focus group sessions, task1 of the focus groups, and the results of the first SMQ). However, some variance did exist between identification of all these factors in focus group tasks and discussions as well as the questionnaire: suggesting due to the pilot nature of that particular research the results should not be considered in isolation. Such findings, however, provided topics for later inclusion and consideration by the research team. The research was constructed such that findings from one step informed the next step thus providing an improved testing instrument over time.

This original study suggested several modifications to the SMQ-1 that were needed to create a safety culture questionnaire tailored to the Australian coal mining industry. The questionnaire once modified (SMQ-2) was then tested for reliability, validity and was subsequently used to assess the magnitude and direction of safety culture within and across the Australian coal mining industry as represented by our sample population. The revised SMQ-2 also included a two scale response modality measuring both attitudes and behaviour. The instrument was provided to all levels of the workforce in the participating mines.

The outcome of this latest round is presented in the preceding sections and resulted in a 6 factor model with both reference data for attitudes and behaviour. No question loaded on factor 6 on the behavioural scale. Also there remain a small number of language problems with some questions that need further attention. These remaining issues are being addressed in the formal revison of SMQ-3 which is currently being tested. A advaced copy of this latest instrument is included in the appendix section.

Further investigation is also required into potential safety sub-cultures within occupational groups and hierarchical structures and also across domains. The results of this research indicate some differences in safety behaviours, attitudes, and directions for differing levels of the workforce, as well as differences between underground and open-cut operations (extending beyond environmental factors). Limited sample sizes and non-representative samples (i.e., focus group participation from OC Mine C) have not permitted analysis of such factors at this stage of the research. It is recommended however, future stages of the research program evaluate such issues and their potential influence over safety culture and their role in the development and modification of the revised SMQ. Perhaps some of tehse issues might be best addressed on an individual mine basis as required by them.

As the research developed over time, clearer identification of safety critical factors not only in terms of a core set widely applicable and generalisable to the Australian industry but also for individual mines enabled the identification of areas for safety advancements and improvements. From this, safety related interventions will be proposed by the research team aimed at improving safety culture through cost effective methods. Identifying and promoting understanding of the underlying factor structure supporting and maintaining safety culture within an organisation and across a national industry enables the identification of required areas for training and safety advancements, ensuring the appropriate allocation of resources in a safety (and production) critical domain such as the Australian coal mining industry.

5.12 Summary

Safety culture is a multi-faceted concept contributed to by an array of critical factors holding combined influence over safety behaviours and performance outcomes. Due to the many components of safety culture, the effective measurement of safety culture is a complex process requiring a multifarious approach. The combination of measurement techniques adds to the validity of the findings and the scientific development of measurement tools. Analysis of concepts such as safety culture must begin with a review of the theoretical and empirical literature. The scientific review conducted as the initial stage of the current research project (presented in section 3 of the extended report) revealed an emerging core set of 10 critical factors contributing to safety culture sourced from a range of HRIs (refer to Table 5.3). The focus groups and SMQ administration in this research indicated the applicability of this core set of critical factors to the Australian coal mining industry. The emerging factor categories of critical importance in the current sample remained largely invariant from the HRI core set. Furthermore the underlying sub-components of each factor varies across mines as does the ranked order of influence of the factor categories. Analysis of the collective data set from Project 1: Stage 1 (including focus groups and SMQ) has identified a 6-factor model (revised from the HRI core set) specific to the critical factors of safety culture within the Australian coal mining industry. The 6-factor model is as follows: (1) production/safety, (2) management commitment/communication, (3) safety systems, (4) procedures, (5) individual responsibility, and (6) risk. The applicability of these 6 ‘factor categories’ (and their underlying sub-components) to a wider industry sample will be continue to be investigated. The revised 6-factor structure was also modified to incorporate dual response scales measuring both behaviour and attitude. Further evaluation of this 6-factor model (including factor categories and the underlying sub-components) will refine the emerging core set of critical factors specifically within the Australian coal mining context. In addition, the revised structure will guide industry specific recommendations for the development of innovative research, training, and evaluation strategies to improve physical safety, safety attitudes, safety behaviours, safety systems, and essentially safety culture through manageable techniques. It is planned that SMQ-3 and its reference tables will be released as an addendum to this report in early 2006.

5.13 Disclaimer

Any opinions, findings, or recommendations expressed in this report are those of the project team as scientifically derived from the research literature and supplementary research project (Project 1: Stage 1 of an extended research program) and do not necessarily reflect the views of Coal Services Pty Limited, the Joint Coal Board Health and Safety Trust, or any other body or mining installation.

This research report forms part of an extensive report prepared for Coal Services Pty Limited and the Joint Coal Board Health and Safety Trust by The University of Newcastle Human Factors Group. The report relates to the first phase of a multi-year research program. The first project (that which is contained in the extensive report) was conducted in order to identify critical factors contributing to safety culture within the Australian coal mining industry from a sample of Hunter Region, NSW, coal mines: both under-ground and open cut. This report presents the methodology and findings of the first phase of Project 1 of the extended research program.

For further information on this report or to discuss access to the extended report, please contact Coal Services Pty Limited.

For further information about the current research project please contact the Human Factors Group from The University of Newcastle, Australia:

Associate Professor H. Peter Pfister

Director – Human Factors Group – The University of Newcastle

Aviation Building, School of Behavioural Sciences,

University Drive, Callaghan, NSW, 2308

Phone: (02) 49215760 – Fax: (02) 49216906

Email: Peter.Pfister@newcastle.edu.au

5.14 Acknowledgements

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H. Peter Pfister
Director
Human Factors Group

Rebecca J. Atkins
Research Officer
Human Factors Group

5.15 Appendices

Appendix A: Project 1: Stage 1 Activity Time Line

Appendix B: Chi Square Analysis Tables for Focus Group Discussions: Occupational Differences

Appendix C: Chi Square Analysis Tables for Focus Group Task 1: Occupational Differences

Appendix D: Chi Square Analysis Tables for Focus Group Task 2: Occupational Differences

Appendix E: Rotated Component Matrices from Factor Analysis of the Safety Management Questionnaire

Appendix F: Safety Management Questionnaire (SMQ-1)

Appendix G: Safety Management Questionnaire (SMQ-2)

Appendix G: Safety Management Questionnaire (SMQ-3)

Table A1

Project 1: Stage 1 Activity Time Line

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
24 & 25/03/03	Project Presentation – Penrith				
26 & 27/03/03	Project Presentation – Emerald				
31/03/03					University Ethics application submitted
23/04/03					Recommendations received from University Ethics Committee
30/04/03	Project Presentation – Cessnock				
01/0503					University Ethics response submitted

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
02/05/03					Faculty Ethics application submitted
12/05/03		Initial on-site meeting			
15/05/03				Initial on-site meeting	
20/05/03		Letter of participation approval obtained	Letter of participation approval obtained	Letter of participation approval obtained	Faculty Ethics response submitted
21/05/03				Open-cut site tour	University Ethics approval granted
22/05/03		Underground site tour			

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
28/05/03		Meeting with Safety Committee			
04/06/03		Article provided for Newsletter			Faculty Ethics Approval Granted
19/06/03		Meeting with Union Representatives	Initial on-site meeting		
02/07/03			Meeting with OH&S Committee		
15/07/03				Meeting with OH&S Committee	
17/07/03				Project Memo distributed amongst workforce and management	

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
22/07/03					Focus Group Training Session
31/07/03	Interim Report Submitted				
05/08/03		2 Focus Groups			
06/08/03		1 Focus Group			
07/08/03		3 Focus Groups			
12/08/03		1 Focus Group			

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
21/08/03				1 Focus Group	
26/08/03			1 Focus Group		
27/08/03			3 Focus Groups		
28/08/03			1 Focus Group		
28/08/03 – 31/08/03					Focus Groups Analysed
01/09/03 – 03/09/03					Safety Management Questionnaire Revised

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
04/09/03					Project Presentation School of Behavioural Sciences Colloquium Series
05/09/03		Article provided for Newsletter	Article provided for Newsletter	Article provided for Newsletter	
10/09/03		3 Pre-Shift Questionnaire Briefings			
11/09/03		Questionnaire Distributed Across Entire workforce		3 Pre-Shift Questionnaire Briefings	
12/09/03		First Questionnaire Response Received	Questionnaire Briefing with Shift Bosses and Safety Training Coordinator	Questionnaire Distributed Across Entire workforce	
12/09/03				First Questionnaire Response Received	

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
16/09/03			Questionnaire Distributed Across Entire workforce		
17/09/03			First Questionnaire Response Received		
29/09/03		Article provided for Newsletter	Article provided for Newsletter	Article provided for Newsletter	
15/10/03		Final questionnaire response received			
16/10/03			Final questionnaire response received		
18/10/03				Final questionnaire response received	

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
22/10/03					Lecture presentation given to pre-professional psychology students
27/10/03					Questionnaire data coded and entered into statistical analysis package
3/11/03 – 18/11/03					Questionnaire data analysis conducted
24/11/03					Interim preparations for final report
03/02/04					Consultation with incoming psychology honours research students
05/02/04					Consultation with incoming psychology honours research students

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
23/02/04					Selection of psychology honours research students for involvement in Project 1: Stage 2
27/02/04		Initial project debrief session with Safety Training Coordinator and Safety Systems Superintendent			Initial Discussions for mine recruitment for Project 1: Stage 2
01/03/04		Project debrief session with Union Reps			
08/03/04			Initial project debrief with Safety Training Coordinator and General Manager	Initial project debrief session with Safety Training Coordinator and HR Manager	Further discussions for mine recruitment for Project 1: Stage 2
09/03/04					Application for Variation submitted to University Ethics Committee
11/03/04					Initial phase of questionnaire revision

Date	Trust Functions	UG Mine A	UG Mine B	OC Mine C	University Functions
15/03/04					Faculty Ethics applications submitted
16/03/04		Project Debrief Session with Company Regional Services Manager	Project Debrief Session with Company Regional Services Manager		Further discussions for mine recruitment for Project 1: Stage 2
23/03/04		Project Debrief Session with OH&S Committee			
06/04/03				Project Debrief Session with Safety Advisory Team and General Manager	
06/04/03				Open-cut site tour	

Appendix B

Chi Square Analysis Tables for Focus Group Discussions: Occupational Differences

Table B1

Individual Chi Square Contributions for Critical Factors of Safety across Occupational Groups Identified in Focus Group Discussions held at UG Mine A

	Occupational Group				
Safety Issue	Day/After	Deputy	Managers	Night	Trade
Communication	14.66*	0.23	0.88	2.81	0.81
Environmental Risk	2.24	2.88	3.12	0.27	1.27
Individual Responsibility	0.38	0.01	2.35	0.02	3.19
Management Commitment	1.01	0.37	2.96	2.02	9.90*
Miscellaneous	1.32	4.91*	1.35	0.15	2.93
Production/Safety	5.12*	0.00	1.21	12.19*	0.25
Risk/Safety Behaviour	0.76	1.54	0.11	6.19*	5.59*
Systems/Procedures	3.94*	0.02	12.79*	4.42*	2.52
Training	2.09	0.00	0.60	3.16	0.80

Table B2

Individual Chi Square Contributions for Critical Factors of Safety across Occupational Groups Identified in Focus Group Discussions held at UG Mine B

	Occupational Group				
Safety Issue	Under-Manag	Prod (Day)	Eng Team Leader	Prod/Trad (Day)	Deputies
Bonus Structure	1.35	0.80	0.01	0.36	0.40
Communication	0.07	0.66	3.58	0.46	4.19*
Contractors	0.01	3.55	3.06	1.53	1.03
Drug and Alcohol	1.68	1.87	0.04	1.00	1.74
Environmental Issues	1.41	4.87*	0.45	1.45	0.48
Fatality	6.79*	0.07	0.40	0.03	1.47
Individual Responsibility	23.84*	1.49	0.60	1.36	1.67
Litigation	2.47	0.36	0.78	0.13	0.23
Management Commitment	0.68	0.76	1.02	6.60*	1.19
New Mining Methods	1.51	3.20	2.40	7.91*	1.88
Personal Limitations	2.41	0.29	0.42	0.01	1.17
Safety/Production	1.43	3.50	0.81	3.46	0.00
Reduction of Workforce	4.53*	5.04*	2.01	9.01*	0.08
Risk	10.23*	4.01*	2.04	2.62	0.67
Safety Attitudes	1.68	1.87	0.17	23.44*	2.09
Safety Equipment	2.59	13.65*	0.54	4.41*	0.45
Shift Length and Type	2.59	3.32	2.03	0.00	1.66

Site Issues	3.96*	0.81	2.08	0.05	0.79
Safety Systems/Procedure	0.06	9.20*	0.48	3.04	0.55
Training	0.77	2.15	0.43	8.07*	1.27

Appendix C

Chi Square Analysis Tables for Focus Group Task 1: Occupational Differences

Table C1

Individual Chi Square Contributions for Critical Factors of Safety across Occupational Groups Identified in Focus Group Task 1 at UG Mine A

	Occupational Group				
Safety Issue	Day/After	Deputy	Managers	Night	Trade
Communication	0.50	2.60	0.15	0.48	0.56
Environmental Risk	0.66	2.23	0.68	0.10	1.28
Individual Responsibility	0.10	2.03	0.09	0.02	1.00
Management Commitment	0.36	2.14	0.01	0.01	0.12
Miscellaneous	3.96*	0.91	0.48	0.15	0.11
Production/Safety	0.26	0.26	1.64	3.19	0.01
Risk/Safety Behaviour	0.94	0.41	0.88	17.04*	1.13
System/Procedures	2.11	0.01	18.48*	1.48	2.53
Training	0.00	0.94	0.02	2.79	0.31

Table C2

Individual Chi Square Contributions for Critical Factors of Safety across Occupational Groups Identified in Focus Group Task 1 at UG Mine B

	Occupational Group				
Safety Issue	Under-Manag	Prod (Day)	Eng Team Leader	Prod/Trad (Day)	Deputies
Communication	0.50	10.84*	2.69	3.13	1.26
Environmental Issues	9.35*	1.23	2.35	2.74	2.66
Litigation	0.01	0.66	8.06*	0.78	0.76
Management Commitment	0.00	2.60	1.28	6.26*	0.00
New Mining Methods	0.56	0.33	0.34	0.39	6.90*
Personal Limitations	1.63	3.47	0.06	3.69	3.99*
Safety/Production	2.83	0.04	0.46	1.23	5.55*
Reduction of Workforce	8.99*	3.48	10.81*	0.48	2.52
Risk	11.04*	0.99	1.01	1.17	1.14
Safety Attitudes	8.48*	6.61*	0.77	1.02	0.89
Safety Equipment	8.43*	16.49*	5.04*	5.87*	18.60*
Shift Length and Type	4.50*	2.64	14.81*	4.79*	3.04
Safety Systems/Procedure	12.01*	6.28*	6.39*	1.59	3.16
Training	1.56	1.76	1.74	21.37*	10.04

Appendix D

Chi Square Analysis Tables for Focus Group Task 2: Occupational Differences

Table D1

Individual Chi Square Contributions for Levels of Responsibility for Safety across Occupational Groups Identified in Focus Group Task 2 at UG Mine A

	Occupational Group				
Job Function/Level of Responsibility	Day/After	Deputy	Managers	Night	Trade
Everybody	0.07	10.48*	0.08	1.48	1.52
Individuals	0.03	0.31	0.00	0.00	0.26
Management	1.27	0.13	1.86	0.79	0.59
Middle management	0.72	0.09	0.81	1.67	0.81
Other	0.89	1.85	0.45	1.04	4.23*
Workmates	0.53	1.74	0.08	2.50	1.46

Table D2

Individual Chi Square Contributions for Levels of Responsibility for Safety across Occupational Groups Identified in Focus Group Task 2 at UG Mine B

	Occupational Group				
Job Function/Level of Responsibility	Under-Manag	Prod (Day)	Eng Team Leader	Prod/Trad (Day)	Deputies
Company	0.03	1.60	3.61	0.00	0.16
Deputies	0.03	0.22	1.60	0.41	1.53
Individual Responsibility	0.80	0.81	0.70	0.15	0.33
Management	1.84	0.30	2.04	0.21	4.13*
Other	0.20	1.95	4.76*	0.93	0.76
Safety Officer	0.00	0.12	0.12	0.01	0.34
Supervisors	1.37	0.01	0.60	0.21	0.00
Undermanager	0.36	2.95	3.02	0.03	0.01

Appendix E

Rotated Component Matrices from Factor Analysis of the Safety Management Questionnaire

Table E1

Rotated Component Matrix for UG Mine A

	Component					
Question	1	2	3	4	5	6
VAR03	.735					
VAR17	.719					-.400
VAR21	.717					
VAR15	.711	.332				
VAR11	.707					
VAR04	.684			.391		
VAR07	.680					
VAR25	-.617		.314			
VAR09	.593			.421		
VAR02	.573					
VAR20	.567	.444				
VAR42	.484	.305				.445
VAR19	.478	.353		.326		
VAR22	.477	.355	-.462			
VAR61	-.419			.374		
VAR37	.302					
VAR55		.779				
VAR32		.737	-.337			
VAR30		.669			-.412	
VAR48		.646	-.392			
VAR24	.312	.606				
VAR33		.583	-.344			
VAR31		.568				
VAR35		-.564	.363		.429	
VAR40		-.560	.493			
VAR60		.539				
VAR28		.520				
VAR41	.330	-.490				
VAR51		-.482			.424	
VAR34	.336	.480	-.414			
VAR43	.349	.430			-.336	

VAR58			.702			
VAR64			.653			.358
VAR47			-.617			
VAR39		-.428	.616			
VAR59			.614			
VAR46			.604			
VAR36		-.385	.559			
VAR53			.550		.336	
VAR38			.526			
VAR44			-.524			
VAR52		-.306	.448		.353	
VAR57	-.421		.445			
VAR54			-.405	.312	-.373	
VAR27				.823		-.321
VAR26				.773		
VAR08				.710		-.304
VAR29				.704		
VAR23				.624		
VAR56			-.395	.476		
VAR06				.450		
VAR12	.384	.385		.438		-.411
VAR01						
VAR50					.717	
VAR49					.661	
VAR13					.604	
VAR62					.589	
VAR63			.552		.553	
VAR45	.386				-.413	
VAR05						.613
VAR16						.580
VAR18				.343		-.554
VAR10						.447
VAR14						-.302
VAR065						

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 8 iterations.

Table E2A

Rotated Component Matrix for UG Mine B (Factors 1-6)

Rotated Component Matrix

	Component					
	1	2	3	4	5	6
VAR00020	0.849					
VAR00022	0.761					
VAR00019	0.756					
VAR00021	0.678					
VAR00025	-0.650					-0.303
VAR00004	0.644	-0.307				
VAR00017	0.613					0.525
VAR00001	-0.580					
VAR00016	-0.559					
VAR00009	0.481					
VAR00011	0.463					
VAR00048	0.399		-0.349			0.327
VAR00063		0.853				
VAR00061		0.825				
VAR00053		0.769				
VAR00057	-0.369	0.763				
VAR00062		0.649	0.488			
VAR00050		0.606	0.388			
VAR00002	0.426	-0.606				
VAR00012	0.343	-0.594				
VAR00007		-0.473			0.415	
VAR00039			0.853			
VAR00038			0.754			
VAR00036			0.686	-0.308		
VAR00040	-0.339		0.581			
VAR00024			-0.482			
VAR00056	-0.327	-0.302	0.443	0.394		
VAR00055				0.852		
VAR00032				0.829		
VAR00008			-0.318	0.733		
VAR00051			0.470	-0.539	-0.304	
VAR00054				0.503		
VAR00028					0.786	
VAR00023					0.766	
VAR00064					-0.674	
VAR00052					-0.620	
VAR00030		-0.431			0.544	
VAR00006					0.471	
VAR00014						0.872
VAR00010						-0.848

VAR00015	0.396					0.750
VAR00018			-0.431		0.413	0.498
VAR00027				0.439		-0.466
VAR00042						
VAR00033				0.393		0.336
VAR00029			-0.369			
VAR00026			-0.304			-0.370
VAR00059						
VAR00058		0.397				
VAR00031						
VAR00047				0.315		
VAR00034			-0.359		0.421	
VAR00013		0.391				
VAR00060						
VAR00044						0.353
VAR00045				0.501		
VAR00005	-0.373					
VAR00043			-0.343	0.376		
VAR00049		0.489				
VAR00003						
VAR00046				0.306		
VAR00041						
VAR00037						
VAR00035	0.371			-0.492		
VAR00065					-0.315	

Table E2B

Rotated Component Matrix for UG Mine B (Factors 7-12)

Rotated Component Matrix	7	8	9	10	11	12
	Component					
VAR00020						
VAR00022						
VAR00019						
VAR00021				0.361		
VAR00025	0.450					
VAR00004	0.325					
VAR00017						
VAR00001						
VAR00016					0.520	
VAR00009		0.331		0.321		
VAR00011				0.418	-0.308	
VAR00048						
VAR00063						
VAR00061						

VAR00053						
VAR00057					0.310	
VAR00062						
VAR00050		0.379				
VAR00002		0.342				
VAR00012						-0.328
VAR00007						
VAR00039						
VAR00038						
VAR00036		0.351				
VAR00040			-0.311	0.374		
VAR00024	0.392		0.381			
VAR00056			0.333			
VAR00055						
VAR00032						
VAR00008						
VAR00051	0.423					
VAR00054		-0.322	0.347			
VAR00028						
VAR00023						
VAR00064				-0.335		
VAR00052	0.327					
VAR00030						-0.428
VAR00006		-0.443				
VAR00014						
VAR00010						
VAR00015						
VAR00018						
VAR00027	0.352	-0.430				
VAR00042	0.839					
VAR00033	0.704					
VAR00029	0.494	-0.319				
VAR00026	0.442	-0.377	0.312			
VAR00059		0.852				
VAR00058		0.697				
VAR00031			0.699			
VAR00047			0.667			
VAR00034			0.573			
VAR00013	0.348		-0.518			
VAR00060	0.374		0.391			
VAR00044	0.315		0.380			
VAR00045				0.661		
VAR00005				-0.621		
VAR00043				0.562		
VAR00049				0.552		
VAR00003					-0.766	
VAR00046					0.692	
VAR00041		-0.351			-0.415	
VAR00037						0.857
VAR00035						0.530
VAR00065						0.520

Table E3

Summary of Rotated Component Matrix for UG Mine B

Factor	*Variables*	*Factors Found*
1	V20, V22, V19, V21, V1 (15)	Risk taking/ rule breaking
2	V63, V61, V53, V62, V50 (10)	Management commitment to communication
3	V39, V38 (14)	Management commitment
4	V55, V32, V54 (14)	Production pressure
5	V28, V23, V64, V52, V6 (6)	Incident reporting
6	V14, V10, V15 (8)	Systems
7	V42, V33 (11)	Systems
8	V58, V59 (10)	Management commitment
9	V31, V67 (9)	Communication
10	V45, V5, V43, V49 (5)	Systems
11	[6]	Miscellaneous
12	V37, V35, V65 (2)	Individual responsibility

Table E4

Rotated Component Matrix for OC Mine C

	Component					
	1	2	3	4	5	6
VAR63	.726					
VAR35	.694					
VAR25	.692					
VAR36	.690					.335
VAR39	.688		-.321			
VAR51	.685	-.326				
VAR38	.676					
VAR52	.624	-.332			-.315	
VAR55	-.600		.407			
VAR57	.591	-.353			-.370	
VAR53	.578					
VAR47	-.546	.345				
VAR58	.533	-.390	-.305			
VAR02	-.531					
VAR50	.466					.365
VAR65	.428				-.382	
VAR59	.414		-.374			
VAR05	.393					
VAR19		.671				

VAR18		.660				
VAR30	-.419	.573				
VAR22		.566	.383			-.376
VAR44		.555				
VAR24		.547	.372		.397	
VAR20		.526				
VAR46		-.505				
VAR15		.492		.449		-.305
VAR09		.490		.369		
VAR34	-.346	.485	.342			
VAR08		.480			.425	
VAR61	.430	-.470				
VAR10	.439	-.460		-.391		
VAR49	.339	-.455				.450
VAR62	.352	-.398	-.301			
VAR33			.773			
VAR48		.327	.645			
VAR42			.604			
VAR27			.559			-.330
VAR43		.329	.521			
VAR32	-.448		.471			
VAR31			.470		.430	
VAR26			.439	.436		
VAR41	.393		-.424		-.370	.314
VAR60			.372			
VAR04				.735		
VAR03				.702		
VAR11		.395		.556		
VAR40	.440		-.441	-.527		
VAR07	-.360			.474		-.314
VAR01				-.395		
VAR29		.307	.324	.341		
VAR06				.423	.691	
VAR23				.393	.573	
VAR64	.312				-.569	
VAR12				.345	.543	
VAR45			.335		.539	
VAR14					.517	
VAR28	-.419			.427	.454	
VAR16						.701
VAR21		.404	.326	.355		-.505
VAR54	-.338		.427	.373		.505
VAR17		.480		.405		-.480
VAR56						-.463
VAR13					-.329	.446
VAR37			.308		.303	.395

Extraction method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 18 iterations.

Appendix F

Original SMQ developed for application in three mines

See next page

Appendix G

SMQ - 2 developed for application in 6 mines for round two testing

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Appendix H

SMQ - 3 developed for application in all mines for round three testing

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Questionnaire not for public release at this stage