ORGANISATIONAL CULTURE AND SAFETY CULTURE AS DETERMINANTS OF ERROR AND SAFETY LEVELS IN AVIATION MAINTENANCE ORGANISATIONS: A LATENT FAILURE APPROACH

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Abstract

ABOUT A DECADE AGO, a model known as the Latent Failure Model became influential in shaping the manner in which the aviation industry approaches the treatment of human error. It suggested that 'latent conditions', introduced into technological organisations, influence the qualitative and quantitative nature of error and safety.

Under the present thesis, the underlying culture of an organisation represents a pervasive latent condition that influences safety. Using quantitative questionnaire methods, this research examined the relationships between culture, and safety and error in aviation maintenance. An Organisational Culture Measure (OCM), a Safety Culture Measure (SCM), and three indicators, which assessed error level and safety, were administered in six aviation maintenance organisations in New Zealand.

The conclusions, based on the analyses of organisationally reported error data, are: (a) organisations reporting a higher number of errors are safer than those reporting lower numbers (it is suggested that this may be due to these organisations having good reporting systems in place), and (b) the control exercised by organisations, exemplified by compliance with rules, performance orientation, power-oriented autocracy, and passion for industry, co-operation, communication, rewards, and the perceived level of safety are related to the levels of error and safety reported in these organisations. Specifically, organisations demonstrating higher levels of control appear to be safer than those with lower levels.

The research also examined errors reported directly to the researcher from individuals in one of the organisations taking part in the study. These data indicated that where employees are developed within the organisation by work diversity and being allowed to develop at a personal level, and where the organisation exercises control, then individuals report fewer errors. This result may seem paradoxical in the light of (a) above, regarding organisational error reporting and its proposed relationship with safety; however, it is suggested that

organisational/institutional reporting is a different phenomenon to individual reporting, the former reflecting the objective performance of organisations, the latter reflecting an individual's self-awareness and the attributions arising from these. In addition, managerial willingness to address safety issues and an appreciation of the importance of safety issues in the workplace have positive relationships with the number of self-reported errors. Management should overtly indicate their approval of safety practices and routinely monitor the safety culture of their organisations.

This research cautiously suggests that the organisational culture of aviation maintenance organisations in New Zealand is relatively homogeneous. This indicates that similar safety interventions can effectively be applied across such organisations.

Whilst the utility of the quantitative methods used in this research has been demonstrated, it is argued that in themselves they provide insufficient detail to explain the complex interactions between organisational culture and safety. The research suggests the value of using a range of methods, both quantitative and qualitative, in the examination of aviation maintenance culture, error, and safety.

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Chapter 1. Overview of thesis

ON THE SATURDAY afternoon of 26 April 1986 a massive explosion at the Chernobyl nuclear power installation in the former Soviet Union released nuclear contaminants into the atmosphere, polluting a great part of Western Europe (Reason, 1990). There was some debate at the time about the causes of the accident (Baker & Marshall, 1988; Reason, 1987a, 1988) and following this the interest in safety culture and its relationship to safety performance and error increased.

Pidgeon and O'Leary (1994) describe the accident at Chernobyl as a good example of how the organisational culture and behaviour of members of an organisation allowed the introduction of a number of errors that collectively contributed to the explosion in the reactor. Seemingly, the perception of organisational culture that existed in Chernobyl was that it was a safe one, but errors were introduced that in hindsight seem unbelievable (Reason, 1997).

Other incidents, such as those at Erebus (Vette, 1983), Bhopal (Shrivastava, 1987), Zeebrugge (Sheen, 1987), and Three Mile Island (Kemeny, 1979) have also provided an impetus to trying to understand more fully the socio-technical processes relevant to such accidents. This has generated demand for empirical applied research leading to adequate models of safety culture (Cox & Flin, 1998a; Edkins & Coakes, 1998; Helmreich & Merritt, 1998; Reason, 1997) and the literature concerning human factors in aviation now contains publications in which this subject is covered, for example, Maurino, Reason, Johnston, and Lee (1995), Reason (1997), and Helmreich and Merritt (1998).

It would seem that there has been an increasing acceptance that elements of organisational culture may make organisations more susceptible to errors and accidents (Maurino et al., 1995, 1998; Reason, 1997). As Lauber (1993) of the National Transportation Safety Board has stated:

> "Human performance is always conditioned by the context in which it occurs, and thus "corporate culture" is a critical

determinant of an organization's safety" (p. 88).

However, the empirical validity of the safety culture concept is still unproven (Cox & Flin, 1998b) and its utility is yet to be determined. It is hoped that the methods and results described in this thesis will provide some useful insights and encourage organisations to take more interest in organisational and safety culture, and that the utility of the safety culture concept will be further demonstrated. An improved understanding of the nature of organisational and safety culture and how these affect safety outcomes, may help industries decrease the risk of such incidents and accidents in the future.

This chapter presents a background to the thesis, explains the purposes of the research, discusses its significance, and describes the research approaches and methods used. The chapter concludes with an overview of the thesis structure.

1.1. Background to the research

This research examines the relationship between organisational culture, safety culture, and safety and error in aviation maintenance. This section provides a brief introduction to each of these areas.

1.1.1. Organisational and safety culture

As recently as ten years ago, this topic had received little or no attention from academics around the world and it is only recently that an interest in safety culture in aviation has developed (Maurino, 1998). The concept of organisational culture has existed for some time but Zohar (1980) first introduced 'safety culture' in the early 1980s.[1] More recently Booth (1996) has discussed the relationship between organisational culture and safety culture and concluded that safety culture may now be considered "a sub-set of, or at least profoundly influenced by," organisational culture (p. 319).

At the start of this research, no work examining safety culture in aviation maintenance had been published. There are perhaps three major reasons for this. Firstly, there are difficulties associated with empirically assessing organisational culture and safety culture. Secondly, there are difficulties in defining and capturing safety-related errors in the aviation maintenance workplace. Thirdly, the influence that organisational and safety culture can have on aviation maintenance practice had not been fully appreciated (Maurino, 1998). Illustrating this last point, Maurino (1998) suggests that from the mid 1980s until the mid-1990s the aviation industry began a transformation in its approach to safety. Coupled with the development of the 'global village'[2] and the increased representation of different nationalities within airlines, the importance of culture in aviation began to be acknowledged. As Head of Flight Safety and Human Factors for the International Civil Aviation Organisation (ICAO), Maurino was in a position to observe a growth in the interest in culture issues and stated that, "the time to seriously think about cultural factors in aviation has come", and also that,

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[1] Zohar (1980) used the term safety climate.

[2] Maurino (1998) uses the term 'global village' to indicate the disintegration of traditionally strongly defended frontiers and the crumbling of social systems based on vanishing beliefs.

"cultural factors are deeply embedded in the very nature of the aviation system" (Maurino, 1998, p. xiv). Maurino further suggested that the upsurge of interest in culture had been driven by the efforts of a few people who recognised the contribution that this concept could make to safety and improved performance in aviation. Maurino cites several aviation accident reports where organisational culture is cited as a contributing factor: Dryden (Moshansky, 1992), the accident at Young, Australia (Bureau of Air Safety Investigation, 1998), Mont Sainte-Odile, Strasbourg (Paries, 1996), and Eagle Lake, Texas (National Transportation Safety Board, 1992).

Reason (1998) has suggested that the involvement of culture in such accidents can be explained by considering the technological and social complexity that exists in aviation, nuclear, medical, chemical, and transport industry organisations. In such organisations, it is common to find defensive systems designed to prevent major incidents or accidents.[3] Such systems are often error-tolerant because of built-in redundancy and back-up systems. These layers of defences are distributed throughout the organisation and are designed to protect the organisation. Reason (1997) argues that these defences are collectively vulnerable to something that is also equally distributed; namely the safety culture that exists in the organisation. Reason further suggests, that in order to have a safe culture, one must first establish an informed culture. This in turn depends upon an effective reporting culture, engendering what Cheyne, Cox, Amparo, and Tomas (1998) have termed "safety condition monitoring" (p. 196). For a reporting culture to exist, a just culture needs to be promoted whereby errors, and the reporting of such, are treated fairly and justly (Johnston, 1993; Reason, 1997). Without this just culture, it is likely that error reporting will be suppressed. This suggests that the promotion of safety culture in an organisation must be pervasive and must occupy all levels of the organisation. Booth (1996) has suggested, "safety culture is not a simple 'thing' that can be just 'bolted on'." (p. 320).

[3] Within aviation safety an 'incident' means any occurrence associated with the operation of an aircraft that affects or could affect the safety of the operation. An accident is defined as an occurrence causing serious damage to the aircraft, or where the aircraft is missing, or there is serious injury to people (Civil Aviation Authority of New Zealand, 1996, personal communication).

The explosion of the space shuttle Challenger, on 28 June 1986, illustrates how organisational culture can contribute to the events leading to an accident. Accident investigation revealed a number of contributing factors; a major one being the fracture of an O-ring seal within the fuel system of the booster rocket assemblies (Vaughan, 1990). The choice of design for the failing component was made 13 years prior to the accident (Pidgeon, 1988; Pidgeon & O'Leary, 1994; Vaughan, 1990) and the risk of failure had been identified by the manufacturer prior to the Challenger launch. The National Aeronautics and Space Administration (NASA) engineering section and the O-ring manufacturer had expressed safety-related concerns on the use of O-rings in low temperature conditions. However, NASA, as an organisation, seemed to regard this situation as representing an acceptable flight risk. Pidgeon (1988) has described this as "an illusion of invulnerability which seemed to exist" in NASA at the time, and this may be one of the reasons why the decision to go ahead with the launch was made (Pidgeon, 1988, p. 357). Reason (1987b) has described this phenomenon as "normalised deviance"; the process by which deviant, extreme, or risky behaviours can become accepted as the norm by members of an organisation. A form of 'group-think' (Janis & Mann, 1972) may have been operating, which in this case, it was hypothesised by Reason (1987b), resulted in the development of a more risk-tolerant organisational culture. Could the organisational culture in NASA at the time have been described as one of risk-taking and denial, which had become normalised and was accepted? If a reliable technology to detect the presence of such a culture had existed at the time, then perhaps this error, and the accident, may have been prevented.

To fully understand how culture can influence incidents and accidents it is important to understand the distinction between two different approaches to accident causation; the 'individual accident' approach and the 'organisational accident' approach (Perrow, 1984). The individual accident approach is where the causes of the accident are delimited to a specific person or group of persons. Traditionally this has been the approach used in the management of error in aviation maintenance. More recently the importance of organisational accident approaches have been advocated; these have emphasised the importance of organisational cultures that promote safe operations (Reason, 1997).[4] Multiple causes are considered, involving a variety of groups and individuals in different areas of the organisation (Maurino, 1998; Maurino et al., 1995; Perrow, 1984; Reason, 1997).

1.1.2. Aviation maintenance error

While accidents and incidents may have any number of causes, it has been suggested that many are a direct result of deficiencies in maintenance. Graeber and Marx (1993) analysed 232 hull loss accidents over a period of ten years. Their focus was on identifying multiple strategies that would have prevented the accidents. Their analysis indicated that changes in levels of maintenance and inspection could have prevented 16% of these hull losses. When all accidents were considered, the figure rose to 20% (see Figure 1). Graeber and Marx also mention the work of Sears[5] (1986, cited in Graeber & Marx, 1993) who analysed 93 major accidents and determined that 12% had maintenance and inspection deficiencies as a significant cause; this dropped to 3% when primary causes alone were considered. Such studies suggest the considerable importance of aviation maintenance in the aetiology of incidents and accidents. Generally, maintenance personnel will detect the errors they make and might be expected to take actions to correct them or their outcomes. When an error remains undetected however, it may introduce a potentially dangerous condition into the aircraft system, which may then remain hidden for a considerable period.

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[4] These approaches will be explored in more detail in Chapter 2.
[5] Attempts at obtaining the Sears' reference were not successful.

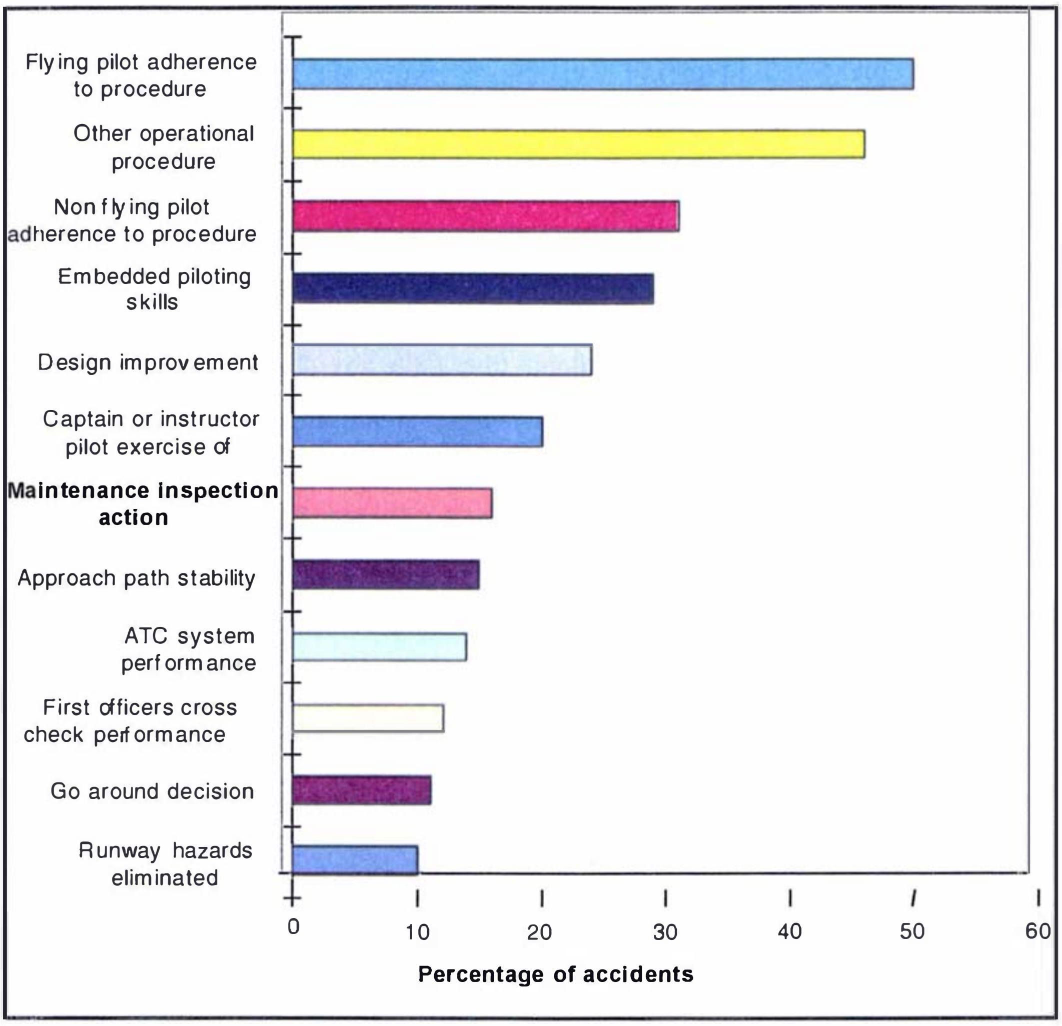

Figure 1: The causes of hull loss accidents from 1982 to 1991 (Adapted from Graeber & Marx, 1993.).

The ease with which maintenance errors can remain undetected is illustrated by an accident on 10 June 1990 involving a BAC 1-11 owned by British Airways (Air Accidents Investigation Branch, 1992; Maurino et al., 1995). In this accident, the Captain's side window blew outwards as the aircraft reached 17,000 ft. The Captain was partially sucked from the aircraft and was saved by a fellow crewmember holding on to his legs. This accident was a direct result of a series of maintenance errors that the aviation maintenance organisation was unlikely to detect once the aircraft had been released to service. Indeed the error remained unknown and undetected until the accident investigation revealed that it was the incorrect selection and installation of securing bolts that had allowed the in-flight separation of the windscreen. Incorrect bolts had also been used to secure the previous windscreen, a fact that became known following this accident. If the windscreen had not been torn from the aircraft, then the errors that had occurred during the previous, and the latest refit, of the window would have remained undetected.

The above accident draws attention to some of the challenges that face aviation maintenance organisations in their effort to combat maintenance error. These are the detection of errors that are occurring, the classification of the errors in a way that provides useful information to analysts, the anticipation of errors and actions that must be taken to minimise such errors in the future; and finally, the mitigation of the effects of such errors. Meeting these challenges in an effective and systematic manner is likely to substantially reduce the impact and consequences of maintenance errors (Helmreich & Wilhelm, 1999).

1.2. Purpose and significance of this research

If organisational and safety culture can be described by dimensions that are reliable and valid descriptors of the organisations in question, then it should be possible to use these dimensions to predict some relationship to safety behaviour in aviation maintenance organisations. Therefore, if this research is able to start unravelling the potentially complex relationship that exists between aspects of organisational culture, human error, and safety performance in aviation maintenance, then this will be a valuable contribution to safety and efficiency in the aviation industry.

The purpose of this research was to investigate the relationships that exist between organisational culture and safety culture, on the one hand, and safety performance and error generation in aviation maintenance organisations on the other. To achieve this it was necessary to produce operational measures of these constructs, which could be practically applied in working aviation maintenance environments. A desired outcome of this research was that the nature of organisational culture and safety culture, within aviation maintenance organisations, might be determined and used to discriminate between organisations that display different levels of maintenance error and safety. This was intended to provide the beginnings of a method of proactively determining 'at-risk' organisations.

This research provides a contribution to the literature on the use of quantitative measures for the assessment of organisational and safety culture and their relationships to maintenance error and aviation safety. It describes the utility of an approach that uses multiple measures based on evaluations of (a) organisational culture and safety culture, (b) subjective evaluation of error performance, (c) observation of safety practice, and (d) recorded error frequencies.

1.3. Research methods

Electronic and paper-based measures were used to collect information about organisational culture, safety culture, safety behaviour/performance and maintenance error. The measures were developed through an examination of the existing literature and consultation with aviation and safety industry experts. They were subject to piloting, reliability, and validation procedures as appropriate. An electronic database record of errors in maintenance was accessed for information on error frequency. Efforts to obtain detailed qualitative information on maintenance errors within the organisations in the study, using tools designed specifically to investigate error in maintenance environments, were not successful.

Procedurally there were to be two distinct research phases. The first was concerned with the development of the measures (see Chapter 3). These were: the Organisational Culture Measure (OCM), the Safety Culture Measure (SCM), the Safety Index Measure (SIM), the Managers' Self-Report General Failure Types (FTman), and a measure to determine the relative frequency of maintenance-related human error events called the Error Frequency Index (EFI).[6] Two additional tools: the Maintenance Error Reporting Notice/Maintenance Error Investigation Notice (MERN/MEIN), and the Maintenance Error Incident Analysis (MEIA), were also developed. These were designed to provide a more detailed analysis of errors occurring in organisations. The measures are shown in Appendix A (p. 243).

In the main study (see Chapters 4 and 5), the measures were used to assess the relationships between organisational culture and safety culture, and maintenance error and safety performance within aviation maintenance organisations in New Zealand. It had been anticipated that each maintenance organisation would contribute three sets of data on each of the measures, separated in time by a period of six months. This would have allowed a comprehensive analysis of the relationships over time. However, for a number of practical reasons, this proved to be too ambitious; the co-operating organisations

[6] The Error Frequency Index (EFI) is calculated from data supplied by the Civil Aviation Authority of New Zealand.

were either unable to provide data or initiate data collection within the planned time line, or, the participants within the organisation could not be encouraged to complete the questionnaires within the first data-collection period. At this point abandonment of the research was considered. However, in consultation with an academic panel within Massey University, it was decided to continue, and fresh attempts to encourage participants to respond yielded sufficient data for a less ambitious analysis. Data were collected over a two-and-a-half year period (including the pilot study) from six aviation maintenance organisations and one regulatory organisation in New Zealand. The respondents were employees of these organisations.

1.4. Structure of the thesis

This manuscript is organised into six chapters. Chapter 1 provides an overview of the reasons for the research being carried out and sets the scene for what is to come. Chapter 2 presents the background literature, aims, and hypotheses. Chapter 3 gives an account of the development of the measures used in the research and the piloting of the organisational culture and safety culture measures within the oil industry. Chapter 4 describes the data collection methods used in this research, the challenges faced and how these were overcome. Chapter 5 presents the results. Each hypothesis is considered separately and in turn. Chapter 6 evaluates the findings within the context of the existing literature and provides some critique of the methods and directions for future research of this type. Finally, the implications of the findings for the industry are discussed.

Chapter 2. Literature review

THE LITERATURE REVIEW provides a background to the topics of aviation maintenance and human error in the context of organisational and safety culture. It is intended to provide a setting for the empirical research that follows, providing a rationale for the design of the study. There are four sections. Section 2.1 describes the nature of aviation maintenance; maintenance-related incidents and accidents are used to illustrate how errors in maintenance can develop and how they can remain hidden within the maintenance system. Section 2.2 describes the nature of human error within the context of the organisation. Section 2.3 explores the organisational culture and safety culture literature and how culture provides a context that influences maintenance error. Section 2.4 summarises the themes emerging from the literature into the conceptual approach used for this research, ending with a presentation of the aims and hypotheses of the study.

2.1. The nature of aviation maintenance

Aviation maintenance is a complex activity consisting of great variety in the tasks and jobs to be performed. It is subject to a number of environmental influences that shape work performance, which ultimately influence maintenance outputs (safe or unsafe aircraft). Figure 2 shows some of these influences.

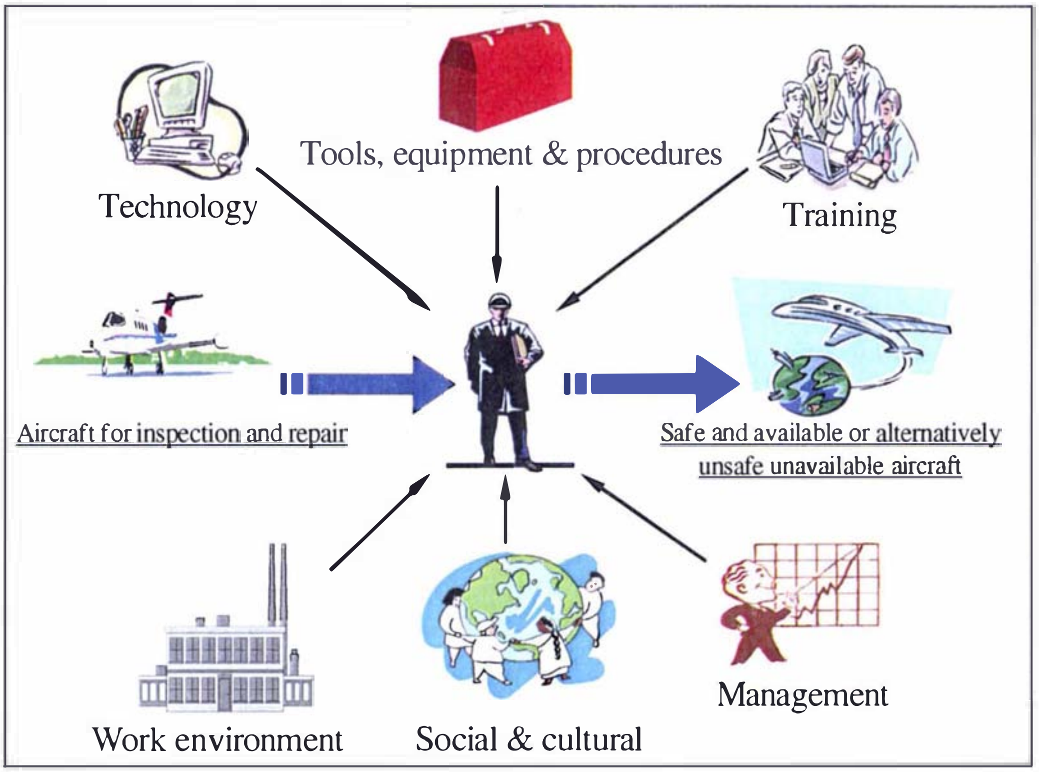

Figure 2: The human in the aviation maintenance system (Adapted from Johnson & Shepherd, 1993.).

In addition, aviation maintenance is frequently performed under time pressure, initiated by systems failures, and may require the application of specialist skills and knowledge that are not routinely part of a maintenance engineer's repertoire (Marx & Graeber, 1994). The latter may be particularly true where the component has a long life or where maintenance is performed infrequently. For example, a rivet inspection in a difficult-to-access location during a C check on an aircraft may involve a number of rarely performed procedures[7]; on occasion this may lead to an accident such as the loss of a Boeing 747 aircraft over Osaka in 1985 (Aviation Safety Network, 2001).

The task variety inherent in aviation maintenance is usefully contrasted with that of pilots. Under normal working conditions, a pilot's tasks consist of routine behaviours that are procedurally driven, initiated by mission events and involving a series of concurrently performed tasks (Ruffner, 1990); re-programming the flight management system several times during a flight provides a good example of this. Ruffner (1990) suggests that maintenance personnel activity differs in both quantity and quality from that of a pilot. Table 1 shows these differences in a normal working situation and provides some idea of the relative complexity and variety in aviation maintenance work. For example, it can be seen that the 'Problem solving requirements' in maintenance activity are in the 'Moderate-high' range, whilst for pilots they are in the 'Low-moderate' range. Aviation maintenance personnel experience a greater variety of physical activity, a more varied work environment, non-regulated and fluctuating shift patterns, and discrete task performance with a great potential for variation in performance and error in the work undertaken (Marx & Graeber, 1994).

[7] C and D checks are detailed airframe and components checks involving a refit of the aeroplane.

Table 1: A comparison of aviation maintenance and flight operation characteristics (Adapted from Ruffner, 1990.).

Characteristic	Aviation maintenance environment	Flight operations environment
Task initiator	System failure	Mission events
Types of tasks	Mostly discrete	Discrete continuous
Temporal attributes of tasks	Often sequential seldom concurrent	Sequential concurrent.
Problem solving requirements	Moderate-high	Low-moderate
Environmental conditions	High varied	Relatively constant
Required work space	Large	Small
Required postures	Highly varied	Relatively constant
Physical accessibility requirements	Moderate-high	Low-moderate
Visual accessibility requirements	Moderate-high	Moderate-high
Physical strength requirements	Moderate-high	Low-moderate
Mobility requirements	Moderate-high	Low-moderate
Tool manipulation requirements	Moderate-high	Low
Workload components	Visual cognitive kinaesthetic physical	Visual auditory cognitive kinaesthetic psychomotor
Contributors to workload	Time pressure	Concurrent tasks

2.1.1. Aviation technologies and aviation maintenance activity

The sophisticated and complex nature of rapidly advancing aviation information and engineering technologies places constantly changing demands on maintenance services. These demand great flexibility and adaptability in the workforce. The introduction of the newer wide-body aircraft with design lives of up to 32 years (three times that of the earlier airliners) will further diversify the world's airline fleet, presenting greater variety in aircraft technologies (Barlay, 1990).

As aircraft become older, and components are replaced or rebuilt, an individual aircraft may become more and more unique, so that two aircraft of the same make, model, and year of manufacture may, ten years later, be carrying components and modifications that differ substantially. Some aircraft may be totally rebuilt over their lifetime, with the original airframe flying for many years without replacement. Originally the design life of an airliner might have been around 20 years but, due to advances in maintenance technologies, many are flying at 30 years plus. Perhaps this is one reason why airframe failure represented approximately 5% of airline hull losses in the early 1980s but increased to 20% by 1984 (Barlay, 1990). This situation is unlikely to improve; towards the end of the 1980s, 13% of jets in service were between 20 and 29 years old (Barlay, 1990) and by the mid-1990s, 32% of the fleet was over 20 years old (O'Connor, 1995). Additionally, the use of such aircraft under extreme operational conditions can accelerate the ageing of the aircraft and its systems. Aircraft that survive this ageing process, and are still operational, are known as 'Geriatric Aircraft'; they can provide unique maintenance challenges to aviation maintenance organisations (Barlay, 1990).

2.1.2. Planning aviation maintenance activity

Aviation maintenance activity presents complex planning challenges for managers. Some of these are shared with other socio-technical industries such as power generation and petrochemicals. If planning is inadequate, leading to poor resource availability and information exchange, not only are errors more likely to occur but informal (non-standard) work practices may develop as an *ad hoc* way of solving maintenance problems. These may expose the organisation to a higher safety risk. In the longer term, if these become the norm, unsafe work cultures may develop (Reason, 1997; Vaughan, 1990).

Difficulties in planning aviation maintenance activity and/or the use of unreliable estimators can produce apparently poor productivity and fluctuating levels of workload. If not handled sensitively by management, this may lead to difficulties on the hangar floor. For large jobs, such as D checks, different teams may not meet planned schedules due to estimation errors. At worst, this poor planning may lead to short cuts being taken which jeopardise the integrity of the aircraft. Additionally, the stress that this may place on an individual, often compounded by working unsociable hours, should not be underestimated. When exposure is ongoing, prolonged exposure to stress leads to error proneness and long-term physical and mental health problems (Morris, 1996).

To summarise, it would appear that aviation maintenance personnel experience great variety in their work, due to a number of environmental influences, and it may be reasonable to assume that this will provide a corresponding variety in the human errors that occur.

2.1.3. Aviation maintenance error

A proposition, central to this research, is that potentially dangerous conditions can be introduced and remain undetected in aviation maintenance systems because maintenance activity is performed within an opaque and complex socio-technical system (Perrow, 1984). This opacity and complexity means that no single individual can have complete knowledge of all possible system interactions and the errors that might develop. Often this is due to built-in redundancy and back-up systems that exist, particularly in fail-safe aircraft[8], and the fact that some systems are not required to operate all of the time or to their design limits. Finally, the technical complexity of aircraft (a Boeing 747-400 has over 6 million parts, 171 miles of cabling and 5 miles of tubing; Boeing Aircraft Corporation, 2001) adds to the capacity for error conditions to remain undetected for some time.

The difficulty in detecting aviation maintenance errors is highlighted by the work of Marx and Graeber (1994), who report that in a sample of engine-related flight delays and cancellations, 50% were caused by aviation maintenance problems. This suggests that improper maintenance can introduce error states into aircraft; these may remain undetected until they cause a disruption to the aircraft's operation after it has been released into service. The previously mentioned accident, involving the BAC 1-11 where the Captain's windscreen became detached from the aircraft, illustrates this point. In this accident, the fitting of incorrect bolts introduced an unknown but dangerous condition into the aircraft,

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[8] Fail-safe aircraft have systems that are designed to tolerate failure, such that if a failure occurs in a system then other systems compensate for this.

namely, the insecure windscreen, which later manifested as an explosive decompression (see Chapter 1, p. 24).

These introduced error states have been termed 'latent failures' (Hudson et al., 1994) or 'latent conditions' (Reason, 1997) because they exist in the organisation without effective action being taken to remove them and may still remain even when an organisation is aware of their existence. The incident to Eastern Airlines Flight 855 illustrates this point. On 5 May 1983, a Tri-Star jet transport aircraft made a one-engine landing at Miami following loss of oil on all three engines. This was caused directly by the omission of the O-ring seals from the magnetic chip detectors, causing an oil leak when the engines were in use (National Transportation Safety Board, 1984). A ground run had failed to detect this leak because it was run for insufficient time for a leak to show. The omission of O-rings had occurred on at least 11 previous occasions (Barlay, 1990) and the airline had experienced five oil-loss incidents leading to engine shutdown in flight (Marx & Graeber, 1994). The repeated omissions were known to the organisation and were thought to be due to the development of informal work practices at variance with correct maintenance procedures (Marx & Graeber, 1994). The organisation had introduced training and new procedures to correct these informal practices. Unfortunately the aviation maintenance personnel who performed the work prior to Flight 855 had not received this training and the new procedures were not followed (Marx & Graeber, 1994; National Transportation Safety Board, 1984). Marx and Graeber (1994) suggest that the pervading organisational culture allowed these informal work practices to continue within the organisation and an attempted 'training solution' was not successful.

An example illustrating the potentially catastrophic effects of failing to detect, rather than successfully resolve, a latent condition can be found in the crash of a United Airlines DC-10 on 19 July 1989 (Degani & Wiener, 1994; National Transportation Safety Board, 1984). In this accident the disintegration and shattering of an engine fan disc severed hydraulic lines thus preventing effective use of the control surfaces of the aircraft. The direction and attitude were controlled using asymmetric thrust from the engines and the aircraft finally made a crash-landing at Sioux City. Accident investigation revealed a flaw in the casting of the disc which occurred during the manufacturing process but had not been picked up by the manufacturer or during routine maintenance inspections (National Transportation Safety Board, 1990). This failure to detect a major flaw, over a period of time, led to the loss of the aircraft and many lives.

In this accident, it was possible to determine that the casting flaw had been in existence since manufacture. However, investigators cannot always determine how long a latent condition has been in place or when it developed. A missing part or piece of equipment can only be recorded as missing from the time it is found. How long, or why, it is missing may be difficult or impossible to ascertain, and even comprehensive investigations may not provide this information. The crash of a Trident aircraft at Staines in 1972 illustrates this point (Beaty, 1992). On 18 June 1972 a BEA Trident Aircraft (Papa India) crashed shortly after take-off from Heathrow (Air Accidents Investigation Branch, 2001). The Trident is a three-engine aircraft with all three engines located at the rear of the fuselage. This makes the aircraft prone to a condition known as deep-stall[9] due to its tail-heavy design. Recovery from deep-stall is not possible and an aircraft in this configuration will crash. To prevent the development of deep-stall, various mechanical defences are in place. One, known as the stick pusher, automatically forces the control column forward using a hydraulic system. This puts the aircraft into a nose-down attitude prior to deep-stall developing, resulting in an increase in airspeed.

In above accident, the Captain appears to have overridden the stick pusher by dumping the hydraulic pressure from the system. The reason for this action is unclear, though the integrity of the stick pusher system, from the crew's perspective, may have been in doubt (Beaty, 1992). A suspected contributing factor was a missing piece of lock wire from a lock-nut on a three-way valve; this may have caused a low-pressure warning light to show on the stick pusher display. The system already had a reputation for giving false indications and thus the crew may have mistrusted these indications. The action of the Captain in

[9] Deep-stall is experienced by rear-engine jet aircraft when in a nose-high, low-speed configuration. The nacelles of the turbine engines experience a disrupted airflow. The heavy tail design means that pushing forward on the yoke has little or no effect. An aircraft in deep-stall will descend to the ground in a flat or slightly tail-down configuration.

overriding the stick pusher removed a mechanical defence and is likely to have contributed to the aircraft entering the deep-stall configuration. In this case, the missing piece of lock wire was only discovered when a detailed inspection of the wreckage was carried out. The lock wire may have been missing for several inspections and it was not possible to ascertain how or when this latent condition may have been introduced.

By definition, the detection of latent conditions is potentially difficult and some will remain in the system indefinitely while others are eliminated without knowledge of them ever having existed. Consequently, it may not be possible to determine, accurately, the risks an operator and the flying public are taking at any moment in time, nor can the organisation or individuals concerned learn from these conditions. Of course, not all maintenance-error-introduced conditions remain undetected and from these it is possible to make some evaluation of the impact of aviation maintenance error on aviation safety.

2.1.4. Impact of aviation maintenance error on aviation safety

The aviation safety literature suggests that maintenance error has a significant impact on aviation safety (Maurino, 1992). In a review of human factors methodologies in maintenance, in which 130 aviation maintenance-related publications were considered, "as much as one-third of all equipment malfunctions were attributed directly to prior poor maintenance or improper application of a maintenance procedure" (Ruffner, 1990, p. 3). Following an analysis of 232 hull losses, between the years 1982 and 1992, Graeber and Marx (1993) suggested that changes in levels of aviation maintenance and inspection could have prevented 16% of hull losses (see Chapter 1, p. 23). Hobbs (1995) reported that maintenance and inspection error contributed to 16% of airline deaths, for the years 1982–1992, and is the second most frequent cause of fatalities after controlled flight into terrain (at 23%). Finally, Allen and Rankin (1995) report figures obtained from the Boeing Aircraft Corporation, which suggest that 15% of airliner accidents from 1982 to 1984 had maintenance errors as a contributing factor.

Clearly, aviation maintenance is significant in the aetiology of accidents; however, less visible operational impacts also deserve consideration. Saul (1993) has analysed aviation-maintenance-related occurrences from overhaul, base, and line maintenance facilities. Recorded under the Civil Aviation Authority of the UK Mandatory Occurrence Reporting (MOR)[10] analysis scheme the data were extracted over a 10-year period for 232 aircraft types, including rotor wing. From 11.418 million flight hours, 1270 MOR events were recorded representing approximately 10 per 100,000 hours. Of these, 230 generated abnormal operational effects, equivalent to two per 100,000 flight hours. Further details of these effects are shown in Table 2.

Table 2: Civil Aviation Authority of the United Kingdom aviation-maintenance-related occurrences generating an abnormal operational effect for the years 1981–1991 (Saul, 1993).

Severity of operational effect	Number of events	Rate per flight hour *10–6
A) Nuisance	29	2.5
B) Operational limitations, including precautionary landing and degrees of emergency procedures	134	10
C) Aborted take-off	29	2.5
D) Emergency procedures, aerodrome fire services, use of emergency evacuation chutes	31	2.7
E) Significant reduction in safety	6	0.52
F) Large reduction in safety, hazardous	1	0.087

The data in Table 2 suggest that serious incidents and accidents represent infrequent, though noteworthy, outcomes of error and that significant operational disturbances represent outcomes that belie the relative infrequency of these incidents and accidents.

[10] The MOR scheme applies to all aircraft, fixed and rotor wing, above the 5700 kg weight break.

2.1.5. The cost of aviation maintenance error

The cost implications of maintenance errors are likely to be considerable in terms of delays and disruptions to flight schedules, operational breakdown (aircraft that break down away from base incur additional maintenance costs), re-working (repeating of maintenance work) and duty time exceedances.[11] Kanki, Blankman-Alexander, and Barth (1998) found that 39% of maintenance errors resulted in a return of the airliner to its departure point. This is an extremely expensive exercise in terms of direct operational costs to the airline and in terms of the disruption to other scheduled operations, organisations, and passengers.

When an error has been detected and related to an operational disturbance, incident, or accident, it is difficult to attribute an exact financial cost to that error; operational disturbances rarely stem from a single cause but are due to confluences within the system. However, estimates of costs can be made. For example, it has been reported that 50% of engine-related flight delays were caused by sub-standard aviation maintenance, that each flight delay may cost US$10,000.00 per hour, each cancellation approximately US$50,000.00, and that a 1-minute delay at the gate costs up to US$600.00 (Marx & Graeber, 1994). Events caused by improper maintenance, such as incorrectly fitted doors, can have significant costs, and British Airways estimate the cost of a missed approach and go-around at Heathrow at £2,000.00 (C. Wright, personal communication, 1994). Clearly, the minimisation of such maintenance-related errors would significantly reduce these costs. Additionally, following an accident, these costs are vastly increased and the financial hardship caused by the damage to the reputation of an organisation, and the industry generally, may be impossible to quantify.

2.1.6. Deregulation and the impact on safety and maintenance error

Over the last 20 years, deregulation has had an impact on aviation organisations worldwide. It has been suggested that deregulation and the subsequent economic changes that this involved have contributed to the increase

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[11] The duty time of a flight crew has legal restrictions that cannot be exceeded. Where delays are significant, crews that may exceed this duty time need to be replaced.

in fatal aviation accidents (Turner & Hallaway, 1994). Under deregulation, the direct monitoring and influence of the State over aviation activity has gradually been reduced. This has led to liberalisation, introduced competition, increased sub-contracting of work, and enhanced the expectation that organisations take increasing responsibility for their own safe operation (Button, 1991). In New Zealand, one effect of deregulation has been that aviation organisations are required to monitor their performance against self-declared standards, agreed with the Civil Aviation Authority of New Zealand (CAANZ) in the form of an exposition document. For the maintenance sections of larger carriers in New Zealand, this means compliance with Rule 145 (Civil Aviation Authority of New Zealand, 1997) against which the exposition is written.[12]

2.1.7. Managing aviation maintenance error through information and data-capture technologies

Computerised aviation maintenance logs and databases may eventually allow information about an aircraft and its components to travel around the world, until then, paper-based systems are in place. These consist of flight manuals, logs, release notes, and tracking tags.[13] These systems are complex and there are many opportunities in which human error and/or intentional violations can have their effects.

International agreements are being made that will allow for the rapid exchange of information on the nature of the errors, incidents and accidents that occur as well as maintenance-related problems in the aviation industry. For example, the Civil Aviation Safety Authority of Australia has a computer-tape exchange agreement with the Federal Aviation Administration and the Civil Aviation Authority of the United Kingdom (Civil Aviation Authority New Zealand, 1994). This provides a data exchange on major defects noted by each Authority. Through an initiative called Maintenance Error Decision Aid

[12] For a more detailed discussion of deregulation, the reader is referred to Button (1991) and Williams (1994).

[13] Tracking tags are attached to the aircraft part. They are used to provide assurance that only genuine approved and serviceable parts have been fitted to aircraft.

(MEDA)[14] (Allen & Rankin, 1995; Rankin & Allen, 1995, 1996; Rankin, Hibit, Allen, & Sargent, 2000), the Boeing Aircraft Corporation is becoming a broker of information common to Boeing aircraft. MEDA encourages operators to use a common method of investigating, recording, and analysis of maintenance defects and errors. It provides a local-level (hangar floor) analysis of events within maintenance and a higher-level analysis in which organisational factors can be examined (Graeber & Marx, 1993).

In the USA, Johnson and Shepherd (1993) have described the development of computerised fault isolation and inspection software and a human factors information guide available to all levels of the aviation maintenance operation. The United States Air Force has the Aircraft Mishap Prevention Program (Diehl, 1991) and the Federal Aviation Administration has developed the On-line Aviation Safety Inspection System (OASIS) (Johnson, 1998) and the Ergonomics Audit Program (ERNAP) (FAA, 1999). OASIS offers Federal Aviation Administration Inspectors access to documentation and databases on-line. ERNAP is a computerised job aid to help managers evaluate or design ergonomically efficient procedures for maintenance and inspection. It evaluates existing and proposed tasks and systems by applying ergonomic principles. ERNAP will also suggest ergonomic interventions based on its evaluation (FAA, 1999).

In Israel, an on-line interactive computer program called Manuals And Amendments Distribution Monitoring And Notification (MADMAN) has been developed (Elazar & Haim, 1994). This software controls the distribution of aviation maintenance manuals and the amendments received from hundreds of sources. British Airways have developed the British Airways Safety Investigation System (BASIS), which is designed to capture aeroplane aviation maintenance discrepancies and which tracks the cost and the frequency of these problems (O'Leary & Fischer, 1993; C. Wright, personal communication, 1994). In New Zealand, some airlines have adopted a commercially available database and information management system called the Aviation Quality Database (AQD). Modelled on the CAANZ database, this system provides a means of recording and

[14] At the time of writing only one operator in New Zealand is contributing to MEDA.

classifying a range of information types including maintenance failure and human factor error cause codes based on the work of Reason (1992, 1995) and O'Hare, Wiggins, Batt, and Morrison (1994). It seems that manufacturers and operators are interested in understanding maintenance error through the use of information technology. However, the industry has some way to go before these error analysis technologies allow the formation of a comprehensive picture of maintenance error.

2.1.8. Management of aviation maintenance error and human resources

The variation in workload within aviation maintenance, the use of shift work, and scheduled and unscheduled work on aircraft within tight time frames, can lead to heavy demands on the work force. At times this will require creative management solutions, particularly if errors are not to increase at times of heavy workload. Some examples of this type of creative thinking are described below.

Japan Airlines assigns dedicated teams to work on a particular aircraft. The idea is that when an aircraft arrives someone from the maintenance team is there to meet it. Through a more intimate knowledge of the aircraft and each other's skills, the team can correct and identify faults more easily and will have more ownership of a problem (ICAO, 1995). This can however make the system vulnerable to other kinds of human factor errors such as complacency, 'group think' (Janis & Mann, 1972), or the development of heuristics[15] about the aircraft that preclude a more critical analysis of a problem.

Other ways of managing error through human resource practices include the restriction of the number of type-ratings[16] that aviation maintenance personnel may hold at any one time. Air Canada allows aviation maintenance personnel a type-rating on up to three types of aircraft only. This procedure is said to decrease the amount of information and skills that aviation maintenance personnel must maintain but allows sufficient variety in workload (Barlay, 1990).

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[15] Heuristics are cognitive schema, beliefs, rules of thumb that humans construct as a shorthand way of construing the world although they may not always be correct (Morris, 1996).
[16] Type-ratings are authorities that air maintenance personnel hold to work on particular types of aircraft or components.

Such a balance is also likely to be important to a healthy and satisfied work force. Of course, shortages in experienced personnel can mean that such a balance is more difficult to maintain.

2.1.9. Summary

Section 2.1 discussed the nature of the work of aviation maintenance personnel and how this provides opportunities for error to be introduced into aircraft systems. Factors such as the ageing nature of the world's airline fleet, the changing and diverse nature of the technologies, have introduced new challenges to aviation maintenance as aircraft operate beyond their design lives. The modification of existing aircraft and the variety of types that exist can provide opportunities for error to be introduced where a non-standard variant is encountered. Information technology is being used to monitor the status of aircraft, documentation, and errors within the industry. Good human resource planning can also improve maintenance efficiency. The diversity of maintenance tasks is likely to increase in the future with the introduction of more complex technologies.

The following section (2.2) considers how organisations influence aviation maintenance human error.

2.2. Organisational approaches of human error

In Western culture there has been an increasing interest in a systems, or organisational approach to error and safety management (Johnston, 1994; Johnson & Shepherd, 1993; Maurino et al., 1995; Pidgeon & O'Leary, 1994; Rankin et al., 2000; Reason, 1990; Wagenaar, 1992). Whilst not dispensing with individual responsibility, this approach places individual actions within a context that allows the organisational influences on human error to be more readily understood and provides new insights into how error can be managed.

2.2.1. The problems with an individual approach to human error

Individual approaches to human error have generally attempted to examine and correct the individual. Often punitive corrective action (Johnston, 1992b, 1993) and/or retraining of the person committing the error is implemented. While such approaches provide some immediate local benefits (at the shop-floor level), they do little to augment the organisation's knowledge about how the organisation contributed to the error, or how it may act to decrease errors of this type in the future. Additionally, isolated individual errors will inevitably occur and these can be regarded as foreseeable hazards that management are in a position to influence by changing the conditions that exist in the organisation (Wagenaar & Groeneweg, 1987).

2.2.2. Benefits of an organisational approach to human error

The arguments for an organisational approach to error management have gained considerable support within the international aviation scene (ICAO, 1993; Krause, 1994; Maurino et al., 1995; Pidgeon & O'Leary, 1994; Reason, 1998; Spooner, 1992; Weick, 1987; Woods, Johannesen, Cook & Sarter, 1994) and may be summarised as follows. The systems, cultures, signals, messages, and constraints provided within an organisation influence individual performance. They can promote efficient but also inefficient outputs, including error, when they set the necessary error-promoting conditions (Reason, 1990). The study of error in the real world involves the study of the individual embedded within a larger system and, as Woods et al. (1994) have stated, "the same factors govern the expression of expertise and error." (p. 20). Errors should therefore be regarded as regular and predictable products of the system as a whole.

The organisational view of error is based on the following two assumptions. Generally, it can be assumed, aviation maintenance personnel do not make errors on purpose (Rankin et al., 2000). Where it can be shown that the individual acted in the same way that any other individual might, given the same circumstances, then perhaps the actions of the individual should not be considered blameworthy but should be seen as an indication of the necessity for action by management to rectify a deficiency in the organisation (Wagenaar, 1992). The second assumption is that managers of organisations could take responsibility for managing the organisational conditions that lead to these errors, minimising their impact when they do occur. It is by now widely accepted that only by adopting such an approach can managers hope to influence error and safety in the long term (Cox & Cheyne, 1995; Cox & Flin, 1998a; Hart, 1989; Helmreich & Wilhelm, 1999; Johnson & Shepherd, 1993; Johnston, 1994; Marx & Graeber, 1994; Maurino, 1992; Maurino et al., 1995; Perrow, 1984; Pidgeon & O'Leary, 1994; Reason, 1997; Wagenaar, 1990; Woods et al. 1994).

2.2.3. How accidents are inherited

An organisational approach to error suggests that 'frontline' staff who are directly involved in unsafe acts immediately preceding an accident, are frequently inheritors of a set of circumstances that are beyond their immediate control and which have been put in place by management. Discussing the capsizing of the Herald of Free Enterprise (Sheen, 1987), Wagenaar and Groeneweg (1987) described how the passengers and crew became inheritors of a set of conditions, inadequate equipment, training and staffing, which contributed to the accident. These conditions were set by management many months prior to the accident (Wagenaar, 1992; Wagenaar & Groeneweg, 1987) and provide an example of situations in which management have taken the risks and employees and passengers have run them, often without any awareness that this has occurred (Wagenaar, 1992).

To place this in an aviation context, in a study of aviation accidents over a 10-year period, analysts assigned contributing factors to each accident using several 'performance shaping categories' (Marx & Graeber, 1994). The following areas, directly under the influence of management, were significant in the aetiology of the accidents: the training that is provided, the tasks and procedures that are used, and the environmental conditions in which work is performed.

It follows, that if managers are to be maximally effective in decreasing errors, it makes sense to target interventions at levels of the organisation that decrease the conditions that promote these errors (Wagenaar, 1990), rather than retrospectively tackling each error on a case-by-case basis. Figure 3 illustrates how interventions at point **X** in an organisation can have influence over potential errors at point **Y**. Such interventions may include the introduction of new procedures, training, or the promotion of safe cultures.

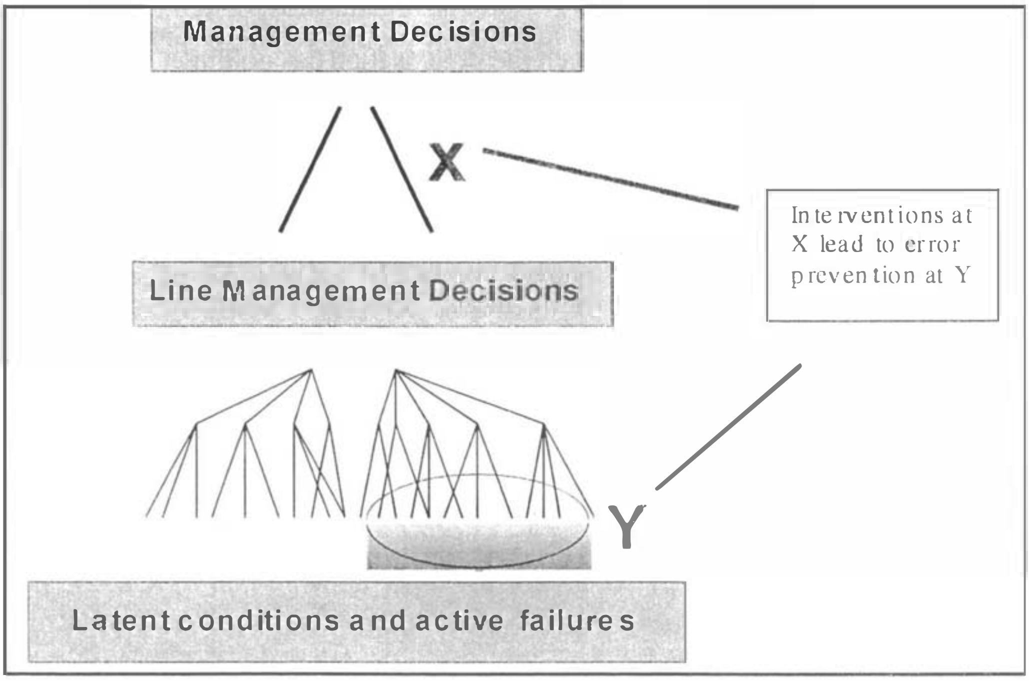

Figure 3: Interventions made at higher levels in the organisation influence the generation of errors at lower levels.

2.2.4. The Latent Failure Model

In some organisations, systems are so complex and opaque that it is difficult to detect that errors are occurring or what their effects are. A variety of authors (Perrow, 1983; Reason, 1990; Turner, 1978, 1991; Wagenaar, Groeneweg, Hudson, & Reason, 1994) have expressed the view that such errors can trigger the existence of latent conditions (introduced error states) within organisations. These can exist for considerable periods of time; where many exist, rigid perceptions, organisational exclusivity, informational difficulties, violations, and a failure to recognise emergent dangers can develop to become an accepted part of the culture of the organisation. This has been termed 'normalised deviance' and can represent a significant threat to safe operations (Reason, 1987a).

The Latent Failure Model (Reason, 1992) provides a way of understanding how an organisational accident or incident can arise by describing the interactive effects of different areas of organisations (Perrow, 1983, 1984). It suggests that latent conditions, existing within an organisation, combine with local triggers (external influences, over which the organisation has no direct control, i.e. the weather), or active failures (usually a human action), to generate an incident or accident. Both active failures and latent conditions are under the influence of organisational processes which include the environment and culture that exist in the organisation (Pidgeon, 1991). Figure 4 shows that for an incident or accident to occur, an active failure or local trigger, and a latent failure/condition, need to be present.

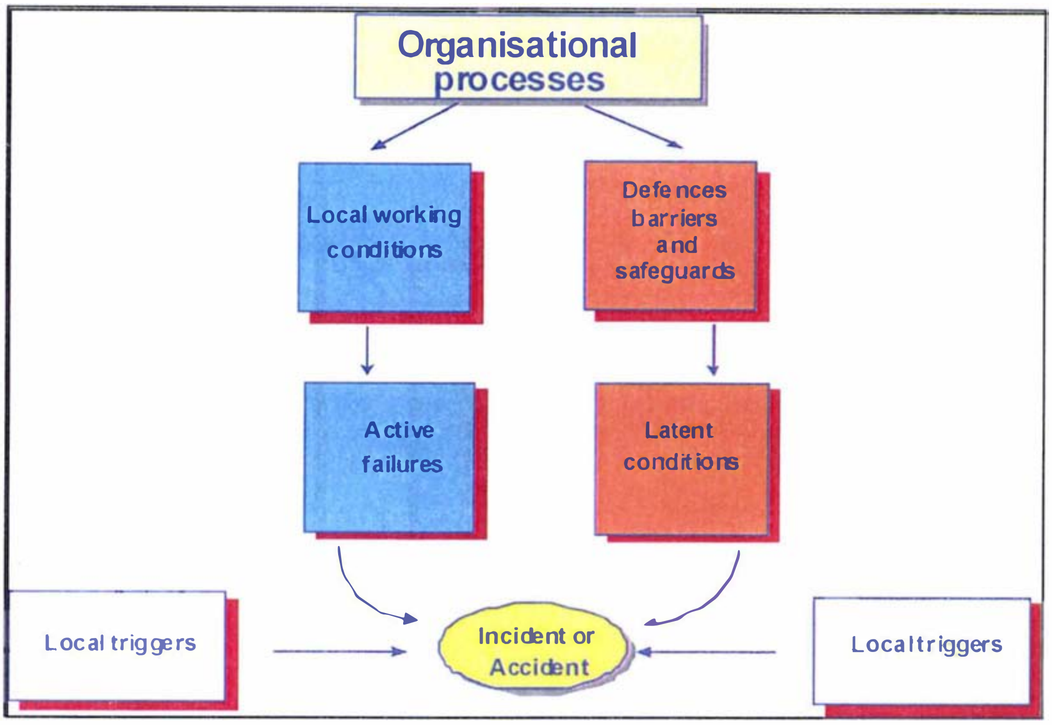

Figure 4: Active and latent failures (conditions) combining to cause an error event (Adapted from Maurino et al., 1995.).

The Latent Failure Model has been conceptualised as a series of barriers (see Figure 5) that stand in the way of an incident or accident occurring once a latent condition has developed in the system. On occasions, breaches (failures) in the barriers appear, caused by the activities at different levels of the organisation. When these breaches line up, the opportunity for an incident or accident has occurred. Generally, serious incidents do not occur because not all of the breaches line up at the same time or because adequate defences are in place. Less serious incidents may also occur and this may lead either to the organisation implementing new defences, or to the removal of the state creating the breach in the current defences. Occasionally a latent condition may directly induce a defence breach and the conditions for a serious incident or accident are then in place.

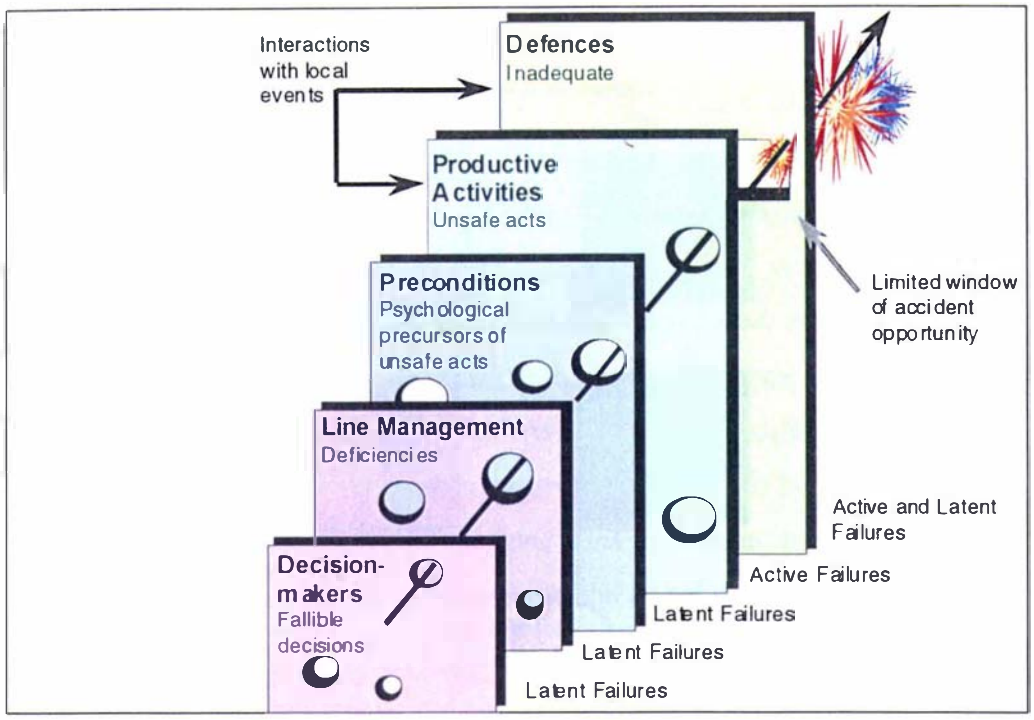

Figure 5: Reason's Latent Failure Model: The arrow shows the trajectory of the effects of a failure through time (Adapted from Reason, 1990, p. 208.).

2.2.5. Introducing latent conditions to organisations

The Latent Failure Model can explain how human errors can introduce latent conditions at a number of levels of the organisation: the level of the organisation, the level of the local task environment, and the level of the individual (see Figure 6).

Although the introduction of these error states may not necessarily lead to a serious incident or accident, they represent potential dangers (pathogens) within the system (Reason, 1990) and their detection may provide one method of determining the safety level that exists in an organisation. As Reason (1990) has suggested:

"For the pathogen metaphor to have any value, it is necessary to establish, *a-priori*, a set of indicators relating to system morbidity and then demonstrate clear causal connection between these indicators and accident liability across a range of complex systems and in a variety of accident conditions" (p. 199).

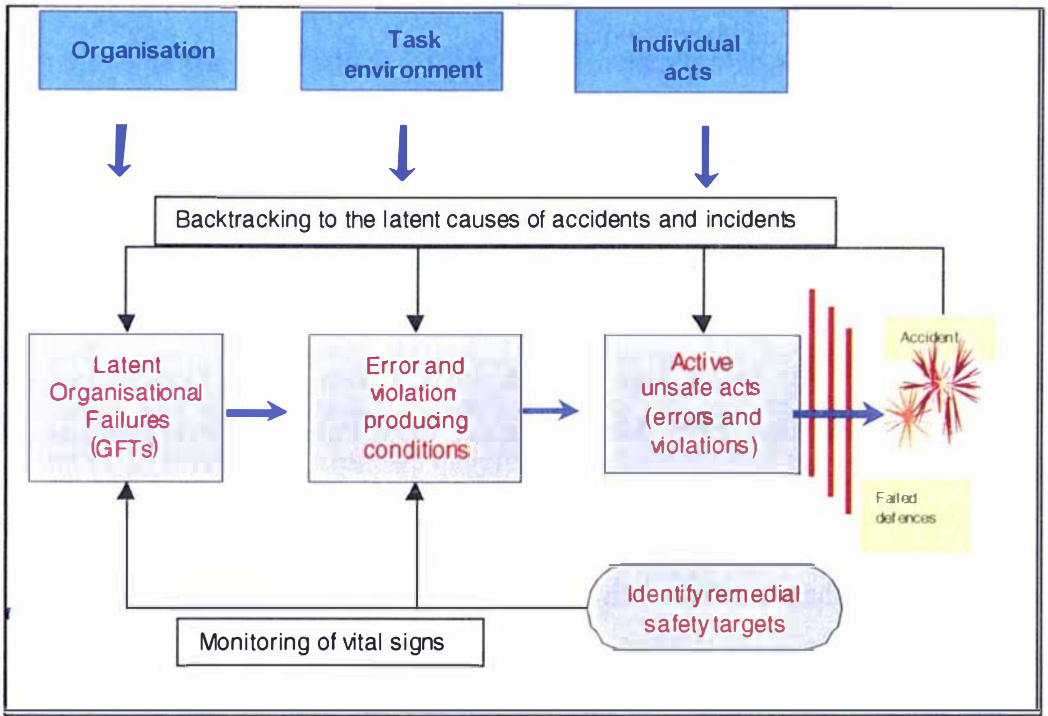

Figure 6: Common elements in the development of an accident (Adapted from Reason, 1992.).

It is the potential for the introduction of error at all levels of the organisation that can expose complex and opaque organisations to risks that individuals are not aware of. Figure 6 also shows that monitoring of vital signs through the detection of errors and latent conditions in the organisation can make these potential dangers more apparent. For example, latent conditions that occur at the managerial or organisational level have been termed General Failure Types (GFTs)[17] (see Figure 6). General Failure Types reflect failures that have a broad

[17] General Failure Types are also termed Organisational Failure Types, the terms are used interchangeably.

influence over areas of operation in the organisation (Wagenaar et al., 1994); an organisation may have a group of failures that seem to be related to planning processes, it may have another set that are related to communication, and so on. Each organisation or industry system is likely to have its own unique profile of General Failure Types that may be determined by appropriate analytical techniques (Reason, 1992). If this information is used to implement fixes at various levels, and if good defences are put in place, then this will reduce downstream failures, incidents, and accidents.

2.2.6. Summary

The Latent Failure Model reflects a theme in the safety literature suggesting that responsibility for improving the safety in organisations rests with the management of organisations (Bailey & Petersen, 1989; Brown & Holmes, 1986; Bureau of Air Safety Investigation, 1996; Cohen, 1977; Dedobbeleer & Beland, 1991; Hopkins, 1995; Maurino et al., 1995; Pidgeon, 1991; Pidgeon & O'Leary, 1994; Reason, 1997). The emphasis on looking at organisational systems leads logically to the suggestion that preventative safety action will be more effective when it is based on management-level decisions (Hopkins, 1995; Reason, 1990; Wagenaar, 1992). There has been a move away from the identification of culpability at the individual level that has been the norm world-wide over the past four decades (Reason, 1997; Slappendel, 1994; Wagenaar, 1990). It is no longer considered useful merely to direct safety solutions at the individual operator on the shop floor alone; as Cambell (1993) has suggested, "where servicing error occurs, generally not only were there reasonable excuses for poor workmanship, but in most cases there was complete exoneration of the tradesman" (Campbell, 1993, p. 1).

Having presented arguments for the importance of an organisational approach to error management, the following section (2.3) considers the relatively intangible, but crucially important, influence that of organisational culture has on human error in organisations. It suggests that organisational culture can represent an overriding latent condition that may influence error generation and safety-related outcomes at various levels.

2.3. Organisational culture; its impact on aviation maintenance error and safety

This section explains what organisational culture is and how this relates to the closely related concept of organisational climate. It discusses in more depth the influence that organisational culture has on error in aviation maintenance organisations and the characteristics of safe organisational cultures.

2.3.1. General Failure Types and organisational culture

In section 2.2 it was suggested that the quantity and quality of latent conditions, and thus the range and number of 'failure types' that exist in organisations, is dictated by the quality of the decision-making and behaviour at all levels in the organisation, but is particularly influenced by the decisions and behaviours of management (Reason, 1995). Reason has further suggested that decisions and behaviours are performed within the context of the culture that exists in organisations. It follows therefore that the culture of the organisation sets some of the conditions for the development of errors (ICAO, 1993; Reason, 1997; Turner, 1991). This is illustrated by the following examples.

An accident to a Continental Express Embraer-120, at Eagle Lake, Texas on 11 September 1991, was caused by the in-flight separation of a de-icing boot from the leading edge of the horizontal stabiliser (National Transportation Safety Board, 1992). The aircraft broke up in-flight killing 14 people. It was found that 47 screws had been removed from the upper surface of the leading edge during scheduled maintenance the night before. The National Transportation Safety Board investigation revealed that the probable cause(s) of this accident were:

> "the failure of Continental Express maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures for the airplane's horizontal stabilizer de-ice boots that led to the sudden in-flight loss of the partially secured left horizontal stabilizer leading edge and the immediate severe nose-down pitchover and break-up of the airplane. Contributing to the cause of the accident was the failure of Continental

> Express management to ensure compliance with the approved maintenance procedures and the failure of the FAA surveillance to detect and verify compliance with approved procedures." (NTSB, 1992, p. 1).

The report discusses the general disregard for following established procedures on the part of the aviation maintenance department personnel, lax attitudes in hangar management, and a failure by the company to establish an effective safety orientation for its employees. The Federal Aviation Administration is also criticised in the report for failing in its supervision of correct hangar practice (Pidgeon & O'Leary, 1994).

Similarly, in the UK, there was an incident on 26 August 1992 involving an A-320. In this incident, spoilers were left in an aviation maintenance configuration, disabling the aircraft so that only right turns were possible (UK Government Press Release, 1995). The press release reads:

> "The engineers who carried out the flap change demonstrated a willingness to work around difficulties without reference to the design authority, including situations where compliance with the Aviation Maintenance Manual could not be achieved" (p. 1).

The release also suggests that such work practices were accepted and commonplace:

> "Local line management did not insist on a rigorous procedural approach to working practices and total compliance with Aviation Maintenance Manuals" (p. 1).

Whilst other causal factors were present in both the Embraer and A-320 events, the release implies that organisational culture was influential in dictating the degree to which practice followed the required procedures.

The position taken in this research is that organisational cultures will have a pervasive influence over safety-related behaviours throughout organisations. For example, an organisational culture that is safety-sensitive may promote vigilance over the errors and failures that are generated. Such vigilance may allow the managers to take action to minimise the conditions that promote the generation of these failures, which in turn lead to incidents occurring. For example, management may wish to decrease the likelihood that aviation maintenance technicians will moonlight as car mechanics for extra cash in the evenings, thus reducing the chances of them making errors due to fatigue or burnout. They will therefore adopt a written policy limiting the number of hours that technicians are allowed to work in any given period. Coupled with a policy of paying reasonable wages, the implicit message is that the organisation 'cares' that its employees have reasonable working conditions.

The incidents described above implicate the involvement of organisational culture in incidents and accidents. It may be reasonable to assume that some cultural factors are indicators and predictors of the latent conditions that an aviation maintenance organisation is carrying and the safety level that exists. For this reason, there may be value in helping organisations to identify potentially pathological cultures (Reason, 1990).

2.3.2. Organisational culture and organisational climate

The concepts of organisational culture and organisational climate have been the subject of lengthy debate amongst academics and management technologists (Reichers & Schneider, 1990). Some discussion of this literature is worthwhile, as it is unclear if organisational culture and organisational climate should be considered as representing different things (Denison, 1996). The term 'organisational climate' first appeared in the literature in the 1930s, with the term 'organisational culture' emerging in the late 1970s.

It has been suggested that organisational climate consists of the shared perceptions of the way things are in the organisation (Reichers & Schneider, 1990), whereas organisational culture is something an organisation possesses, has, or is; "the expression of unconscious psychological processes" (Smircich, 1983, p. 351). It has also been suggested that the difference between the two constructs can be reduced to the level of the quantitative methods that have been used to measure climate and the qualitative approaches used for culture (Glick, 1985).

Organisational climate seems to have been concerned with the influences of organisational systems on groups and individuals, and the "perceptions of observable practices and procedures that are close to the surface of organisational life" (Denison, 1996, p. 622). Additionally, organisational climate has tended to use more quantitative methodologies (Denison, 1996) that lend themselves to larger scale studies, with easier replication and comparison (Cooke & Rousseau, 1998). The term organisational climate has undergone a number of re-definitions in the literature and may currently be more closely related to the organisational culture concept of today's literature. Some authors consider the two concepts so closely related that they may be considered the same thing (James, James, & Ashe, 1990; Reichers & Schneider, 1990).

Growing out of the organisational climate literature in the 1970s and 1980s, the concept of organisational culture seems to have evolved around qualitative research methods, with an understanding of the unique aspects of the social settings (Denison, 1996). Organisational culture emphasises the importance of underlying assumptions and the development of social systems over time.

However, when organisational culture researchers begin to describe organisational culture in terms of comparative traits or dimensions, then the similarity to the work of organisational climate researchers is remarkable. To illustrate this point, Denison (1996) notes the similarity between the dimension of 'power-distance' from Hofstede's organisational culture work (Hofstede, 1980, 1983, 1984), and 'aloofness', described by Haplin and Croft's (1967) work on organisational climate. Similarly, Reichers and Schneider (1990) comment that it is puzzling that two concepts with similar conceptual properties have developed in parallel rather than in tandem. They suggest that it is possible to view organisational culture and organisational climate as both monolithic and multidimensional constructs by which individuals in organisations make sense of and share meaning about their environment, and that the separation between organisational climate and organisational culture research will diminish in the future. Denison (1996) summarises a lengthy literature and takes the position that:

> "organisational culture refers to the deep structure of organisations which is rooted in the values, beliefs and

assumptions held by organisational members ... Organisational climate, in contrast, portrays organisational environments as being rooted in the organisation's value system" (Denison, 1996, p. 624).

He suggests that at the philosophical level, organisational culture and organisational climate can be seen to be different perspectives of the organisational environment but in applied practice "it is far less clear that they actually examine distinct organisational phenomena" (Denison, 1996, p. 625). Similarly, Cox and Flin (1998b) and Furnham and Gunter (1993) believe that the terms are used interchangeably in the literature and that the differences are minimal at the applied level of analysis. Cox & Flin (1998b) further suggest that the differences between the concepts of safety culture and safety climate are insufficient to justify their independence.

Schneider (1990) has described defining organisational culture as rather like trying to nail jelly to the wall. It is an elusive concept that has been variously described as: "the collective programming of the mind which distinguishes the members of one group or society from those of another" (Hofstede, 1984, p. 82); "the way we do things around here" (Bower, 1966, cited in Deal & Kennedy, 1982, p. 4); and by Deal and Kennedy (1982) as informal rules that indicate how members of the organisation are to behave. Similarly, Schein (1990) has suggested that no single definition of organisational culture exists, although the following definition of organisational culture is proffered. Organisational culture is:

"(a) a pattern of basic assumptions, (b) invented, discovered or developed by a given group, (c) as it learns to cope with its problems of external adaptation and internal integration, (d) that has worked well enough to be considered valid and therefore (e) is to be taught to new members as (f) the correct way to perceive, think, and feel in relation to those problems" (Schein, 1990, pp. 1–11).

From this definition, Schein (1990) developed a model of organisational culture. This consists of three levels that vary in their visibility to the external observer (see Figure 7). It allows an understanding of culture that accommodates the debate on whether climate is something different, by showing organisational culture as a series of levels of awareness. At the deepest level are the assumptions that underlie the values that exist in the organisational culture, and on the surface are the artefacts, the manifested behaviours, symbols, and social systems. Schein regards organisational culture as a more deeply held construct than organisational climate, which is visible 'on the surface' of an organisation as a manifestation of organisational culture. Hatch (1993) has used Schein's outline to develop a cultural dynamics perspective of culture. In this scheme, Schein's levels are shown as a wheel with the various levels interacting, giving rise to the observable surface level, symbols, and processes. Rousseau (1990) has suggested a similar 'levels model' (see Figure 8) in which observable artefacts of culture exist near the surface of organisational life. It is these surface-level manifestations that are amenable to direct observation and may be more readily interpreted, by some, as climate (Reichers & Schneider, 1990).

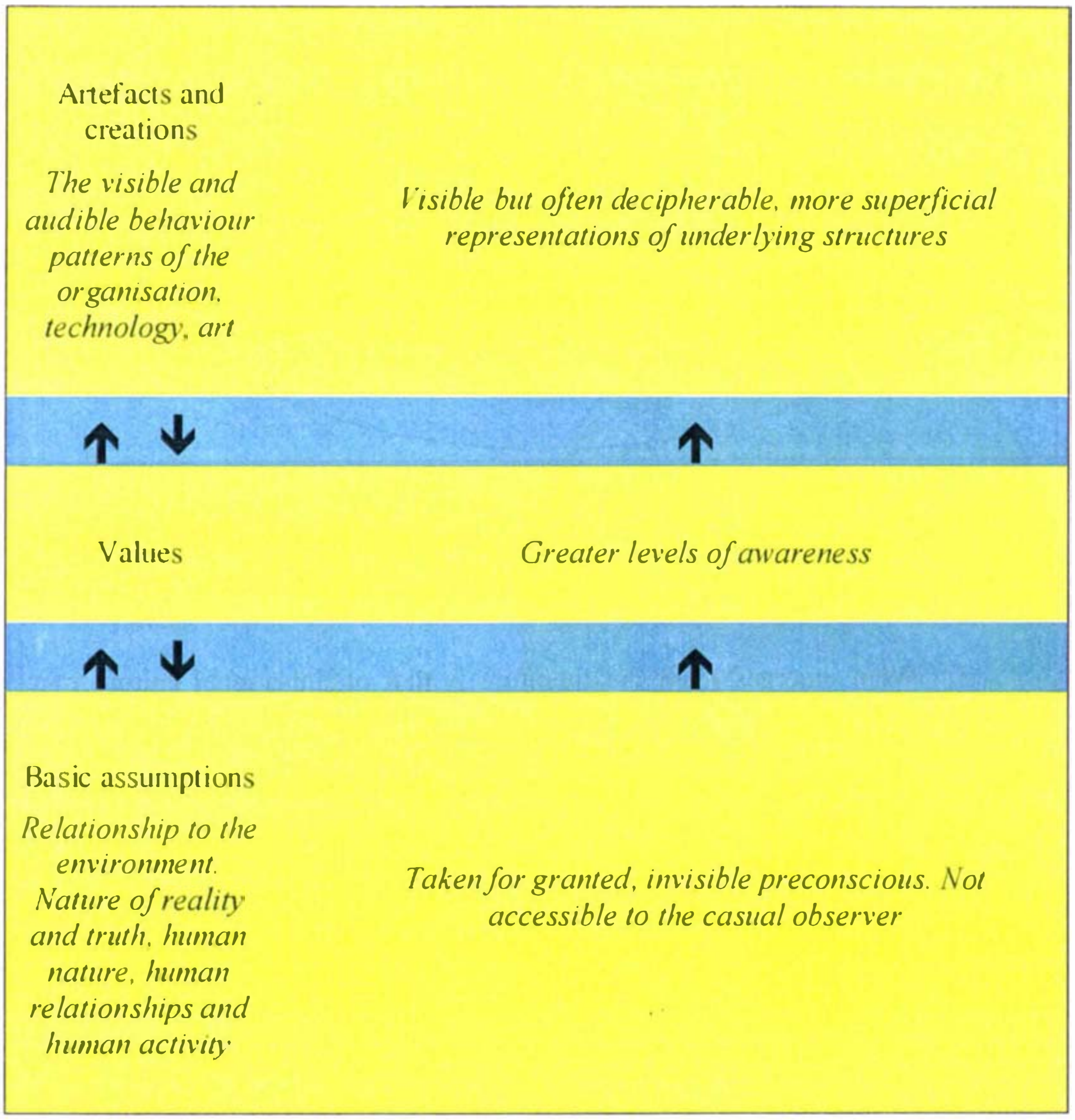

Figure 7: Representation of Schein's (1990) model of organisational culture.

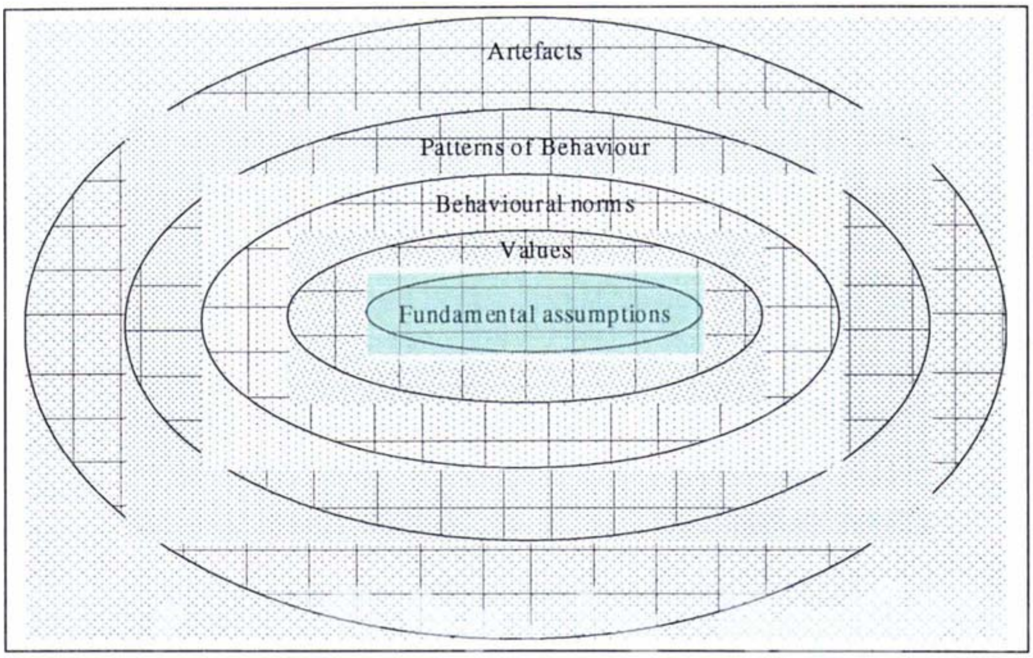

Figure 8: Layers of organisational culture in an organisation (Rousseau, 1990).

What emerges from the literature is that organisational culture may generally be regarded as a deeper, perhaps unconsciously held, set of assumptions that manifest as beliefs, values, behaviours, and symbols that are characteristic of a particular organisation. It is these manifestations that are sometimes referred to as climate and which are more readily accessible to conscious awareness, reporting, and observation (Denison, 1996; Reichers & Schneider, 1990). The literature also suggests that, at the applied level of behavioural research, organisational culture and organisational climate may share much common ground and can be regarded essentially as the same thing (Denison, 1996; Cox & Flin, 1998a, 1998b). This is the position taken for this research.

2.3.2.1. Organisational culture in the national and international context

Aviation maintenance organisations in New Zealand do not exist in a void. They are subject to a range of cultural influences; professional, organisational, national, and international (Helmreich & Merritt, 1998). Organisational culture is dynamic and does not recognise geographical boundaries, such as the movement of people, technology, expertise, and equipment. It can vary across sub-units of organisations and organisational sub-cultures may be created and dissolved as routines and tasks are performed (Pidgeon & O'Leary, 1994). Even the smaller domestic operators in New Zealand are subject to these influences. Figure 9 shows the influences of international, national, and organisational cultures on aviation maintenance culture at the organisational level. For example, trade unionism, political and economic reform may serve to influence organisational culture.

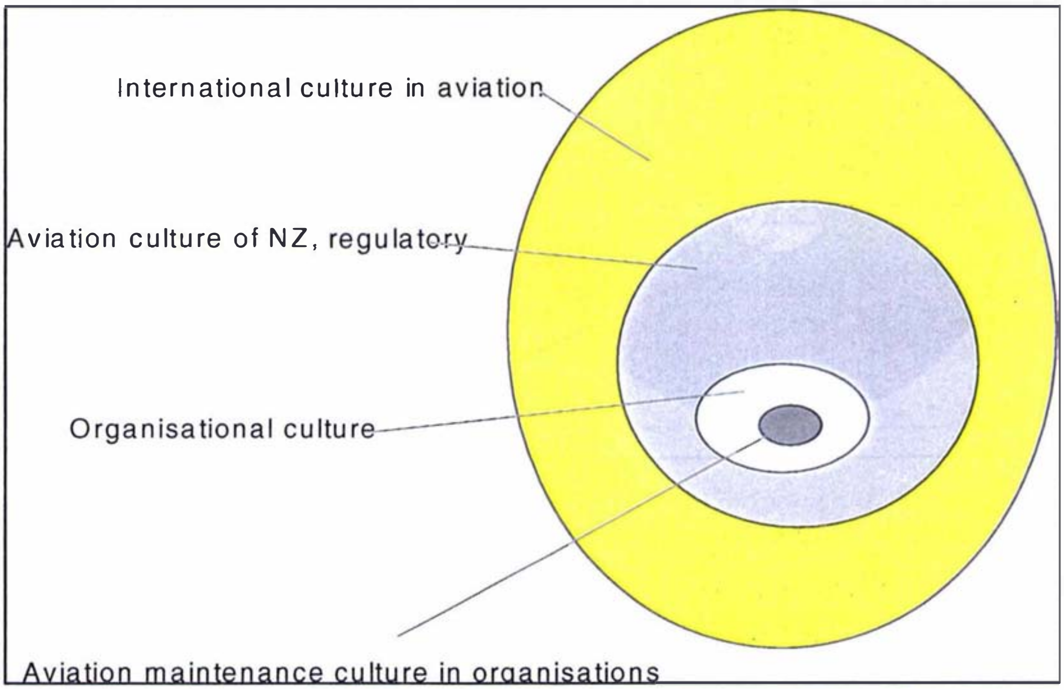

Figure 9: An aviation maintenance organisation in New Zealand nested within a variety of shells of cultural influence.

Approaching organisational culture from an applied perspective, Hofstede (1983) has described culture as "collective mental programming" which is historically determined and socially constructed (Hofstede, 1983, p. 75). Hofstede's (1984) research, based on an international survey of company culture, determined four indices of national culture: power/distance, uncertainty/avoidance, individualism/collectivism, and masculinity/femininity. One of the attractions of the model generated is its implicit suggestion that national culture influences organisational culture.

Similarly, Helmreich and Wilhelm (1999) have provided a representation of the multiple cultures influencing the behaviour of flight crew. In this professional culture (e.g. pilot or engineering culture) and the influences of Crew Resource Management are also represented (see Figure 10).[18]

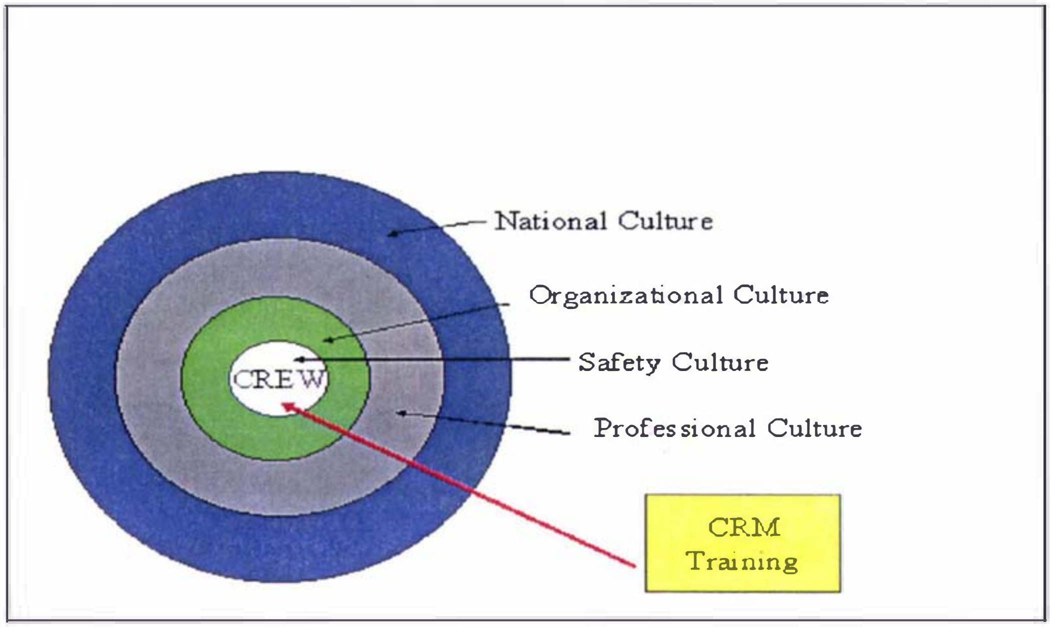

Figure 10: The multiple cultures surrounding flight crews (Helmreich & Wilhelm, 1999).

Developing this theme further, Helmreich and Merritt (1998) and Helmreich and Wilhelm (1999) have suggested that organisational culture, rather than professional or national culture, has the most influence over the safety behaviour of organisations; "it is the organizational culture which ultimately channels the effects of national and professional culture towards standardised practices, and it is the organisational culture which shapes attitudes towards safety and productivity" (Helmreich & Wilhelm, 1999, p. 110). This is shown in Figure 11 where the organisational culture is seen to influence safety culture, and ultimately the safety behaviour, of the organisational members[19]. This line of reasoning may merit further enquiry, particularly if it can be ascertained which

[18] Cockpit resource management is training provided to flight crew to improve team performance.

elements of organisation culture predispose individuals to more or less safe behaviours.

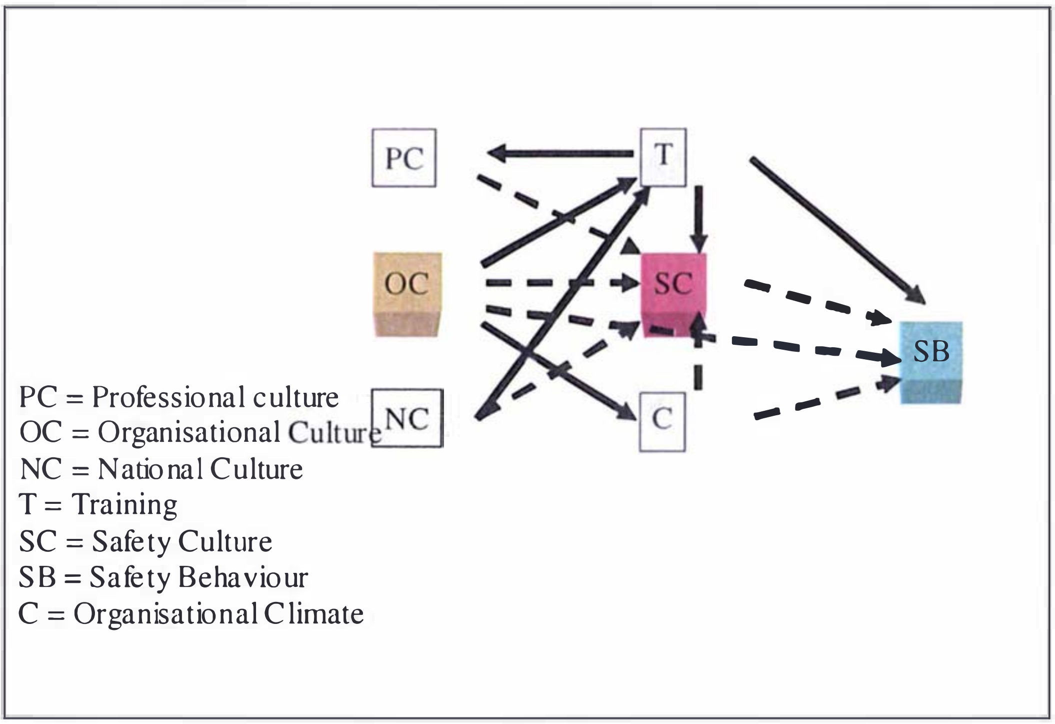

Figure 11: Theoretical model of the paths between different aspects of culture and their influences upon crew performance (Adapted from Helmreich & Wilhelm, 1999; the relationships of interest to this thesis are shown in colour.). The solid lines indicate relationships for which empirical evidence exists; dotted lines are hypothesised relationships.

Within the national culture frame of reference, Helmreich and Meritt's (1998) work with aircrew has suggested that autocratic leadership and individualism lead to a higher probability of safe flight, whilst respect for

[19] Helmreich and Wilhelm (1999) also show the influence of organisational climate.

[20] High uncertainty avoidance cultures are characterised by respect for and adherence to rules (Helmreich & Merritt, 1998).

[21] What they mean by positive behaviours is not defined in their work.

compliance with rules[22] (uncertainty/avoidance) may lower this probability. Within the professional culture frame of reference, positive behaviours[23] lead to a higher probability of a safe flight and positive morale leads to safer operations. No work has addressed these influences in aviation maintenance environments, although there is reason to suppose that such investigations will yield some interesting findings.

From a different perspective, O'Reilly, Chatman, and Caldwell (1991) have suggested that "organizations' cultures tend to be similar when organizations are in relatively homogeneous industries." (O'Reilly et al., 1991, p. 510), and that "organisational culture may vary more across industries than within them" (Chatman & Jehn, 1994). National, international, and professional culture influences are therefore likely to produce organisational culture homogeneity across aviation maintenance organisations in New Zealand; this may allow the development of safety interventions that might be applied universally across a number of organisations. Notwithstanding this homogeneity, organisations are likely to manifest their own idiosyncratic features due to the unique local influences (see Figure 2, p.31).

Having considered the concept of organisational culture, some consideration will now be given to the more specific concept of safety culture.

2.3.2.2. Organisational safety culture

The concept of safety culture was included in the theoretical model of the paths between different aspects of culture and their influence on crew performance (see SC in Figure 11). A number of authors have identified the lack of a safety culture within organisations as being significant in the aetiology of incidents and accidents (Bureau of Air Safety Investigation, 1996; ICAO, 1993, 1995; Helmreich & Merritt, 1998; Maurino et al., 1995; Moshansky, 1992; Pidgeon, 1991; Pidgeon, Turner, Toft, & Blockley, 1992; Reason, 1997; Weick, 1987; Woods et al., 1994; Zohar, 1980). Furthermore, it has been suggested that

[22] High uncertainty avoidance cultures are characterised by respect for and adherence to rules (Helmreich & Merritt, 1998).
[23] What they mean by positive behaviours is not defined in their work.

establishing a good safety culture in organisations will decrease incidents and accidents (Bureau of Air Safety Investigation, 1996; Carroll, 1998; Edkins, 1998a, 1998b Edkins & Pollock, 1996; Eiff & Lopp, 1998; Reason, 1997). This leads to the question of whether characteristics can be identified that are related to safe organisational cultures and what can be done to facilitate the establishment of these characteristics.

In the aviation safety literature, the term 'safety culture' seems to address a construct which relates to overt safety-related attributes that organisations possess and that influence safety outcomes (Edkins, 1998a, 1998b; Edkins & Coakes, 1998; Maurino et al., 1995; Pidgeon, 1991; Reason, 1997). Within the present research it is assumed that the construct forms part of the organisational culture construct and that, although in general terms the elements that make up safety culture are accepted, it remains an empirically unverified concept (Cox & Flin, 1998a, 1998b). A particular safety culture may or may not be directly reflected by all individuals or sub-groups within the organisation and it is likely that in some organisations sub-cultures (i.e. cultures existing in opposition to each other) may exist (Cooke & Rousseau, 1998). Identifying these sub-cultures may be important when they represent a safety hazard and concerns might be raised if there are large discrepancies in the safety culture between management and other divisions of an organisation. For this reason, a measure that is sensitive to organisation cultural differences might have some utility for the proactive management of safety risk in the industry, particularly if elements of safety culture can be clearly defined and related to other safety criteria.

2.3.2.3. Characteristics of safe and unsafe cultures

If complex socio-technical systems are to be safe, management must be confident that their goals and aspirations for safety carry through to all levels of the organisation and, ultimately, to the products of that organisation; there must be congruence on the safety outputs that are expected throughout. Safety culture is likely to be an influential background factor intertwined with safety performance (Johnston, 1992a; Pidgeon & O'Leary, 1994). Wiener and colleagues have developed a model known as the 'four P's' (Philosophy, Policy, Procedure, and

Practices) that provide an outline for achieving this congruence (Degani & Wiener, 1994; Wiener, Kanki, & Helmreich, 1993). They propose that organisational practice should be demonstrably related to the written procedures. These in turn, should relate directly to the company policy and ultimately the philosophy of the organisation. There needs to be a clear thread of meaning throughout (Degani & Wiener, 1994). If marked discrepancies exist between the four P's, then senior management is not truly in control or sufficiently informed about the activity of the organisation (Degani & Wiener, 1994; Wiener et al., 1993). Intuitively, this implies that good communications are a prerequisite, though insufficient on their own, for the maintenance of safety in organisations. It is likely that many other characteristics will also be important.

The characteristics of safe organisational cultures have been described by a number of authors. Pidgeon and O'Leary (1994) use the term safety culture to describe four areas: location of responsibility for safety at strategic management level, distributed attitudes of care and concern throughout the organisation, appropriate norms and rules for handling hazards, and ongoing reflection on safety practice. Reason (1997) has suggested that good safety culture is generative, dynamic, reactive, with good communication, shared responsibility throughout the organisation, and requisite variety[24] among the staff. Eiff and Lopp (1998) have described safe cultures as possessing the following characteristics: personnel are informed, they report problems, the culture is just, flexible, and promotes learning. They observe that safety initiatives are often lost in organisations as they filter down to the frontline workers. In addition, they suggest that safety is a shared responsibility but have also identified the importance of a highly visible and proactive management, which promotes safer industrial activity. Edkins and Coakes' (1998) work supports this position whereby employees perceive safety as a shared responsibility both of the individual and of the management.

Using focus-group methodology, Cox and Flin (1998b) concluded that management commitment to safety and action, workforce involvement, personal responsibility, attitudes to hazards, rule compliance, workplace conditions, and the priority given to safety, communication and employee involvement, were the most important factors in influencing organisational safety culture. Predictably, their study found that accident frequencies are lower where positive attitudes to safety exist. Management complacency, role ambiguity, poor communications, and low prioritisation of safety, coupled with high pressure for performance, were considered detrimental to a safe culture. In addition, Cox and Flin (1998a) maintained that safety as a primary goal, decentralised authority, redundancy within systems, organisational learning, and senior management commitment to safety are all critical to safe operations.

La Porte (1996) reported that, where production and safety are held as equally important, then high-reliability organisations[25] will show an integration of mission accomplishments and production with safety culture. This is evidenced by "operator member élan" (enthusiasm) and "a prideful wariness, autonomy, commitment to ownership of a problem by the person who finds it, personal responsibility, and a high value placed upon operational knowledge and experience" (La Porte, 1996, p. 65).

Zohar (1980) found good agreement between the quality of workplace safety programmes, as ranked by inspectors, and safety climate. Dedobbeleer, Beland, and German (1990, cited in Edkins, 1998b) found relationships between safety culture and organisational factors prevalent in most safety programmes. Glennon (1980) found that organisations with poor safety climate scores had higher accident rates as measured by lost-time injury frequency. Bailey and Petersen (1989), surveying railroad safety over a 9-year period, found that high safety performance railroad units were generally the ones that generated the highest positive responses[26] to safety survey questions. Cheyne et al. (1998) identified five areas that were significant to higher safety organisations: safety management, communication, individual responsibility, safety standards and goals, and personal involvement in safety; management actions were highlighted

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[24] Requisite variety describes the variety of skills and experience that operators bring to the role.

[25] High-reliability organisations are organisations that have "large-scale operating systems already performing at an extraordinary level of safety and productive capacity in the face of demanding circumstances" (La Porte, 1996, p. 60).

[26] They do not define precisely what they mean by 'highest positive response', it is assumed that this refers to items in the questionnaire that were positively related to safety.

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as a prime area for intervention. The importance of safe organisational culture at management levels of an organisation has also been highlighted by a number of authors (Cohen, 1977; ICAO, 1993; Johnston, 1993; Krause, 1994; Lautman & Gallimore, 1987; Maurino et al., 1995; Perrow, 1983; Pidgeon, 1991; Pidgeon & O'Leary, 1994; Reason, 1997; Wagenaar, 1990; Wagenaar & Groeneweg, 1987; Zohar, 1980).

The International Civil Aviation Organisation has identified a good safety culture as consisting of the following components: senior management placing an emphasis on safety, the willingness of management to accept criticism and an openness to opposing views, feedback encouraged, employees' understanding of hazards, communication of relevant safety information, and education and training in the consequences of unsafe acts (ICAO, 1993).

Finally, Keenan, Kerr, and Sherman (1951) determined that a clean and comfortable working environment is a predictor of good safety performance and that greater promotion prospects predict lower accident rates. This would suggest that where the 'housekeeping' standards are high then organisations are likely to be safer.

Central themes running through the safety culture literature are flexibility, reflexivity, the notion of safety as a shared responsibility that is pervasive and congruent throughout the organisation, and the importance of management demonstrating a clear commitment to safety (Brown & Holmes, 1986; Cohen, 1977; Griffiths, 1985; Zohar, 1980). This commitment to safety has been noted within aviation organisations with exceptionally good safety records (Glennon, 1980; Lautman & Gallimore, 1987).

2.3.2.4. Safety culture and organisational structure

The structure of an organisation may influence culture in a variety of ways; for example, hierarchical organisations, with many layers of management, can increase the perceived distance between the workforce and management. Flatter hierarchies may promote a co-operative organisational culture, where managers are seen as problem-solvers (Maurino, 1992). Such hierarchies may promote a more hands-on problem-solving style, providing the opportunity for wider responsibility, increased involvement, and empowerment of staff (Ackroyd, 1995). Complex hierarchies on the other hand, see managers as experts with the answers at hand, but may suffer from bureaucracy, which in itself may lead to errors. Additionally, employees in a complex hierarchy may feel disempowered, insignificant, and unable to influence the errors that occur (Vogel, 1992).

2.3.2.5. Safety culture and the learning organisation

It seems reasonable to assume that organisational cultures that learn from their mistakes will be safer than those that do not. The term 'reflexivity' has been used to describe organisations that learn from experience in an active way, as opposed to organisations that do not actively exploit such an experience (Toft, 1992). Presumably, the safest organisational cultures are those that demonstrate reflexivity. The organisational culture that learns, is receptive to new ideas, whilst not casually dispensing with the old, is likely to promote innovation and safe practice. Pidgeon and O'Leary (1994, p. 36) term this "ongoing reflection". Similarly, Westrum (1993), in describing how organisations use new information, used the term 'generative' for organisations that respond to feedback and modify their behaviours in a positive fashion (see Table 3).

Table 3: How organisations treat information (Westrum, 1993).

Pathological	Bureaucratic	Generative
Don't want to know	May not find out	Actively seek information
Messengers are shot	Listened to if they arrive	Messengers are trained
Responsibility is shirked	Responsibility is compartmentalised	Responsibility is shared
Bridging is discouraged	Allowed but neglected	Bridging is rewarded
Failure is punished or covered up	Organisation is just and merciful	Inquiry and reflection
New ideas are actively crushed	New ideas present problems	New ideas welcomed

Hudson (1997) adapted Westrum's model substituting 'Calculative' for 'Bureaucratic'; he suggested that when an organisation reaches the Calculative stage on a continuum from Pathological, Calculative, and Generative, then safety is evaluated in terms of a cost–benefit analysis. Once the organisation has passed this stage and moves into generative information exchange, a 'safe culture' can develop. Intuitively, one might expect generative organisations to be safer; an organisation that discourages a free exchange of information will not learn from its employees' mistakes and, where punitive measures are taken against people who err, communication about such errors is further discouraged (Pidgeon & O'Leary, 1994; Westrum, 1993).

2.3.2.6. Safety culture and blaming organisations

Johnston (1992b, 1993) offers powerful arguments stating that retribution primarily serves social purposes, though it is frequently justified for its assumed role in preventing future acts or omissions of a similar nature. Even where punitive action is justified, for example, in cases of extreme violations such as sabotage, it is unlikely to help the organisation reduce the risk that the error will re-occur (Johnston, 1993). Indeed, it has been argued that the search for someone to blame can obscure the true causes of accidents. If there exists a preconceived notion of where the error lies, it is a relatively simple task to find the evidence to support this position (Macfarlane, 1991; Vette et al., 2000); many past air accident investigations world-wide illustrate this form of hindsight bias. The crash of an Air New Zealand DC 10 aircraft into the slopes of Mount Erebus in Antarctica provides an example. Initial accident investigation of the Mount Erebus accident led to the conclusion that the flight crew made a decision to fly into an area of low visibility and that this was the major reason for the loss of the aircraft (Vette et al., 2000). A subsequent court of inquiry indicated that other factors, namely sector white-out and re-programming of the flight management computer onto a new track, without the crew's knowledge, were probable material causes (Macfarlane, 1991). The crew's behaviour, in the light of this new information, may be seen as reasonable and less blameworthy. It is suggested that communicating, non-blaming organisational cultures, where management is seen to support safety-related behaviours, will tend to promote the development of a safety culture (Johnston, 1992b, 1993), and this in turn will reinforce safety-promoting behaviours.

2.3.2.7. Safety culture and error reporting

It has been suggested that good safety cultures provide fewer opportunities for the development of the conditions, latent or otherwise, and errors that contribute to incidents or accidents. Therefore, a potentially useful indicator of safety is likely to be the frequency of errors that an organisation generates. However, there exists a question about the reliance that might be placed on reports of error frequency as an indicator of safety.

An examination of aviation maintenance error reporting systems in New Zealand suggests that these are not well developed. Eiff and Lopp (1998) have highlighted the difficulties in collecting such information, citing errors in taxonomy (classification systems) and the difficulty in assigning human factor explanations to errors, and the implications of such data. Additionally, normal work practices, informal and formal, will often serve to redress errors that occur, so that senior management never hears about them. It has even been suggested that low accident and incident rates are a reflection of poor reporting and information capture mechanisms and many so-called safe organisations have a track record of concealed accidents and safety breaches (Sagan, 1993). The logical corollary of this is that organisations reporting errors more may be considered safer.

Using survey methods (Clarke, 1998a, 1998b), research on railroad safety indicates that under-reporting of incidents may be related to organisational factors such as: "the proliferation of relatively minor accidents, bureaucratic form-filling procedures, poor management response and lack of positive feedback on reports" (Clarke, 1998b, p. 287). This same study suggests that it is the train drivers' perception of managers' attitudes towards incident reporting, that affects their tendency to under-report incidents.

Collectively the work on error reporting, described above, implies that safer organisations are those that report the occurrence of errors accurately (Cheyne et al., 1998; Cox & Cox, 1991; Sagan, 1993). However, a paradox exists for safety researchers who wish to use error reporting as an indicator of safety. Safe organisations, with fewer errors, are likely to have good systems for capturing and reporting errors, tending to increase the frequency of errors reported. Unsafe organisations, with many errors, are likely to have less efficient reporting systems tending to decrease the errors reported.

Table 4 shows how the production and detection of errors may interact to produce a distorted picture of true error rates in an organisation. Hypothetically, an organisation may occupy cells A, B, C, or D at any point in time. An organisation occupying cells A or C is likely to appear safer than if it occupies cells B or D. Ideally organisations should strive to occupy cell D.

This relationship is shown for a hypothetical organisation in Figure 12. The red line represents the true frequency of errors. It can be observed that the true rate of error decreases over time as we move from left to right. However, as the true error rate is decreasing, the detection efficiency (blue line) is increasing. The net effect is that no change in the detected error rate (black line) is observed. Thus, the resulting detected errors are a function of the number of errors and the efficiency of the reporting of these errors.

Table 4: Detection of errors.

	Low detection (appears safe)	High detection (appears unsafe)
	A	B
High frequency of errors (organisation is unsafe)	Where detection is very low the organisation appears safe but is unsafe	Appears unsafe and is unsafe
	C	D
Low frequency of errors (organisation is safe)	Appears safe and is safe	Where detection is high the organisation may appear unsafe but is actually safe

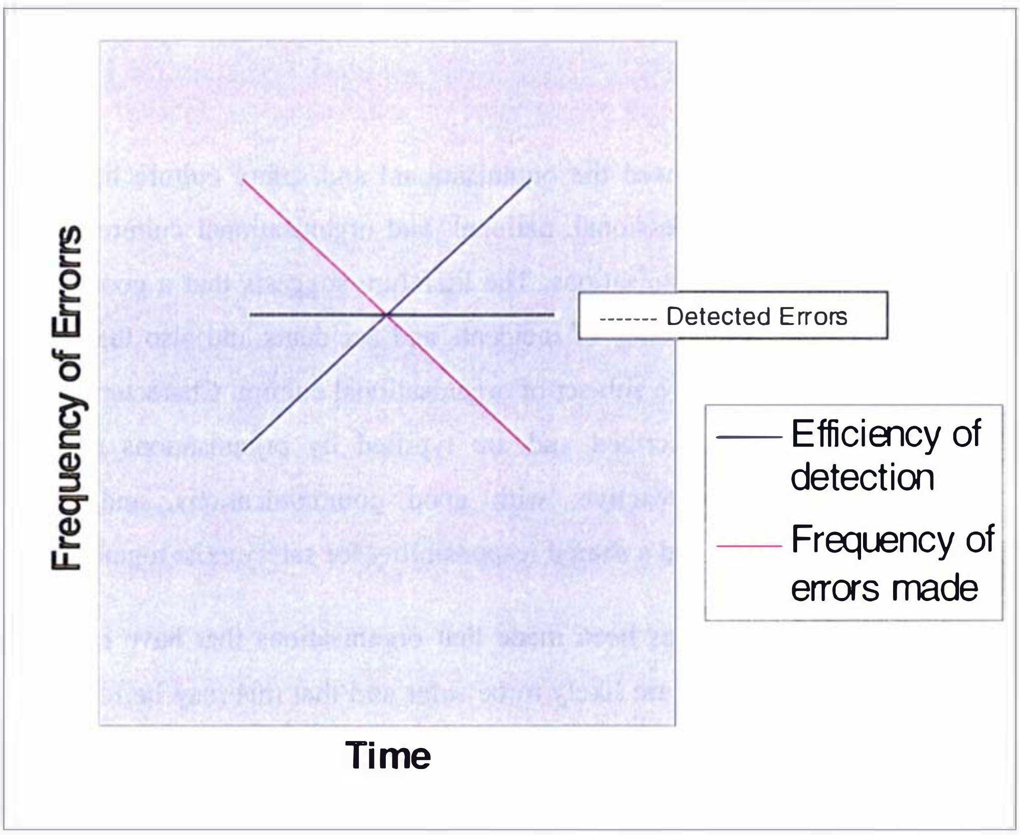

Figure 12: Hypothesised error detection rates; the effects of error frequency and efficiency of error detection.

To test the assertion that organisations reporting more errors are safer, it would be useful to demonstrate an association between the reported error level and other indicators of safety. For example, the paradox may be resolved by showing that higher numbers of reported errors are associated with better safety cultures[27] and other indices of safety such as expert ratings, other types of self-report, and checklists. (Zohar, 1980; Reason, 1997).

Within the aviation industry, no research has attempted to quantitatively measure organisational safety culture (Helmreich & Wilhelm, 1999; Helmreich, Wilhelm, Klinect, & Merritt, 1999) and then attempt to demonstrate a relationship with error performance and safety. In the future, such measures may be used proactively in order to manage the safety culture and the associated human errors. In addition, once it is established what constitutes a safe culture then it may be possible to engineer/promote this within the industry.

2.3.3. Summary

Section 2.3 reviewed the organisational and safety culture literature. This has indicated that professional, national, and organisational culture affects the safety behaviours of organisations. The literature suggests that a good safety culture will reduce the frequency of incidents and accidents and also that safety culture should be considered a sub-set of organisational culture. Characteristics of safe culture have been described and are typified by organisations that are generative, dynamic and reactive, with good communications, and where management commitment and a shared responsibility for safety exist together.

The suggestion has been made that organisations that have effective systems for capturing errors are likely to be safer and that this may be related to other indices of safety and superior safety cultures. The relationship between the true error rates in organisations and the reported error rates has been described and the potential paradox in the recording of errors as indicators of safety was discussed. It was concluded that it would be useful to examine the suggestion that organisations reporting a greater number of errors are safer and that an

[27] To date no research has attempted to relate this directly to measures of organisational and safety culture.

examination of the organisational safety culture, and its relationship to error performance and safety, might assist in the proactive management of safety.

2.4. The theoretical and conceptual framework for this research

The literature review has identified some of the organisational influences on human error in aviation maintenance and an outline of the Latent Failure Model (Reason, 1997) has been provided. This model suggests that latent conditions and error states, which have the potential to cause an incident or accident, can be introduced into aviation maintenance organisations where they can remain hidden until they are triggered by some local event or action. It has also been suggested that organisational culture can have a pervasive influence on the development of human errors and latent conditions (Cox & Flin, 1998b; Lauber, 1993; Reason, 1997).

The Latent Failure Model provides a framework for understanding the concept of organisationally induced error and implies that senior management in organisations has a significant influence over the many conditions that allow maintenance errors to occur. These include the promotion of philosophies, attitudes of care and concern for safety, and the extent that management may be said to influence and be influenced by the culture that exists in organisations (ICAO, 1993; Reason, 1997; Turner, 1991). Furthermore, a poor safety culture can represent an underlying latent condition that pervades all areas of an organisation (Edkins, Brown, & Maccaulay, 1997). It has been suggested that it may be possible to identify organisational and safety cultures that promote safer organisational behaviours than others (Reason, 1997), and that organisational and safety culture may provide some valuable clues to the background preconditions to safe organisations that may otherwise be difficult to determine (Pidgeon, 1991).

The value in identifying potentially damaging organisational cultures and relating these to the occurrence of errors, latent conditions, and the safety levels that exist in organisations has been indicated in the aviation literature though little empirical work has been completed (Pidgeon & O'Leary, 1994). It is only recently that psychometric methodologies for the assessment of organisational and safety cultures have emerged in the literature (Cox & Flin, 1998a, 1998b).

Within the theoretical framework, outlined above, this present research attempts to provide some empirical evidence to support the notion of culture as a latent condition that influences the safety behaviour of organisations. It will do this by examining a number of themes within the literature.

2.4.1. Themes emerging from the literature

Two main themes have emerged from the literature. The first relates to aviation maintenance error reporting systems and how the information they generate might be used to evaluate safety. The second theme relates to the organisational cultures that exist in organisations. When combined, these generate a third theme, which relates to the influences that culture has over error and safety.

The literature review has shown that aviation maintenance error reporting systems in New Zealand are currently not well developed. Awareness of the potential failure types (latent conditions and errors) and their causes may ultimately allow the managers of maintenance organisations to minimise the circumstances under which these are introduced, but at present such techniques are still under development. The Latent Failure Model (Reason, 1992, 1997) suggests that these failure types might be analysed at three levels: (1) the level of the organisation (General Failure Types/Organisational Failures), (2) the level of the local task environment (Local Errors and Local Violations), and (3) the level of the individual (Active Failures). This has provided a framework for the classification of human errors within the New Zealand aviation industry.

Taken in isolation, the frequency of errors reported by an aviation maintenance organisation may not be a reliable indicator of safety, as frequency is also related to the efficiency of the reporting system. It has been suggested that low incident rates may reflect poor reporting and error capture mechanisms; consequently, so-called 'safe organisations' (with a low frequency of organisationally reported errors) will be more likely to have a track record of concealed incidents, safety breaches, and possible accidents (Sagan, 1993). Opinion on error reporting suggests that safer organisations are those which report the occurrence of errors, although comparison of the absolute frequencies of these across organisations does not provide useful information unless other safety indicators are also used (Cox & Cox, 1991; Cox & Flin, 1998a, 1998b; Sagan, 1993). These assertions should be tested by empirical work.

If aviation maintenance organisations are subject to the same international, national, and professional influences, then their organisational culture profiles are likely to be similar (Helmreich & Merritt, 1998; Helmreich, Merritt, & Sherman, 1996; Helmreich & Wilhelm, 1999; Helmreich et al., 1999; O'Reilly et al., 1991). Notwithstanding this relative homogeneity, organisations are nevertheless likely to manifest their own unique organisational cultures related to safety performance, and which may allow the discrimination of these organisations from each another.

The literature has suggested a number of areas of organisational culture that influence safety in organisations. These include: a commitment from management to safety (Cohen, 1977; Williams, 1991), reflexivity and requisite variety (Reason, 1997), generative organisations (where the flow of safety and error information is encouraged) (Westrum, 1993), reflection on safety practices (Pidgeon & O'Leary, 1994), a safety culture permeating throughout the entire organisation (Lautman & Gallimore, 1987), and good communications (Vaughan, 1990). Collectively, these indicators might provide a comprehensive 'picture of safety', as no single indicator is likely to be adequate. Again, empirical work might usefully be completed in this potentially fruitful area.

This section has indicated the themes that will be explored in this research. The following section provides a detailed account of how the research questions will be addressed, by providing a series of aims together with their associated hypotheses.

2.4.2. Aims and hypotheses for this research

This research examines the nature of the errors that occur in aviation maintenance organisations in New Zealand. It makes a quantitative assessment of organisational and safety culture within these organisations. These are then examined in the context of error and safety performance as indicated on a number of indices generated for this purpose. With reference to Figure 13, this research will examine the relationships that may exist between Organisational Culture (OC), Safety Culture (SC), and Safety Behaviour (SB). The measurement tools used to assess these are shown in bubbles within the figure and a detailed explanation follows in Chapter 3. For a brief description of the measures see Table 5, p. 88).

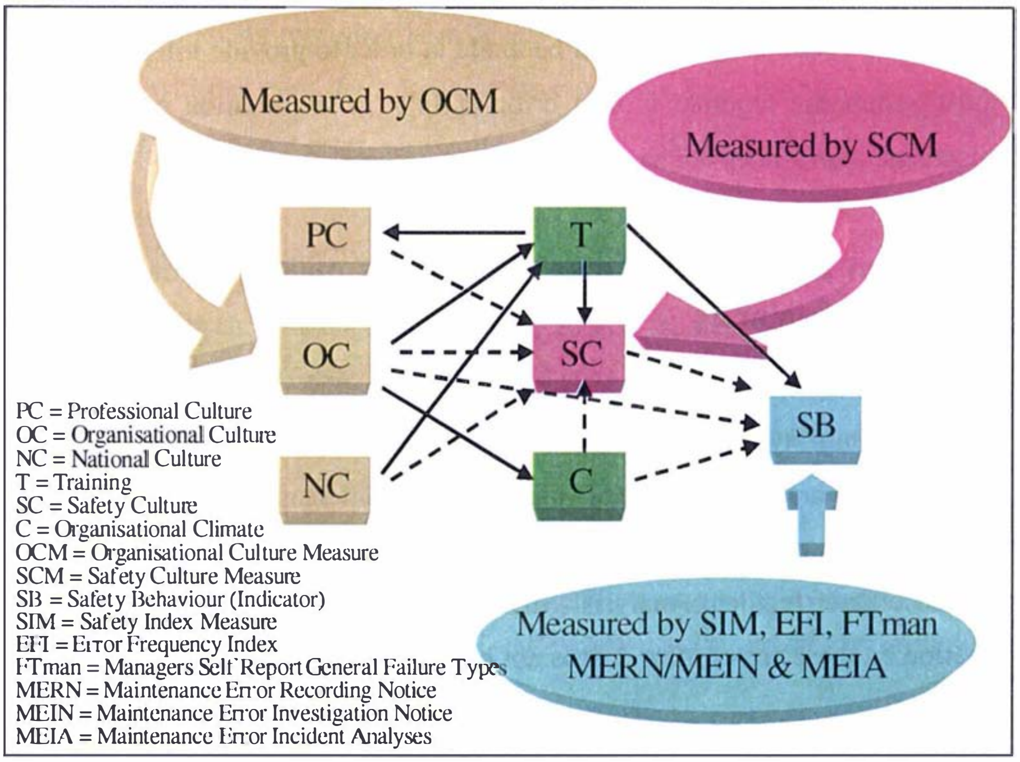

Figure 13: Theoretical model of the paths between different aspects of culture and their influence upon crew performance. The balloons show the various measures developed for this research (Adapted from Helmreich & Wilhelm, 1999.).

The suggestion offered is; if organisational culture and safety culture can be described by dimensions that are both valid and reliable descriptors of aviation maintenance organisations, then it should become possible to use these dimensions to predict some relationship to safety behaviours/indicators in these organisations. If this research is able to start unravelling the potentially complex relationship that exists between aspects of organisational culture, human error, and safety performance in aviation maintenance, then this will be a valuable contribution to safety and efficiency in the aviation industry. The following six aims were identified for the research, these are specified in terms of specific hypotheses that are stated in the alternative form.

2.4.2.1. Aim 1: Investigation of human error types in aviation maintenance in New Zealand

An examination of the relative frequency of human error failure types existing on the CAANZ database will be made in order to provide information on the most commonly reported human error failings in six aviation maintenance organisations. Aim 1 does not have a research hypothesis.

2.4.2.2. Aim 2: Qualitative measurement of maintenance error in New Zealand

Aim 2 was designed to determine the nature and causes of errors performed within aviation maintenance organisations in New Zealand. An examination of incidents reported using the Maintenance Error Recording Notice/Maintenance Error Investigation Notice (MERN/MEIN) or the Maintenance Error Incident Analysis (MEIA) procedures will provide qualitative information on these errors. Aim 2 does not have a research hypothesis.

2.4.2.3. Aim 3: An examination of error frequency and safety performance in aviation maintenance organisations in New Zealand

The literature review has suggested that organisational and safety culture may provide useful information about organisations that are carrying different levels of safety risk. It also indicated that safer organisations are those that report more errors even though this represents something of a paradox, as safer organisations are also likely to generate fewer errors.

To resolve this paradox, it would be helpful if the level of reporting (Error Frequency Index (EFI)) could be shown to be associated (correlated) with other indicators of safety. Empirical support will be sought for the suggestion that organisations reporting more errors may be considered safer than organisations reporting fewer errors. This will be demonstrated by associations between levels of error reporting and other measures of safety performance (indices of safety that include non-reactive/observable indicators of safety (Safety Index Measure (SIM)) and managers' subjective evaluation of error levels (Managers Self-Report General Failure Types (FTman) and safety culture (Safety Culture Measure (SCM)) (Cox & Cox, 1991; Cox & Flin, 1998a, 1998b; Sagan, 1993). This aim will be examined under Hypotheses 1, 2, and 3. Aim 3 will also investigate whether individuals reporting high levels of personal error (Self-Reported Error (Err-self)) will perceive their organisations as being less safe; it is suggested that high levels of personal error may lead to this less-safe attribution.

2.4.2.3.1. Hypothesis 1

For the maintenance organisations studied in this research, the frequency of errors (Error Frequency Index) reported on the CAANZ database will show a positive correlation with the Safety Index Measure (SIM). This association can exist where high safety leads to increased error reporting by organisations and an increase in observable safety indicators. Higher reported errors equate to higher safety because organisations have systems in place to capture errors.

2.4.2.3.2. Hypothesis 2

For the maintenance organisations studied in the research, the frequency of errors (Error Frequency Index) reported on the CAANZ database will show a negative correlation with the Managers' Self-Report General Failure Types (FTman). This association exists where a high level of safety is reflected by an increase in organisational error reporting. This also creates in managers the confidence that their organisation is safe, leading to a lower score on the Managers' Self-Report General Failure Types scores.

2.4.2.3.3. Hypothesis 3

For the maintenance organisations studied in the research, the frequency of errors (Error Frequency Index) reported on the CAANZ database will show a positive correlation with the Safety Culture Measure (SCM). This association exists when a high safety level is expressed in a corresponding increase in error reporting and higher perceived levels of safety in the organisation.

2.4.2.3.4. Hypothesis 4

Participants reporting higher levels of personal error (Self-reported Error (Err_self)) will rate the organisation as less safe on the Safety Culture Measure. This association exists where high levels of personal error lead to the attribution that the organisation is less safe.

At first sight, Hypothesis 4 may seem to contradict Hypothesis 1. However, under Hypothesis 1 high reporting is considered 'more safe' because organisational systems are capturing safety-related events, i.e. more 'organisational' reporting indicates higher safety, whilst under Hypothesis 4, participants reporting high numbers or errors in themselves (or others) are making an unsafe attribution regarding their organisation; i.e. higher numbers of 'self-reported' errors indicate that their organisation is less safe.

2.4.2.4. Aim 4: The homogeneity of organisational culture in aviation maintenance organisations in New Zealand

If aviation maintenance organisations are relatively homogeneous for organisational culture (Chatman & Jehn, 1994) then this may indicate the feasibility for the development of universally applied safety approaches across the industry. This research seeks to test the suggestion of homogeneity across aviation maintenance organisations in New Zealand using the Organisational Culture Measure (OCM) developed for this purpose. The internal consistency of the sub-scales within the measure and the factor structure will be determined. The measure will also be used to determine whether it predicts variance in personally reported errors. This aim will be examined by Hypotheses 5, 6, and 7.

2.4.2.4.1. Hypothesis 5

The Organisational Culture Measure sub-scales will generate similar profiles, across maintenance organisations, when plotted as a line chart. The Safety Culture Measure score will be treated as a sub-scale of organisational culture for this purpose.

2.4.2.4.2. Hypothesis 6

Factor analysis of the Organisational Culture Measure developed for this research will support the 20 sub-scale structure in the measure.

2.4.2.4.3. Hypothesis 7

The factors obtained from the factor analysis of the Organisational Culture Measure will predict variance in Self-Reported Errors (Err_self) in Organisation 7.[28]

2.4.2.5. Aim 5: Cultural characteristics and safety level of aviation maintenance organisations in New Zealand

Notwithstanding Aim 4, the measures of organisational and safety culture were developed with the aim of facilitating discrimination between aviation maintenance organisations on the basis of safety. This research will examine whether the measures of organisational culture and safety culture can successfully distinguish between organisations based on an index (a summed-rank) that ranks organisations for their level of safety. This rank will be based on objective measures of observable safety indicators in the maintenance workplace, managers' subjective impression of human error rates, and the frequency of reported human errors.

The discrimination should highlight the salient distinguishing features of culture that are associated with higher levels of safety in maintenance organisations. The measure of organisational culture will have predictive qualities

[28] Organisation 7 (Org 7) is the identifier for the largest maintenance organisation in the research and the only one in which Self-Reported Error data was available.

with regard to the safety culture measure and the safety behaviour (indicator). This is shown in by the path OC → SC → SB in Figure 13 (p. 79).

Finally, the validity of organisational and safety culture measures will be supported if they are shown to be sensitive to differences in the self-reported error that exists between sites (different locations) of the same organisation, where error awareness and, by implication, safety awareness differs.

Aim 5 will be examined by Hypotheses 8, 9, and 10.

2.4.2.5.1. Hypothesis 8

The Organisational Culture Measure and Safety Culture Measure will discriminate between organisations that are assigned to high, medium, or low safety groups. This will demonstrate the usefulness of the measures and their ability to detect culture differences among organisations that show different levels of safety. The groups will be assigned on the basis of the summed-ranks obtained from three safety indices: the Safety Index Measure, the Managers' Self-Report General Failure Types, and the Error Frequency Index.

2.4.2.5.2. Hypothesis 9

The Organisational Culture Measure sub-scales will predict variance within the Safety Culture Measure. This will provide information on the features of organisational cultures that are associated with safety culture.

2.4.2.5.3. Hypothesis 10

For cases reporting Self-Reported Errors (Err_self) in Organisation 7, a discriminant function analysis using the Organisational Culture Measure and Safety Culture Measure will predict the site of origin (7a or 7b) to which cases belong at a greater-than-chance level. This will indicate the discriminating ability of the Organisational Culture Measure sub-scales and the Safety Culture Measure between the two sites of Organisation 7, for cases where error awareness is indicated, providing support for the validity of the measures.

2.4.2.6. Aim 6: Assessment of safety culture in aviation maintenance organisations in New Zealand

The Safety Culture Measure developed for this research will be examined to determine whether it has an eight-factor structure that is similar to the safety climate measure of Zohar (1980) on which it is based.

2.4.2.6.1. Hypothesis 11

Factor analysis of the Safety Culture Measure developed for this research will show an eight-factor structure similar to Zohar's measure on which it is based.

2.4.2.6.2. Hypothesis 12

The factors obtained from the analysis of the Safety Culture Measure will predict variance in Self-Reported Errors (Err_self) in Organisation 7.

2.5. Chapter summary

This chapter presented a literature review in the area of aviation maintenance as it relates to human error, safety and organisational culture. It examined the nature of the work of aviation maintenance personnel, the technologies available and how these may influence aviation maintenance error. It then described the Latent Failure Model (Reason, 1990), which suggests how errors can develop in complex organisations; introducing the idea that preventative safety action is best implemented through interventions at the management level. This led to a discussion on various aspects of organisational and safety culture, which represent the overriding latent conditions influencing maintenance error.

Drawing together this literature are sections describing the areas of interest in this research. These relate to three main areas.

1. That organisational culture represents an overriding feature influencing maintenance error and safety and that determination of the aspects of culture that promote safety behaviours is worthwhile.

2. Taken in isolation, the frequency of errors reported by maintenance organisations may not be a reliable indicator of safety. This is a function of the efficiency of the reporting system as well as the absolute frequency of errors; the premise to be tested is that organisations reporting more errors are in fact safer.

3. Aviation maintenance organisations have relatively homogeneous cultures.

Finally, the aims and hypotheses arising from these three areas were presented. To investigate these, it was necessary to develop a number of measures; the literature had revealed a paucity of tools that might be used for this purpose. Chapter 3 describes the development of the measures that were used in the main body of this research.

Chapter 3. Development of the measures

THIS CHAPTER describes the development of the measures used to test the hypotheses described in Chapter 2. The concepts of validity and reliability are discussed first providing background information to assist in the understanding of the development of the Organisational Culture Measure (OCM), Safety Culture Measure (SCM), and the Safety Index Measure (SIM).

The development of the pilot versions of the Organisational Culture Measure and Safety Culture Measure are then described, including the methods used to test for their internal consistency. The results were used to generate the final versions of the measures that were later used within aviation maintenance settings.

Next, the development of the Safety Index Measure, Managers' Self-Report General Failure Types (FTman), Error Frequency Index (EFI), Maintenance Error Reporting Notice and Maintenance Error Investigation Notice (MERN/MEIN), and Maintenance Error Incident Analysis (MEIA) are described. Finally, the construction of a Summed Safety Rank, used to assign safety ratings to maintenance organisations, is explained.

Table 5 provides brief descriptions of the measures.

Table 5: Measures developed for the research.

Abbreviated measure name	Purpose of measure
	To measure organisational and safety culture
OCM	Organisational Culture Measure. This measure provides a numerical value for 20 sub-scales of organisational culture. High scores on the sub-scales of this measure indicate that more characteristics of that sub-scale are present.
SCM	Safety Culture Measure. This measure generates a numerical value for an organisation's safety culture. High scores on this measure indicate that safety is perceived as being higher.
	To assign a safety rank
SIM	Safety Index Measure. This measure generates a numerical index that indicates the observed level of safety in the work environment. This measure is expressed out of 100. High scores on the SIM indicate that observable indicators of safety are in place; high scores indicate that the organisational environment has higher safety levels.
FTman	Managers' Self-Report General Failure Types. This measure is subjective assessment of the perceived level of organisation failures that managers perceive the organisation has been experiencing. This measure is expressed out of 100. High scores on the FTman indicate that managers perceive their organisation as having a high number of errors at the organisational level. This can be taken to indicate they do not have confidence in the safety of the organisation's systems and therefore that the organisation is less safe; high scores indicate lower safety as perceived by management.
EFI	Error Frequency Index. This is an index derived by taking the frequency of maintenance-related human factor failure types reported to the CAANZ and dividing this by the number of employees in the maintenance area of the organisation.
	To provide qualitative information on aviation maintenance error
MERN/MEIN	Maintenance Error Reporting Notice and Maintenance Error Investigation Notice. This is a two-stage investigative process generating qualitative and quantitative information on errors.
MEIA	Maintenance Error Incident Analysis. This is an investigative process generating qualitative and quantitative information on errors.

3.1. Validity and reliability in measurement

For valid measurement to take place, resources must be invested in obtaining evidence that optimally reflects the characteristic under examination. It is suggested that the relationships observed among variables must be identified and shown to behave consistently, and in such a way that they can be described by mathematical models that encompass the underlying theory, nature and means of measurement of these variables (Cliff, 1982). The numerical values derived from such measurements will then consistently and precisely describe these relationships and may then be accepted as a scientifically valid way of presenting, comparing and understanding these variables.

The measures developed in this research will ultimately require the development of mathematical models that support the underlying theories used to describe the relationships among the variables. The bases of such models are the probabilities that these relationships could be observed by chance alone where no underlying relationship exists. However, in the early stages of the development of new measures within a subject area, the knowledge and empirical data needed to construct these models may not exist at all, or may be limited, and the initial judgement about the validity of the measures must be based on their face value and their content. This was the case for the measures developed for this research.

In developing the measures, consideration was given to the issues of validity and reliability. Historically, validity has been based on qualitative reviews of the literature, although more recently quantitative methods and meta-analysis have become common practice; these provide a more empirical approach to the treatment of validity and reliability (American Psychological Association, 1996).

Validity can be considered to be a unitary concept having four overlapping elements: face validity, content validity, construct validity, and criterion validity. These elements combine in such a way to provide support for the adequacy of a measure (American Psychological Association, 1996). They do this by examining evidence from a number of sources. The types of evidence deemed most appropriate is a matter of professional judgement, which comes with the development of expertise in that subject area. In this sense, validity is determined by a collectively held wisdom, substantiated by empirical data and mathematical models. In the initial development of the constructs, and the design of the measures, all forms for validity must be developed concurrently.

Face validity is perhaps the most straightforward (and may not be considered as constituting validity in the technical sense (Landy, 1989). This is the degree to which a measure appears to measure what it is meant to be measuring (Sanders & McCormick, 1976).

The construct underlying a measure represents the conceptual framework on which it was developed. Construct validity refers to the degree to which a measure, as a whole, reflects the underlying construct being assessed. It reflects the adequacy of the content and is often determined from a number of research studies that support the construct (Landy, 1989). Many practical applications of the measure may be required for the construct to gain acceptance. For example, the construct of 'safety culture' used in this research has yet to develop a pedigree in the literature that would permit its general acceptance.

Content validity refers to the adequacy with which items in a measure are sampling different aspects of the construct. For example, if a measure was required to evaluate the safety level within an aviation hangar, then the items should sample the specific characteristics of that environment that indicate safety. Content validity is therefore specified at the conceptual level (Landy, 1989), with items in a measure being representative of the construct.

From the point that content is generated, relationships between the components of the content are sought in order to support the construct validity in the measure. The content can be generated from any number of sources, experts may generate this or observations may be made. Content should be representative of the entire domain under examination, although the superficial similarity of items does not necessarily mean that they will be useful in sampling the construct and superficial dissimilarity does not preclude inclusion of content.

Finally, criterion validity refers to the degree to which the measure predicts scores on externally valid criteria that have been accepted as valid measures of the construct being assessed (Landy, 1989). For example, in a research study of safety culture, an extreme score on a valid safety culture measure could be expected to predict extreme scores an objective indicator of safety such as the true error or accident record of an organisation.

Where criterion validity is used to assess the validity of a measure, consideration must be given to the sample size. Where sample size is small, the power of the test may be insufficient to generate a statistically significant result. This may lead to the conclusion that there are no relationships between the predictor and dependent (criterion) variables. It is therefore possible for an association between the predictor and dependent variable to exist but to be ignored on the basis that statistical significance has not been attained. Over-reliance on statistical significance testing can therefore lead to potentially interesting findings being dismissed, and repeated observation of an effect should be considered just as persuasive of a relationship as a statistically significant result (Carver, 1978). Predictive validity is the term used to describe the statistical ability of a measure to predict criterion scores in some future measure or score. Concurrent validity describes the ability of a measure to predict a score on some other criterion measure at the same point in time.

Two other forms of validity, which relate to the manner of application of a measure, are also important. (1) The internal validity of a measure refers to the degree to which changes in the measure reflect a meaningful change in the measured characteristic. (2) The external validity[29] refers to the degree to which changes in the measure accurately reflect equivalent changes in a measured characteristic across a number of settings. A measure that is sensitive to safety culture change in an organisation may have good internal validity for that organisation. The degree to which the same measure is sensitive to safety culture change in all possible organisations represents its external validity.

[29] The term ecological validity is also used to refer to the degree to which a measure is generally valid for the population it is designed to assess.

An objective for the measures developed for this study was that they should be comprehensive in their coverage of the construct they were designed to measure. For this reason, a large number of items were included in each measure with the expectation of increasing their content validity, sampling much of that construct domain. It was anticipated that this would increase the likelihood that the measures would capture the elements of interest. For example, the pilot version of the Organisational Culture Measure contained a several items each within a sub-scale. These sub-scales sampled different constructs within the organisational culture construct. In total, there were 170 items and 21 sub-scales in this pilot version (see Appendix C, p. 290). This increased the likelihood that a valid and comprehensive measure of organisational culture would be produced. Too few items included at the early stages could have restricted the coverage of the measure to selected aspects of organisational culture. The measure would then have been less comprehensive and potentially less valid as a measure of organisational culture.

In general, valid measures should also consider which features of measurement are the important ones. They should be sensitive, providing detailed information about the object being measured, and should measure only what they are intended to measure. The validity of a measure can be considered as an "inquiry into the soundness of the interpretations proposed for the scores from a test" (Cronbach, 1990, p. 58). They should be readily accessible, have practical utility, and be economical, extracting maximum information with the minimum number of items.

Reliability is a prerequisite for validity and "refers to the degree to which a measure is free from errors of measurement" (American Psychological Association, 1996, p. 19). Reliable measures are both consistent and reproducible (Landy, 1989). For example, a highly reliable measure will give the same result on two occasions unless there has been a change in the 'thing' being measured. Such changes can include maturation, external influences, attrition, or response inconsistency. The variability in the observed results, when no change has taken place, indicates the degree of reliability error in the measure. Where reliability is poor, less confidence can be placed in the measure. It is essential that such measurement errors are identified and minimised during the development of a measure.

The reliability of a measure is generally tested by determining how well matched pairs of scores are, under identical conditions. For example, measurement of the safety level in an organisation, using the same measure on two occasions by the same observer, should yield the same result, provided that the actual safety level has not changed. Any change in the measure under these conditions is due to measurement error and indicates the reliability inherent in the measure.

Reliability coefficients are commonly used to indicate reliability and are based on the shared variance between pairs or sets of scores. These generally take the following two forms. (1) The correlation coefficient is calculated for scores obtained between two administrations of the same measure. This indicates the degree of match between the administrations, with a correlation of one indicating a perfect reliability and a correlation of zero indicating poor reliability. The administrations of the measure by the same observer may be separated in time(test–retest reliability) (Landy, 1989) or measurements taken by different observers may be compared (inter-observer reliability). (2) Split-half reliability and Cronbach's alpha (α) (Cronbach, 1990) are techniques used to test for the internal reliability (consistency) of items contained within a measure and can be used to test for item homogeneity. Split-half reliability involves calculating the correlation between the scores obtained on one-half of the measure with scores on the other half. Cronbach's α is more sophisticated and is equivalent to correlating each score with every other score in the measure.

3.2. Repeated measures, internal consistency (reliability) and validity

Repeated measures and correlation evidence are frequently advocated as evidence for the reliability of a measure and it was anticipated that a repeated measures approach would be a feature of this research. However, caution needs to be exercised in the interpretation of such evidence. Changes in the values obtained from the measures in this research may be caused by changes in an organisation, indeed this is what the measures are intended to detect, but may also be due to the participants becoming more aware of the content of the measures and the nature of the study, a maturation effect not related to a 'real' change in the organisation. Additionally, extreme scores on a measure regress to the mean when the measure is repeated, and consequently there is a tendency to understate the measure of agreement between extreme scores recorded at two points in time (Bereiter, 1962). Finally, changes in the numerical values on a measure may not represent qualitatively equivalent changes in the level of the construct being measured. For example, a decrease of 10 intervals for a safety culture score of 80 to 70 may not be equivalent, in qualitative terms, to a change from 60 to 50. When interpreting repeated measures data, due consideration must be given to these limitations.

The approach to validity and reliability taken in this research may be summarised as follows. Traditional methods of assessing internal consistency (e.g. Cronbach's α) will be used where appropriate. Repeated measures will be obtained to determine the degree to which the various measures remain constant over time. It can be argued that if they are consistent then they are reliable. The reliability and validity of the measures will also be supported if the observed values change in some organisations, whilst in others they remain the same. The repeated measures approach will provide added confidence in both the validity and reliability of the measures (Carver, 1978).

The validities of the new measures developed for this research are based primarily on the item content and, to a lesser extent, the construct validity, until such time that this or future research provides additional empirical evidence for the criterion validity of the measures.

3.3. Development of the Organisational Culture Measure (OCM) and Safety Culture Measure (SCM)

When this work began in early 1994, literature searches yielded little in the way of validated measures of organisational, safety culture suited to the needs of this research, and no measures had been applied to the aviation maintenance context. The development of new measures was undertaken with a view to applying these within aviation maintenance environments.

3.3.1. Background to the development of the Organisational Culture Measure

Because organisational culture may be regarded as both a monolithic and a multidimensional concept, its assessment can differ depending on the level of analysis required and the conceptual approaches taken (Reichers & Schneider, 1990). For example, the models of organisational culture as described by Rousseau (1990) and Schein (1990) conceptualise organisational culture as a series of layers that vary is their transparency to an external observer (see Chapter 2, p. 55). It has been suggested that the outer layers are the most easily assessed by structured instruments (quantitative measures, checklists, etc.), where the behaviours, attitudes and values are more easily observed (Denison, 1996; Reichers & Schneider, 1990). This allows inter-organisational and intra-organisational comparisons to be made of these relatively accessible features. More traditional open-ended qualitative approaches to the assessment of organisational culture (Schein, 1990) may allow access to the deeper layers, providing considerable detail about an organisation's culture, but makes comparisons across companies difficult. For these reasons, research that requires inter-organisational comparisons is limited to an examination of the surface manifestations of culture and this is best achieved by using a psychometric approach (Quinn & Spreitzer, 1991).

The psychometric approach to assessing organisational culture has been reviewed by Furnham and Gunter (1993), Broadfoot and Ashkanasy (1994) and Rousseau (1992). Furnham and Gunter (1993) and Rousseau (1992) concluded that the organisational culture measures reported in the literature were variable in the content they measured, with poor or no psychometric data available to support them. Reporting on 18 measures of organisational culture and climate, Broadfoot and Ashkanasy (1994) reached a similar conclusion, in that "none were without serious flaws" (Broadfoot & Ashkanasy, 1994, p. 1). Whilst it is not uncommon for organisational consultants to carry out organisational culture audits based on interview protocols and checklists (Furnham & Gunter, 1993), the literature has indicated that there is no universal agreement on the dimensions and concepts that comprise organisational culture (Furnham, 1997). Psychometrically valid methods of assessing organisational culture in socio-technological industries do not to currently exist in the literature.[30]

The work reported by Broadfoot and Ashkanasy (1994), Harrison (1972), and Furnham and Gunter (1993) on the assessment of organisational culture has provided the non-validated measures that were used as the basis of an organisational culture measure developed for this research. Limited psychometric analysis data were only available for the Broadfoot and Ashkanasy measure.

Broadfoot and Ashkanasy (1994) constructed a 50-item, 10-dimensional measure, derived from 18 other survey instruments, perhaps avoiding the problem of researcher bias. This measure potentially provided a comprehensive profile of organisational culture; it contained sub-scales relating to: Leadership, Structure, Innovation, Job Performance, Planning, Communication, Environment, Humanistic Factors, Individual Growth, and Socialisation on Entry. Validation with 151 participants in a health service and factor analysis revealed a three-factor structure consisting of Innovative leadership, Organisational structure, and Relationships (Broadfoot & Ashkanasy, 1994). Subsequent work on this measure by Falcus (1998) determined that there was empirical support for a two-factor solution described as Goal-Driven and Creative-Development. Either these results may indicate instability in the Broadfoot and Ashkanasy measure or that it suffers from being a narrowly delineated measure with a restricted focus. The Broadfoot and Ashkanasy (1994) measure appeared too late for incorporation into the pilot study of this research

30 In fact more recently these have started to appear (Cox & Flin, 1998a); however, at the inception of this research they did not exist.

although items from it were incorporated into the main study.

Furnham and Gunter (1993) describe two measures for the assessment of organisational culture: (1) Roger Harrison's *Diagnosing Organisational Ideology* (Harrison, 1975), and (2) Furnham and Gunter's *Corporate Culture Questionnaire* (see Appendix B, pp. 268-271). Harrison's measure reflects four separate ideologies that determine the compatibility of an organisation's interest with those of the employees. The ideologies defined are: (1) Power orientation, (2) Role orientation, (3) Task orientation, and (4) Person orientation. The participants on this measure are required to rank statements for their closeness to the organisation's position; they then repeat the ranking for the organisation, as they would prefer it to be. This measure addresses only 15 areas of functioning within the organisation, for example, "A good boss is", or, "Decisions are made by the ...". No psychometric evaluation of the Harrison measure was available. Additionally, the measure falls into the category of measures that 'type' organisations into particular classifications rather than describing them in the way that profiles do (Falcus, 1998). For the purposes of this research, a descriptive measure was required.

The pilot version of the Organisational Culture Measure used in this study was adapted from Furnham and Gunter's (1993) Corporate Culture Questionnaire. This contains a relatively comprehensive range of items (94 items in total) that the authors claim assess organisational culture. The items contained in it cover many behavioural and attitudinal aspects of organisational culture (Furnham & Gunter, 1993). It measures employees' opinions on a range of beliefs, values, behaviours, and attitudes across a range of 15 dimensions of organisational culture: Initiative-taking orientation, Risk-taking orientation, Performance quality orientation, Planning orientation, Power orientation, Achievement orientation, Co-operation orientation, Supportive orientation, Communication orientation, Rewards orientation, Morale orientation, Autonomy, Self-expression orientation, Diversity orientation, and Personal growth orientation. This measure lends itself to a Likert-type format[31] allowing for

[31] Likert-type formats require the respondent to indicate their answer by ticking their preferred response to an item, often on a numeric scale of 1 to 7.

quantitative analysis of the sub-scales and easy adaptation for use in the aviation maintenance environment. This is described in the next paragraph.

To compensate for the areas in which the Furnham and Gunter measure was lacking in its coverage of organisational culture, additional items were incorporated. These were generated from the organisational culture literature and in consultation with aviation and oil industry personnel such as maintenance managers, safety investigators/auditors, maintenance personnel, academics, and delegates to a Human Factors conference in 1995 (Patterson, 1995). A pilot version of the Organisational Culture Measure consisting of 170 items (see Appendix C, p. 290) and 21 sub-scales was produced. This represented a comprehensive questionnaire suited to the socio-technical environments peculiar to oil and aviation maintenance settings.[32] It was available in paper form in late 1995 and was then developed for computerised administration for the pilot study.

3.3.2. Administration of the Organisational Culture Measure

The development of the pilot version of the Organisational Culture Measure resulted in a 7-point Likert-type scale. This required participants to select how much their work environment promoted the stated beliefs, values, attitudes, or behaviours. Participants could also choose a 'No opinion' option. The administration was hosted on a computer within a Windows environment. Figure 14 shows two screens from the data-collection software.[33] A copy of the software is contained in Appendix D (p. 301), together with the supporting documentation for its administration.

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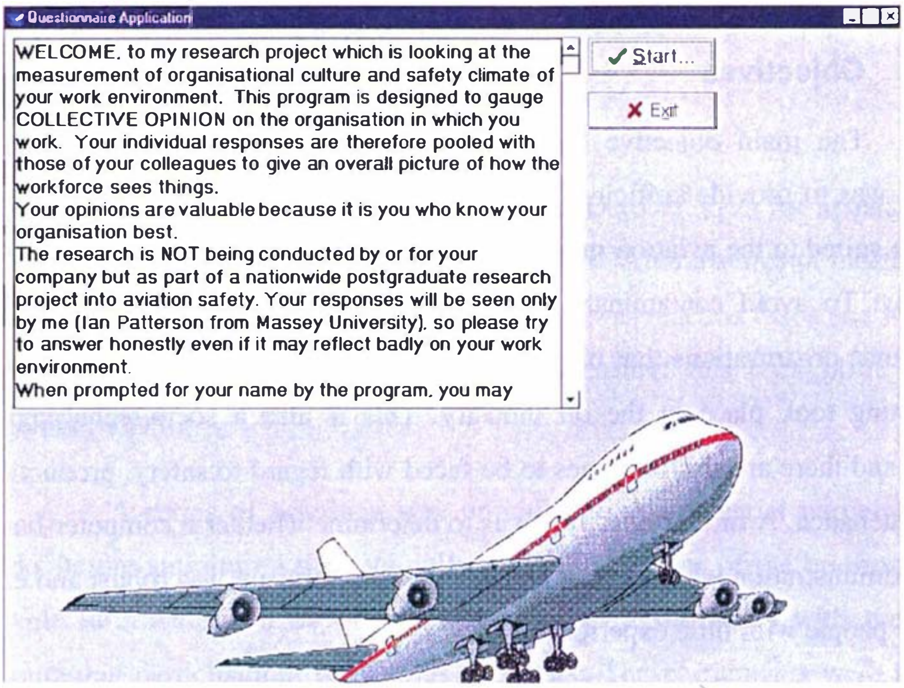
[32] For example, the nature of checking and countersigning and the use of standard procedures which might reflect a 'supervision' or 'low in autonomy' culture.

[33] Within the software the Safety Culture Measure was referred to as the Safety Climate Measure, This was partly for historical reasons, but the name was retained until the paper version of the measure was administered. The item content was the same.



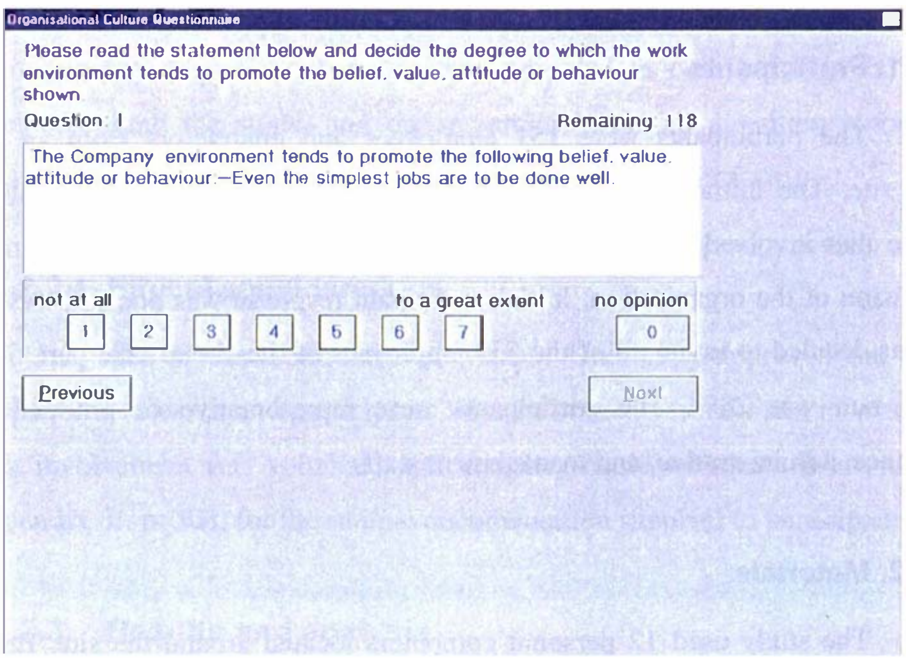


Figure 14: Screens from the data-collection software.

3.3.2.1. Objectives

The main objective for the piloting of the Organisational Culture Measure was to provide sufficiently valid and reliable items within the measure that were suited to the aviation maintenance environment and the requirements of this study. To avoid contamination of the relatively small number of aviation maintenance organisations that might be available to take part in the main study, this piloting took place in the oil industry. This is also a socio-technological industry and there are similar issues to be faced with regard to safety, production, and maintenance. A further objective was to determine whether a computer-based remote administration was practical and whether the software was robust and easy to use by people with little experience of computers.

3.3.2.2. Method

3.3.2.2.1. Participants

The participants were 151 employees and contractors from an oil industry site. The initial selection of participants involved a random sampling technique that involved issuing an invitation to every second employee within each division of the organisation. Initial participant response was poor, however, and it was decided to invite all of the 539 employees of the site to take part. The response rate was 28%. The participants were representative of production, maintenance, administrative, and management staff.

3.3.2.2.2. Materials

The study used 12 personal computers located around the site. Each computer contained a copy of the Organisational Culture Measure. A practice measure was included for training purposes. Use of the software required rudimentary mouse and keyboard skills; instructions and help screens were embedded within the software and were available in paper form. The software development is described in Appendix D (p. 301).

A telephone help-line to the researcher, who was on site for the data collection, was established at each location.

3.3.2.2.3. Procedure

The oil company was approached in October 1995 for assistance with the piloting of the Organisational Culture Measure. After a series of meetings with the executives of this organisation, an agreement was reached that a site within the organisation could be used to develop the measure; this took place in early December 1995.

A series of briefings was provided to the potential participants two weeks before and during the data collection. The purpose of the briefings was to provide information on the nature and purpose of the study with the aim of encouraging participation, which was voluntary. The participants were informed that they could remain anonymous if they wished. They completed the measure during the same session, which took place during 40 minutes of work-time. A follow-up free phone number was also provided in case participants had any questions about the study, and the researcher provided a written report to the company, which was circulated in both electronic and paper form.

3.3.2.2.4. Ethical considerations

The Ethics Committee of Massey University approved the methods used in this research and participants were informed, verbally and in writing, that their involvement was voluntary and that they could withdraw at any time (see Appendix E, p. 308, for the sample documentation supplied to participants).

3.3.2.3. Results and analysis

The items within each of the original 21 sub-scales were examined using internal consistency statistics (Cronbach's α). An iterative process was used whereby items were deleted from each sub-scale in stepwise fashion leading to a maximised α for a minimum number of items. Good internal consistency was obtained for the sub-scales (see Table 6) with the exception of Finance orientation and Safety orientation. Generally, a Cronbach's α value of .7 is considered acceptable (Hair, Anderson, Tatham, & Black, 1995). This criterion may be relaxed slightly where the study is exploratory (D. Meyer, personal communication, December 1998).[34]

[34] Factor analysis and principal components analysis were considered to determine the factor structures in the Organisational and Safety Culture measures. On statistical advice (J. Spicer, personal communication, January, 1996) this was not done because of the inherent instability caused by the case-to-variable ratio available; 151 participants (cases) and 170 items (variables) (Tabachnick & Fidell, 1989).

Table 6: Internal consistency of the 21 sub-scales (170 items) of the Organisational Culture Measure ($p < .05$).

	Sub-scale	Number of items in scale	Cronbach's α for sub-scale
1.	Initiative-taking orientation vs conforming cultures	6	.7
2.	Caution-taking orientation	3	.4
3.	Performance quality orientation	6	.8
4.	Planning orientation emphasis	9	.8
5.	Power orientation	8	.7
6.	Achievement orientation	7	.7
7.	Co-operation orientation affiliation/supportive*	14	.9
8.	Supportive orientation combined with 7*	–	–
9.	Communication orientation	8	.8
10.	Rewards orientation	5	.9
11.	Moral orientation, satisfaction	8	.8
12.	Autonomy of work orientation	5	.6
13.	Self-expression orientation	4	.8
14.	Work diversity orientation	3	.6
15.	Personal growth orientation	4	.7
16.	Finance orientation	–	.3
17.	Passion for industry	6	.7
18.	Avoidance or fatalistic culture	5	.7
19.	Compliance with rules culture	5	.7
20	Safety orientation	–	.2
21	Relationship to outside environment	3	.6
	Total items retained in the measure	109	

Note: * In Furnham and Gunter's (1993) measure, the sub-scales Co-operation orientation (α = .8) and Supportive orientation (α = .8) are distinct. For this study they are combined because of the similarity in their content and wording; in addition, the combined sub-scale achieves a higher Cronbach's α value.

3.3.2.4. Post pilot study development of the Organisational Culture Measure

Nineteen sub-scales have statistical support for their internal consistency. However, the sub-scales Finance orientation and Safety orientation had low Cronbach's α values, indicating poor internal consistency. The Cronbach's α values for these two sub-scales were the best that could be achieved by deleting items from each sub-scale; it was therefore decided to eliminate these sub-scales from the measure. The sub-scales of Co-operation orientation and Supportive orientation were combined to give a higher Cronbach's α value; item content within these two sub-scales was similar.

Following the completion of the pilot study, unpublished measures, described by Broadfoot and Ashkanasy (1994), came to the attention of the researcher (see Appendix B, p. 284). These contained items which, on reflection, seemed to capture areas not covered by the post-pilot version of the Organisational Culture Measure. Ten of these items were included, introducing two new sub-scales of Leadership orientation and Degree of structure (see Table 7), thus providing a more complete coverage of aspects of organisational culture that the literature had indicated might be useful indicators of safety. Given the exploratory nature of the research, the inclusion of new and revised items at this stage was considered acceptable, the revised measure being subjected to further internal consistency statistics later in the research process, i.e. in the main research study. The revised Organisational Culture Measure consisted of 20 sub-scales comprising 119 items (see Table 7). The items in each sub-scale are shown in Appendix B (p. 295).

Table 7: Sub-scales contained in the final version of the Organisational Culture Measure.

	Sub-scale	Number of items
1.	Initiative-taking orientation vs conforming cultures	6
2.	Caution-taking orientation	3
3.	Performance quality orientation	6
4.	Planning orientation emphasis	9
5.	Power orientation	8
6.	Achievement orientation	7
7.	Co-operation / supportive / affiliation orientation	14
8.	Communication orientation	8
9.	Rewards orientation	5
10.	Morale orientation, satisfaction	8
11.	Autonomy of work orientation	5
12.	Self-expression orientation	4
13.	Work diversity orientation	3
14.	Personal growth orientation	4
15.	Passion for industry	6
16.	Avoidance or fatalistic culture	5
17.	Compliance with rules culture	5
18.	Relationship to outside environment	3
19.	Leadership orientation*	5
20.	Degree of structure*	5
	Total items	119

Note: *These two sub-scales added subsequent to pilot study were based on the work of Broadfoot and Ashkanasy (1994).

The attributes of culture assessed by the sub-scales may be considered exhaustive when compared to other measures of this type. This was particularly important if the scale was to avoid reflecting a narrow range of theoretical constructs from organisational culture (Broadfoot & Ashkanasy, 1994). It would be also desirable to have roughly the same number of items within each sub-scale; however, as this was an exploratory study involving the scale's development, it was decided to leave all the items in at this stage. Further refinement of the measure might then allow the reduction of numbers of items within the larger sub-scales, to yield a shorter, more easily administered measure.

3.3.2.5. Conclusions from the development of the Organisational Culture Measure

The aim of producing a questionnaire based on Furnham and Gunter's (1993) measure was achieved. One hundred and nine items showed acceptable internal consistency within their respective sub-scales. These sub-scales were supplemented by the addition of ten items representing the sub-scales Leadership orientation and Degree of structure, providing a more comprehensive coverage of areas that the researcher considered important to assess. This generated an Organisational Culture Measure consisting of 119 items.

3.3.3. Background to the development of the Safety Culture Measure

The literature on the psychometric assessment of safety culture is not extensive. From an academic perspective, Zohar (1980) began the psychometric investigation of what he called safety climate.[35] Zohar examined safety climate in 20 Israeli factories, across four industry groups: chemical, metal, textile and food, using a 40-item Likert-type measure. All items were phrased positively, with higher scores indicating greater safety. He attempted to validate his climate measure against 'hard' measures of safety such as severity and rate of accidents but was unable to complete this part of the work because of the poor reliability/validity of these data.[36] As an alternative, Zohar used experienced safety inspectors to assign safety ranks based on safety practices and accident prevention programmes within the organisations. The measure was then validated against these ranks using Spearman rank correlations; correlations between .5 and .9 were obtained (probability levels were not provided).

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[35] Early versions of the Safety Culture Measure used in this Ph.D. research also used the term 'Climate' in the title of the measure. However, the researcher now considers 'Culture' to be the more appropriate term for the item content.
[36] These data were also used for compensation purposes, and at some factory sites accident figures were thought to be inflated.

Zohar (1980) used a forward stepwise discriminant function analysis to determine the smallest number of climate dimensions that discriminated between the organisations. He determined that two climate dimensions were influential in determining safety climate levels: 'perceived relevance of safety to job behaviour' and 'perceived management attitude towards safety' (Zohar, 1980, p. 99). The first four columns of Table 8 provide a summary of the research available on Zohar's measure. Zohar performed a principal components analysis with varimax rotation on the data and this yielded eight dimensions or factors. However, subsequent work on American populations by Brown and Holmes (1986) identified only three factors within Zohar's original questionnaire. Dedobbeleer and Beland (1991) tested Brown and Holmes' findings using a nine-variable measure and determined two factors within safety culture. Using a modified version of Zohar's original questionnaire, Vitro (1991) produced a five-dimensional measure of safety climate. However, factor analysis, using principal axis factoring of the measure, showed that it was essentially unidimensional.

Using a factor-analytic approach for successful safety programmes, Cohen (1977) produced a model of safety culture that described seven factors. These are also shown in Table 8. It may be tentatively concluded that management involvement in safety, perceived risk, involvement by the workforce in safety, safety training/indoctrination, and good safety housekeeping are common themes. Despite the similarities across these pieces of work, it should be noted that all the measures used, with the exception of Cohen's work, have their roots in Zohar's original measure and it is necessary to exercise caution in drawing firm conclusions from these efforts because of this common conceptual framework, which may not encompass all aspects of safety culture.

Table 8: Comparison of safety culture factors from empirical research studies.

Zohar (1980): Eight-factor model	Brown and Holmes (1986): Three-factor model	Dedobbeleer and Beland (1991): Two-factor model	Vitro (1991): Unidimensional structure	Cohen (1997): Seven general factors
1. Perceived importance of safety training 2. Perceived effect of required work pace on safety 3. Perceived status of safety committee 4. Perceived status of safety officer 5. Perceived effects of safe conduct on promotion 6. Perceived level of risk in the workplace 7. Perceived management attitude toward safety* 8. Perceived effect of safe conduct on social status	1. Employee perception of how concerned management was with their well-being* 2. Employee perception of how active management was in responding to their concern* 3. Employee physical risk perception	1. Management's perception of safety attitudes and actions* 2. Workers' involvement in safety	1. Perceived management commitment to safety, perceived employee involvement in safety matters, perceived availability of safety training, perceived importance placed on conventional safety practices, and perceived importance placed on housekeeping practices.	1. Strong management commitment* 2. Close contact between levels in the organisation 3. Less turnover. Large number of married, older, longer in jobs 4. High level of housekeeping. 5. Well-developed selection, advancement, support services 6. Training indoctrination, early into safety 7. Additional safety features to conventional

Note: * Indicates concordance across the studies on the importance of management in the success of safety programmes.

The pilot version of the Safety Culture Measure used in this present study was adapted from Zohar's (1980) 40-item measure of safety climate. This had not been published but a personal approach to Zohar yielded a copy. Designed for use within Israeli factories, some of the items in the measure required re-wording for the New Zealand environment. These items were supplemented with items taken from the work of Brown and Holmes (1986), Cohen (1977), and Dedobbeleer and Beland (1991). This process generated 11 additional items that were included in a revised pilot of the measure (Safety Culture Measure); this contained 51 items and was available in July 1995. Final feedback from industry groups was obtained at the same time as for the Organisational Culture Measure. The paper version of the measure was also adapted for computer administration. The items in the Safety Culture Measure were presented in Likert format and are summed to generate a safety score that indicates the perceived level of safety in an organisation; higher scores indicate higher perceived levels of safety.

3.3.4. Administration of the Safety Culture Measure

The development the pilot version of the Safety Culture Measure also resulted in a 7-point Likert-type scale. This was similar to the Organisational Culture Measure, with a 'Not relevant' option rather than 'No opinion available'.[37] A copy of the software is contained in Appendix D (p. 301), together with the supporting documentation for its administration.

3.3.4.1. Objectives

The main objective for the piloting of the Safety Culture Measure was to provide sufficiently valid and reliable items, measuring the domain of safety culture. The remaining objectives were identical to those of the Organisational Culture Measure study.

3.3.4.2. Method

The Safety Culture Measure was administered during the same session, using the same procedures, and to the same participants, as described for the Organisational Culture Measure study.

3.3.4.3. Results and analysis

Internal consistency analysis resulted in the retention of 49 items from

[37] Within the software the Safety Culture Measure was referred to as the Safety Climate Measure, This was partly for historical reasons, but the name was retained until the paper version of the measure was administered. The item content was the same.

the original version of the measure (51 items) (see Appendix A, p. 227).[38]

3.3.4.4. Post pilot study development of the Safety Culture Measure

After completion of the pilot study, minor modifications to the wording of four of the items were made in order to make their meaning clearer.

3.3.4.4.1. Conclusions from the development of the Safety Culture Measure

The aim of producing a Safety Culture Measure based on Zohar's Safety Climate Measure was achieved. This new measure contains 49 items and was longer than Zohar's original; it shows good internal consistency. Remote administration using computers to collect the data worked well, there were no spoiled sets of data and no problems were reported with the software.

[38] A factor analytic procedure to check for dimensional structure was not performed due to the low participant to item ratio (151:51).

3.4. Development of the Safety Index Measure (SIM)

No measure of this type previously existed for the aviation maintenance environment although a range of checklists and references for assessing general occupational safety had been developed in other industries (Bailey, 1993; Bailey & Petersen, 1989; Cohen, 1977; Dedobbeleer & Beland, 1991; Dejoy, 1985; Mattila & Hyodynmaa, 1988; Mattila, Rantanen, & Hyttinen, 1994; Sulzer-Azaroff, 1987; Young, 1997; Zohar, 1980). These sources were examined for ideas and items that might be included in a Safety Index Measure. Inspections of operations during industry visits, and in the course of CAANZ audits, generated additional items that were specifically related to the aviation maintenance environment. Consultation with industry and CAANZ permitted a refinement of these items.

The Safety Index Measure is founded on the premise that self-completion tools can be used as an assessment of objective risk (Reason, 1997; Rundmo, 1994). Designed to be a relatively objective measure of the observable features of safety that exist in aviation maintenance organisations (hangar or workshop), this is a pencil and paper checklist which records the presence or absence of features that indicate the existing safety level in a work environment. For example, two items enquired whether shadow boards[39] or drip trays, to catch leaking fluid, were being used. An essential requirement was that the researcher and an observer within the organisation could administer the measure during site visits with minimal disruption to the work environment. The observer marks items as present or absent and an index can be determined by counting the number of safety items present out of the total number applicable to that environment, expressing this as a percentage. Higher scores represent higher levels of safety. The Safety Index Measure was administered in two aviation maintenance organisations to determine its usability, detect any ambiguity or confusing wording in the items and to rectify any potential administration problems in the measure. The Safety Index Measure was available in July 1995, and a reliability analysis was undertaken on the data collected from the aviation maintenance

[39] Shadow boards are used to store tools, they have a silhouette of the tool that belongs in a particular position on the board making it easy to see whether a tool is present or not.

organisations during the main study. The Safety Index Measure is shown in Appendix A (p. 233).

3.4.1. Reliability of the Safety Index Measure

Generally, the information required to complete the items in the Safety Index Measure was available from only one individual in an organisation.[40] For this reason it was not possible to have multiple raters provide this information and inter-rater reliability measures could not be made. It was possible however, to repeat the measures in four of the organisations. In Organisations 1 and 2, this was done three times and in Organisations 4 and 5, twice. The gap between the data collection was a minimum of five months. It is suggested that a delay of this length of time would minimise any memory effects and allow a testing of temporal stability in the measure across the administrations (J. Spicer, personal communication, January 1995).

The agreement, on items across the separate administrations, is shown for all organisations' data pooled, and for each organisation separately (see Table 9). Agreements were measured on an item-by-item basis and an adaptation of the McNemar test (Siegel, 1956) was used to determine the agreement between subsequent administrations.[41] Where the calculated value (measure of agreement) from the test exceeds the critical value (CV) then the probability that the levels of agreement would be observed by chance is given by the associated probability level. The obtained value exceeded the critical value; it is unlikely that the levels of agreement observed occurred by chance (see Table 9). Details of how the McNemar test was applied and computation of the measure of agreement on the Safety Index Measure are shown in Appendix F (p. 311).

[40] This was the person in the organisation who might be expected to be most informed about safety. For example, the safety officer or the quality assurance manager.

[41] That is the agreement on items between the first administration (Time 1) and subsequent administrations (Time 2 and Time 3), and the agreements between Time 2 and Time 3.

Table 9: Measure of agreement for the Safety Index Measure.

ID	Measure of agreement	Percentage agreement
All organisations	39	66
Org 1	28	68
Org 2	31	75
Org 4	18	35
Org 3	20	59
	Critical value 10.83, 1 df (p =.001)	

Note: There were no repeated measures data available for Orgs 5, 6, and 7.

The results indicate that the Safety Index Measure exhibits some agreement across the repeated administrations and reliability was considered adequate.

The agreement indicated above has further support from a calculation of the Pearson product moment correlation obtained from pairs of scores (total SIM scores) across the subsequent administrations of the measure. The obtained r = .54 (p =.05); this further supports the reliability of the measure in that subsequent administrations share around 29% variance (see Appendix F, p. 314).

3.4.2. Conclusion from the development of the Safety Index Measure

The Safety Index Measure shows good agreement across repeated administrations and confidence may be placed in it as being a reliable measure. Criterion validation of the Safety Index Measure is reported in Chapter 5.

3.5. Development of the Managers' Self-Report General Failure Types (FTman)

This was a paper and pencil measure that was designed to measure how well managers consider their organisation was performing with respect to the incidence of General Failure Types (failures at the organisational level). These were defined according to the CAANZ database (see Appendix G, p. 315). Managers who work in, or have direct involvement with aviation maintenance, complete this measure for each maintenance environment under examination. The database provides definitions for 18 General Failure Types, i.e. areas in which organisations may fail at the management level. These were identified, by the researcher and the CAANZ, as representing the main areas in which aviation organisations are likely to experience organisational failures. The participants were required to indicate, on a 5-point Likert-type scale, the degree to which the organisation has been experiencing each of the General Failure Types over the previous month. This was then expressed as a percentage of the maximum score that could have been obtained; higher scores on this measure indicate managers believe their organisation is having higher levels of failure and indicate lower safety. This measure can be individually administered across separate organisational units within larger organisations. In smaller organisations only one administration may be required. A copy of this measure is contained in Appendix A (p.238).

3.6. Development of the Error Frequency Index (EFI)

The Error Frequency Index was derived by taking the frequency of maintenance-related human factor failure types recorded on the CAANZ database and dividing this by the number of employees in the maintenance area of the organisation. The database codes are shown in Appendix G (p. 315).

3.6.1. Background to the development of the Error Frequency Index

Aviation error data have numerous sources that are often remote in location, this generates problems when collecting such error data. Firstly, an error must be noticed and then adequately described. Secondly, it is necessary to establish which of the many contributing causes are significant and worthy of record. Thirdly, this process needs to be done consistently and reliably by different individuals and across different organisations and locations. Logistically this is a time-consuming and challenging exercise. Ideally, the research required a method of capturing, describing, classifying and coding the human factor element in aviation maintenance errors, and two procedures (MERN/MEIN and MEIA) were developed for this (see Appendix A, p. 243). Unfortunately, in consultation with the organisations in the study, it became apparent that the recording of detailed information on the nature of errors was not a practical option, due to the resource requirements this would place on the organisations concerned. Fortunately, at that time the CAANZ data-capture system was being implemented. This included a taxonomy for the classification of human error events in aviation.

The CAANZ human error taxonomy is based on the Latent Failure Model[42] and other human factor error models (Norman, 1981; O'Hare et al., 1994; Reason, 1997). The taxonomy allows each cause contributing to an occurrence to be coded to a failure type cause code. This cause code can exist at the organisational level, as a General Failure Type, the Task Environment Level (as either an Error or a Violation Enforcing Condition) and at the Human Active Failure Level (see Appendix G, p. 315). At the Human Active Failure Level, an

[42] Shell petroleum had pioneered the use of the Latent Failure Model for error capture in the oil industry and Reason had encouraged its application in the field of aviation.

individual makes some form of active failure based on a mishandling or information-processing failure. O'Hare's et al's. (1994) Cognitive Failure Analysis was used for this part of the database taxonomy. In total, 70 human error cause codes were made available on the CAANZ database, and each had a unique code number.

The development of this taxonomy brought with it the requirement that individuals be trained in its use. The researcher was involved in the production of the training materials and in the delivery of training, first to CAANZ staff (auditors and analysts) then to industry groups, some of whom were participants in this study. The data held on the Database can be analysed at a national as well as the organisational level. The CAANZ database also contains data on the number of employees. This was used as an index of the size of the operation.

3.7. Self-Report Error Measure (Err-self)

The error data from the CAANZ database had proved to be limited in quantity by the time that Organisation 7 joined the research study. For this reason, two additional items to measure maintenance error were introduced to the measures made in Organisation 7. Participants were asked to provide an estimate of the subjective frequency of errors occurring among their colleagues (this measure yielded no data) and an estimate of the subjective frequency of errors occurring to themselves (Err_self, see Appendix A, p. 232). The Self-Report Error Measure was a two-item measure consisting of the following items.

Please indicate / estimate how many occurrences[43] have occurred to colleagues in the last 12 months	
Please indicate / estimate how many occurrences have occurred to you personally in the last 12 months	

There was only a very short window of opportunity to gather data on this additional measure. Consequently, piloting of these two items was not possible.

[43] The term 'occurrences' has a defined meaning within the measure and is a technical term used by the Civil Aviation Authority of New Zealand.

3.8. Determination of the Summed Safety Rank

Each organisation was ranked on the Safety Index Measure, Managers' Self-Report General Failure Types, and the Error Frequency Index, where high ranks represent high safety. The Summed Safety Rank was obtained by adding together the individual ranks. The value obtained represents the relative safety level among the organisations. It is given by the following formula

$$\text{Summed Safety Rank } i = \text{Rank (SIM) } i + \text{Rank (FTman) } i + \text{Rank (EFI) } i$$

Where *i* represents the organisation.

3.9. Chapter summary

When this research began, no research had been undertaken to investigate organisational and safety culture in the field of aviation maintenance and appropriate scales of measurement did not exist for this industry. Additionally, human error capture and recording technologies were, and still are, rather crude. This chapter has provided an overview of the issues related to validity and reliability in the development of new measures. It has described some of the challenges faced in building up a collective wisdom on what constitutes a valid measurement tool. The chapter has described the development of a number of measurement tools that provide the beginnings of a technology in these areas. These include the Organisational and Safety Culture Measures, three indices of safety, and a Self-Report Error Measure. Two other qualitative measures were also developed but, as these were not used in the main part of the research study, they are not discussed in depth here.

The remainder of this thesis will describe the application of these measures in aviation maintenance environments.

Chapter 4. Method

THIS CHAPTER DESCRIBES the methods and procedures used to investigate the hypotheses shown in Chapter 2, section 2.4. Figure 15 shows the time line for the research.

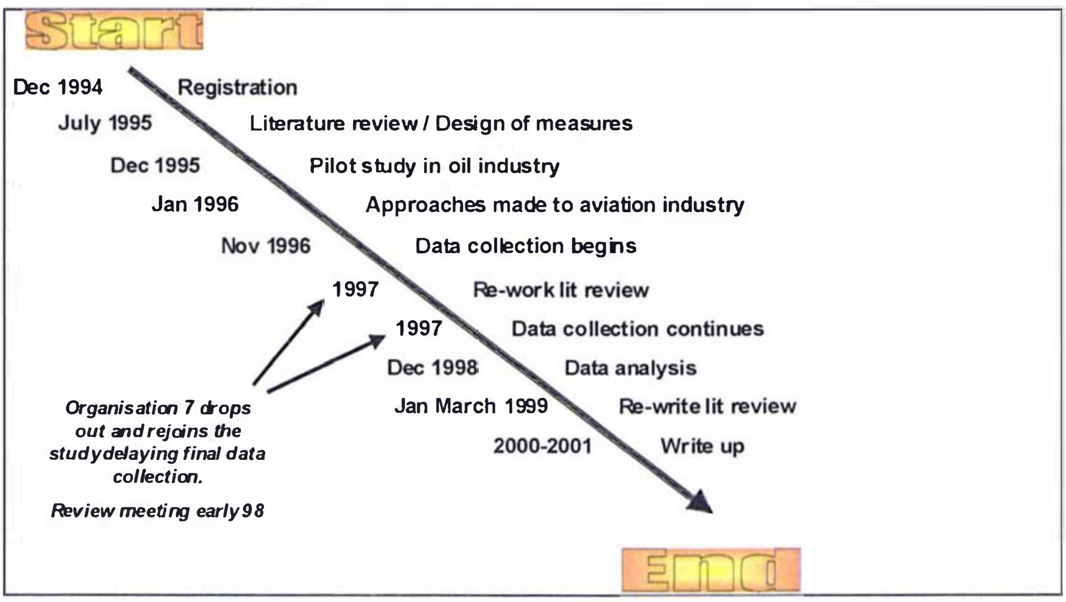

Figure 15: Time-line for research.

4.1. Description of organisations and participants

4.1.1. Organisations

Seven aviation organisations contributed to this research. With the exception of Organisation 6 (a regulatory organisation), all were engaged in the maintenance of air transport aircraft and operated maintenance services round the clock. Organisation 7 was considerably larger than the other organisations and was located on two sites. The numbers employed in the maintenance organisations varied considerably from fewer than 20 to almost 2000.

4.1.2. Participants

The participants providing data for the Organisational Culture Measure (OCM) and Safety Culture Measure (SCM) were 520 employees from six aviation maintenance organisations and one regulatory organisation. Table 10 shows a breakdown of participants by organisation. The participants were engaged in the maintenance of aircraft and/or the supporting administrative activities that this entails. The organisations varied in size and consisted of a predominantly male workforce.

Table 10: Participants by organisation responding to the Organisational Culture Measure and Safety Culture Measure data collection.

Organisation ID	Number of employees in organisation	Numbers responding	% response
Org 1	52	46	88
Org 2	120	43	36
Org 3	18	6	33
Org 4	33	22	66
Org 5	16	12	75
Org 6	127	16	13
Organisation 7 (split between two sites, Org 7a and Org 7b)	1933	375	19
Total	2299	520	22

Within the maintenance organisations, managers and quality assurance personnel were approached and recruited to provide information on the Safety Index Measure (SIM) and the Managers' Self-Report General Failure Types (FTman). Organisation 7 participants provided Self-Report Error Measure data (Err-self). Organisations were also approached with a view to implementing one of the qualitative error investigation measures, either the Maintenance Error Reporting Notice/Maintenance Error Investigation Notice (MERN/MEIN) or the Maintenance Error Incident Analysis technique (MEIA). The organisations were not able to provide information on these (see Section 3.6.1, p. 115). Personnel within the CAANZ enabled access to data on human errors related to maintenance activity in the organisations.

4.1.3. Materials

The measures described in Chapter 3 were used for the collection of data, these were:

1. Organisational Culture Measure (OCM) (a 7-point Likert scale in paper and computer formats).
2. Safety Culture Measure (SCM) (a 7-point Likert scale in paper and computer formats).
3. Managers' Self-Report General Failure Types (FTman).
4. Safety Index Measure (SIM).
5. Error Frequency Index (EFI) from the CAANZ database.
6. Self-Report Error Measure.

4.1.4. Procedure

The management and union representatives of seven aviation maintenance organisations and one regulatory body were approached to determine whether they would support the collection of data in their organisations. Seven organisations agreed and one declined. Because of industrial problems, data were collected from the two sites of Organisation 7 subsequently to the other organisations.

The workforce of each organisation was briefed on the nature of the study and a liaison person was appointed to facilitate data collection. Computerised versions of the Organisational Culture Measure and Safety Culture Measure were installed on personal computers within each organisation. Documentation containing instructions on the use of the software and background to the research were also available at each computer location. The telephone number of the researcher was available to participants.

For Organisation 7, a paper-based administration was required due to the large number of personnel involved. Paper versions of the Organisational Culture Measure (containing the Self-Report Error Measure) and Safety Culture Measure were circulated to all personnel within the maintenance section of this organisation. A total of 1830 questionnaires were distributed, 1010 to Org 7a, and 820 to Org 7b. The questionnaire contained a covering letter explaining the research (see Appendix E, p. 308) and an article introducing the research was written for an in-house publication that was circulated to all maintenance staff. Given the difficulties in obtaining participants in previous parts of the research, an incentive to return the questionnaire was offered and participants' names were entered in a draw to win a dinner for two.[44] Six weeks were allowed for the return of the questionnaires. Three hundred and seventy five questionnaires were returned, yielding a response rate of 20%.

The manager for each maintenance organisation completed the Managers' Self-Report General Failure Types questionnaire and the safety manager or quality assurance personnel member completed the Safety Index Measure. (In Organisation 7, multiple maintenance environments existed and multiple measures where made (see Appendix H, p. 319). Human error cause codes for each organisation, for the 24-month period preceding the end of the data-collection period, were extracted from the CAANZ database.

At the outset of this research it was envisaged that each maintenance organisation taking part would be the subject of three data-collection events, separated in time by six months. For the researcher this would have involved a minimum of two familiarisation visits and three subsequent data-collection visits to each site (a minimum of 35 site visits over approximately 18–20 months).

The three-phase data collection was initiated, but it became apparent during the first data-collection period that the process of collecting data would be less straightforward, more time-consuming, and would require more site visits than originally anticipated. Delays in the return of data, the paucity of information that subsequent collections yielded, resource limitations, and feedback that further data collection attempts would not be enthusiastically received by the participants, led to the abandonment of this repeated measures approach.[45] Some repeated measures data was forthcoming for the Safety Index Measure due to the positive relationship that the researcher had built up with the various safety officers in the organisations. For the other measures, repeated measures data were not collected

[44] Massey University Ethics Committee approval was sought and granted for this procedure.
[45] The repeated measures approach could not be achieved given the geographical locations and the resource availability from the organisations and the time constraints of the Ph.D. program.

at all, or the data were poor in quality and quantity. The outcome of the data collection process is shown in detail in Table 11.

A major challenge to the collection of data was maintaining contact and enthusiasm within the participating organisations; staff turnover and other time pressures often meant that accessible staff resources were limited. The research budget allowed only a certain number of follow-up visits and telephone contact was often the only way to 'chase' participants for the return of data, which often never arrived. Some of the challenges, which almost led to the research being abandoned entirely when it became apparent that repeated measures were not possible, are further described in Appendix I (p. 321). Notwithstanding these challenges, a large amount of data was collected for the single data collection period.

Table 11: Outcome of data collection process.

Organisation ID	Outcome of data collection process
Org 1	Data collection commenced but it was four months before the final participant completed the questionnaires. A second set of data was collected in but this generated only six responses to the Organisational Culture Measure and Safety Culture Measure.
Org 2	Data collection was completed promptly but data were lost by the IT department of the organisation in a back-up process. The collection had to be repeated.
Org 3	This organisation was co-operative but slow. Data took several weeks to collect despite the small number of participants. This was due to problems with computer availability.
Org 4	The contact person facilitating the data collection in Org 4 was working under contract to the organisation and gave assurances to the researcher that data collection was ongoing. At one point, the contact person indicated that the data had been couriered to the researcher when this was not the case. Repeated requests were made and assurances from the contact were given but it was apparent after several weeks that no data collection had taken place. The researcher contacted the Chief Executive Officer (CEO) of the organisation who had given permission to proceed with the data collection. It transpired that the contact person had been dismissed for reasons that were not given to the researcher, but related to performance issues. A new contact person was appointed and data collection proceeded three months later.
Org 5	The CEO of this organisation was very keen for his organisation to be involved. However, resistance within the organisation meant that only one division was involved. The division that agreed to the data collection was unable to respond immediately due to changes in senior management. Data collection took place several months after commencement of the data collection in Org 1.
Org 6	The numbers responding in this organisation were low and slow coming in. A number of reminders to the workforce were required.
Org 7	This organisation agreed to the study then pulled out, re-joining much later. Industrial relations problems were the reason for this. The data had been collected from the other organisations by the time this organisation re-joined the study. The withdrawal of this organisation almost led to the research being abandoned through lack of data and the difficulties described above.

4.2. Chapter summary

This chapter outlined the time line for this research and the procedures used to obtain organisational culture data, safety culture data, self-report error data, and safety indices data from six aviation maintenance organisations and one regulatory organisation. The participants were described and their numbers provided. Some of the difficulties in collecting the data have been highlighted. Finally, the outcomes of the data collection process were described.

Chapter 5. Results and analyses

THIS CHAPTER PRESENTS the analysis of the data relating to the aims and hypotheses presented in Chapter 2, section 2.4. A description of the raw data is provided, followed by an analysis of the results related to each aim and associated hypotheses.

5.1. Description of the raw data

Table 12 shows the number of participants providing data, by organisation.

Table 12: Participants providing data by organisation.

Organisation ID	Organisational Culture Measure (OCM) and Safety Culture Measure (SCM), number of participants contributing	Safety Index Measure (SIM), number of observations made	Managers' Self–Report General Failure Types (FTman) number of observations made	Error Frequency Index (EFI), number of observations made
Org 1	46	3	1	1
Org 2	43	3	1	1
Org 3	6	2	1	1
Org 4	22	2	1	1
Org 5	12	1	1	1
Org 6	16	NA	NA	NA
Org 7	375	1 composite value each for sites 7a and 7b	1 composite value each for sites 7a and 7b	1
Total	520	–	–	–

For the Organisational Culture Measure (OCM) and Safety Culture Measure (SCM), 520 cases contributed data. Missing data or No opinion responses were substituted by the neutral value 4 (on the 7-point scale in the measures); representing 3% of the data. Known as cold deck imputation (Hair et al., 1995), this procedure avoided casewise deletion of data during the analyses that would have resulted in a much reduced data set. Inspection of data files showed no single item possessing a disproportionate number of these missing data or No opinion responses. The correlation matrix for the participants' responses on the Organisational Culture Measures and Safety Culture Measure was examined and showed reasonable correlations (up to r = .6) among the items within the measures. This indicates that the items in the measures were associated with each other; reasonable correlations are necessary for multivariate procedures that rely on shared variance among variables. No item was singular with any other and the Tolerance test indicated that multicollinearity was not a threat to multivariate analyses (see Appendix J for associated descriptive statistics, p. 326).

5.2. Aim 1: Investigation of human error types in aviation maintenance in New Zealand

The purpose of Aim 1 was to obtain data on human error related to maintenance events for the six maintenance organisations in the study. This information is recorded on the CAANZ database. The relative frequencies of these errors were examined.

5.2.1. Frequency analysis of human error failure types existing on the Civil Aviation Authority database

A frequency analysis was performed. This showed a total of 291 human error failure types that were contained on the CAANZ database. Table 13 shows that the most frequently used category of failure is the Organisational Failure Type. The Active failure category is the second most frequent. The cause code descriptions: Primarily structural mechanical, Inadequate specifications/requirements, Inadequate checking, Procedure not followed, Poor procedures, Inadequate control and monitoring, Inappropriate goals or policies, Inadequate communications, and Poor procedure (action) were the most common human error cause codes (poor producers represented 15% of errors coded; shown shaded in Table 13). These error types are further described and discussed in Section 6.2 (p. 186).

Table 13: Human error cause codes on CAANZ database for the six maintenance organisations in the 24-month study period.

Code	Organisational Failure Type	Count
1308	Inadequate specifications/requirements	40
1305	**Poor procedures**	**15**
1300	Inadequate control and monitoring	13
1296	Inappropriate goals or policies	11
1298	Inadequate communications	10
1301	Design system deficiencies	7
1302	Inadequate defences	6
1303	Unsuitable materials	4
1307	Poor co-ordination	4
1299	Poor planning	3
1297	Organisation structural deficiencies	2
1304	Unsuitable equipment	1
1306	Poor training	1
1309	Poor decisions	1
1310	Poor resource management	1
1313	Other organisational factor	1
	Total	**120**
	Local error	
1329	Inadequate checking	22
1323	Risk misperception	9
1328	Poor instructions/procedures	7
1322	Negative task transfer (habits)	4
1327	Task/education mismatch	4
1326	Lack of knowledge	3
1343	Other error-enforcing condition	3
1316	Time shortage	2
1325	Inexperience (not lack of training)	2
1315	Task unfamiliarity	1
1345	Lack of safety culture	1
1386	Task overload	1
	Total	**59**

Table 13 cont: Human error cause codes on CAANZ database for the six maintenance organisations in the 24-month study period.

	Local violations	Count
1354	Complacency (i.e. it can't happen)	3
1348	Poor supervision and checking	2
1355	Learned helplessness (i.e. who cares)	2
1350	Hazard misperception	1
1353	Risk-taking culture encouraged	1
1356	Perceived licence to bend rules	1
1358	Other violation-enforcing condition	1
	Total	**11**
	Active failures	
1360	Primarily structural/mechanical	63
1385	**Procedure not followed**	**18**
1366	**Poor procedure (action)**	**10**
1364	Inappropriate "strategy"	4
1363	Inappropriate "goal"	3
1361	State change not detected "information"	2
1362	Inaccurate system diagnosis	1
	Total	**101**
	Grand total	**291**

5.2.2. Summary: Aim 1

It was possible to determine the relative frequencies of maintenance-related error for the organisations in the research, although the number of codes existing on the database was disappointingly low. Organisational failures represent the most frequently used category of human error cause codes in the database.

5.3. Aim 2: Qualitative measurement of maintenance error in New Zealand

Under Aim 2, detailed investigation of maintenance error incidents using the Maintenance Error Recording Notice/Maintenance Error Investigation Notice (MERN/MEIN) or the Maintenance Error Incident Analysis (MEIA) procedures was to be carried out.

5.3.1. Summary: Aim 2

This aim was not met; the maintenance organisations were not able to allocate the resources to provide this information. This is further discussed in Section 6.2, p.186.

5.4. Aim 3: An examination error frequency and safety performance in aviation maintenance organisations in New Zealand

Aim 3 was designed to investigate whether safer organisations are those that report more errors. This represents something of a paradox, as it has been argued that safer organisations are also likely to generate fewer errors. To resolve this paradox, empirical support was sought for the suggestion that organisations reporting more errors may be considered safer than organisations reporting fewer errors. This will be demonstrated by associations between levels of error reporting and measures of safety performance. Aim 3 also investigated whether individuals reporting high levels of personal error (Self-Reported Error (Err-self)) perceived their organisations as being less safe; it is suggested that high levels of personal error may lead to this less-safe attribution. Aim 3 was examined under Hypotheses 1, 2, 3, and 4.

A potential challenge to obtaining significant correlations with this data set is the low number of pairs of observations for each correlation; there were only six organisations providing data. The absence of significance does not preclude there being some association between the variables and, where significance is not obtained, visual inspection of the scatterplots may provide an additional source of evidence.

5.4.1. Hypothesis 1

For the maintenance organisations studied in this research, the frequency of errors (Error Frequency Index) reported on the CAANZ database will show a positive correlation with the Safety Index Measure (SIM).

The Pearson product moment correlation obtained for the Error Frequency Index with the Safety Index Measure was $r = -.5$, $N = 6$ ($p = .32$). This result suggests that higher frequencies of errors reported to the CAANZ were associated with lower levels of safety as indicated by the Safety Index Measure. Visual inspection of the scatterplot (see Figure 16) is difficult to interpret, as strong support for the suggested negative correlation but may suggest the presence of two groups. These are indicated by the two lines in the figure and are suggestive, although not convincingly so, of a positive association. The low number of pairs of observations contributing to these data ($N = 7$) is a likely cause of the low level of probability obtained. There are insufficient data points within the scatterplot to provide an easily interpreted result.

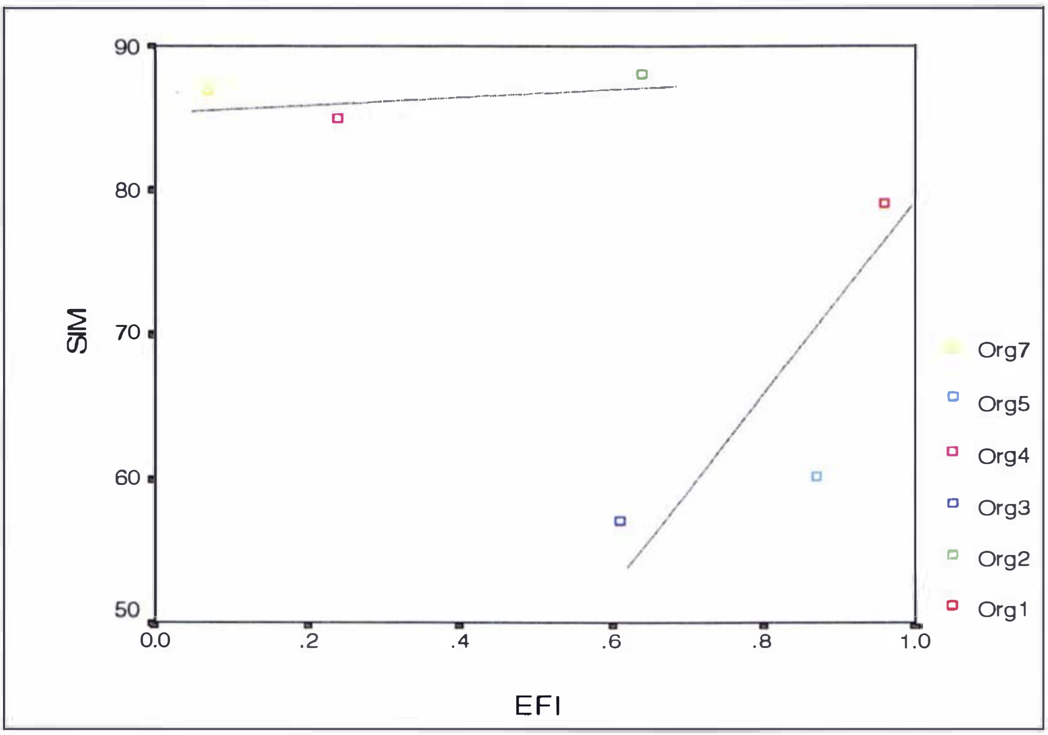

Figure 16: Scatterplot for the Error Frequency Index (EFI) and the Safety Index Measure (SIM).

5.4.2. Hypothesis 2

For the maintenance organisations studied in the research, the frequency of errors (Error Frequency Index (EFI)) reported on the CAANZ database will show a negative correlation with the Managers' Self-Report General Failure Types (FTman). The Pearson product moment correlation obtained for the Error Frequency Index with Managers' Self-Report General Failure Types was $r = -.26$, $N = 6$ ($p = .62$). This suggests that higher frequencies of errors, as reported to the CAANZ, were associated with a reduction in the managers' perceived levels of organisational error (higher safety), as indicated by the Managers' Self-Report General Failure Types (FTman); this result supports Hypothesis 2, though again statistical significance is not achieved. The scatterplot does not provide support for the reported negative correlation (see Figure 17). Visual inspection of this is difficult to interpret. There is a suggestion of one linear group at the top left of the plot (and possibly another bottom right) and this may be interfering with the reported negative correlation. Again, the data are insufficient to provide a conclusive interpretation.

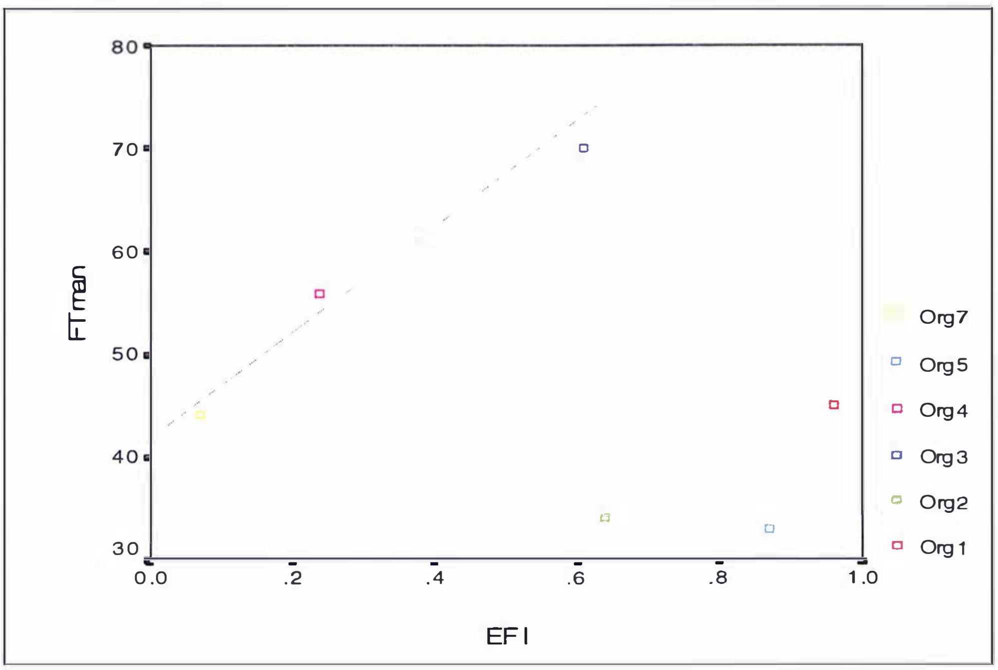

Figure 17: Scatterplot for the Error Frequency Index (EFI) and the Managers' Self-Report General Failure Types (FTman).

5.4.3. Hypothesis 3

For the maintenance organisations studied in this research, the frequency of errors (Error Frequency Index (EFI)) reported on the CAANZ database will show a positive correlation with the Safety Culture Measure (SCM).

The Pearson product moment correlation obtained for the Error

Frequency Index with the Safety Culture Measure was r = .29, N = 6 (p =.58). This indicates that higher frequencies of errors reported to the CAANZ were associated with a higher perceived level of safety; this result supports Hypothesis 3, though this is not statistically significant. The correlation increases to r = .98 (p =.003) when Organisation 7's data were removed from this analyses. This indicates that Organisation 7 had a disproportionate influence over the data and that this masked the characteristics of the smaller organisations.

The scatterplot for this correlation is shown in Figure 18. Visual inspection of the scatterplot supports the positive correlation observed between the measures. When Organisation 7 (Org 7) is removed, this observed association is more pronounced. This provides some confidence in the assertion that higher error reporting, at least in smaller maintenance organisations, occurs in organisations with higher safety. This visual evidence supports the assertion that where the perceived level of safety is higher, then the error reporting in organisations is also higher. The safety Culture Measure was developed from Zohar's Safety Climate measure, which has empirical support in the literature; this adds credence to the assertions that the Safety Culture Measure is a valid measure of safety, and that higher error reporting is associated with higher safety.

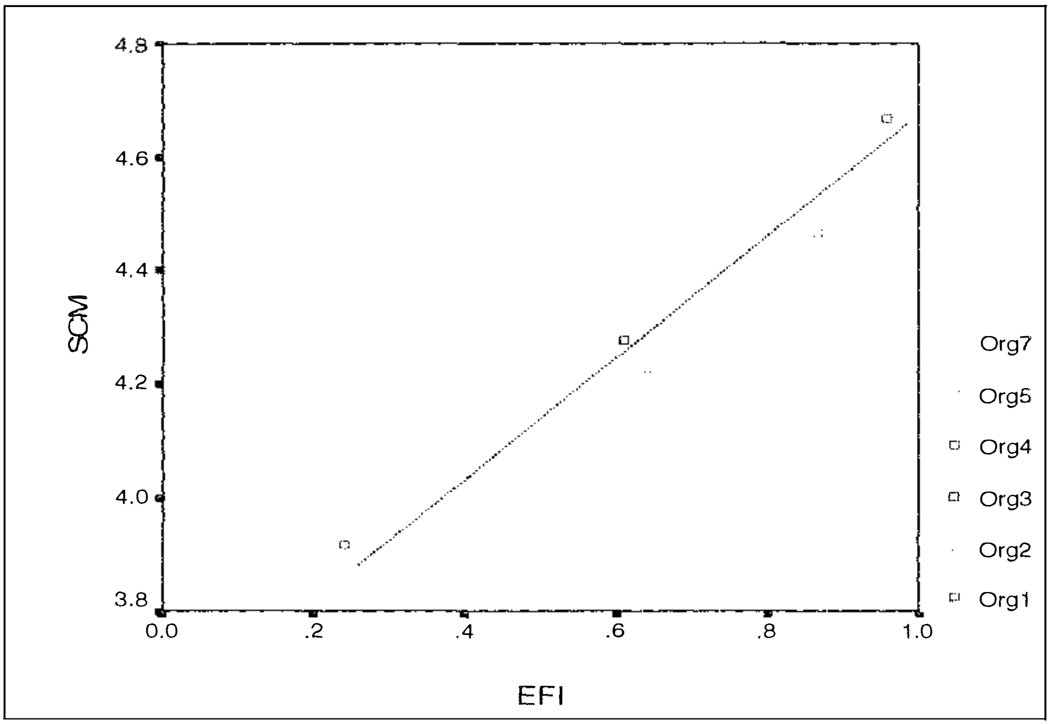

Figure 18: Scatterplot for the Error Frequency Index (EFI) and the Safety Culture Measure (FTman).

5.4.4. Hypothesis 4

Participants reporting higher levels of personal error (Self-reported Error (Err_self)) will rate the organisation as less safe on the Safety Culture Measure.

Data for this analysis were available for Organisation 7 only and a correlation of $r = -.14$, $N = 116$ ($p = .05$) was obtained between Self-Reported Errors (Err_self) and the Safety Culture Measure (SCM).

Fifteen items from the Safety Culture Measure had significant individual bivariate correlations (Pearson's r) with the Self-Reported Errors (Err_self) in Organisation 7 (see Table 14). With a p level set to .05, $N = 116$, the 49 items in this study were likely to generate approximately three items that showed significant correlations by chance alone and where no association existed.

Thirteen of the 15 significant correlations were more negative than the overall correlation, indicating support for Hypothesis 4. This result also suggests that other items, that did not have statistically significant individual correlations, were responsible for reducing the strength of the overall correlation ($r = -.14$) between the frequency of Self-Reported Errors and the Safety Culture Measure, which would otherwise have demonstrated a more powerful effect. This low negative correlation might be interpreted as weak support for Hypothesis 4.

Table 14: Correlation coefficients between items on the Safety Culture Measure and the Self-Reported Errors (Err_self) in Organisation 7 ($p < .05$).

Item	Correlation	Item text
Item 3	.21	An employee who behaves recklessly will receive a negative evaluation from supervisors
Item 14	–.23	Management acts quickly to correct safety problems
Item 15	–.20	My chance of being involved in an accident is low
Item 16	–.22	The safety committee in our organisation has a very positive effect on what is happening here
Item 17	–.25	Managers in this organisation take care and try to reduce risk levels as much as possible
Item 21	.22	Generally, there is a belief that it is only a matter of time until one is involved in a safety-related incident
Item 24	–.23	The safety issues relating to the work done here are taken very seriously
Item 25	–.19	When a manager realises that a hazardous situation has been found, he/she immediately attempts to put it under control
Item 30	–.23	Compared to other comparable organisations, I think this one is pretty safe
Item 35	–.18	When a safety regulation is issued, the work force complies with it
Item 40	–.20	This company considers safety a good advertisement for its services
Item 41	–.19	Health and Safety Regulations have much influence here
Item 42	–.20	Hazard control is given a lot of attention here
Item 44	–.20	Safety is given priority over the operational priorities
Item 45	–.28	There is a high awareness of factors that contribute to a safe operation

5.4.5. Summary: Aim 3

The results from the analysis under Aim 3 were not conclusive. The correlations were generally in the expected direction but the probability levels obtained make it difficult to have confidence in the results.

Aim 3 was designed to investigate whether safer organisations are those that report errors. The correlations obtained are not significant under any of the hypotheses, which makes it difficult to have confidence in them. However, examination of Figure 18 shows that when Organisation 7 (Org 7) is eliminated from the data (Org 7 was the largest organisation in the study) then a linear relationship between the errors (Error Frequency Index) and the perceived level of safety (Safety Culture Measure) is observed. The positive correlation between the Error Frequency Index and the Safety Culture Measure, which became stronger and statistically significant when Organisation 7 was removed, is encouraging. This result supports the assertion that higher error reporting is associated with higher safety. Furthermore, the Safety Culture Measures is based on Zohar's measure, which has empirical support in the literature.

The Managers' Self-Report General Failure Types negative correlation with the Error Frequency Index is in the expected direction but is not significant. The suggestion of a negative correlation of organisationally reported errors (Error Frequency Index) with the Safety Index Measure does not support the position that higher reporting organisations were safer than those reporting fewer errors.[46]

Based on this information, consideration might be given to eliminating the Managers Self-Report General Failure Types and the Safety Index Measure from further analysis, on the basis that they may not be reliable and valid. However, as indicated in Section 3.1 (p. 89) the validity and reliability of a measure is likely to be obtained through an iterative development process and it was considered premature to eliminate these measures, given the exploratory nature of this research. They were retained in further analyses and are reported so as to investigate further their utility and validity.

[46] Both the SCM and the EFI are measures that are taken across the entire organisation, perhaps reflecting organisational characteristics. The SIM and FTman, on the other hand, are reported by one individual within the organisation. It is possible that the strength of the association between these latter two safety indices and the SCM is weakened by this individuality characteristic.

Individuals from Organisation 7 who are reporting higher frequencies of errors in themselves tend to perceive their organisation as less safe (Safety Culture Measure) than those reporting fewer errors.

5.5. Aim 4: Homogeneity of organisational culture in aviation maintenance organisations in New Zealand

Aim 4 was designed to investigate whether aviation maintenance organisations have similar cultural characteristics. The organisational culture characteristics of the organisations in the research were examined using data from the Organisational Culture Measure and the Safety Culture Measure. Organisational culture profiles were determined for each organisation and factor analysis was used to determine the factor structure of the Organisational Culture Measure. These factors were entered in a multiple regression to determine whether they predicted variance in Self-Reported Errors (Err_self). This aim was examined under Hypotheses 5, 6, and 7.

5.5.1. Hypothesis 5

The Organisational Culture Measure sub-scales will generate similar profiles, across maintenance organisations, when plotted as a line chart. The Safety Culture Measure score will be treated as a sub-scale of organisational culture for this purpose.

5.5.1.1. Organisational Culture Measure sub-scales, Safety Culture Measure profile analysis

The observed means for the Organisational Culture Measure (OCM) sub-scales and the Safety Culture Measure (SCM) score for each of the organisations taking part in the study are shown in and Table 15 and Figure 19. Cronbach's α's for the Organisational Culture Measure sub-scales and the Safety Culture Measure indicate high levels of internal consistency (see Table 15).

Table 15: Mean scores for the Organisational Culture Measure sub-scales and the Safety Culture Measure, and associated Cronbach's α' coefficients ($p < .05$). (All Org is the data for all the organisations pooled and the two sites of Organisation 7 are shown separately.)

Variable	Org 1	Org 2	Org 3	Org 4	Org 5	Org 6	Org 7a	Org 7b	All Org	Cronbach's α
SCM	4.67	4.23	4.28	3.92	4.47	4.72	4.52	4.77	4.42	.95
Initiative	4.95	4.73	4.56	4.42	5.07	4.90	4.78	4.72	4.74	.77
Caution	5.02	4.46	5.33	3.71	4.56	5.02	4.63	4.42	4.59	.74
Performance	5.01	4.76	5.11	3.97	5.03	4.72	5.10	4.97	4.81	.91
Planning	4.71	3.94	4.33	3.74	4.46	4.26	4.17	4.18	4.16	.85
Power	4.56	4.90	3.96	3.94	4.38	4.00	4.85	4.8	4.40	.71
Achievement	4.55	4.28	4.81	4.16	4.68	4.41	4.30	4.45	4.44	.79
Co-operation	4.41	4.00	5.18	4.33	4.49	4.76	4.10	4.21	4.44	.89
Communication	4.08	3.96	4.44	3.8	4.06	4.32	3.63	3.79	4.00	.85
Rewards	2.93	3.07	3.53	2.41	3.73	3.79	3.09	3.25	3.27	.89
Morale	4.24	4.21	4.77	3.88	4.58	4.73	4.05	4.2	4.34	.87
Autonomy	4.40	4.22	4.77	4.23	4.65	5.10	4.40	4.3	4.52	.68
Self-expression	3.93	3.79	4.75	3.67	3.88	4.50	3.61	3.93	4.02	.84
Work diversity	4.41	4.43	4.50	4.32	5.03	3.60	4.93	4.69	4.50	.82
Personal	4.51	4.51	4.71	4.32	5.31	4.78	5.15	4.96	4.82	.81
Passion	4.63	4.67	5.19	4.49	4.81	4.66	4.36	4.48	4.67	.81
Avoidance	3.21	3.27	3.10	3.82	3.4	3.06	3.49	3.29	3.35	.76
Compliance	5.32	4.78	5.00	4.34	5.05	5.10	5.14	5.37	4.97	.85
Relationship	5.38	5.02	4.94	4.65	5.25	4.83	5.28	5.27	5.04	.70
Leadership	4.15	3.88	4.00	3.44	4.27	4.38	3.77	3.99	3.96	.89
Structure	4.95	4.75	4.81	4.21	4.65	4.20	4.91	5.03	4.65	.67

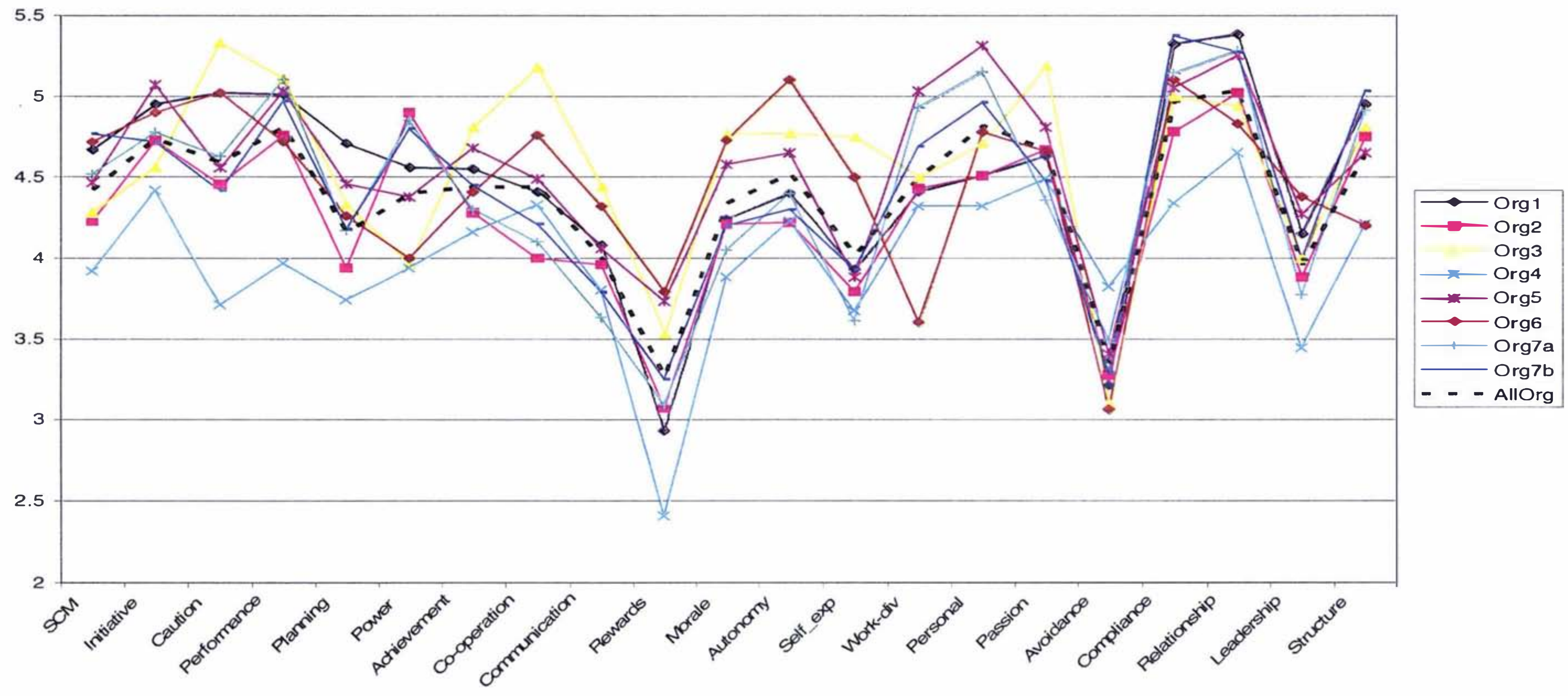

Figure 19: Organisational Culture Measure sub-scale score and Safety Culture Measure score profiles.

Visual inspection of the profiles suggests that organisational culture across organisations may be homogeneous; the profiles show a similar pattern of peaks and troughs. The exception to this was Organisation 4, which has the lowest extreme scores on 13 of the sub-scales, including the Safety Culture Measure, and the highest score for Avoidance Orientation.

To investigate homogeneity across the maintenance organisations a discriminant function was conducted to determine if the sub-scales and the Safety Culture Measure could discriminate the organisations. This was significant (Wilks' $\lambda = 0.56$, $\chi^2 = 286$, df 72 (p =.001)). The twelve sub-scales contributing to the discrimination are shown in the shaded part of Table 16; this table was generated using maintenance organisation data only.

Examination of the univariate Wilks' λ (see Table 16) allows further interpretation of the results. (The univariate Wilks' λ expresses the ratio of the within-groups sums of squares to the total sums of squares and can take values between 0 and 1. Values close to zero indicate that the group means are different, and values close to one indicate that the group means are not different. Values equal to one indicate that the means are the same. In this sense, univariate Wilks' λ can be used to indicate the 'degree of sameness'.) The sub-scales with high values of Wilks' λ (close to one) indicate that, in isolation, the means, when compared between organisations may not generally be considered 'very' different, and yet, when used in the discriminant function, 12 are different enough to be combined in such a way as to discriminate among the organisations. The univariate Wilks' λ values indicate that there are statistically significant differences between the means on nine of the Organisational Culture Measure sub-scales and the Safety Culture Measure (p =.05); these are shown in bold in Table 16. For the remaining 11 sub-scales, the differences are not statistically significant.

On balance, the interpretation placed on the sub-scale data is that a degree of homogeneity is present across the aviation maintenance organisations in this study. This is based on the observation that 11 of the sub-scales cannot be said to have different means and the values of Wilks' λ for each organisation approaches one. To check the degree of homogeneity would require a comparison with organisations from other industries.[47]

Table 16: Tests of equality of group means for the Organisational Culture Measure sub-scales and Safety Culture Measure for the maintenance organisations.

Sub-scales contributing to the discriminant analyses	Univariate Wilks' λ, test of equality of group means	*p*-level
SCM	**.93**	**.00**
Caution Orientation	**.96**	**.00**
Performance Orientation	**.97**	**.01**
Planning Orientation	**.97**	**.00**
Power Orientation	**.94**	**.00**
Co-operation Support	**.98**	**.05**
Communication Orientation	.98	.10
Rewards Orientation	**.98**	**.05**
Work Diversity	.96	.06
Personal Growth	**.95**	**.00**
Passion for Industry	.98	.25
Structure Orientation	**.96**	**.00**
Sub-scales not contributing to the discriminant analyses	**Univariate Wilks' λ, test of equality of group means**	***p*-level**
Initiative	.99	.43
Achievement Orientation	.99	.29
Morale Orientation	.98	.30
Autonomy	.98	.70
Self-Expression	.98	.06
Avoidance Orientation	.99	.33
Compliance Orientation	**.96**	**.00**
Relationship to Outside	.98	.15
Leadership Orientation	.99	.28

[47] Org 6, the regulatory organisation (from the aviation industry) does not appear to have radically different profile from the maintenance organisations. Ideally a comparison group from totally different industry groups is required.

5.5.2. Hypothesis 6

Factor analysis of the Organisational Culture Measure developed for this research will support the 20 sub-scale structure in the measure.

5.5.2.1. Factor analysis of the Organisational Culture Measure

Factor extraction, using the principal axis method, was performed on the 119 items within the Organisational Culture Measure. There were 520 cases from seven organisations, and 119 variables, representing a ratio of 4.4 to 1. This was at the absolute limits of stability for an analysis of this type (Tabachnick & Fidell, 1989). The correlation matrix was examined and showed reasonable correlations among variables, indicating that the items in the measure were related to each other. No multicollinearity or singularity was in evidence.

Eleven factors were initially extracted based on an Eigenvalue of set to 1, ensuring that the factors selected were contributing more variance than a single variable. Examination of the Eigenvalues (see Table 17) and scree plot (see Figure 20) suggests the possibility of a six-factor structure accounting for 43% of the variance. The factor analysis was re-run with the number of factors set to six. A varimax-normalised procedure aimed at maximising the variances of normalised factor loadings across variables for each factor was used; this is equivalent to maximising the variances in the columns of the matrix of normalised factor loadings.

The factor matrix generated is shown in Appendix K (p. 335). Examination of the variables loading on the six factors suggests the factors shown in Table 18. With the exception of Factor 4, Cronbach's α values for the items in the factors show good internal consistency. The descriptions of factors were based on items loading in excess of .5 on a factor. Fifty-nine items from the Organisational Culture Measure were retained out of 119.

Table 17: Eigenvalues from the principal axis factoring of the Organisational Culture Measure.

Factor	Eigenvalue	Variance % of total	Cumulative Eigenvalue	Cumulative %
1	34.7	29.1	34.7	29.1
2	5.0	4.2	39.6	33.3
3	4.0	3.4	43.6	36.7
4	2.7	2.3	46.3	38.9
5	2.2	1.8	48.5	40.8
6	2.0	1.7	50.5	42.5
7	1.5	1.2	52.0	43.7
8	1.3	1.1	53.3	44.8
9	1.2	1.0	54.5	45.8
10	1.0	0.9	55.6	46.7
11	1.0	0.9	56.6	47.6

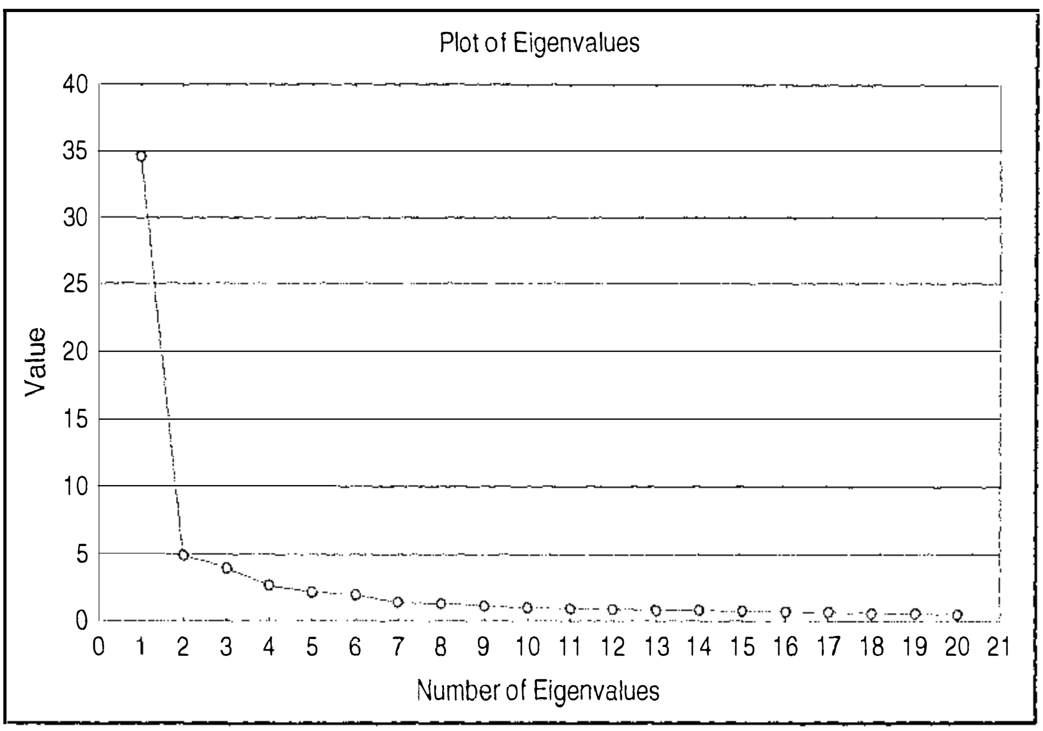

Figure 20: Eigenvalues from the principal axis factoring of the Organisational Culture Measure.

Table 18: Description of factors extracted from the principal axis factoring of the Organisational Culture Measure. Items loading at .5 or above (Field, 2000).

Factor	Cronbach's α	Item Numbers	Description of the factor
Factor 1 Desirability of the work place	.96	30 items 22 32 44 50 51 52 53 54 55 57 58 61 62 63 64 65 67 69 71 72 73 74 79 80 82 83 110 111 112 113	This is a global factor encompassing 30 items from a range of sub-scales on the measure. Factor 1 generally relates to the desirability of the work environment. Sub-scales captured by this factor include the Co-operation orientation and supportive orientation, Communication orientation, Rewards orientation, Positive Morale orientation, Self Expression orientation, and Leadership orientation from management.
Factor 2 Work diversity orientation and personal growth orientation	.90	11 items 68 70 76 84 85 86 87 88 89 90 107	This is a factor encompassing the Work diversity orientation and the Personal growth orientation sub-scales of the Organisational Culture Measure.
Factor 3 Performance orientation	.90	8 items 10 11 12 13 14 15 16 17	This factor encompasses the Performance orientation sub-scale of the Organisational Culture Measure.
Factor 4 Power oriented autocracy	r = .42 A simple correlation is shown here as only two variables are in Factor 4	2 items 28 29	This factor encompasses the Power orientation sub-scale.
Factor 5 Co-operation orientation and support orientation	.80	4 items 41 42 48 49	This factor encompasses the Co-operation orientation sub-scale of the Organisational Culture Measure.
Factor 6 Compliance with rules orientation	.83	4 items 102 103 104 117	This factor encompasses the Compliance with rules orientation sub-scale of the Organisational Culture Measure.
Total		59 items	The items contained in the measure are shown in Appendix A (p. 227).

The factors were subject to an orthogonal rotation and were therefore independent of each other. The Cronbach's α values obtained show good internal consistency within the factors. The factor structure derived consists of one main factor and five smaller factors. This has provided some support for the following sub-scales in the Organisational Culture Measure: Work diversity orientation and Personal growth orientation sub-scales together, Performance orientation, Power orientation, Co-operation orientation, and Compliance with rules orientation. Because the results do not support all 20 sub-scales within the Organisational Culture Measure, Hypothesis 6 was not supported by the data. The distribution of variance tends toward unidimensionality in the measure and the content of the factors makes them difficult to interpret with confidence and clarity.

5.5.3. Hypothesis 7

The factors obtained from the factor analysis of the Organisational Culture Measure (OCM) will predict variance in Self-Reported Errors (Err_self) in Organisation 7.

5.5.3.1. Multiple regression of the factor analysis of the Organisational Culture Measure onto Self-Reported Errors (Err_self)

A forward stepwise multiple regression was performed on the six principal factors extracted from the Organisational Culture Measure. The independent variables were Factors 1–6 and the dependent variable was the Self-Reported Errors from Organisation 7. Cases were selected if an error rate greater than zero was reported and 116 were selected for inclusion on this basis. The F to enter probability level was set to p =.1. The results from the multiple regression were R = .35, R^2 = .13, $F(3,112)$ = 5.36, N =116 (p < .002). The independent variables explain 13% of the variance in the dependent variable. The analysis indicates that Factors 2 and 4 were significant and show negative B values, indicating a negative relationship with the dependent variable (see Table 19).

Table 19: Multiple regression of the six principal factors extracted on to the Self-Reported Errors (Err_self) in Organisation 7.

Factor	**B**	***p*-level**
Intercept	7.90	.001
Factor 2	−3.24	.01
Factor 4	−2.96	.02

The partial correlations show Factors 2 and 4 (see Table 20) were predicting a significant proportion of variance in the number of Self-Reported Errors (Err_self). Factor 2 was accounting for 6.25% of unique variance in the dependent variable and Factor 4, 4.8%.

Table 20: Partial correlations for Factors 2 and 4 with Self-Reported Errors (Err_self).

Factor	**Partial Correlation**	***p*-level**
Factor 2	−.25	.01
Factor 4	−.22	.02

Hypothesis 7 has some support; the factors extracted from the Organisational Culture Measure predicted variance in Self-Reported Errors (Err_self).

5.5.4. Summary: Aim 4

The Organisational Culture Measure sub-scales profiles show similar shaped profiles. This suggests that organisational culture is relatively homogeneous in the aviation maintenance industry.

Factor analysis of the Organisational Culture Measure shows a six-factor solution accounting for 40% of the variance in the model. The nature of the variance tends towards unidimensionality in the measure and the item content within the factors makes them difficult to interpret.

Factors 2 and 4 predict 13% of the variance in the number of Self-Reported Errors (Err_self) in Organisation 7. The results suggest the importance of Work diversity orientation, Personal growth orientation, and Power orientation in predicting Self-Reported Errors (Err_self).

5.6. Aim 5: Cultural characteristics and safety level of aviation maintenance organisations in New Zealand

The objectives of Aim 5 were to develop measures of organisational and safety culture with the aim of using these to discriminate among aviation maintenance organisations based on safety. Such measures will be most useful if they highlight areas of organisational culture that are predictive of particularly high or low levels of safety. This aim was examined under Hypotheses 8, 9, and 10.

5.6.1. Hypothesis 8

The Organisational Culture Measure (OCM) and Safety Culture Measure (SCM) will discriminate among organisations that are assigned to high, medium, or low safety groups. This will demonstrate the usefulness of the measures and their ability to detect culture differences among organisations that show different levels of safety. The groups will be assigned based on the summed-ranks obtained from three safety indices the Safety Index Measure (SIM), the Managers' Self-Report General Failure Types (FTman), and the Error Frequency Index (EFI).

5.6.1.1. Determination of safety ranks

Each maintenance organisation in the study generated an index value for each of the following measures: the Error Frequency Index, the Managers' Self-Report General Failure Types and the Safety Index Measure. Each organisation's value on an index was compared with the others and a rank assigned for that index (see Table 22).[48] The rationale for assigning the ranks was based on the content validity and the 'theoretical' construct validity in the measures (see Table 21).

[48] The calculation of the indices for the Safety Index Measure (SIM) and the Managers 'Self-report General Failure Types (FTman) for Organisation 7 are shown in Appendix H (p. 319).

Table 21: Rational for assigning safety ranks.

Measure	Rationale for assigning rank
Safety Index Measure (SIM)	High scores on the Safety Index Measure indicate that observable indicators of safety are in place Therefore a high safety rank is assigned for a high Safety Index Measure score.
Managers' Self-Report General Failure Types (FTman)	High scores on the Managers' Self-Report General Failure Types indicate that managers perceive their organisation as having a high number of errors at the organisational level. This can be taken to indicate they do not have confidence in the safety of the organisation's systems and therefore the organisation is less safe. Therefore, a low safety rank is assigned for a high Managers' Self-Report General Failure Types score.
Error Frequency Index (EFI)	High scores on the Error Frequency Index are taken to indicate that an organisation has systems in place to record errors and may be seen as safer. Therefore, a high safety rank is assigned for a high Error Frequency Index score. Some empirical support exists for this (see Section 5.4.5, p. 140.

These ranked values were summed for each organisation, generating a 'Summed Safety Rank' reflecting a contribution from each of the measures. The maximum Summed Safety Rank score that could be obtained was 18 and the minimum 3.

Summed Safety Rank i = Rank (SIM) i + Rank (FTman) i + Rank (EFI) i
Where i represents the organisation

The organisations were then classified into high, medium, and low groups, based on the Summed Safety Rank, with two organisations in each group (see Table 22). Accordingly, the two highest scores were placed in the high group and the two lowest scores in the low group. The two scores falling in the middle were placed in the medium group. (Organisation 6 did not produce safety indices data; it was not engaged in maintenance activity.)

Table 22: Ranks assigned to each organisation, representing the safety orientation, high ranks equate to high safety.

Organisation ID	FTman	FTman Rank	EFI	EFI Rank	SIM	SIM Rank	Summed-ranks	Safety Group Assigned
Org 1	45	3	.96	6	79	3	12	Medium
Org 2	34	5	.64	4	88	6	15	High
Org 3	70	1	.61	3	57	1	5	Low
Org 4	56	2	.24	2	85	4	8	Low
Org 5	33	6	.87	5	60	2	13	High
Org 7	44	4	.07	1	87	5	10	Medium

Note: It was not possible to generate a separate safety rank for the two sites of Org 7, as error data was only available for the complete organisation

The relatively low value obtained on the Error Frequency Index for Organisation 7 (Org 7) merits comment. Organisation 7 employed 1933 maintenance staff and was 16 times larger than the second largest organisation, employing 120 maintenance employees. It was therefore likely to possess different organisational characteristics to the other organisations; this may account for the large difference in the Error Frequency Index obtained for Organisation 7.[49]

5.6.1.2. Discriminant function analysis of the Organisational Culture Measure sub-scales and the Safety Culture Measure on the safety groups

A forward stepwise discriminant analysis was performed to test Hypothesis 8. The independent variables were the 20 Organisational Culture Measure sub-scales and the Safety Culture Measure, the dependent variable was the safety group to which the organisations were assigned, i.e. a high, medium or low group. Five hundred and four valid cases, from the six maintenance organisations, were entered in the analysis; the 'proportion equals priors' option was selected. The F to enter probability level was set to p =.05. The overall case-

[49] The relatively low number of errors reported may in part be a function of the administrative complexity of this much larger organisation, such that errors are harder to track and report.

to-variable ratio of 24:1 provides a stable solution for these data; however, the smallest group (28 cases) may compromise this stability where the case-to-variable ratio was 4:1. Due to the small sample size (Hair et al., 1995), it was not possible to use a split sample procedure to determine whether overfitting had occurred.

Two discriminant functions were calculated and the model retained eight variables. Wilks' λ = .74, $F(16,988) = 9.4862$, $\chi^2 = 150.46$, $N = 504$ ($p <$ 0001), indicating the means of the discriminant scores show moderate differences between the groups. The canonical correlation, R = .46, indicates that the independent variables were predicting 21% of the variance in safety level among the groups. Table 23 shows the variables contributing to the discrimination. The univariate Wilks' λ values indicate high sums of squares within the groups compared with the overall variability; all were statistically significant indicating that the group means may be considered separate.

Table 23: Univariate Wilks' λs.

Variable	Wilks' λ	p-level
Power	.84	.001
SCM	.95	.001
Passion	.88	.001
Performance	.80	.001
Co-operation	.78	.001
Rewards	.74	.001
Compliance	.81	.001
Communication	.76	.010

Table 24 shows the loading matrix; the correlation between the independent variables and the discriminant functions. For Function 1, higher correlations ($r > .3$) were observed for Power orientation, the perceived level of safety (Safety Culture Measure), Performance orientation, and Compliance with rules. For Function 2, a higher correlation was noted for Power orientation only.

Table 24: Loading matrix, correlation of variables with canonical functions.

Variable	Function 1	Function 2
Power	.40	.37
SCM	.44	−.19
Passion	−.13	−.19
Performance	.29	.06
Co-operation	−.12	−.20
Rewards	.14	.20
Compliance	.34	.13
Communication	−.11	.16

Table 25 shows the standardised coefficient matrix; the weighting assigned to each variable used to generate the canonical function. Perceived level of safety (Safety Culture Measure) and Co-operation orientation have the highest loadings on Functions 1 and 2 respectively.

Table 25: Standardised coefficient matrix.

Variable	Function 1	Function 2
Power	0.49	0.50
SCM	0.69	−0.50
Passion	−0.68	0.70
Performance	0.46	0.37
Co-operation	−0.39	−1.35
Rewards	0.38	0.47
Compliance	0.45	−0.33
Communication	−0.34	−0.93

The loading matrix (see Table 24) suggests that Power orientation, perceived level of safety (Safety Culture Measure (SCM)), and Compliance with rules explain variance in Function 1. The remaining variables are likely to be unstable in their effects (D. Meyer, personal communication, 2000). For Function 1, the standardised coefficient matrix (see Table 25) indicates positive loadings for Power orientation, perceived level of safety (Safety Culture Measure), Performance orientation, Rewards orientation and Compliance with rules. Negative loadings exist for Passion for industry, Co-operation orientation, and Communication orientation.

The loading matrix (see Table 24) suggests that Power orientation explains variance in Function 2. The correlations of the remaining variable are likely to be unstable and are not considered further. The Standardised coefficient matrix (see Table 25) shows that Co-operation orientation loaded strongly negatively on Function 2, compared with the other variables. Communication orientation, perceived safety (Safety Culture Measure), and Compliance with rules also load negatively. Power orientation, Passion for industry, Performance orientation and Rewards orientation have positive loadings.

A person who scores high on Function 1 is likely to perceive their organisation as higher in Power orientation, perceived level of safety (Safety Culture Measure), Compliance with rules and, to a lesser extent, Performance orientation. They may tend to perceive Passion for industry, Co-operation orientation, and Communication orientation as lower, although these effects are likely to be unstable in the model. Function 2 is more difficult to interpret; a person who scores highly on Function 2 is likely to see their organisation as high in Power orientation but low in Co-operation orientation.

Collectively, these functions are able to classify 86% of cases correctly. Correct classification frequencies are shown in bold on the main diagonal in Table 26. The discriminant function was less successful in classifying high safety cases to the correct group than it was for low and medium groups. Overall, the discriminant function was best at classifying cases from the medium safety group; it correctly classified 414 out of a maximum of 421.

Table 26: Classification matrix for the Organisational Culture Measure sub-scales and the Safety Culture Measure, predicting membership of high, medium and low ranked safety groups, based on Summed Safety Ranks.

Rows: Observed classifications **Columns: Predicted classifications**	**Cases in each group**	**% correct**	**HIGH**	**LOW**	**MEDIUM**
			p =.11	p =.06	p =.84
HIGH	55	15	8	1	46
LOW	28	46	0	13	15
MEDIUM	421	98	0	7	414
Total	504	86	8	21	475

Note: p (proportion) of cases that would be classified by chance alone.

To test the classification success of the model the proportional chance criterion was employed. This is given by the following formula:

$$Cp = \sum \left(\frac{pi}{N}\right)^2$$

Where Cp was the proportion of cases that would be correctly classified by chance, pi was the number of cases in each of the groups 1 to i and N was the total number of cases. Inserting the values taken from Table 26, the critical value was 71%; the observed value was 86%. The discriminant function analysis was classifying cases to the correct groups at a higher-than-chance level.

Figure 21 shows the discriminating ability of Functions 1 and 2 for the Organisational Culture Measure and the Safety Culture Measure. Function 1 discriminates between the low safety group and the medium safety group the most, and Function 2 between the high safety group and the low safety group. Table 27 shows the means of the canonical variables, representing this separation numerically.

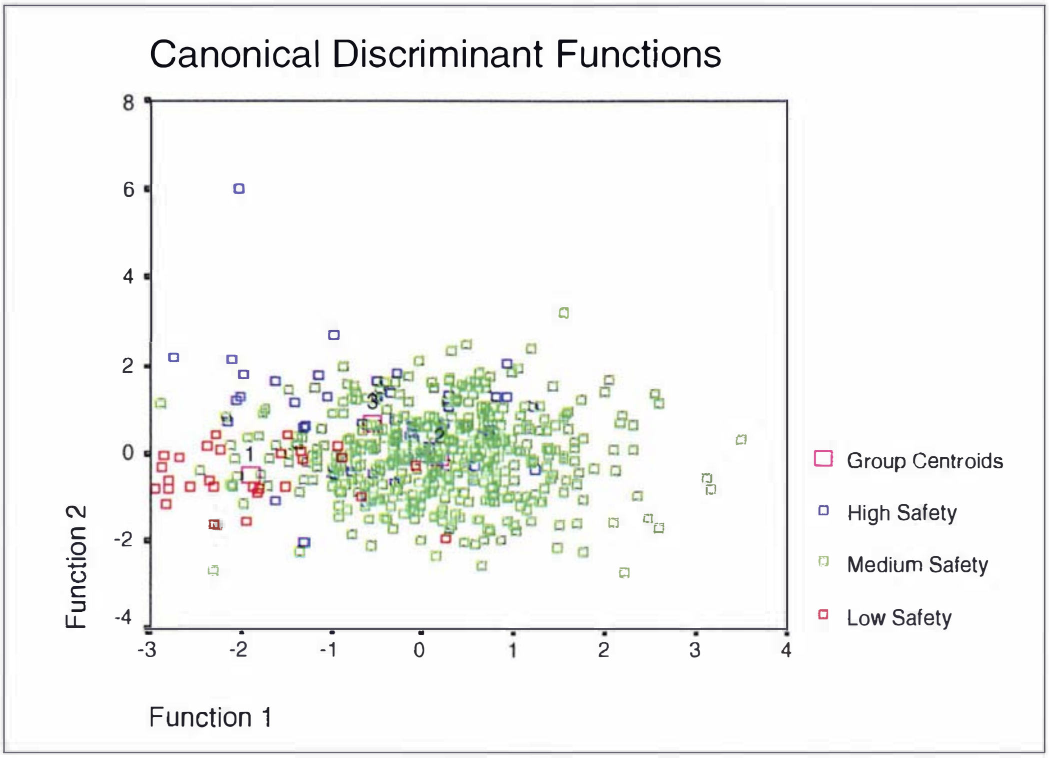

Figure 21: Scatterplot showing the discriminating ability of Functions 1 and 2.

Table 27: Means of the canonical variables for each group.

Means of canonical variables	Function 1	Function 2
HIGH	−0.54	0.71
LOW	−1.88	−0.49
MEDIUM	0.20	-0.06

With reference to Table 24, Table 25, and Table 27, it can be concluded that high scores on Function 1 will lead a case to be classified into the medium safety group. These are individuals who perceive their organisation as higher in Power orientation, perceived level of safety (Safety Culture Measure), Compliance with rules and, to a lesser extent, Performance orientation. Low scores on Function 1 lead to classification into the low safety group. Low scores on Function 2 (associated with low Power orientation but high Co-operation orientation), in combination with low scores on Function 1, lead to cases being classified into the low safety group.

5.6.1.3. Testing for conceptual overlap in the measures

The use of judgements/perceptions of safety level and performance in the evaluation of organisations is commonly found in the literature (Brown & Holmes, 1986; Bureau of Air Safety Investigation, 1996; Reason, 1997; Vitro, 1991; Zohar, 1980). However, such methods can present challenges to data analysis when independent variables and dependent variables both have an element of perceptual subjectivity. In addition, the design and content of measures can introduce conceptual overlap that can lead to unwanted shared variance being present when one measure is used as a predictor variable for another. For this reason, it was desirable to have an objective measure of safety.

5.6.1.3.1. Testing for conceptual overlap between the Organisational Culture Measure and the Safety Culture Measure, and the Safety Index Measure

To minimise the effects of perceptual subjectivity and conceptual overlap, the Safety Index Measure was designed to be a primarily non-reactive (objective) measure in which a majority of items (safety features of an organisation) could be observed and scored to be clearly present or absent. It is acknowledged, however, that it is difficult to eliminate such subjective effects totally and therefore a degree of conceptual overlap between the Organisational Culture Measure and Safety Culture Measure, and the Safety Index Measure, may exist. One method of controlling for conceptual overlap is to remove any suspect items from the measures, although this will not necessarily fix the problem, or, more pragmatically, remove a measure altogether from the independent (predictor) or dependent variables and ascertain any effects on the overall pattern of results. When the Safety Culture Measure was removed as an independent variable and the three-group discriminant analysis, reported in the previous section, was repeated, using the same entry criterion (see 5.6.1.2, p. 156), similar correct classifications for the safety groups were achieved and the overall classification success of the model (86%) did not change (see Appendix L, p.

341).

When the Safety Index Measure was removed from the dependent variable (Summed Safety Rank), new summed-ranks were generated (see Table 28). This generated a two-group split; high and low safety.

Table 28: Ranks assigned to each organisation (Summed-Rank minus the Safety Index Measure).

Organisation ID	FTman	FTman Rank	EFI	EFI Rank	Summed-Rank minus SIM	Safety Group Assigned
Org 1	45	3	.96	6	9	High
Org 2	34	5	.64	4	9	High
Org 3	70	1	.61	3	4	Low
Org 4	56	2	.24	2	4	Low
Org 5	33	6	.87	5	11	High
Org 7	44	4	.07	1	5	Low

Discriminant function analysis of the two-group split did not provide adequate discrimination between these two groups (*F* to enter probability level was set to p =.05). However, when the summed-ranked scores (effectively creating four safety groups) were used as the basis for a discriminant function analysis (*F* to enter probability level was set to p =.05), then the results shown in Table 29 were generated (Wilks' λ = .721, N = 520 (p =.0001)).

Table 29: Classification matrix for the Organisational Culture Measure sub-scales and the Safety Culture Measure, predicting the rank score for Error Frequency Index/Managers' Self-Report General Failure Types (EFI/FTman).

Rows: Observed classifications Columns: Predicted classifications for EFI/FTman rank scores summed	Cases in each group	% correct	4	5	9	11
			p =.55	*p* =.74	*p* =.18	*p* =.02
4	28	46.4	13	13	2	0
5	375	95.5	7	358	10	0
9	89	12.4	1	77	11	0
11	12	0	1	10	1	0
Total	504					

Note: *p* (proportion) of cases that would be classified by chance alone.

To test the classification success of the model the proportional chance criterion (*Cp*) was employed. Inserting the values taken from Table 29, the critical value was 59; the observed value was 76. The discriminant function analysis was classifying cases to the correct groups at a higher-than-chance level. This indicates the Organisational Culture Measure sub-scales and the Safety Culture Measure can discriminate safety groups in the absence of the Safety Index Measure component.

Removing the variables in turn (first the Safety Culture Measure then the Safety Index Measure) from the independent and dependent sides of the discriminant analyses did not nullify the discriminating effects of the measures. These results do not mean that conceptual overlap does not exist (between the Safety Culture Measure and the Safety Index Measure) but, rather, if it does, then it was not wholly responsible for the discriminating ability of the measures when incorporated into the Summed Safety Rank.

5.6.1.3.2. Testing for conceptual overlap between the Organisational Culture Measure and the Safety Culture Measure

There exists the possibility of conceptual overlap between the Organisational Culture Measure and the Safety Culture Measure.

A principal components analysis[50] was run on the data from the Organisational Culture Measure and the Safety Culture Measure. Two components were specified for the solution retaining items loading with a coefficient of >.4 (Field, 2000) and using varimax rotation to keep the factors orthogonal. This was to determine whether the two components contained primarily items from each of the measures respectively. Table 30 shows the variance explained by the two components and percentage of items from each of the measures that load only on the respective components (see Appendix M, p. 343).

Table 30: Principal components analyses of the Organisational Culture Measure and Safety Culture Measure items, to test for conceptual overlap.

	Variance explained	Cumulative variance	OCM items	SCM items
Component 1	18.27	18.27	81/219 (65%)	
Component 2	13.26	31.53		41/49 (91%)

This result shows that 65% of items within the Organisational Culture Measure load uniquely on Component 1 and 91% of the items in the Safety Culture Measure load uniquely on Component 2. As the components are orthogonal, this supports the relative independence of the item content in the measures.

[50] Principal components analysis was used because it uses all the variance within the items, this is required to test for conceptual overlap.

5.6.2. Hypothesis 9

The Organisational Culture Measure (CM) sub-scales will predict variance within the Safety Culture Measure (SCM). This will provide information on the features of organisational cultures that were associated with safety culture.

5.6.2.1. Bivariate correlations between Safety Culture Measure and the Organisational Culture Measure sub-scales

Examination of the bivariate correlations (Pearson's *r*) of the Safety Culture Measure with the Organisational Culture Measure sub-scales indicates reasonable correlations across most of the sub-scales (generally these were $r > .3$ (75% in excess of $r = .5$, see Table 31). Compliance with rules orientation, Leadership orientation, Planning orientation and Passion for industry have the highest correlations ($r > .6$) and most of the sub-scales correlate positively with the Safety Culture Measure. A negative correlation was observed between Avoidance orientation and the Safety Culture Measure ($r = -.34$).

Table 31: Correlation coefficients (Pearson's) of the Organisational Culture Measure sub-scales and Safety Culture Measure ($N = 520$. $p < .001$).

	Initiative	Caution	Performance	Planning	Power	Achievement	Co-operation	Communication	Rewards	Morale	Autonomy	Self_exp	Work-div	Personal	Passion	Avoidance	Compliance	Relationship	Leadership	Structure
Caution	.48																			
Performance	.58	.60																		
Planning	.67	.61	.71																	
Power	−.19	−.20	−.26	−.28																
Achievement	.59	.42	.51	.62	−.17															
Co-operation	.57	.52	.57	.70	−.33	.69														
Communication	.54	.52	.53	.71	−.36	.63	.80													
Rewards	.40	.39	.41	.53	−.23	.55	.64	.65												
Morale	.49	.47	.53	.67	−.35	.58	.75	.72	.68											
Autonomy	.46	.39	.43	.57	−.24	.56	.65	.61	.52	.67										
Self-expression	.54	.46	.50	.66	−.31	.67	.71	.72	.62	.71	.61									
Work diversity	.31	.22	.31	.35	−.05	.33	.37	.30	.34	.48	.48	.34								
Personal	.34	.24	.37	.40	−.02	.38	.37	.31	.33	.47	.53	.36	.73							
Passion	.57	.46	.55	.68	−.22	.63	.72	.67	.54	.72	.56	.65	.37	.40						
Avoidance	−.37	−.39	−.49	−.47	.37	−.27	−.34	−.34	−.26	−.42	−.29	−.32	−.21	−.25	−.41					
Compliance	.46	.50	.62	.65	−.26	.48	.53	.56	.44	.58	.44	.56	.34	.39	.59	−.49				
Relationship	.41	.38	.48	.56	−.14	.46	.45	.50	.42	.53	.48	.47	.46	.50	.57	−.41	.67			
Leadership	.50	.43	.47	.64	−.22	.55	.62	.69	.55	.61	.53	.64	.26	.27	.63	−.31	.56	.53		
Structure	.40	.38	.48	.51	−.02	.35	.39	.41	.29	.43	.32	.37	.28	.33	.47	−.27	.57	.51	.50	
SCM	.48	.44	.50	.60	−.11	.53	.56	.55	.50	.53	.46	.56	.29	.38	.59	−.34	.61	.57	.60	.52

5.6.2.2. Multiple regression of Organisational Culture Measure sub-scales onto the Safety Culture Measure

A forward stepwise multiple regression was performed. The independent variables were the 20 sub-scales from the Organisational Culture Measure; the dependent variable was the Safety Culture Measure score. Five hundred and twenty cases were selected for inclusion in the analysis. The F to enter probability level was set to p =.05. The results of the multiple regression were R = .74, R^2 = .54, $F(8,511)$ = 75.66, N = 522 (p < .001), (see Table 32). Examination of residuals showed two cases (less than 1%) that were in excess of three standard deviations from the predicted score, indicating that error in the model is acceptable (Field, 2000). Removal of these extreme cases produced a minor improvement in the model (R = .76, R^2 = .57).

Table 32: Forward stepwise multiple regression of the Organisational Culture Measure Sub-scales onto Safety Culture Measure.

Variable	B	*p*-level
Intercept	1.25	.001
Compliance	0.13	.001
Leadership	0.10	.001
Achievement	0.09	.010
Structure	0.12	.001
Rewards	0.07	.001
Relationship	0.08	.010
Power	0.07	.020
Planning	0.08	.020

The forward stepwise multiple regression retains eight predictor (independent) variables (sub-scales) from the original 20. All eight were significant and account for 54% of the variance in the Safety Culture Measure (perceived level of safety).

Table 33 and Table 34 indicate that Compliance orientation and the Leadership orientation account for most of the variance in the model that predicts the Safety Culture Measure.

Table 33: Forward stepwise multiple regression of the Organisational Culture Measure sub-scales onto Safety Culture Measure; variables entered at each step.

Variable	Step +in/-out	Multiple R	Multiple R-square	R-square change	p level
Compliance	1	.61	.37	.37	.001
Leadership	2	.69	.47	.10	.001
Achievement	3	.71	.50	.02	.001
Structure	4	.72	.52	.02	.001
Rewards	5	.73	.53	.01	.001
Relationship	6	.73	.53	.01	.001
Power	7	.73	.54	.00	.040
Planning	8	.73	.54	.00	.020

Table 34: Partial correlations for Organisational Culture Measure sub-scales with Safety Culture Measure.

Variable	Partial correlation	% unique variance accounted for	*p*-level
Compliance	.18	3.2	.001
Leadership	.19	3.6	.001
Achievement	.11	1.2	.010
Structure	.14	2.0	.001
Rewards	.13	1.7	.001
Relationship	.12	1.4	.010
Power	.10	1.0	.020
Planning	.10	1.0	.020

Hypothesis 9 was supported by the results. The sub-scales that predict variances in the Safety Culture Measure were Compliance with rules, Leadership orientation, Achievement orientation, Degree of structure, Rewards orientation, Relationship to outside environment, Power orientation, and Planning orientation.

5.6.3. Hypothesis 10

For the cases reporting Self-Reported Errors (Err_self) in Organisation 7[51], a discriminant function analysis using the Organisational Culture Measure (OCM) and Safety Culture Measure (SCM) will predict the site of origin (7a & 7b) to which cases belong at a greater-than-chance level. This will indicate the discriminating ability of the Organisational Culture Measure sub-scales and the Safety Culture Measure between the two sites of Organisation 7 for cases where error awareness is indicated, providing support for the validity of the measures.

5.6.3.1. Discriminant function analysis of the Organisational Culture Measure sub-scales and the Safety Culture Measure on the site of origin in Organisation 7

A forward stepwise discriminant function analysis was performed to test Hypothesis 10. The independent variables were the Organisational Culture Measure sub-scales and the Safety Culture Measure. The dependent variable was site of operation (Org 7a & Org 7b). The F to enter probability level was set to p =.05. One discriminant function was calculated and five variables were retained by the model. Wilks' $\lambda = .78$, $F(5,110) = 6.15$, $\chi^2 = 27.48$, $N = 116$ ($p < .001$). The results indicate there were differences between the group means. The case-to-variable ratio of 5.5:1, was at the limits for a stable solution (Tabachnick and Fidell, 1989). The canonical correlation, $R = .47$, indicates that the independent variables were predicting 22% of the variance attributed to site of origin.

[51] Only a limited number of participants (116) reported errors of this type. This data was only available from Organisation 7.

Table 35: Discriminant function analysis summary of the Organisational Culture Measure sub-scales and Safety Culture Measure (SCM) predicting site in Organisation 7.

Variable	Wilks' λ	*p* level
Structure	.84	.010
Planning	.89	.001
SCM	.83	.010
Work diversity	.84	.010
Morale	.81	.040

The loading matrix (see Table 36) shows the correlation between the independent variables and the discriminant function. Higher correlations ($r > .3$) were observed for; Degree of structure perceived safety (Safety Culture Measure).

Table 36: Loading matrix, correlation of variables with Function 1.

Variable	Function 1
Structure	–.39
Planning	.22
SCM	–.34
Work diversity	.27
Morale	–.07

The standardised coefficient matrix (see Table 37) shows the weighting assigned to each variable used to generate the canonical function; Planning orientation has the highest weight.

Table 37: Standardised coefficient matrix.

Variable	Function 1
Structure	−0.67
Planning	1.24
SCM	−0.69
Work diversity	0.67
Morale	−0.68

Table 36 and Table 37 indicate that there are differences between the two sites of Organisation 7 on Degree of structure, perceived level of safety (Safety Culture Measure), and Planning orientation. Work diversity and Morale make a lesser contribution to the discrimination. It is suggested that Function 1 is a meta-variable related to the degree of structure, planning, and safety issues, perhaps indicating 'managerial control' as an overriding influence over safety between these sites.

The discriminant function analysis correctly classifies 78% of cases to the correct group (see Table 38). Correct classification frequencies are shown in bold on the main diagonal.

Table 38: Classification matrix for the Organisational Culture Measure sub-scales and the Safety Culture Measure, predicting site in Organisation 7.

Rows: Observed classifications Columns: Predicted classifications	Cases in each group	% correct	Org 7a	Org 7b
			p =.51	p =.49
Org 7a	59	80	**47**	12
Org 7b	57	75	14	**43**
Total	116	78	61	55

Note: p (proportion) of cases that would be classified by chance alone.

To test the classification success of the model, the proportional chance criterion was employed (p. 160). Inserting the values taken from Table 38, the observed value was 78 and the critical value was 50, and therefore the discriminant function analysis was classifying cases to the correct groups at a higher-than-chance level.

Table 39: Means of standardised canonical variables for each group.

Organisation 7	Function 1
Org 7a	0.52
Org 7b	–0.53

Table 39 shows the distance between the canonical means on Function 1 for Org 7a and Org 7b. Low scores on Function 1 are associated with cases from Org 7b. These individuals are likely to be characterised by higher levels of perceived safety (Safety Culture Measure) and the Degree of structure, in the organisation (see Table 36 & Table 37). This result suggests higher perceived safety levels in Org 7b. High scores on Function 1 are associated with cases from to Org 7a and are likely to be characterised by higher levels of planning.

Hypothesis 10 was supported. The discriminant function was classifying at a higher-than-chance level. The Organisational Culture Measure and Safety Culture Measure predicted 22% of the variance related to site membership indicating the usefulness of the measure in discriminating between the two sites of Organisation 7. It is suggested that the function may be related to differences in the degree of managerial control between the two sites. The validity of the Organisational Culture Measure and the Safety Culture Measure was supported by this result. The model may be marginally stable due to the poor case-to-variable ratio.

5.6.4. Summary: Aim 5

The Organisational Culture Measure sub-scales and the Safety Culture

Measure classify organisations into the correct safety group at a better than chance level. The Organisational Culture Measure sub-scales and Safety Culture Measure predicted 21% of the variance among the high, medium, and low safety groups. Some care must be taken in interpreting these results; over-fitting may have occurred due to the size of the smallest group and the resulting case-to-variable ratio.

There was no evidence that conceptual overlap in the measures was preventing their discriminating ability. Eight Organisational Culture Measure sub-scales were retained in the multiple regression model, which explains 54% of the variance in the Safety Culture Measure. Leadership orientation and Compliance with rules orientation account for most of this variance.

The Organisational Culture Measure sub-scales and Safety Culture Measure classify Self-Reported Errors (Err_self) levels at better than chance, explaining 22% of the variance in the sites of origin for Organisation 7. High levels of perceived safety and planning are associated with Org 7b.

Aim 5 was met, the measures of organisational and safety culture were able to discriminate aviation maintenance organisations based on safety and have highlighted areas of organisational culture that were predictive of higher levels of safety; the utility of the measures was supported.

5.7. Aim 6: Assessment of safety culture in aviation maintenance organisations in New Zealand

The objectives of Aim 6 were to examine the Safety Culture Measure and determine whether it has an eight-factor structure similar to the Safety Climate Measure developed by Zohar (1980) and whether these factors predict Self-Reported Errors (Err_self). This aim was examined under Hypotheses 11 and 12.

5.7.1. Hypothesis 11

Factor analysis of the Safety Culture Measure (SCM) developed for this research will show an eight-factor structure similar to Zohar's measure on which it was based.

5.7.1.1. Factor analysis of the Safety Culture Measure (OCM)

Factor analysis, using principal axis method, was performed on the 49 items within the Safety Culture Measure; there were no significant outliers. The sample size (520) and the variable numbers (49) represent a ratio of 10.6:1, which should generate a stable multivariate solution. The correlation matrix was examined and showed reasonable correlations among variables, indicating that the items in the measure were related to each other.

Four factors were extracted initially based on an Eigenvalue set to 1. However, examination of the Eigenvalues (see Table 40) and scree plot (see Figure 22) suggested that a three-factor structure was more appropriate, accounting for 42% of the variance. The factor analysis was re-run with the number of factors set to three.

Table 40: Eigenvalues from the principal axis factoring of the Safety Culture Measure.

Factor	Eigenvalue	Variance % of Total	Cumulative Eigenvalue	Cumulative %
1	16.00	32.65	16.00	32.65
2	3.09	6.31	19.09	38.96
3	1.35	2.77	20.45	41.73
4	1.04	2.13	21.49	43.86

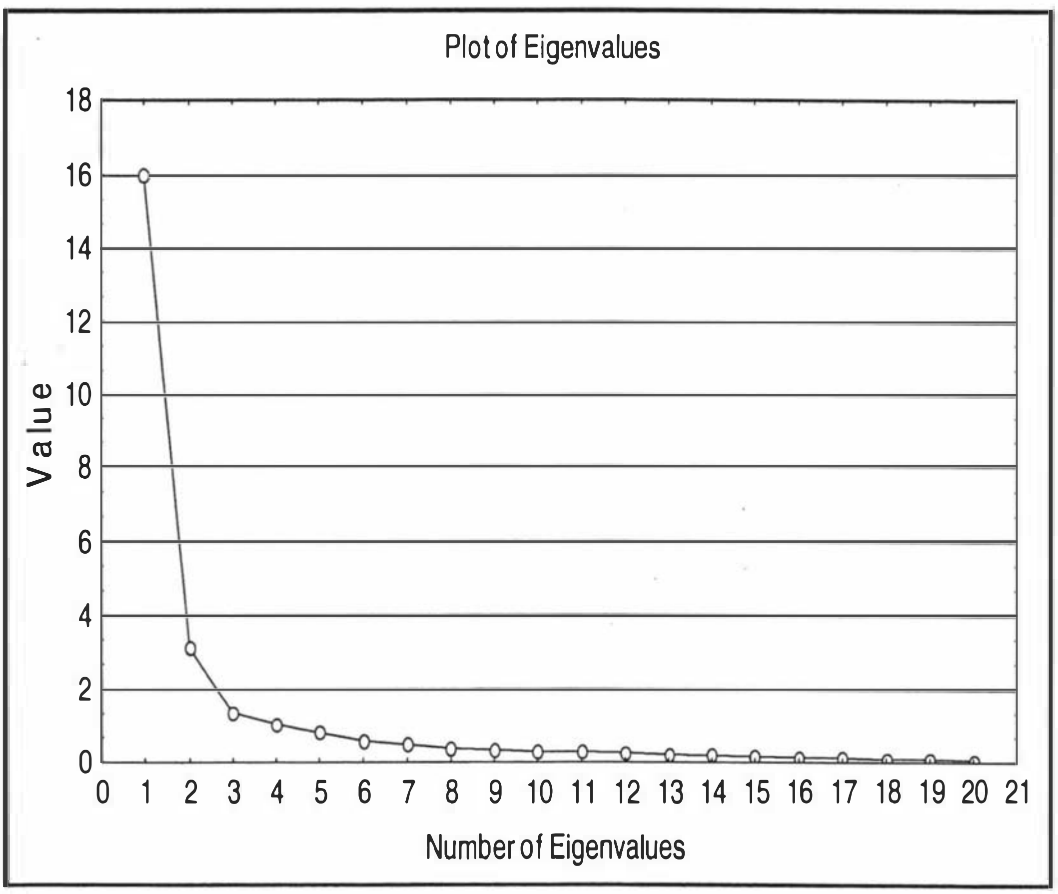

Figure 22: Eigenvalues from the principal axis factoring of the Safety Culture Measure.

A factor matrix was generated using a varimax-normalised procedure aimed at maximising the variances of normalised factor loadings across variables for each factor. This was equivalent to maximising the variances in the columns of the matrix of normalised factor loadings. The factor matrix generated is shown in Appendix K (p. 339).

Examination of Table 41 shows the items loading on the three factors and a description of each factor. The factor definitions were based on items loading in excess of .5 on a factor. The three factors have been subject to an orthogonal rotation and were therefore independent of each other. The Cronbach's α values obtained were high, indicating good internal consistency. The structure emphasises managerial action and involvement in safety, management investment in safety, appreciation of safety generally and safety behaviour, including the importance of safety training.

Hypothesis 11 was not supported. One main factor and two lesser factors were generated. Factor 1 was similar to one of Zohar's factors (perceived management attitude toward safety; Zohar, 1980).

Table 41: Description of factors extracted from the principal axis factoring of the Safety Culture Measure.

Factor	Cronbach's α	Item Numbers	Description of the factor
Factor 1 Managerial willingness to address safety issues	.96	25 items 6 7 10 11 14 16 17 20 22 24 25 30 32 35 36 39 40 41 42 43 44 45 46 48 49	Factor 1 generally relates to the existence of formal procedures, priorities, quality standards and action by management to safety concerns, safety behaviours and awareness of safety issues.
Factor 2 Appreciation of the importance of safety	.80	5 items 8 9 12 23 26	Factor 2 relates to appreciation of the importance of safety.
Factor 3 Safety behaviour of individuals	.71	4 items 4 18 29 34	Factor 3 relates to the behaviour of individuals in relation to safety issues, such as training, and behaviour at work.
Total		34 items	The items contained in the measure are shown in Appendix A (p. 227).

5.7.2. Hypothesis 12

The factors obtained from the analysis of the Safety Culture Measure will predict variance in Self-Reported Errors (Err_self) in Organisation 7.

5.7.2.1. Multiple regression of the principal factors of the Safety Culture Measure onto Self-Reported Errors (Err_self)

A forward stepwise multiple regression was performed. The independent variables were Factors 1–3 and the dependent variable was the Self-Reported Errors (Err_self) from Organisation 7. One hundred and sixteen cases were selected for inclusion in the analysis based on a participant reporting an error rate of greater than zero.

The F to enter probability level was set to p =.1. Factors 1 and 2 were significant. The results of the multiple regression were R = .30, R^2= .09, $F(3,112)$ = 3.79 (p < .01) (see Table 42). The independent variables explain 9% of the variance in the dependent variable. Examination of residuals revealed two scores in excess of three standard deviations. Removal of these extreme cases did not change the model.

Table 42: Multiple regression of the principal factors extracted onto the Self-Reported Errors (Err_self) in Organisation 7; only significant factors are shown.

Factor	B	*p*-level
Intercept	7.93	.001
Factor 1	−3.08	.010
Factor 2	1.97	.090

The partial correlations (see Table 43) indicate that Factor 1 explains 6.25% unique variance and Factor 2 explains 2.6% unique variance in the number of Self-Reported Errors (Err_self).

Table 43: Partial correlations for Factors 1 and 2 with Self-Reported Errors (Err_self) in Organisation 7.

Factor	Partial correlation	*p*-level
Factor 1	−.25	.01
Factor 2	.16	.09

Hypothesis 12 was supported; three factors predict 9% of the variance in the Self-Reported Errors (Err_self) in Organisation 7. These Factors were Factor 1, Managerial willingness to address safety issues and Factor 2, Appreciation of the importance of safety; and Factor 3, Safety behaviour of individuals. Where management was perceived as more willing to address safety issues, the frequency of Self-Reported Errors (Err_self) decreases, where the appreciation of the importance of safety issues increases, the frequency of Self-Reported Errors increases. This rather curious result is discussed later (see Section 6.3.2 p. 198)

5.7.3. Summary: Aim 6

The Safety Culture Measure has a three-factor structure similar to that found by Brown and Holmes (1986), whose work was based on the Zohar measure. It has one main factor and three smaller factors; these predict Self-Reported Errors (Err_self) in Organisation 7.

5.8. Main findings from the research.

This section summarises the main findings from the research.

A total of 291 human error failure types were found on the database. Organisation Failure represented the most common category. The classifications; Primarily structural/mechanical, Inadequate specifications/requirements, Inadequate checking, Procedure not followed, Poor procedures, Inadequate control and monitoring, Inappropriate goals or policies, Inadequate communications, and Poor procedure (action) were the most common human error cause codes.

In organisations reporting higher frequencies of organisational errors (Error Frequency Index), there is a suggestion that there were higher levels of perceived safety. This effect is most noticeable and significant in the data from smaller organisations. There is a suggestion that higher frequencies of organisational errors were associated with a reduction in the managers' perceived levels of safety, as indicated on the Managers' Self-Report General Failure Types. Curiously, this higher frequency of organisational error was not associated with higher safety levels on the Safety Index Measure. The low number of cases on which these analyses are based are suggestive, rather than persuasive of relationships among the variables and reliance in the content validity in the measures is required, at this early stage in their development, if any tentative conclusions are to be made.

The Organisational Culture Measure and Safety Culture Measure showed high levels of internal consistency. The factor analyses do not support the original structures proposed for these measures.

There is a suggestion in the data that the aviation maintenance organisations demonstrate a degree of organisational culture homogeneity.

The Organisational and Safety Culture Measures (OCM/SCM) discriminated between organisations with different safety levels (Summed Safety Rank). The results indicate that Power, Compliance, and Performance orientation were present in safer organisations; this suggests that 'control over behaviour related to safety' is higher in 'safer' organisations.

The models generated by the factor analyses of the Organisational and Safety Culture Measure are likely to be unstable because of the case-to-variable ratio (Tabachnick and Fidell, 1989). For this reason, the original sub-scales from the Organisational Culture and the Safety Culture Measure were used in the discriminant function analysis of the safety groups. The internal consistency statistics were used to justify this practice.

With respect to the multivariate analyses performed, overfitting of the data remains a possibility when the case-to-variable ratio is low. Generally, the limit for this kind of analysis is 5:1 (Tabachnick and Fidell, 1989). The case to variable ratio and the limitations it places on the interpretation of the data are within acceptable limits for exploratory research of this type.[52]

[52] Good scientific practice dictates that where a statistical procedure is used then the probability levels should be within acceptable limits and the procedures used should be appropriate. Where these limits are reached, or where an analytic procedure is used in a manner that is at the limits of its conditions for a stable solution, then attention was drawn to this. The alternative was to use only descriptive statistics. It was accepted in the writing of the interpretation of these results that the comments and conclusions are circumspect and absolute confidence in them would require further corroboration.

Chapter 6. Discussion

IN REVIEWING THE RESULTS within the context of the aims and hypotheses provided in Chapter 2, section 2.4, it became apparent that there where two main areas of the research that should be discussed. The first concerns the research process (what was planned and what actually happened), the various issues that surrounded the data collection in aviation maintenance environments, and the 'lessons learnt'. The second concerns the outcome of the data analyses, what the results showed and their implications for future research and the management of aviation maintenance error. Within this second area were four themes. The first three relate directly to Figure 11 (p. 63), first described in Chapter 2.

1. The Safety Behaviours/Indicators (SB) that exist in aviation maintenance organisations; as measured by the errors contained on the CAANZ (Error Frequency Index (EFI)), the Safety Index Measure (SIM), the Managers' Self-Report General Failure Types (FTman), and the Self-Report Error Measure (Err_self).
2. The Organisational Culture (OC) and Safety Culture (SC) that exists in aviation maintenance organisation as measured by the Organisational Culture Measure (OCM) and the Safety Culture Measure (SCM).
3. The relationships that exist between the various components listed in 1 and 2 above.

The remaining theme concerned.

4. The implications for future research and the aviation maintenance industry.

6.1. What was planned and what actually happened

The resources available for this research placed limitations on the amount of travel, access to organisations, and methods that were available. For this research, a questionnaire approach was a practical way to gain access to the participants who were scattered geographically throughout New Zealand and who were generally working within a 24-hour shift structure. The Pilot study in the oil industry represented a major study in its own right and involved liaison and meetings with senior people in that organisation over several months prior to data collection. Similarly, the main study involved much correspondence and a number of liaison meetings prior to the fieldwork taking place. It was apparent, from this preliminary work that both oil and aviation industry employees were wary of an outside study that was investigating safety in their organisations. Notwithstanding these challenges, the industry co-operation was generally good and resistance, where it was encountered, was usually related to resource limitations that prevented involvement.

As is sometimes the case with applied research, practical considerations caused a change in focus of the work from the time of its inception to its completion. These changes were required because of factors that were not possible to foresee and that were beyond the control of the researcher. They caused some major transformations in the manner in which the work proceeded and help to illustrate, in a qualitative way, the nature of the aviation maintenance industry and its approach/attitude to error and safety.

With hindsight, the intention to perform three data collections within seven separate maintenance organisations, all of which were involved in air transport operations, was too ambitious for the time frame and resources available within the research programme. The time required to forge relationships, set up agreements, and the conflicting and fluctuating demands on the organisations, made access to this data more challenging than anticipated. The generally well-intended individuals from the organisations involved were unable to resource the research to the level that would have improved the quality of the data. Whilst many of the individuals involved saw value in such work, the commitment and time required proved to be a deterrent and some organisations chose not to be involved, or, once they had become involved, experienced difficulty in providing data.[53] An additional unforeseen difficulty was the intensity of supervision and follow-up required by the researcher, to ensure that data were delivered, while he was working part-time within the Ph.D. programme, and where he was distant geographically from the research sites.

The use of a smaller number of organisations had been considered, potentially allowing the researcher to spend more time to help the organisations set up error collection processes. Potentially this would have provided more complete data but with a smaller sample of organisations. It would have exposed the research to the risk of a very limited data set if these organisations had been unable to provide the information required or if they had withdrawn support for the study. A decision was taken to use seven organisations, representing more adequately the range of maintenance organisations in New Zealand, and decreasing the risk of obtaining no data.

During the data analyses, the researcher was forced to make some compromises on what might be considered a truly scientific approach. A major limiting factor was the lack of availability of larger aviation maintenance organisations in New Zealand for statistical significance to be achieved within multivariate analyses. This was further compounded by the poor response rate from the participants. The small sample sizes that were available for analysis did not permit the probability level of 0.05 to be used universally in the analyses. Strict adherence to the 0.05 criterion would have required some of the results to be ignored altogether.

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[53] The researcher requested a meeting with senior members of the Department of Psychology at Massey University subsequent to the withdrawal of the largest organisation from the study. During this meeting he expressed concerns over the data quantity and quality (no detailed error data had been forthcoming). This meeting resolved that the research should proceed if the large organisation could be re-engaged and the CAANZ database used. This was achieved and the research continued (see Appendix I p. 321).

6.2. Safety Behaviour (SB) and the nature of error in aviation maintenance

At the outset of this study, it had been anticipated that the error data available from industry would be richer and greater in quantity. The Maintenance Error Recording Notice/Maintenance Error Investigation Notice (MERN/MEIN) and the Maintenance Error Incident Analysis (MEIA) tools had been developed to provide information on the qualitative nature of errors and whilst the people within the organisations saw merit in the information such tools might provide, the resources required to carry out such investigations were considered too great. This characteristic probably represents a significant source of bias in the data; ("the bias of what is not reported", Chappell, 1994, p. 154) but is not entirely without precedent. In a study lasting nine months, involving eight domestic and international airlines using Maintenance Error Decision Aid (MEDA), only 74 completed reports were returned (Rankin et al., 2000)[54], these contained 250 contributing factors (3.4 factors per report).

Results such as these indicate that organisations are not able to produce error reports for anything other than the more obvious, or serious, maintenance errors and this may be a reflection on the level of resources and training required to collect this type of information. Of course, other factors such as the existence of blame cultures (Johnston, 1992b, 1993), the lack of an immunity policy (Rankin & Allen, 1995), and perceived attitudes of management to safety and error within the organisations, are also likely to affect error reporting (Reason, 1998). The anecdotal evidence extracted from conversations with personnel within the industry suggested to the researcher that, whilst the identification and reduction of error was regarded by the industry as desirable, such error was an unfortunate and inevitable 'cost' of doing business. From the researcher's perspective, the hidden costs of error seemed not to be fully appreciated, though one of the organisations in the study had initiated a maintenance re-work cost-evaluation programme.

54 Since this present research was completed, Rankin et al. (2000) have reported that around 40 airlines are now using the MEDA system.

Marx (1998) has also identified this form of institutional resistance in a report to the Federal Aviation Administration:

> "The problem today is one of the chicken and the egg. Maintenance error cannot be quantifiably managed unless the culture and systems are put in place to collect the data from which productive and quantifiable prevention strategies will spring. Yet error management systems will not be put in place until business managers can be convinced of the savings." (p. 55).

Marx further suggests that the technologies for the assessment of aviation maintenance error are sufficiently developed but that annually the United States aviation industry continues to dispatch some 48,000 commercial aircraft in a technically un-airworthy condition, induced by maintenance error. "It is this population of data, if properly investigated and analysed, which can provide the basis for quantifiable maintenance error management programs." (Marx, 1998, p. 55.)

It had been expected by the researcher that the then newly implemented CAANZ database would also provide an alternative source of human error data; the paucity of this data could not have been known in advance. More complete error data would have allowed a greater understanding of the human factor errors that were occurring in aviation maintenance, and the research could have concentrated on a more in-depth error analysis relating it to the organisational and safety culture data. There was to have been a more detailed analysis of the patterns and nature of error as this related to the organisations involved. However, the data obtained were limited in quantity and the focus of the research changed, a greater emphasis was placed on the data provided by the other measures such as the safety indices. These were untested measures and this represented something of a gamble, the risk being that no useful data would be generated. This was not the case but generally these data did not provide strong effects and it is perhaps premature to have a high degree confidence in some of the findings.

Examination of the frequency of human error failure types on the CAANZ database identified 291 occurrences with a human factors cause code.[55] This figure was much lower than had been anticipated by the researcher at the outset of the research and there was anecdotal evidence that it was understating the true error rate due to under-reporting in the industry and difficulties in classifying the error data to the database (Civil Aviation Authority of New Zealand, personal communication, 1998). The CAANZ had, at that time, only recently trained their investigation personnel in the use of the database and this was perhaps one reason for the lower than expected number of occurrences coded.

The researcher's personal involvement in the training of the investigation personnel indicated that they were experiencing problems in classifying the errors in a timely and reliable fashion. Considerable debate took place during training sessions on what was, or was not, a material error and hence some variety in the quality of the database undoubtedly exists. Two possible reasons are suggested for this variety. First, defining when an error has occurred was less clear for investigators than one might expect; this may be a function of the terms of reference of an individual. For example, someone from an engineering background is likely to interpret the sequence of events leading to an incident in a different way than a psychologist might. This is likely to change the nature of the information (whether, who, and what) that is reported following an error event (Chappell, 1994). Second, in discussion with personnel using the database, it became clear that whilst one person may perceive behaviour A as the most salient in an error sequence, another person might perceive it to be behaviour B.

55 The term 'occurrence' is used here in the technical sense described by the Civil Aviation Authority of New Zealand and is defined as: any event notified that has a safety-related consideration.

Other research in the aviation arena has reported similar challenges to capturing and classifying error data. The Bureau of Air Safety Investigation (1997) present a similar conclusion in an analysis of the frequency of errors reported in maintenance incident reports "the reliability of coding between the two coders was low" (p. 17). In a research study using HERA (Human Error in Air Traffic Management Technique), in which participants were required to use an error taxonomy, the researchers decided to pre-identify the error events for the persons classifying the errors because, during a trial of the technique:

> "disagreement was detected among subjects; it could not be determined whether this was due to different ways of applying HERA to the same error cause codes or that the analysts were focussing on different events or errors within the same incident report"(EUROCONTROL, 2001, p. 7).

It was not possible to pre-identify errors within the 'live' database, merely for this current research purpose. This research required the use of 'real' data rather than artificial error data generated for the purpose of testing agreement within a taxonomy.

It had been anticipated by individuals within the CAANZ that some common terms of reference would be developed by which errors would be coded to the CAANZ database. There seemed to be an expectation that, as experience with the database increased and follow-up training was completed, more confidence could be placed in the database (Civil Aviation Authority of New Zealand, personal communication, 1996). The researcher did not share this view and considered such an approach insufficiently rigorous. He suggested to the CAANZ that it should implement some inter- and intra-observer measure of agreement that would determine the consistency of use of the error taxonomy and hence the validity and reliability of the human error data held on the database. Should this be achieved, then a greater degree of confidence might be placed in the database and a 'truer' system of error measurement may be said to be in place (Carver, 1978). As Chappell (1994) has indicated, "If large numbers of *independent* reports on a topic are available, it is reasonable to assume that consistently reported aspects are true", italics added by author (p. 154). The researcher was not aware of his suggestion being implemented but considers it important if the CAANZ is to have confidence in its error database.

As a final comment on error classification systems, it should be noted that error taxonomies and investigation techniques may become unstable as technologies develop and new ways of understanding error are devised. This represents something of a challenge if archival data is to be used subsequently and represents a potential threat to longitudinal studies.

Despite the difficulties in obtaining quality error data and the question over how reliable this data is, an analysis of the errors from the CAANZ database indicates that the use of the Latent Failure Model (Reason, 1992, 1995, 1997) as a framework for the investigation and classifying of human error is logistically possible. Individuals can grasp its theoretical underpinnings and the frequencies of error codes used within the classes available indicates that users of the database can code to the three main classes, Organisational Failure Type, Local Error/Violation, and Active Failure. A similar framework, based on the Latent Failure Model, has also been applied to an aviation error classification system in Australia (Bureau of Air Safety Investigation, 1997).

The most frequently used category of failure on the database is Organisational Failure Type (General Failure Types) with Active Failure a close second (the Local Error and Local Violation categories were used at half the frequency of these).

The high frequency of causes coded within the Active Failure category might be explained by their immediacy to the adverse effect that they cause (Reason, 1997). Such failures are often the actions of individuals, performed in the execution of the job, and may be considered a more traditional cause attribution. Akin to 'pilot error', they are often impossible to predict but are often easy to detect in hindsight, mainly because the person performing the error was the last person in the chain of events that led to the error being observed. At the local level (level of the hangar floor) inadequate checking, risk misperception, poor instructions and procedures were major error causes.

'Primarily structural and mechanical' was the most commonly used error cause code within the human factors part of the database. Strictly speaking, this does not seem to be a human factors failing. In discussions with the database designers, the researcher established that this cause code was included so that investigators would have an option to code an error that could not be ascribed to an individual, or part of the organisation. An example would be an error that had been introduced from some external source, the nature of which could not be established in the investigation process (R. White, personal communication, 1997).

Possible explanations for Organisational Failure Type being the most frequent category used are: (1) it is the most prevalent; (2) the CAANZ has placed and increasing emphasis on investigating organisational factors and causes in the aetiology of occurrences, incidents, and accidents; (3) the Latent Failure Model has been recently introduced into investigator training; this also has a systems/organisational emphasis (Civil Aviation Authority of New Zealand, personal communication, 1995). To determine relative influences of each of the above would require a detailed analyses of the decision making process investigators use to classify error and some form of inter-observer agreement being made. In this way, some of the subjective bias may be determined.

Within the category Organisational Failure Type, examination of the cause codes on the database indicates that inappropriate goals, poor communications, control and monitoring, poor procedures, and inadequate specifications were the most frequent error causes identified. This is not surprising; the literature has suggested that where information exchange is problematic, for example, where communication is low, the opacity of the organisation is likely to be high and thus the risk of unknown error states developing will also be high (Cox & Cheyne, 1995; Perrow, 1983, 1984). As Westrum (1993) has indicated, generative organisations encourage the transmission of information, which leads to high reliability; this in turn is likely to lead to higher levels of safety. In contrast, bureaucratic organisations, where messages may be listened to but rarely acted on, or pathological organisations, where denial is common and messages are actively suppressed, are likely to exhibit lower levels of safety. Degani and Wiener (1994) also suggest the necessity for congruency of expectation and good communications throughout organisations as a prerequisite for safe and efficient organisations, whereby the outputs will only meet management expectations if the philosophy, policies, procedures, and practices are communicated well and commonly held by the workforce.

Errors related to procedures, either the writing-of or the execution-of, were relatively frequent at 15% (see Table 13, p. 132). When the cause codes Inadequate specifications/requirements, Inadequate control and monitoring, Inadequate communications, and Inadequate checking (all of which may be considered to be related to procedures or their execution) are added to this figure, then the level jumps to around 44%. Similarly high levels of procedurally related error have been found in other research from the aviation industry. Results from a study at the Bureau of Air Safety Investigation (Bureau of Air Safety Investigation, 1997) showed that 'Procedures' was the most frequent organisational factor contributing to airworthiness events (32%); the Bureau's taxonomy is similar to the CAANZ's and is also based on the Latent Failure Model (Reason, 1991). A NASA study of 102 aviation maintenance-related safety reports, filed between 1986 and 1992, found 60% of errors to be related to procedures (Kanki et al., 1998).

It would seem that procedurally related actions are a relatively common cause of errors in both operational and maintenance settings. This is to be expected given the commonly held belief in flight-operations-environments that, compliance with 'standard operational procedures' leads to more effective and safer operations (Degani & Wiener, 1994). The results from this research would indicate that effort should be directed to the implementation of more adequate and greater compliance with procedures.

Communication also features as a relatively frequent error cause within the Organisational Failure Type category in this research. Rankin et al. (2000) and Lee (1998) also found this to be the case. However, caution must be exercised in making such comparisons without detailed knowledge of the error codes used within such classification systems. Published research does not always contain sufficient detail; the labels for error codes may suggest similar causes but may not actually represent the same behavioural events. For example, within the CAANZ database, the Authority had defined the Organisational Failure Type cause codes and O'Hare et al. (1994) had provided a method of arriving at definitions for the Active Failures class, but the meaning of the Local Error and Local Violation cause codes was left to the interpretation of the investigator.

6.2.1. Error Frequency and safety behaviour in aviation maintenance organisations in New Zealand

The Error Frequency Index correlated negatively with the Managers' Self-Report General Failure Types (FTman), indicating that high organisational error reporting is associated with higher levels of safety, as perceived by the managers and perhaps indicating greater confidence in the safety of the organisation's systems.[56]

The Error Frequency Index has a positive correlation with the Safety Culture Measure, supporting the suggestion that high error reporting was associated with higher perceived safety. The increase in the observed correlation, which became statistically significant when Organisation 7 was excluded from the analysis, strengthens this position (for smaller organisations) and perhaps helps to resolve the paradox between error reporting and error frequency. This result also indicates that safety is either higher or perhaps more transparent to the members of smaller organisations; Organisation 7 was considerably larger than the other organisations. Similarly, Edkins and Coakes (1998), in an analysis of safety culture within airlines in Australia, report that airlines operating smaller aircraft (fewer than ten seats) also have a better safety culture than those operating larger aircraft. This may seem perplexing to individuals working within the industry in New Zealand where there seems to be a perception that the larger operators are safer. It is possible that the reality differs from the commonly held belief. Alternatively, it is conceivable that the smaller organisations merely 'think'/perceive themselves as more safe when in reality they are not. This would agree with the result from Organisation 7, where higher levels of self-reported

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[56] Low scores on the FTman indicate higher safety.

errors were associated with low perceived safety. Such a conclusion would challenge the suggestion, in the organisationally reported error data, that high error reporting equates to high safety, as one would be required to assume that the perception of high safety in the smaller organisations was a delusion. If smaller organisations indeed perceive themselves to be safer than they actually are, then action may be required to demonstrate this to the employees, and educate them about the true error rates and observed safety behaviours in their organisation.

It had been predicted that the Error Frequency Index would correlate positively with the Safety Index Measure (Hypothesis 1). Unfortunately, the negative correlation observed casts some doubt on the suggestion that high reporting by organisations is associated with higher safety. This is difficult to explain in the context of the results described above. It is possible that the Safety Index Measure was not assessing the same elements of safety as the Safety Culture Measure and the Managers' Self-Report General Failure Types, both of which are perception-type measures, whereas the Safety Index Measure contains observable indicators of safety. Mearns and Flin (1999) raised a similar issue in a review of the concepts of safety culture and climate by suggesting that the perceptual/attitudinal aspects of safety may not always be congruent with the reality, and organisations may appear safe on the surface when the underlying behaviours supporting the cultures are unsafe. Similarly, Vaughan (1990) has also suggested that the judgement about risk and safety is made according to the social, as well as the technical environment, which can lead to objectively less safe behaviours being performed, but accepted as safe, because such behaviours become institutionally normalised as acceptable. Turner (1978) has expressed the similar opinion that accidents and disasters can arise from the incubation of errors which are at odds with the perceived assumptions that an organisation is safe. It is also conceivable that the so-called 'observable indicators' of safety are not good indicators at all and that organisations that 'look good' may not be safe, and visa versa. Intuitively this may seem unlikely, but the conflicting results among the correlations found for this research indicate that refinement and further validation of the measures is required.

6.3. Organisational and Safety Culture in aviation maintenance organisations

Within the organisations, the response rate to the Organisational Culture Measure and Safety Culture Measure was 22% and the range 13–88%. This was considered disappointing and the range variation may be a reflection of the size of the organisations. Generally, the smaller maintenance organisations had a higher return rate. This might be explained by the relative ease with which participants could be prompted to return questionnaires in the smaller organisations, although numerous telephone calls were made to achieve this. With hindsight, shorter measures may have improved the quantity of data returned. The potential content of such shortened measures is indicated by the items within the sub-scales that posses the highest internal consistency and associations with other safety indicators. This is discussed in more detail in the pages that follow.

Because of the low number of questionnaire returns, the case-to-variable ratio represented a challenge to the multivariate analyses that were performed. Generally, the multivariate models generated for the Organisational Culture Measure and Safety Culture Measure have to be considered marginally stable; this is particularly the case for the factor analytic-based analyses. The planned repeated measures would have allowed greater confidence in these if similar factor structures had been found in subsequent administrations.

The sub-scales of the Organisational Culture Measure show good internal consistency (none were below a Cronbach's α of .67). The Cronbach's α obtained for the Safety Culture Measure was .95. These results lend support to the internal reliability and, to a degree, the construct validity of the sub-scales of the two measures and some permitted some confidence in the examination of the related profiles.

6.3.1. Organisational Culture

The organisations in the study appeared to show some degree of homogeneity and a shared culture across the industry (Hypothesis 5). This is concordant with the suggestion of O'Reilly et al. (1991) that organisational cultures tend to be similar within organisations involved in similar activity, and that organisational culture varies "more across industries than within them" (Chatman & Jehn, 1994, p. 522). The validity and degree of homogeneity cannot be ascertained with authority from these data alone; a comparative study of other industry group profiles would be required for this. Additionally, the use of visual inspection as a means to determine cultural characteristics may be criticised for its lack of scientific rigour; however, the relative shape of the profiles provides useful information that would not be available from a mere inspection of the means. Visual inspection of the profiles shows clusters of points (see Figure 19, p. 145). For example, the sub-scale 'Performance orientation' shows a cluster of scores around the value 5. This would seem to indicate that a number of the organisations perceive that the emphasis on performance was reasonably high. Similarly, the trough in the graph for the sub-scale 'Rewards orientation' would seem to indicate that the industry employees do not feel rewarded in their work.

The suggestion of homogeneity implies that methods to promote safety may be generally applied across the industry with some expectation of success. The result that the organisational cultures within this industry group were low in 'Avoidance orientation' and high in 'Compliance orientation' (see, Figure 19, p. 145) suggests that safety interventions, in the form of rules or directives that explicitly state the actions to be taken to improve safety, might be a useful strategy to increase safety in maintenance organisations. Organisations receiving this information are likely to act because they are low in avoidance and high in compliance. Such a finding has implications for a deregulated industry where such rules and directives are less likely to be generated by the regulating body, such as a Civil Aviation Authority.

At the risk of being overly cautious, care must also be exercised where an analysis of organisational and safety culture suggests areas into which management might direct safety efforts. Interventions may create complex interactions between the dimensions of organisational culture that potentially change the cultural dynamic, which may lead to deterioration in safety performance. Similarly, Williams (1991) suggests that even where safety behaviour and cultural change is synchronous, to establish a causal relationship is another matter. Other corroborating indicators may be required before safety interventions are made and an organisation's safety performance may only be indirectly related to organisational culture and may be more directly related to the organisation's emphasis on quality generally.

One of the smaller maintenance organisations (Organisation 4) scored lowest, or joint lowest, on a large number of Organisational Culture Measure sub-scales and on the Safety Culture Measure (see Figure 19, p. 145). The culture of this organisation might be described as low in perceived safety, initiative, caution, performance, planning, power, achievement, rewards orientation, positive morale, autonomy, self-expression, and personal growth. Additionally, compliance with rules orientation was lower, with fewer relationships to the outside environment, and poorer leadership and structure relative to other organisations in the study. The lower scores observed for these sub-scales, including perceived safety (Safety Culture Measure), and the high score for Avoidance orientation for this organisation is interesting and lends support to the literature regarding what constitutes a safer organisation. For example, it has been suggested that safer organisations are those in which management takes an interest in safety issues, and where reflexivity (learning) (Westrum, 1993), and requisite variety are present (Reason, 1997) (as measured by autonomy and work diversity in this study). Further investigation of Organisation 4 might have revealed whether this low scoring profile indicates that the organisation is carrying an unacceptable safety risk. The use of qualitative methods, interview, and observation, could be used to obtain this more detailed picture of the culture that existed in this organisation (Schein, 1990).[57] Although this was not possible within the constraints of this research, a combined quantitative and qualitative approach is likely to provide a more compelling and richer understanding of organisations. Such an approach will also provide increased validity and reliability for both methods. Importantly, the approaches used in this research have allowed the identification of areas of organisational culture where more detailed examination is indicated.

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[57] Anecdotally, this was the organisation in which the initial collection of the data was actively sabotaged by the contracted member of staff who was later dismissed.

The 20 sub-scale structure of the Organisational Culture Measure was challenged by the factor analysis. Distinct sub-scales may exist within this measure, but the factor analysis suggested that these may be broader than proposed by the original design (one major factor and five secondary factors were determined). With hindsight, it would have been beneficial to have attempted a reduction of the number of items within the measure prior to its use within aviation environments. This would have generated two potential benefits. It would have increased the case-to-variable ratio, potentially generating a more stable factor structure, and may have increased the likelihood of participants being amenable to providing a repeated measure. Still, at worst this finding represents a useful pointer for future research.

6.3.2. Safety culture

Factor analysis of the Safety Culture Measure generated a three-factor structure. Factor 1 may be described as managerial willingness to address safety issues, Factor 2 as the appreciation of the importance of safety, and Factor 3 as the perceived safety behaviour of individuals. These findings have some overlap with the work of both Brown and Holmes (1986) and Edkins and Coakes (1998). Brown and Holmes (1986) also identified three factors: (1) employees' perception of management's concern for their welfare, (2) employees' perception of how active the managers are in the area of safety (these two factors are similar to Factors 1 and 2 in the present research), and (3) employees' risk perception (see Table 8, p. 108). Edkins and Coakes (1998) administered a 25-item safety culture measure to 150 regional airline employees, followed by a refined 10-item measure to 642 employees. Factor analysis of their data showed a predominance of one factor that they claimed was related to safety information and another related to safety reporting. Examination of the item content in this factor, and the factors generated by this present research, shows similar item content in both studies, reflecting 'action by management', 'safety behaviours', and 'awareness of safety'.

The structure and content of the factors in this research also indicate the predominance of one factor accounting for most of the variance (managerial willingness to address safety issues). This factor is related to procedures, priorities, quality, safety concerns, awareness, and action by management. The two lesser factors relate to appreciation (how valued safety is) and the safety behaviour of the individual. As these factors are orthogonal, it can be surmised that safety has a two private components, appreciation-of (that is distinct from a mere awareness-of safety), and behaviour-related-to, safety. These results also suggests that awareness of safety issues may considered to be different to appreciation of safety issues.

Multiple regression of the three factors from the Safety Culture Measures onto Self-Reported Errors generates the following picture. As 'managerial willingness to address safety issues increases', self-reported error (Err_self) decreases. This can be explained by the managers' actions causing a decrease in the actual number of errors generated. In addition, as the 'appreciation of safety issues increases', so does the self-reported errors. This can be explained by increasing the appreciation of ones own errors, leading to higher levels of reporting. These findings are consistent with research conducted in a regional airline in Australia. This suggested that organisations that were sensitive to their errors may be considered safer (Edkins et al., 1997). The result from this factor analysis and regression is also supportive of the research that suggests that managerial commitment to safety is an important factor in safe organisations (Cheyne et al., 1998; Cohen, 1977; Edkins & Coakes, 1998; Eiff & Lopp, 1998; Glennon, 1980; Lautman & Gallimore, 1987; Pidgeon, 1998; Zohar, 1980).

There would seem to be an increasing amount of evidence, supported by this present research, that managerial involvement / engagement and the presence of safety information are integral features of safety culture.

6.4. Relationships that exist between Organisational Culture (OC), Safety Culture (SC), and Safety Behaviour/Indicators (SB)

The safety ranks assigned to the six aviation maintenance organisations do not follow a pattern based on the size of the organisation. In addition, it can also be argued that there was no way of determining whether a material difference among the ranks exists, for example, the difference between a summed-rank of 12 for Organisation 1 and 13 for Organisation 5. Nevertheless, splitting the organisations into high, low, and medium safety groupings, based on rank, was considered a sufficiently objective/actuarial-based approach.

The use of multiple indices represented an attempt to produce a less biased (generic) index of safety. The use of a single index could only have been considered if it had been shown to be a more valid and reliable measure of safety level than the multiple indices. At this stage in the development of the measures it was not possible to make this claim.

The classification results indicate that the sub-scales of the Organisational Culture Measure and the Safety Culture Measure were most successful in discriminating medium safety organisations and were least sensitive for high safety organisations (see Table 26, p.160). None of the medium and low safety cases were incorrectly classified into the high safety classification. This may indicate the conservative nature of the measures; they do not easily indicate a high safety classification. The measures are able to classify maintenance organisations to a level of accuracy 15% above that expected by chance alone.

Table 44 is provided to assist in the interpretation of the range of statistically significant findings which were determined.

Table 44: Sub-scales of the Organisational Culture Measure and the Safety Culture Measures (SCM) and their relationship to safety indicators ($p < .05$).

Sub-scale	Discriminates safety groups High, Medium, and Low	Contributing to multiple regression onto SCM	OCM sub-scales Pearson's r with SCM
Compliance	☼	☼	.61
Planning		☼	.60
Leadership		☼	.60
Passion	☼		.59
Relationship		☼	.57
Self-expression			.56
Co-operation	☼		.56
Communication	☼		.55
Morale			.53
Achievement		☼	.53
Structure		☼	.52
Rewards	☼	☼	.50
Performance	☼		.50
Initiative			.48
Autonomy			.46
Caution			.44
Personal			.38
Work diversity			.29
Power	☼	☼	–.11
Avoidance			–.34
SCM	☼		N/A

The discriminant function performed on the Organisational Culture Measure sub-scales and Safety Culture Measure, predicting safety group, produced a model whereby 21% of the variance used to assign cases to the three safety groups (low, medium, and high) was explained (Hypothesis 8). The first discriminant function (see Table 24 and Table 25, p. 158) suggested that 'control over behaviour', as evidenced by the Power orientation and Compliance orientation, was present in higher safety organisations and should be encouraged. This is counter to the suggestions of Helmreich and Merritt (1998) that lower power distance (lower autocracy) provides for safer flight operations, though of course safe maintenance environments may have very different characteristics from those found on the flight deck. These areas of cultural difference and influence merit further investigation. Function 1 is also positively associated with perceived level of safety. Seemingly paradoxically, Co-operation orientation suggested a mildly negative association to Function 1 (though this may be unstable, $r = -.12$) and a negative association with Function 2 (see Table 24 and Table 25, p.158). Conceivably, where co-operation is perceived as low, then there is a necessity for power and control to be exercised, to provide higher levels of safety.

The discriminant analyses of the Organisational Culture Measure sub-scales and the Safety Culture Measure, predicting safety group, has also suggested areas of organisational culture that might provide proactive information on 'at risk' organisations. What was not so clear was why some of the other sub-scales do not also contribute, for example, 'Degree of structure' or 'Leadership orientation'. This might be expected, considering the generally high correlations observed between the sub-scales and the Safety Culture Measure (see Table 31, p. 167). Given larger sample sizes, more of the sub-scales might predict membership of the safety groups and the stability of the model could be tested. Additionally, further development of the safety indices, leading to refinement of safety rank, is likely to be beneficial.

Multiple regression of the Organisational Culture Measure sub-scales onto the Safety Culture Measure determined that the eight sub-scales (Compliance with rules orientation, Leadership orientation, Achievement orientation, Degree of structure, Rewards orientation, Relationship to outside environment, Power orientation, and Planning orientation) predict the perceived level of safety in an organisation's Safety Culture Measure score, supporting Hypothesis 9 (p. 166). The regression suggests that where Leadership orientation, Degree of structure, Power orientation, and Planning orientation is high, then this creates, or is at least associated with, an increase in the perceived levels of safety. Logically this might be expected, given the suggestion in the literature of the importance of managements' involvement in successful safety programmes. The observed association of perceived safety (Safety Culture Measure) with Compliance with rules does seem to contradict the assertion of Helmreich and Merritt (1998) that individualism improves safety within flight operations environments.[58] It may be explained by differences between the flight deck and maintenance environments, or that compliance results from autocracy (power and compliance) in organisations, which, Helmreich and Merritt (1998) also maintain, improve safety. The latter position seems credible in the light of the relationship between Power orientation and perceived safety that was observed from the discriminant function of the safety groups. The remaining sub-scales suggest the importance of what may be termed 'personally fulfilling factors' (Achievement orientation, Rewards orientation, and the relative importance of Relationships to outside organisations) in the development of higher levels of safety culture.

Bivariate correlations (Pearson's *r*) were performed on the sub-scales of the Organisational Culture Measure and the Safety Culture measure (see Table 31, p. 167). Whilst simple bivariate correlations are a less rigorous procedure for the interpretation of the data than the multiple regression described above, they are worth mentioning. The Safety Culture Measure correlates with most Organisational Culture Measure sub-scales. As would be expected from the regression above, high scores on the sub-scales of the Organisational Culture Measure are associated with high levels of perceived safety. Perceived safety was associated most highly with Compliance with rules, Planning orientation, and Leadership orientation. Again, this is consistent with the literature, which indicates the importance of managerial involvement in safety. A negative correlation was observed between 'Avoidance orientation' and the Safety Culture Measure; this suggests that in organisations where avoidance is high, safety may be less of a priority in the organisation. However, this sub-scale did not contribute to the multiple regression of the Organisational Culture Measure onto the Safety Culture Measure, indicating that it may not provide a stable proactive indicator of unsafe organisations despite the apparent association observed within the correlation.

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[58] Individualism is said to improve the safety level on the flight deck where the crew are from Western culture (Helmreich & Merritt, 1998).

6.4.1. Discussion of Organisation 7's results

Two of the factors derived from the factor analysis of the Organisational Culture Measure suggested that as 'Work diversity orientation', 'Personal growth orientation', and 'Power orientation' increased, the number of Self-Reported Errors (Err_self) decreased in Organisation 7. this indicates some support for Hypothesis 7 (p. 83). This result suggests that where employees are developed within the organisation by job variety (Work diversity orientation) and are allowed to develop at a personal level (Personal growth orientation), collectively representing higher levels of individualism, but where the organisation is exercising some 'control' (Power orientation), the employees reported making fewer errors. In a related finding, Keenan, Kerr, and Sherman (1951) determined that, greater promotion prospect predict lower accident rates. This result may seem paradoxical in that increasing both individualism and organisational control was associated with safer organisations. It can be explained, if the view is taken that individualism (Personal growth and Work diversity) can be fostered within a controlled environment providing for a safer organisation. This result may be considered in the light of the literature, which suggests that safer cockpits have high individualism and low autocracy (lower control) (Helmreich & Merritt, 1998), whilst the present research suggests higher levels of power and control are safer for maintenance environments. On the other hand, Lee (1998) also reports that low levels of accidents in nuclear power plants were associated with low autocracy and democratic leadership styles, where good organisational learning and reflexivity existed. It is conceivable that different aspects of an operation or different occupational groups may require different levels of control to promote higher safety. This implies that local investigations should be undertaken to determine appropriate interventions.

The perceived level of safety (Safety Culture Measure), Degree of structure and Planning orientation (and to a lesser extent Work Diversity and Morale) were most significant in discriminating between the two sites of Organisation 7. Helmreich and Merritt (1998) have also observed that different cultures and attitudes can exist within the same organisation. Planning orientation and Degree of structure were strongly represented in the discriminant function, indicating that 'control' was different between the two sites.

Organisation 7a scores more highly than Organisation 7b on the function that has a negative association with Degree of structure and perceived safety (SCM) but a positive one with 'Planning orientation'. This indicates a greater presence of planning where structure and safety are poor. This finding is not easily explained unless a scenario is imagined where an organisation expends considerable effort on planning, at the expense of other activity, such as may be present in a highly bureaucratic organisation (Westrum, 1993). The suggestion is that structure relates directly to safer organisations; in Organisation 7b structure and perceived safety were both higher. These results provide support to the validity of these measures as discriminating tools and has indicated further that 'control' may be an important safety element in maintenance organisations.

Within Organisation 7, a negative correlation was observed for the Safety Culture Measure Score with the number of Self-Reported Errors, indicating that individuals, reporting higher levels of errors in themselves, perceive Organisation 7 as less safe (Hypothesis 4). Participants making the attributions that their organisation is less safe, based on their own error rate, can explain this. It might also indicate a greater awareness of safety issues within that individual, i.e. they were more 'tuned in' to safety issues. This reasoning would also be consistent with the work of Edkins and Coakes (1998), whose work suggests that an "individual's awareness of company safety requirements is related to their motivation and involvement in safety activities" (p. 8), which presumably includes error reporting. Of course, it cannot be easily determined whether awareness leads to safety or the presence of safety leads to awareness, though intuitively an increased requirement on employees to comply with safety practices is likely to lead to greater safety awareness. Where employees become more engaged in safety behaviours, then the perceived value of safety is likely to increase. Such a phenomenon is explained by the rationalising effect of Dissonance Theory (Festinger, 1957; Helmreich & Merritt, 1998), which suggests that people are motivated to reduce inconsistent cognitions about themselves and the world. The effect of this would be that safety would have increasing value the more that individuals engage in safety-related behaviours. Such is the influence of management in some organisations, their involvement in promoting safety behaviours, or otherwise, will be likewise valued. As Zohar (1980) has indicated, the perceived importance of the person(s) dealing with safety is an indication of the value that management place on this activity; and as such, it is not surprising that the success of safety programmes hinges on demonstrated management behaviour.

Items showing the highest correlations with Self-reported error were concerned with the influence of the safety committee or management action. This indicates that where the executive of an organisation was perceived as acting, then the organisation is perceived as being safer. This is consistent with the work of Cheyne et al. (1998), where management actions were highlighted as a prime area for the development of higher safety organisations.

Finally, with respect to error reporting by organisations and by individuals, it was argued that this research has shown that Self-Reported Errors and organisationally reported error have opposite signs in respect of their relationships to perceived safety. The two might be used in conjunction with one another to provide an indicator of 'at risk' organisations. These would be characterised by a low Error Frequency Index (representing poor reporting and lower safety according to the current thesis) and high Self-Reported Errors (Err_self) (representing low confidence in the safety of the organisation by the employees providing this data). This would have to be tested with further empirical research.

6.5. The implications for future research and the aviation maintenance industry.

Generally there is little agreement in the literature on how culture should be measured (Denison, 1996) and the argument for multiple methods (i.e. surveys, questionnaires, observations, and checklists) where a range of quantitative and qualitative methodologies are used, has been made (Rousseau, 1990). Where more intensive analysis is required, qualitative approaches have the advantages of being adaptable to the organisation concerned, providing more detailed information for the purposes of safety analysis and for the proactive diagnosis of problems. Indeed, Mearns and Flin (1999) suggest that Repertory Grid Technique (Kelly, 1955), Critical Incident Technique (Flanagan, 1954) and in-depth interviews provide the means to determine fundamental values within organisations. They suggest that it may be advisable for researchers to become part of the organisation in order to obtain the detail required. For large-scale studies involving a large number of participants in disparate locations, such as this one, questionnaires and checklists (quantitative) are more practical. Questionnaires have utility for the quantitative analysis of organisational characteristics (e.g. culture) and comparisons can be more easily made across different organisations (Reichers & Schneider, 1990; Rousseau, 1992; Sagan, 1993). They might provide and 'early warning system' that could be used to indicate the necessity of in depth qualitative analysis. For example, the organisational profile data obtained for Organisation 4 (Organisation 4) in this research or the low safety organisations that were identified.

Regular monitoring using questionnaire-type measures may seem to be a soft approach to the measurement of such an important issue as safety. Difficulties in reconciling the constructs, idiosyncratic terminology, and the classification systems used, represent some of the challenges to making sense of such work. Nevertheless, they continue to be used extensively to provide a picture of organisational health and safety (Cox & Flin, 1998b). Themes have been identified by a number of researchers and also in this research; management commitment to safety, involvement of the workforce, personal responsibility, attitude to hazards, compliance with rules and the workplace conditions (Cheyne et al., 1998; Cohen, 1977; Cox & Flin, 1998b; Edkins & Coakes, 1998; Eiff & Lopp, 1998; Glennon, 1980; Lautman & Gallimore, 1987; Pidgeon, 1998; Zohar, 1980).

A strength of the methods used in this research is the use of multiple criteria by which safety is evaluated. Each of the indices was designed to evaluate different aspects of safety. For example, the Safety Index Measure contains observable items that reflect the presence or absence of safety features in an organisation. The Managers' Self-Report General Failure Types measures primarily the subjective view of the managers. These measures were designed to supplement the error data that was to be collected. For this reason, no rigorous empirical or psychometric evaluation had been undertaken prior to the main study. In retrospect, this was unfortunate because the paucity of the error data required that more reliance was placed on these new and untested measures. Nonetheless, the use of subjective and untested measures is not unprecedented (Edkins, 1998a, 1998b; Zohar, 1980), though ideally they should be substantiated against other measures of safety if these were developed; at present they do not exist.

With reference to Figure 13 (p. 79), the relationships that exist between Organisational Culture (OC), Safety Culture (SC), and Safety Behaviour/Indicators (SB) have been examined by a variety of measures produced for this purpose. However, such measures may retain bias due to the theoretical orientation of the developer (Lanigan-Fox & Tan, 1997); the use of predetermined sub-scales and items can be criticised because they reflect the researchers' values (Neuijen, 1992), and on the basis that the broad spectrum of themes and characteristics cannot be captured solely by such measures (Schein, 1990). Furnham (1997) has stated that "a definitive list of dimensions of organisational culture has not, and will not, be resolved" (p. 561), and there is no consensus in the literature on the dimensions and concepts of organisational culture (Furnham, 1997). Similarly, Alexander, Cox, and Cheyne (cited in Mearns & Flin, 1999), report that in a study in 1995, involving 1080 employees from an oil company, they were unable to generate a reliable measure of safety culture. Notwithstanding these comments, the use of the Organisational Culture Measure and the Safety Culture Measure in discriminating among organisations with different levels of reported error and safety has been demonstrated. Further development of the Organisational Culture Measure, and Safety Culture Measures (SCM) validated against safety indices (criterion validation), might allow a benchmark or norm-based profile for aviation maintenance organisations to be developed, whereby individual organisations or sections of organisations might be gauged. Those falling outside of a 'safe profile' might be subjected to an increased frequency of safety audits, by internal or external agencies, to identify safety-related problems more precisely. This would represent a proactive safety management tool sensitive to more subtle organisational culture issues. This research has demonstrated that remote computer administration of questionnaires is possible and this is likely to become easier as technologies, accessibility, and familiarity with information technology grows.

Future work might use more condensed versions of the Organisational Culture and Safety Culture Measures; these might even be combined into a single and more easily administered measure. A shorter measure with more substantive psychometric support would allow more stable multivariate analyses to be carried out. Population sizes in New Zealand would represent a challenge here but the present measures represent a first step into this territory. As Edkins and Coakes (1998) have suggested, measuring safety culture over time will be useful to determine the effectiveness of a safety management programmes.

This research has indicated the feasibility of assessing organisations on a variety of indices for safety and the utility of a safety rank as a means of determining overall safety level. It is not suggested that the ranking used for this work is airtight, rather that the process has some merit that might be further explored and refined so that some agreement can be reached on which indices are the most valid and reliable indicators of safety.

The measurement of error in this research was the least encouraging outcome; rigorous qualitative measures of error (MERN/MEIN & MEIA) could not be made because the organisations considered the investigative processes to be too time-consuming. The quantitative data were limited due to the relative infancy of the database and the difficulty in capturing and coding errors. It was anticipated that a greater emphasis would be placed on the analysis of these data;

this was not possible and the validation of the other measures was somewhat compromised.

Commenting on the difficulties inherent in capturing human factors data, Harle (1994) states:

> "Unfortunately, many critical human factors do not lend themselves to simple measurement and are thus not entirely predictable. As a result, much human factors information does not allow an investigator to draw indisputable conclusions." (p. 141).

The acquisition and accuracy of error data are a problem for this type of research. Error taxonomies are not standardised and even defining what constitutes an error can be difficult. The technology for the determination of the error frequency and more objective measures of safety need to be refined. This research has experienced some of the challenges in capturing and reporting error; notwithstanding these difficulties, this has been accomplished, albeit on a smaller scale than originally envisaged. Additionally, it is one thing to determine that errors are occurring but quite another to assert that these will compromise safety. It is conceivable that certain types of error compromise safety whilst others are less important. To obtain this detailed information on error it is likely that qualitative methods will be required. For example, an organisation experiencing a high number of errors may actually be safer than an organisation experiencing a low number of errors, where it is demonstrated that the quality of the errors is less severe. Unfortunately, this degree of detail was not available during this study and for the purposes of this research it was necessary to rely on the relationship of errors to the other indices of safety.

There is some evidence from this research that safer organisations were those that reported a higher number of errors; and this has also been suggested by the literature (Cheyne et al., 1998; Cox & Cox, 1991; Sagan, 1993). In contrast, individuals reporting higher levels of their own errors perceive their organisations as less safe and it is suggested this may be due to attribution errors (Festinger, 1957) made by these individuals. This research suggests that 'control over behaviour', as evidenced by Power orientation, Compliance with rules, and Performance Orientation is present in organisations with higher levels of safety. Compliance with rules and Leadership Orientation were also associated with higher perceived levels of safety.

The paradox of error reporting versus true error rate requires that some form of substantive investigation technique be developed to determine the 'true' relationship of reported error to safety. This further suggests the need for mixed-method approaches that use questionnaires, observations, and interviews to acquire such error and safety data (Helmreich & Merritt, 1998). Such methods represent the best option for determining the organisational norms and values that relate to safe practice and requires that observers 'get inside' the organisation for a fuller understanding.

This research took place over a four-year period during which time the effects of deregulation were being experienced in the industry. Deregulation requires organisations to take an increasing responsibility for the in-house monitoring and regulation of safety. This is likely to introduce changes in the cultures that exist and the approaches to safety and error management over time. Anecdotally this was apparent, with organisations becoming more interested in safety and error, the recent appointment of safety advisors, the development of internal auditing procedures, and training on safety and error over the research period. The time-line over which the data were collected meant that some organisations in the study provided information ahead of others. This may have had a maturing effect on the data influencing the outcome of the research; for this reason, longitudinal studies of cultural stability might be indicated. Additionally, the CAANZ is promoting a culture of reporting throughout the industry. This is likely to change the nature of reporting and attitudes to safety, though sadly it is likely that there will always be organisations where error suppression and denial of safety problems will exist.

6.5.1. Summary of the conclusions and implications from this research

The conclusions and implications of this research for the industry have been described and are summarised below.

1. Organisations reporting more errors are safer than those reporting lower levels of errors.

2. Control exercised by organisations, as exemplified by power and compliance, is related to increased levels of safety and may indicate that deregulation of the industry needs careful consideration. A number of Organisational Culture Measure sub-scales were identified as being associated with safety and provide useful indicators to managers about areas they should examine if they wish to influence safety outcomes. These are shown in Table 44 (p. 201).

3. This research suggests that the organisational culture of aviation maintenance organisations in New Zealand is homogeneous. This may mean that similar safety interventions can be applied across such organisations.

4. The importance of understanding the nature of the error mechanism in aviation does not seem to be fully appreciated. The resource costs of collecting error data were a constant impediment in collecting information of this type.

5. Managerial commitment demonstrated by behaviours and an awareness of safety throughout the organisation is likely to be important in the improvement or adoption of safety behaviours by the workforce.

6. Organisations should routinely monitor the safety culture of their organisations to ensure that safety awareness is maintained. Management should overtly indicate their approval of the importance of safety by their behaviour.

7. Work diversity and personal growth should be encouraged, as this appears to decrease the number of errors that individuals perform.

The results from this study allow a limited degree of confidence in the culture measures or the safety indices as criterion variables. Future work might concentrate on a refinement of these measures. In short, the correlations and observed significance levels indicate that further development and psychometric evaluation is required, analysis based on these measures may be suggestive of relationships among variables rather than being persuasive.

This study, like others in the field, has a foundation in a relatively limited literature base. Accordingly, the measures developed share a conceptual framework and further empirical work is still required in order to test the fundamental basis of the safety culture concept; to fail to do so will result in restricted context-dependent measures that have limited utility and application (Cox & Flin, 1998b). It should be noted, however, that even the most objective (scientific) approaches are never airtight. Researchers with a highly empirical orientation may claim statistical significance as support for a particular theory when in fact the scientific, and objective, basis is less than perfect. Such claims can be particularly flawed when applied research is undertaken with human-referenced variables and where elements of subjectivity and conceptual overlap in the measures can exist. Measures of culture, safety, and error are likely to contain such subjectivity and bias. They are bound by the conceptual philosophies and mathematical properties of the number systems describing the measured values, as well as the implicit biases of the individuals. This does not necessarily devalue quantitative research, but research of this type should be interpreted with this in mind and used in adjunct with qualitative methods. It is certain that more empirical work is required and that this must provide a clear theoretical framework relating to the existing literature (Cox & Flin, 1998a); multi-method approaches are suggested as the preferred means to achieving this.

This research has generated potentially useful findings. It is, however, not sufficient merely to collect the data and release a thesis. It is hoped that this research will find application within the aviation industry and other socio-technical industries. It would be pleasing if this thesis and similar work raised the awareness of the importance of organisational safety culture, leading to a mitigation of its potentially undesirable effects (Hayward, 1998) and the development of safer practices. Indeed, raising awareness and enhancing safety culture is considered a core activity for station managers within Nuclear Electric in the UK (Ackroyd, 1995) and, as Helmreich and Merritt (1998) have stated:

> "A safety culture is the outcome that is reached through a strong commitment to acquiring the data and taking proactive steps to reduce the probability of error and the severity of those that occur." (p. 4).

In closing, it is perhaps important to note that safety may be considered a fashion; what is considered safe for one culture may not be acceptable for another. Acceptable safety risk (Safety at Reasonable Cost)[59] is thus a subjective and negotiated social activity (Pidgeon, 1998) that allows institutionally normalised deviations (Vaughan, 1990) from standards that would be unacceptable in other settings. In this sense, it might be expected that an interest in safety culture and the perceived value of such activity is culturally determined and subject to changes in fashion. From the perspective of a consumer of aviation services, it is to be hoped that this fashion does not fade.

Despite the challenges faced in completing this research, it has added to the literature on safety culture and error in the field of aviation maintenance. The utility of the methodologies used has been demonstrated and, although the findings were indicative rather than unequivocal, they are suggestive of an extended line of enquiry that might be pursued. It is hoped that this work will contribute in some way to increasing safety within the industry.

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[59] Safety at reasonable cost; motto adopted by the Civil Aviation Authority of New Zealand.

Appendices

Appendix A: Measures used in this research

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all						To a great extent	
	1	2	3	4	5	6	7	No opinion
1. The organisation believes it is vital for business success to keep up with new developments.								
2. The organisation believes that it should avoid doing things in the same, predictable ways.								
3. The organisation believes successful organisations generally keep one step ahead of the rest.								
4. The organisation believes people should look for new ways of solving problems.								
5. The organisation seeks to develop and improve on procedures.								
6. Generally workers look for constructive ways of overcoming problems.								
7. The organisation thinks very carefully before acting.								
8. The organisation does not take unnecessary chances.								
9. The organisation believes caution is the best policy.								
10. Even the simplest jobs are to be done well.								
11. That quality comes before quantity.								
12. The organisation believes if a job is worth doing, it is worth doing well.								
13. Always take time to do things right.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all 1	2	3	4	5	6	To a great extent 7	No opinion
14. The organisation believes in pursuing a high standard of excellence.								
15. Never settle for half measures when doing a job.								
16. The organisation believes that alternatives should be explored before acting.								
17. The organisation believes it is essential to think ahead.								
18. A successful organisation always knows where it is going.								
19. The organisation believes that one can never spend too much time planning ahead.								
20. Crises are rare around here.								
21. Work is well organised.								
22. The organisation believes training of the work force is important.								
23. Order and tidiness are considered important.								
24. Goal setting happens here.								
25. You have to play politics to get on.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all 1	2	3	4	5	6	To a great extent 7	No opinion
26. Successful people are those who are loyal to their boss.								
27. Subordinates should be hard- working and loyal.								
28. The organisation believes controlling people is all-important.								
29. You have to be hard and tough to get on.								
30. There needs to be a more consultative atmosphere here.								
31. People in this company like to manage								
32. A great distance exists between the work force and management.								
33. Success comes to those who believe in getting the job done.								
34. Personal commitment to attaining goals is of utmost importance for people in this organisation.								
35. Successful people in this organisation are the ones who take on challenging tasks.								
36. The organisation believes one should always strive for better ways of achieving goals.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents _Not at all_ and 7, _To a great extent_.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all						To a great extent	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**No opinion**
37. Around here everyone likes a winner.								
38. Customers are the first priority around here.								
39. People strive to improve in this organisation.								
40. Success comes to those who get on with others.								
41. People get on with their colleagues around here.								
42. Working together is important around here.								
43. Teamwork comes first.								
44. Managers are involved at the grass roots level during day to day operations.								
45. Seeking advice is encouraged.								
46. Everyone in this organisation is a customer of the other.								
47. People around here show concern for the needs of others.								
48. Workers generally try to help their colleagues.								
49. Warmth among colleagues helps get the job done.								
50. This organisation believes that people are more important than things.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all					To a great extent		
	1	2	3	4	5	6	7	No opinion
51. People are told when they have done well.								
52. Management helps workers do their jobs better.								
53. Feedback is encouraged in the organisation.								
54. Ideas generally flow freely.								
55. The organisation believes that open communication is best.								
56. Everyone in an organisation is to be kept informed.								
57. Around here policy decisions are always based on sound information management.								
58. Company goals and objectives are clearly communicated.								
59. People can bypass their boss or go to someone else with a problem.								
60. Problems can be taken to anyone in the organisation.								
61. Senior management understands very well the work undertaken in the maintenance area.								
62. The organisation believes that people need regular rewards.								
63. Rewards go to those who are committed to their work.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all 1	2	3	4	5	6	To a great extent 7	No opinion
64. People are rewarded for doing their job well.								
65. Rewards follow quickly on performance.								
66. Rewards for effort are appropriate.								
67. The organisation believes happy workers are more productive.								
68. A healthy team spirit is important to a successful organisation.								
69. The organisation believes people are best motivated with friendliness.								
70. An organisation, which takes care of its employees, can expect them to work well.								
71. Working here is very satisfying.								
72. People like working here.								
73. People who work here generally think it is a positive work environment.								
74. The organisation looks after the staff here.								
75. It is best to give individuals the freedom to do things in their own way.								
76. Giving workers a major say in how they do their jobs improves performance.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all 1	2	3	4	5	6	To a great extent 7	No opinion
77. People are held accountable only for things for which they are responsible.								
78. People are allowed to get on with their job here.								
79. Expression of ideas is encouraged.								
80. The company promotes spontaneous and creative behaviour in work.								
81. The organisation believes that employees should always try to improve their understanding of their job.								
82. Employees are helped to realise their full potential.								
83. Workers are encouraged to be enthusiastic about their work.								
84. Job variety builds a happy work force.								
85. Employees can benefit their organisation by trying different jobs.								
86. Workers work best if they are given different things to do.								
87. Employees need to explore ways of realising their full potential.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all 1	2	3	4	5	6	To a great extent 7	No opinion
88. A mature person is one who always strives to improve.								
89. A company can only grow if it allows its work force the freedom to develop.								
90. People generally feel that training staff helps the company grow.								
91. Most people are here because of their passion for the industry.								
92. The organisation believes that the most successful companies in this business are the ones who believe in what they are doing.								
93. People in this organisation are as enthusiastic as in any other organisation.								
94. This organisation is the best at what it does.								
95. The organisation believes it is important to be critical of itself and its performance.								
96. This is a proud work force.								
97. No matter what you do things will go wrong anyway.								
98. This organisation will make do where it can.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all 1	2	3	4	5	6	To a great extent 7	No opinion
99. It'll come right without interference.								
100.This organisation believes that as long as it works out OK most of the time that's OK.								
101.She'll be right.								
102.This organisation really does all it can to meet its legal and moral obligations.								
103.Rules and regulations are there for a good reason.								
104.All levels of this organisation work hard to be in compliance with regulations.								
105.All levels of this organisation take responsibility for everyone's safety.								
106.This organisation will undertake to report all observed notifiable non-compliances and non-conformance's even if it reflects badly on the organisation.								
107.Communication with other 'players' in the industry is a good thing.								
108.Care is taken to ensure the company is aware of all legislative changes.								
109.This company responds quickly to the demands of the industry.								

Please work through the statements in the page order in which they are stapled together.

Organisational Culture Questionnaire

Please read the statements in the table below and decide the degree to which the work environment tends to promote the belief, value, attitude or behaviour shown. Where 1 represents *Not at all* and 7, *To a great extent*.

My work environment tends to promote the belief value, attitude or behaviour:-

	Not at all						To a great extent	
	1	2	3	4	5	6	7	No opinion
110. Senior people here demonstrate by example, their own commitment to the organisational goals.								
111. The senior people here symbolise the values and beliefs of the organisation.								
112. Managers in this environment set precedents that others follow.								
113. Management keeps the organisation on course.								
114. Generally the people who work here are clear about what is expected of them.								
115. The work environment is rule oriented.								
116. Organisational policies and procedures are helpful well understood and up to date.								
117. In this environment there are rules for everything that's done.								
118. Rules are generally followed even when they are not sensible or wrong.								
119. The work environment is very structured.								

Please work through the statements in the page order in which they are stapled together.

Safety Culture Questionnaire

Please read the statements in the table below and decide the degree to which you agree with the statement. Where 1 is strongly disagree and 7 is strongly agree.

Strongly disagree Strongly agree

	1	2	3	4	5	6	7	Not relevant
1. When a worker is approached on a matter of safety or is warned, it improves their safety behaviour.								
2. Workers who violate safety regulations aggravate their fellow workers even when no harm has resulted.								
3. The safety issues related to my job concern me quite a bit.								
4. Workers who behave safely have a higher chance for promotion than those who do not.								
5. People usually inform their supervisor about safety hazards								
6. Supervisors take action to correct safety hazards.								
7. Our general manager is well informed about safety issues in this organisation.								
8. The investment of money and effort in safety training programs is a worthy investment because it improves performance on the job.								
9. The best people in our department care about safety and they want other workers to behave according to the regulations.								
10. The safety adviser/manager has much influence on safety issues in the organisation.								
11. Management in this organisation is willing to invest money and effort to improve the safety level here.								

Please work through the statements in the page order in which they are stapled.

Safety Culture Questionnaire

Please read the statements in the table below and decide the degree to which you agree with the statement. Where 1 is strongly disagree and 7 is strongly agree.

Strongly disagree Strongly agree

	1	2	3	4	5	6	7	Not relevant
12. My safety training really helps me, both in my work and at home.								
13. An employee who behaves recklessly will receive a negative evaluation from supervisors.								
14. Management acts quickly to correct safety problems.								
15. My chance of being involved in an accident is low.								
16. The safety committee in our organisation has a very positive effect on what is happening here.								
17. Managers in this organisation take care and try to reduce risk levels as much as possible.								
18. Being a member of our organisations safety committee gives a person more status around here.								
19. When a worker violates safety regulations it has an adverse effect on his/her supervisor's evaluation of him/her even when no harm was caused.								
20. Our managers view safety regulation violations very seriously even when they have resulted in no apparent damage.								
21. Generally there is a belief that it is only a matter of time until one is involved in a safety related incident.								
22. I think safety issues are assigned high priority in management meetings.								

Please work through the statements in the page order in which they are stapled.

Safety Culture Questionnaire

Please read the statements in the table below and decide the degree to which you agree with the statement. Where 1 is strongly disagree and 7 is strongly agree.

Strongly disagree   Strongly agree

	1	2	3	4	5	6	7	Not relevant
23. The efforts invested in organising safety training programs really pay back to the company.								
24. The safety issues relating to the work done here are taken very seriously.								
25. When a manager realises that a hazardous situation has been found, he/she immediately attempts to put it under control.								
26. Workers who work safely try to emphasise it and make sure others appreciate it.								
27. Workers who take safety-training courses are less involved in accidents than those who don't.								
28. Workers who use personal protective equipment are considered to be good and tidy workers, rather than cowards.								
29. Workers who take safety-training courses have a better chance for promotion than those who don't.								
30. Compared to other comparable organisations, I think this one is pretty safe.								
31. Being involved in an accident has an adverse effect on the worker's reputation.								
32. Management in this organisation is always willing to adopt new ideas for improving the safety level.								

Please work through the statements in the page order in which they are stapled.

Safety Culture Questionnaire

Please read the statements in the table below and decide the degree to which you agree with the statement. Where 1 is strongly disagree and 7 is strongly agree.

Strongly disagree Strongly agree

	1	2	3	4	5	6	7	Not relevant
33. When a worker confronts a dangerous situation in his/her work environment he/she reports it to the person responsible for safety.								
34. Workers who take safety-training courses are doing a better job than those who don't.								
35. When a safety regulation is issued, the work force complies with it.								
36. Enough attention is paid to promoting a safe operation here.								
37. There is always room for much more emphasis on safety.								
38. This organisation is unlikely to have an accident.								
39. This organisation is safer than any others I know.								
40. This company considers safety a good advertisement for its services.								
41. Health and Safety Regulations have much influence here.								
42. Hazard control is given a lot of attention here.								
43. Where a safety infringement occurs, it is investigated.								
44. Safety is given priority over the operational priorities.								

Please work through the statements in the page order in which they are stapled.

Safety Culture Questionnaire

Please read the statements in the table below and decide the degree to which you agree with the statement. Where 1 is strongly disagree and 7 is strongly agree.

Strongly disagree Strongly agree

	1	2	3	4	5	6	7	Not relevant
45. There is a high awareness of factors that contribute to a safe operation.								
46. The people here are constantly reflecting on how safe the operation is.								
47. Safety violations are taken seriously by people at the shop floor level.								
48. Safety violations are taken seriously by people at the supervisor level.								
49. The mangers who have responsibility for safety perform this role well.								

Used in Organisation 7 only.

When you have filled in this section and the previous questionnaires, please enter your name and contact number, if you want to go in the draw. Send you completed questionnaires off in the SAE.

Please think back over the last 12 months. Can you think of any maintenance error occurrences, in which you, or your colleagues have been involved? Think of an error as an event which could have led to an unsafe condition, re-work or a departure from accepted maintenance procedures. See the list below for examples.

- Incorrect installation of parts
- Fitting of wrong parts
- Electrical wiring discrepancies (including cross-connections).
- Loose objects (tools etc.) left in aircraft.
- Inadequate lubrication.
- Cowlings, access panels and fairings not secured.
- Fuel/oil caps and refuel panels not secured.
- Shortcuts, i.e., replacing components without first loosening connections.
- Over torqueing nuts.
- Incomplete recording and paperwork.
- Delay or postponing of essential maintenance.
- Poor record keeping and paperwork.
- Out of date manuals.
- Landing gear lock pins not removed before departure.

Work section name e.g., Aircraft Maintenance, Materials, QA.____________________

Please indicate / estimate how many occurrences have occurred to colleagues in the last 12 months; [ ]

Please indicate / estimate how many occurrences have occurred to you personally in the last 12 months; [ ]

Briefly describe one example of an error occurrence. Continue overleaf if necessary.

List what you think the causes were leading to this occurrence. To help, think about what corrective actions were needed to fix it, this will help you see what the causes were. For example; if the corrective action was; '*the engineer will consult the available manual*' then the cause is, '*the engineer did not consult the available manual*'. Note if no manual was available then an additional corrective action is, '*manuals will be made available*' and the cause is that '*manuals were not available because.....*'.

What defences / precautions (other checks, tooling, training) could have prevented the occurrence?

If you wish to be entered in the draw for the free meal at a restaurant of your choice, to the value of $120.00, please enter your name below.

Name. ____________________ **Contact phone number.** ____________

Safety Index Measure

The following items when present in an organisation represent a token of safety and may be used in the generation of a safety index measure. The items can be checked as present or not present in the organisation. Where the item does not apply or is inappropriate to the setting the n/a, n/o box should be ticked.

The items should be completed as the observer moves through the organisation. Reliance should only be made on actually observed occurrences or where there is strong evidence that state exists in the organisation. This measure is interested in all aspects of safety in the organisation, NOT just those related to the operation of aircraft.

The following codes apply;

- Yes — is used if the item is present;
- No — is used where the item has not been observed to be present.
- n/a — where the item is not appropriate to that organisation or unit.
- n/o — where there is no opportunity to observe the item.

This data can be collected by trained observers auditors, safety analysts and the researcher.

	Item observed in organisation		
Item	**yes**	**no**	**n/an/o**
Atmosphere			
1. Can errors be safely discussed without fear of recrimination.			
2. Presence of negative graffiti in relation to aspects of the organisation.*			
3. Is there a feeling of insincere rhetoric about safety.*			
4. There is a great deal of opportunity for informal management employee interaction.			
5. Good standard of housekeeping.			

Workplace environment			
1. Generally clean and unadulterated working environment.			
2. Places for tools on benches.			
3. Suitable containers for catching lubricants correctly placed.			
4. Ventilation adequate.			
5. Adequate lighting.			
6. Clear signs and labels, fire exit signs, markings on floor.			
7. Workshop floors and surfaces clean and orderly.			
8. Sanitary facilities clean and adequate.			
9. Heat levels acceptable for the work being performed.			
10. Noise levels within acceptable levels.			
11. Vibration levels within acceptable levels.			
12. Protective clothing provided and evidence of general usage.			
13. There is a good design and layout of work processes.			
14. Machinery has adequate safety devices present.			
Equipment and parts management			
1. Correct tooling available.			
2. Are appropriate document holders, work surfaces and toolboards being used?			
3. Test equipment calibrated and checked with appropriate documentation.			
4. Are appropriate methods for tracking spares being used?			
5. Are appropriate methods for 'tools out' and 'tools in' being used.			
6. Is a method of quarantining spares and non-serviceable tools used?			
7. Contaminated or unserviceable parts clearly identified.			
8. Parts are stored in an orderly manner, on shelves away from the main work areas.			
9. Are scrap parts locked away and destroyed.			
10. Used parts recorded and logged for destruction/renovation.			

Work practice			
1. Deviations from standard maintenance procedures documented and provided to engineering management. Evidence seen for this.			
2. Evidence of supervisory checking on the shop floor.			
3. Breaks from work taken.			
4. Manuals incomplete and or out of date.*			
5. Manuals clearly not used when one would expect them to be consulted.*			
6. Do items remain un-repaired for long periods of time.*			
7. Foreman has a limited area of responsibility.			
8. Significant maintenance performed outside of the organisation.*			
9. Awareness of legislative changes or changes in specifications.			
10. Evidence of retrospective record keeping, records filled in after the event as evidenced by faded or different ink types.*			
Work conditions			
1. Conditions of service considered reasonable.			
2. Shifts generally eight hours or less.			
3. Presence of shift system that involves frequent disruption to home life. i.e. back to back shifts.*			
4. Minimum time off taken between shifts, reasonable.			
5. Procedures exist for job placement and advancement.			
6. Recreational programs for employees.			
Training			
1. Formal training exists for staff in maintenance roles.			
2. Evidence that workers know about the safety policy.			
3. Evidence of further formal trade training/professional development.			
4. Training budget held by maintenance section of organisation.			
5. Company pays for further training.			
6. Does the company extend CRM (crew resource management) to maintenance activity.			

Safety			
1. Is there a safety policy.			
2. Safety meetings are held regularly.			
3. Is there a safety officer/adviser..			
4. Safety officer holds high rank in organisation.			
5. Does the safety officer/committee have executive power.			
6. Is this post separated from a maintenance function within the organisation.			
7. Does this post have outside contact with any safety organisation outside of the company.			
8. Is top management closely involved in maintenance safety programs.			
9. Does top management receive regular safety reports.			
10. Is top management represented at safety meetings.			
11. Does top management chair these meetings.			
12. Does management actively pursue safety recommendations made by safety officer or committee.			
13. Are safety plans and objectives given a high profile by top management.			
14. Does the safety officer follow up on his plans.			
15. Does the safety advisor/officer hold review and analysis sessions with the workforce, to look at the outcome of plans.			
16. Does this post attend safety conferences and training programs outside of the company.			
17. Safety rules are reviewed when a safety-related incident occurs.			
18. Safety rules are reviewed yearly at least.			
19. Are safety-related incidents publicised, communicated or published within the organisation.			
20. Safety briefings held at least once per year. Documentary evidence of these needs to be seen			
21. Records exist on all injuries that have occurred, disabling (lost time) as well as non-disabling ones.			
22. There is evidence that most staff comply with the safety rules.			
23. Staff are given formal safety training in orientation.			
24. Supervisors are given special safety training.			
25. Safety equipment, fire extinguishers clearly visible and current. Presence of fire alarms, other emergency notification system.			
26. Special posters/signs exist to alert people to special hazards.			
27. Safety practices are actively given recognition by management and supervisors.			
28. Safety investigations occur where a safety related incident happens on the shop floor.			

29. Does a mission statement or other philosophy document highlight safety as a goal of this organisation.			
30. A non-punitive humanistic approach is adopted with safety violators.			
Health			
1 Requirement for certified engineers to be medically fit, psychologically fit.			
2 Presence of company health service.			
3 Injury record keeping system is used.			
4 Presence of personal accident/incident cost analysis system.			
5 Personal counselling services, employee assistance exists.			

Top Management General Failure Types (FTman)

General Failure Types Explanatory Notes; for every reported human error in maintenance there will be a selection of organisation failings that set the conditions in which the error occurred. Human beings will make errors more frequently when certain conditions exist. These conditions have been broadly classified into 18 General Failure Types (GFTs). Indicate the frequency with which the organisation has been experiencing the described General Failure Types over the past four-week period. Use specific instances that you can recall where the GFTS in question had its effects.

Infrequently ↔ Frequently

Organisation Failure Items (GFT)	1	2	3	4	5
1. Inappropriate Goals or Policies					
2. Organisation Structural Deficiencies					
3. Inadequate Communications					
4. Poor Planning					
5. Inadequate Control and Monitoring					
6. Design System Deficiencies					
7. Inadequate Defences					
8. Unsuitable Materials					
9. Unsuitable Equipment					
10. Poor Procedures					
11. Poor Training					
12. Poor Co-ordination					
13. Inadequate Specifications/Requirements					
14. Poor Decisions					
15. Poor Resource Management					
16. Poor Work Environment					
17. Inadequate Regulation					
18. Other Organisation Factor					

A more detailed description of the Organisational Failure items is given below.

Inappropriate Goals or Policies:

Unclear or inappropriate organisation goals or policies which may compromise or conflict with required or expected safety objectives and priorities, for example, an organisation's sole goal is to make a financial profit with no mention of safety objectives.

The conflict the worker has to solve between production, financial, governmental, social or individual priorities and optimal working routines: for example, an in flight APU failure, where replacement had been deferred in excess of normal limits because of time pressures and line operation requirements requiring the aircraft to be on the ramp and ready to go. The error here may be seen as the LAME releasing an aircraft which has a suspect APU. One contributing factor to the decision was incompatible goals in the organisation.

Organisational Structural Deficiencies:

Ambiguous, vague or otherwise inadequate definition and implementation of personnel responsibilities and authorities and in particular, interrelationships between key personnel. Tasks and activities not being carried out by appropriate personnel, for example, the CEO of an organisation having a heavy involvement in day-to-day operational matters.

A catch-all GFT that encompasses, ill defined management roles and systems, poor lines of accountability, unclear mechanism for introducing fixed and evidence that the organisation failed or is unable to learn from it's experience (both good and bad) evidenced by an organisation that is having repeatedly similar errors.

Inadequate Communication:

Deficiencies in the provision, or transfer, of information at both the formal and informal level between key personnel either within or beyond the organisation (for example, with the regulatory authority). Poor two-way communications between management and staff.

Inadequate communication between the various regions, departments or employees in the company, that is, information transfer where communications relating to, for example, the operation of an aircraft are confused, not received, misinterpreted or otherwise corrupted. This might be related to logs and records, manuals or organisational policies and procedures.

Poor Planning:

Inadequate effort or resource dedicated to effective planning. Little in the way of a structured approach to planning activities. Little forethought given to the likely consequences of proposed changes.

This can involve poor scheduling of labour or physical resources, indeed any thing that indicates that poor planning has contributed to the occurrence. Insufficient resources. Lack of time, no documented planning process.

Inadequate Control and Monitoring:

Lack of, or inadequate, monitoring, supervision and feedback systems for ensuring the proper control of processes. This will be most likely evidenced by variability in the quality of the actual products or services by the organisation.

Where the organisation has failed to ensure that adequate monitoring of activity is taking place. This might be evidenced by poor supervision or lax practices or practices that have been adopted at a local level, that are considered normal and acceptable by those concerned.

Design Deficiencies

Design of equipment does not mean stated requirements. This will be evidenced by failures or deficiencies occurring at a rate higher than that expected or required.

Ergonomically inadequate design, or a whole installation as well as individual tools and equipment. This may also be a failure in the design of the hardware used in the system of operations. It might involve plant or component design failure.

Inadequate Defences:

Lack of error tolerant or fail safe procedural or physical systems giving the potential for otherwise minor problems to result in major or critical occurrences.

Ultimately all incidents can be prevented with adequate defences, what is looked for here is the absence of defences that might be considered normal and prudent for the operation concerned. Where the organisational framework contributes to incidents and errors by making it difficult for them to be detected.

Unsuitable Materials:

The use of contaminated materials, non-approved parts, or material of an inferior quality. It might also include the use of unsuitable software.

Unsuitable Equipment:

The facility, installation, system tools or measuring equipment is incapable or otherwise unsuitable to perform the operations required.

Poor state, availability or suitability of machinery tools and equipment.

Poor Procedures:

Vague, ambiguous, misleading or the complete absence of, documented procedures for ensuring the control of processes and hence the quality of products and/or services.

Inadequate quality or availability of procedures, where poor procedures as indicated in company documents can e shown to have contributed. Care must be taken to make sure that it is the written procedure that contributed to the occurrence. On occasions procedures are not followed and the actual practice differs. (Procedures are what's written that people are supposed to do and practice is what actually happens).

Poor Training:

Non-existent or inappropriate training of personnel. The balance struck between knowledge and training requirements must be adequate to meet the demands of the tasks and operations required to be performed by personnel.

No or inadequate training, selection or craftsmanship of people. People who have not been trained properly will often be operating at their general knowledge based level rather than completing tasks using learned rules or skills.

Poor Co-ordination:

Inadequate operation of a company or inadequate management of projects, stemming from shortcomings in the ability to bring people and resources together at the right place at the right time.

Inadequate Specifications/Requirements:

Incorrect, vague, ambiguous, misleading or complete absence of specifications or requirements necessary to assure the quality of a product or service.

This relates to failures in components or processes where the correct standards have not been adequately specified.

Poor decisions:

Incorrect or otherwise inappropriate decisions made by key personnel due to the misinterpretation of valid information or inappropriately qualified personnel assigned to the decision-making process.

This relates to people misinterpreting the information they receive and relating this to the operational environment. It also applies to management's' abilities to receive timely feed back on the operational environment and incorporate this information in the corporate decision-making process.

Poor Resource Management:

Inadequate assignment or allocation of resources to ensure that products or services meet quality and, in particular, timeliness requirements. Resources inadequate for planned tasks.

Where management has been shown to be inadequate resulting in work scheduling difficulties and poor resource allocation.

Poor Work Environment:

Adverse working conditions or other conditions limiting human capabilities, for example, inadequate lighting or heating. Distraction created by excessive noise. Housekeeping items such as accumulation of rubbish in the work area.

Inadequate Regulation:

This relates to monitoring by outside agencies. Where regulations or monitoring is poor then organisations may not be aware of how this can contribute to incidents.

Other:

For example, the working environment is greatly influenced by the culture of the organisation. On occasions, failure by regulators and management may not always address the negative influences that environment and culture can have. Industrial strife is one area, which may have a detrimental impact.

Qualitative Measures of Maintenance Error

Maintenance Error Reporting Notice and Maintenance Error Investigation Notice (MERN/ MEIN)

This is a two stage investigative process generating qualitative and quantitative information on errors. It is based on the MEDA technique and adapted for New Zealand conditions. It was rejected by the industry as being too time consuming to administer.

Maintenance error incident analysis technique (MEIA)

Based on critical incident technique this is an investigative process generating qualitative and quantitative information on errors. It was rejected by the industry as being to time consuming to administer.

Capturing the errors at ******

The premise behind the method suggested for the capture, investigation and coding of errors is that 'simple is best'. Put simply it involves a two stage process and two individuals. These roles have to be kept separate to ensure objectivity. The process is shown in Figure 2 below.

Figure 2

Process showing proposed method of maintenance error capture in ****

Stage 1

Role of the reporting person

Maintenance error recording undertaken. According to the following steps.

1. Error occurs or is noticed
2. Is this maintenance related??? yes/no

   yes, go to 3 no, refer to appropriate unit manager
3. Enter the information on Maintenance Error Recording Notice
4. Pass notice to authorised investigator

This information is recorded on the Maintenance Error Recording Notice or MERN

Stage 2

Role of the investigator

Maintenance error investigation undertaken. According to the following steps.

1. The reporting person is interviewed an event description recorded. This will be a concise description of the event which is not open to interpretation but includes the persons involved and the salient facts that leave no doubt in the readers mind

2. The causes are the established by asking why several (at least three) times. These cause/s are recorded in a concise manner using a short sentence of around twenty words. They are then coded. Note it is the causes that are coded not the corrective actions.

3. Corrective actions are recorded against each cause. The corrective action will generally address the cause directly. Often the corrective action/s will help to clarify in the investigators mind what the cause/s was / were.

The investigator will assign a cause coding from the Reason model that will identify two codes.

The Rules Table shown below will assist with this.

The Organisation / Person code from list 1a, or Person code, from list 1b.

The Organisational Failure (GFT) list 2c or Error list 2a, or Violation coding, list 2b, that most fits that cause.

This information is recorded on the Maintenance Error Investigation Notice or MEIN

Rules Table

For coding the cause of the error.

Rules for creating an ****, Maintenance Investigation Recording Notice

1. Your description should indicate clearly the nature of the event, what was wrong, not merely describe the circumstances which drew attention to the error.

2. Each cause/s should each have a corrective action attached to them.

3. Each cause text entered on the form should include 'who', being a selection from 1a or 1b. This is entered in the Organisation/Person Person space of the MERN form.

If an Organisation/Person code (list 1a) is identified in the cause then an Organisational Factor cause code (GFT) should be entered from list 2c

If a Person (group of persons, list 1 b) is identified in the cause statement then a Error or Violation cause code should be used, see list 2a and 2b.

Allowable combinations of codes shown in table below

Organisation or Person Code	Organisation Failure (GFT) Cause Code	Error Item Cause Code	Violation Item Cause Code
Organisation/Person Code selected from list 1a	Yes select from list 2c	Code not available	Code not available
Person Code selected from list 1b	Code not available	Yes select from list 2a	Yes select from list 2b

Maintenance Error Recording Notice

******

Section 1

Reference No	Location Noted	Person identifying error	Date Identified
Registration	Aircraft Type	Engine type	Time
Date Corrective action taken by		Ref of related record	

Section 2 Describe the error noticed or the error in performance you or colleague made. Use simple language and try to use not more than 20 words this will force you to be as concise as possible.

Section 3 Phase of operation the error was identified or the effect, tick one.

Maintenance		Flight Operation	
Base Check	☐	In flight	☐
Line check	☐	Post push back	☐
Other check	☐	On ramp/pre or post flight	☐

Section 4 Describe the effect of the error on the organisation, tick one

Re-work required	☐	Flight cancelled	☐
Injury	☐	Gate return	☐
Flight delay Days	☐	In-flight shutdown	☐
Hours	☐	In-flight deviation from SOP	☐
Minutes	☐	In-flight emergency	☐
Aircraft damage	☐	Air turn back	☐

Section 5 Determine which of the following applies to the error recorded above.

1 Improper installation

- a. Required equipment not installed ☐
- b. Wrong equipment installed ☐
- c. Wrong orientation ☐
- d. Improper location ☐
- e. Incomplete installation ☐
- f. Extra parts installed ☐
- g. System equipment not re-activated, de-activated. ☐
- h. Access panel not close ☐
- i. Damaged part ☐
- j. Other, explain below ☐

2 Improper servicing ☐

- a. Insufficient fluid ☐
- b. Too much fluid ☐
- c. Wrong fluid ☐
- d. Required servicing not performed ☐
- e. Other, explain below. ☐

3 Improper or incomplete repair, explain below ☐

4 Improper fault isolation / inspection / testing

- a. Degradation not found ☐
- b. Access panel not closed ☐
- c. Not properly tested ☐
- d. Not properly isolated ☐
- e. Not properly inspected ☐
- f. Other, explain below ☐
- g. System equipment not re-activated, de-activated. ☐

5 Actions causing FOD damage

- a. Material left in aeroplane or engine ☐
- b. Debris on ramp ☐
- c. Debris in open system (not protected) ☐

6 Action causing surrounding plant damage

- a. Damage to surrounding area during repair ☐
- b. Spilling fluids ☐
- c. Other, explain below ☐

Other explanation from table above.

Section 6 Describe below the corrective actions you have identified to fix the error. Include all things that are necessary to stop the error from occurring again.

When you have completed this form hand it to your supervisor. Thank you.

Maintenance Error Investigation Notice

Section 1 Person Investigating Reference No

Section 2 Step 1, 2 and 3 must be completed with the persons involved present.

Step 1, Description During investigation and interviews with the people involved, describe in the error or event in your own words. Use simple language and try to use not more than 20 words this will force you to be as concise as possible.

Step 2 Cause Ask the persons involved why the event occurred. Do not stop at their first answer but continue to ask 'why' until you have a complete picture of the contributing causes. Record each major cause in a short (no more than twenty words) sentence below. For each cause establish the corrective action required and write this down in simple clear English. If you have more than three attach a new form with the same reference. Describe the corrective action and assign a Organisation/Person and an error/violation or General Failure Type code.

Cause 1 Check that your cause is clear and not open to miss-interpretation. Include who a person(or group of persons) or it must be and organisational part or system.

Corrective action. (This should include who, will do what, by when.)

Organisation/Person (1a) or Person (1b) Organisational (GFT, 2c) Error (2a) Violation (2b) cause code

Cause 2 Check that your cause is clear and not open to miss-interpretation. Include who a person(or group of persons) or it must be and organisational part or system.

Corrective action. (This should include who, will do what, by when.)

Organisation/Person (1a) or Person (1b) code

Organisational (GFT, 2c) Error (2a) Violation (2b) cause

Cause 3 Check that your cause is clear and not open to miss-interpretation. Include who a person(or group of persons) or it must be and organisational part or system.

Corrective action. (This should include who, will do what, by when.)

Organisation/Person (1a) or Person (1b) code

Organisational (GFT, 2c) Error (2a) Violation (2b) cause

Step 3 Describe any Defences that are need to stop re-occurrence of this error.

Once you have written your Maintenance Investigation Recording Notice run through it again and ask yourself the following.

- Is my English simple and clear. Is it unambiguous. If it can be misinterpreted then re-write it.
- Does the cause text identify the real cause of the event. Check to see that you have not just reworded the Description.
- Is the organisation/person or person identified as responsible for that cause correctly identified. Are the cause codes a true reflection of the cause text.
- Ask yourself "why might this be the wrong choice". This is probably the most important check and helps to avoid the phenomenon known as confirmation bias.

List 1a Organisation/Person code	CAA category code number may be entered on the form
Aircraft Operator	
Training Organisation	
Maintenance Organisation	
Manufacturer	
Aerodrome Operator	
Air Traffic Service Provider	
Aero Telecomms Provider	
AIS Provider	
Met Service Provider	
Security Service Provider	
Freight Forwarder/Courier	
CAA	
Each of the above may be further broken down by the following sub-headings.	
{private }Ho Management	
Unit Mgmnt/Supervisory	
Staff	
Other	

List 1b Person Individuals may be generically defined by the following:	CAA category code number may be entered on the form
Pilot-In-Command	
Co-Pilot	
Instructor/Check Pilot	
Pilot Of Other Aircraft	
Dual Student/Pilot Under Check	
Flight Engineer	
Other Flight Crew	
Cabin Crew	
Passenger	
Loader	
Driver Of Vehicle	
Ground Instructor	
Ramp/Line Crewman	
Flight Ops Officer/Dispatcher	
Air Traffic Controller	
Flight Service Officer	
Meteorological Briefer	
Meteorological Forecaster	
Telecommunications Technician	
Aircraft Maintenance Engineer	
CAA Assessor	
Member Of Public	
Other	

List 2a Error	CAA category code number may be entered on the form
Task Unfamiliarity	
Time Shortage	
Poor Signal: Noise	
Poor Human-System Interface	
Designer User Mismatch	
Error Irreversibility	
Information Overload	
Negative Task Transfer (Habits)	
Task Overload	
Risk Misperception	
Poor System Feedback	
Inexperience (Not Lacking Of Training)	
Lack Of Knowledge	
Task/Education Mismatch	
Poor Instructions/Procedures	
Inadequate Checking	
Hostile Environment	
Other Environmental Factor (e.g., Weather)	
Interpretation Difficulties	
Disturbed Sleep Patterns	
Fatigue — Other	
Drugs/Alcohol	
Visual Illusion	
Disorientation/Vertigo	
Physiological Other	
Monotony/Boredom	
Lack of Confidence	
Poor Attention Span	
Psychological Other	
Other Error Enforcing Condition	

List 2b Violation	CAA category code number may be entered on the form
Lack of Safety Culture	
Management/Staff Conflict	
Poor Morale	
Poor Supervision & Checking	
Group Violation Condoning Attitude	
Hazard Misperception	
Lack of Management Care/Concern	
Lack Of Pride In Work	
Risk Tasking Culture Encouraged	
Complacency (i.e., It Can't Happen)	
Learned Helplessness (i.e., Who Cares)	
Perceived License To Bend Rules	
Age/Sex Factor	
Other Violation Enforcing Condition	

List 2c Organisation Failure (GFT)	CAA category code number may be entered on the form
Inappropriate Goals or Policies	
Organisation Structural Deficiencies	
Inadequate Communications	
Poor Planning	
Inadequate Control and Monitoring	
Design System Deficiencies	
Inadequate Defences	
Unsuitable Materials	
Unsuitable Equipment	
Poor Procedures	
Poor Training	
Poor Co-ordination	
Inadequate Specifications/Requirements	
Poor Decisions	
Poor Resource Management	
Poor Work Environment	
Inadequate Regulation	
Other Organisation Factor	

A more detailed description of the Organisational Failure items is given below.

Inappropriate Goals or Policies:

Unclear or inappropriate organisation goals or policies which may compromise or conflict with required or expected safety objectives and priorities, for example, an organisation's sole goal is to make a financial profit with no mention of safety objectives.

The conflict the worker has to solve between production, financial, governmental, social or individual priorities and optimal working routines: for example, an in flight APU failure, where replacement had been deferred in excess of normal limits because of time pressures and line operation requirements requiring the aircraft to be on the ramp and ready to go. The error here may be seen as the LAME releasing an aircraft which has a suspect APU. One contributing factor to the decision was incompatible goals in the organisation.

Organisational Structural Deficiencies:

Ambiguous, vague or otherwise inadequate definition and implementation of personnel responsibilities and authorities and in particular, interrelationships between key personnel. Tasks and activities not being carried out by appropriate personnel, for example, the CEO of an organisation having a heavy involvement in day-to-day operational matters.

A catch-all GFT that encompasses, ill defined management roles and systems, poor lines of accountability, unclear mechanism for introducing fixed and evidence that the organisation failed or is unable to learn from it's experience (both good and bad) evidenced by an organisation that is having repeatedly similar errors.

Inadequate Communication:

Deficiencies in the provision, or transfer, of information at both the formal and informal level between key personnel either within or beyond the organisation (for example, with the regulatory authority). Poor two-way communications between management and staff.

Inadequate communication between the various regions, departments or employees in the company, that is, information transfer where communications relating to, for example, the operation of an aircraft are confused, not received, misinterpreted or otherwise corrupted. This might be related to logs and records, manuals or organisational policies and procedures.

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This can involve poor scheduling of labour or physical resources, indeed any thing that indicates that poor planning *has contributed to the occurrence. Insufficient resources. Lack of time, no documented planning process.*

Inadequate Control and Monitoring:

Lack of, or inadequate, monitoring, supervision and feedback systems for ensuring the proper control of processes. This will be most likely evidenced by variability in the quality of the actual products or services by the organisation.

Where the organisation has failed to ensure that adequate monitoring of activity is taking place. This might be evidenced by poor supervision or lax practices or practices that have been adopted at a local level, that are considered normal and acceptable by those concerned.

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Design of equipment does not mean stated requirements. This will be evidenced by failures or deficiencies occurring at a rate higher than that expected or required.

Ergonomically inadequate design, or a whole installation as well as individual tools and equipment. This may also be a failure in the design of the hardware used in the system of operations. It might involve plant or component design failure.

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Lack of error tolerant or fail safe procedural or physical systems giving the potential for otherwise minor problems to result in major or critical occurrences.

Ultimately all incidents can be prevented with adequate defences, what is looked for here is the absence of defences that might be considered normal and prudent for the operation concerned. Where the organisational framework contributes to incidents and errors by making it difficult for them to be detected.

Unsuitable Materials:

The use of contaminated materials, non-approved parts, or material of an inferior quality. It might also include the use of unsuitable software.

Unsuitable Equipment:

The facility, installation, system tools or measuring equipment is incapable or otherwise unsuitable to perform the operations required.

Poor state, availability or suitability of machinery tools and equipment.

Poor Procedures:

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Inadequate quality or availability of procedures, where poor procedures as indicated in company documents can e shown to have contributed. Care must be taken to make sure that it is the written procedure that contributed to the occurrence. On occasions procedures are not followed and the actual practice differs. (Procedures are what's written that people are supposed to do and practice is what actually happens).

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Non-existent or inappropriate training of personnel. The balance struck between knowledge and training requirements must be adequate to meet the demands of the tasks and operations required to be performed by personnel.

No or inadequate training, selection or craftsmanship of people. People who have not been trained properly will often be operating at their general knowledge based level rather than completing tasks using learned rules or skills.

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Inadequate operation of a company or inadequate management of projects, stemming from shortcomings in the ability to bring people and resources together at the right place at the right time.

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Incorrect, vague, ambiguous, misleading or complete absence of specifications or requirements necessary to assure the quality of a product or service.

This relates to failures in components or processes where the correct standards have not been adequately specified.

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Incorrect or otherwise inappropriate decisions made by key personnel due to the misinterpretation of valid information or inappropriately qualified personnel assigned to the decision-making process.

This relates to people misinterpreting the information they receive and relating this to the operational environment. It also applies to management's abilities to receive timely feed back on the operational environment and incorporate this information in the corporate decision-making process.

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Inadequate assignment or allocation of resources to ensure that products or services meet quality and, in particular, timeliness requirements. Resources inadequate for planned tasks.

Where management has been shown to be inadequate resulting in work scheduling difficulties and poor resource *allocation.*

Poor Work Environment:

Adverse working conditions or other conditions limiting human capabilities, for example, inadequate lighting or heating. Distraction created by excessive noise. Housekeeping items such as accumulation of rubbish in the work area.

Inadequate Regulation:

This relates to monitoring by outside agencies. Where regulations or monitoring is poor then organisations may not be aware of how this can contribute to incidents.

Other:

For example, the working environment is greatly influenced by the culture of the organisation. On occasions, failure by regulators and management may not always address the negative influences that environment and culture can have. Industrial strife is one area, which may have a detrimental impact.

Maintenance Error Incident Analysis

The interviewer reads out the italic sections.

Introduction

Hello my name is Ian Patterson. I am doing PhD study at Massey University, Department of Psychology, into the area of aviation safety and maintenance.

This is a structured interview designed to elicit incidents and occurrence of maintenance related errors. It is to be used by the interviewer with employees of the company who have been selected using a representative sampling method. This will sample participants from all areas of maintenance related activity.

Background

The italics below can be shown to participants.

In examining error in high technology industries, like aviation, the view may be taken that these occurrences may be reasonably seen as a result of poor managerial decision making.

To illustrate this point an example may help.

The accident involving the in-flight separation of a rubber boot on the T fin of an Embraer aircraft has been described as resulting from a series of failures. These included poor shift work procedures imposed by management and a lack of supervision and guidance from the Federal Aviation Administration.

Elaborate as required.

In your company incidents of safety related nature may never have lead to a full blown accident but nevertheless some of the preconditions for an accident might exist. I am particularly interested in maintenance and how human behaviour (human factors) on the shop floor can influence the overall safety record of a company.

This research takes the view that errors in maintenance are ultimately the responsibility of management. It is no longer seen as useful to blame individuals within an organisation as this serves only to hide where the real problems are. To make errors is normal and indeed to be expected. The focus then is how to produce early detection, in a system that is conscious of the likelihood of such errors

So what is this interview is about?

I hope to get an idea about how maintenance errors occur in this organisation. These might be errors that you have made or errors from other sources. I would like to ask you a series of questions about errors that you know about whether or not they have been reported to your seniors. Thank you for agreeing to talk to me about your work. Can I first take down some contact details. This is in case I need to check back with you on something that I have not understood. Please be assured that I am the only person that will know that you provided the information.

No other person will have access to the individual information that you provide which will be kept in my possession in a locked filing cabinet.

Emphasise that; only the researcher will see the responses that the participant makes. That no other party will know of the source of the information.

Could you please provide the following information. Code numbers are used to keep your information confidential to the researcher only. I keep a record of your identifier only so I can clarify something at a later stage if I need to.

Phone contact ....

Job title...................................... Age.....................years

Time in job............................. Time with this company....................years.

Prior job to this one...

Qualifications

First of all can you tell me a little about the nature of your work. Describe what you did on your last complete working day. This will give me an idea of your typical routine. Before we start would you mind if I tape record what you say. I cannot always remember exactly what people say even when I take notes. Only I will hear the tape which will later be erased.

List of Incidents

I would like you to think back over the last six months. Try and recall the incidents of maintenance errors that you have observed in the workplace. We will spend a little time on this together. The incidents do not have to be serious. To give you an indication of the types of errors that commonly occur in maintenance operations I refer you to this card. Such errors may not have occurred within this organisation but some will have.

Incident Description Detail; describe unsafe departures from accepted normal or correct procedures, or where an unnecessary exposure to a hazardous situation has been generated, or conduct reducing the level of safety normally present. The hazardous situation does not need to have actually happened, merely the error could have caused one.

Incident description. Please describe the incident.	**Date.** What was the approximate date of occurrence or other identifier.	**Frequency of the above incident.** Please give an indication of the number of times this incident or one similar occurred in the past _____months.

Continue overleaf if necessary.

For each incident error described above consider the following;

1. **Defences** In relation to the error just described decide whether sufficient defences were in place to prevent that maintenance error occurring. What, if any defences could be put in place.

2. **Unsafe acts** What act/s actually immediately caused the error. Could be acts completed by different people coincidentally leading to the error. Slips and mistakes relevant here.

3. **Psychological Precursors** What psychological precursors can be identified. Fatigue, hurry to get the job done, workload. Bounded rationality and perception of problem space. Levels of error, Skill, Rule and knowledge, based. Errors are more likely to be notice if they are rule and knowledge based.

4. **General Failure Types (Latent Failures)** These have been around for a long time and may be seen as promoting the psychological precursors and thus the unsafe acts. See list.

Severity of incident in terms of safety

Incident description number above................

Now that you have described the incident give an indication of the severity of the incident on a scale of 1 to 13, where 1 is not severe and 13 is very severe.

tick one box only ✓

Not severe Very Severe

1.	2.	3.	4.	5.	6.	7.

What do you se as the logical consequences of the incident number that you described, if it remained undetected.

Reporting

Was this occurrence reported to anyone else in or outside the organisation.	tick ✓
colleague	
supervisor	
senior management	
an official outside of the organisation	
other	

Examples of the commonest types of maintenance error.

1. Incorrect installation of parts
2. Fitting of wrong parts
3. Electrical wiring discrepancies (including cross-connections)
4. Installation of damaged worn or non certified parts.
5. Items, spacers washers etc missing, missing parts.
6. Loose objects (tools etc.) left in aircraft
7. Cowlings, access panels and fairings not secured, fastenings left undone.
8. Fuel/oil caps and refuel panels not secured, filler breather caps loose or missing.
9. Inadequate lubrication
10. Landing gear lock pins, covers, blanks not removed before departure.
11. Shortcuts i.e. replacing components without first breaking, loosening connections.
12. Over torqueing nuts and seals.
13. Incomplete recording and paperwork.
14. Delay or postponing of essential maintenance.

Types of error observed in maintenance

How often have these common maintenance errors have occurred in the last month.

Item	Frequency
1. Incorrect installation of parts	
2. Fitting of wrong parts	
3. Electrical wiring discrepancies (including cross-connections)	
4. Installation of damaged worn or non certified parts.	
5. Items, spacers washers etc missing, missing parts.	
6. Loose objects (tools etc.) left in aircraft	
7. Cowlings, access panels and fairings not secured, fastenings left undone.	
8. Fuel/oil caps and refuel panels not secured, filler breather caps loose or missing.	
9. Inadequate lubrication	
10. Landing gear lock pins, covers, blanks not removed before departure.	
11. Shortcuts i.e. replacing components without first breaking, loosening, connections.	
12. Over torqueing nuts and seals.	
13. Incomplete recording and paperwork.	
14. Delay or postponing of essential maintenance.	
Total	

Notes on treatment of the Incident Data

This treatment will measure the degree to which experts agree on allocation of critical incidents to the GFT model described. High agreement will indicate two things. Clarity of the GFT model and the incident descriptions.

1. Each incident will be inspected by a panel of experts and will be assigned to one of the General failure types definition. A measure of agreement as special case of association will be made. Log linear modelling may be used for this.

2. The degree of agreement for the items destination GFT will be calculated.

$$\text{agreement} = \frac{(\text{agreed GFT category})}{\text{agreed GFT category} + \text{disagree}} * 100\%$$

Need to check this out. If there are 13 possible GFT types. Each expert if behaving randomly might assign an incident to GFT one by accident a second expert might also assign randomly to this GFT. Thus we have a case of accidental or random agreement. This needs to be controlled for.

Where marked disagreement occurs then the incident will be placed in the GFT favoured most.

- The frequency with which this incident is thought to have occurred in the last six months is given an integer value by the respondent.
- The severity is translated from the 13 point scale to 7-point integer value.
- From the qualitative data provided the experts will also assign a severity rating based on the item description and the logical consequences data. Experts will be provided with de identified data. Measures of agreement will be made between the experts and the respondents, using Pearson's R.

General Failure Types explanatory notes

Senior managers will be interviewed using the following procedure.

The GFT model is outlined to the managers concerned. Explanations are given of how the GFT model seeks to explain occurrences, incidents and accidents in terms of latent failures within the organisation/system under consideration. The manager is asked to consider each GFT area and give an indication of the frequency with which each has occurred. This process can be repeated with the mangers over several months giving them an opportunity to monitor their organisation and at the same time providing training in the model. This represent a form of self appraisal of how well the organisation in doing.

For every reported human error in maintenance there will be a selection of organisation failings that set the conditions in which the error occurred. Human beings will make errors more frequently when certain conditions exist. These conditions have been broadly classified into 18 General Failure Types (GFTs)

For the incident, event or occurrence under consideration, it is necessary to be able to identify those aspects of organisations that contribute to failure. Of course more than one GFT may contribute to any one failure.

Appendix B: Measures reviewed in the literature

Furnham and Gunter's measure (1993)

This questionnaire is about CORPORATE CULTURE which is the commonly held beliefs, attitudes, and values that exist within an organization. Put more simply, corporate culture in your organization is 'the way we do things around here'.

Please think about how people behave in your organization, and the expectations people have of you. What are the policies and practices work colleagues expect you to follow and believe in? Then read each question and indicate the importance attached to those beliefs and values.

The higher the number you circle, the more important and valued that set of behaviours are by the company. The lower the numbers, the less importance your organization attaches to these values.

IN YOUR ORGANIZATION, TO WHAT EXTENT DO PEOPLE ENDORSE EACH OF THE BELIEFS AND VALUES LISTED BELOW

A Task dimension

1 Initiative-taking orientation

		Great extent … Not at all	
1	It is vital for business success to keep up with new development	7 6 5 4 3 2 1	
2	Try to avoid doing things in the same, predictable ways.	7 6 5 4 3 2 1	
3	Successful organizations generally keep one step ahead of the rest	7 6 5 4 3 2 1	
4	New ideas and procedures should always be treated with caution	7 6 5 4 3 2 1	
5	People should always look for new ways of solving problems	7 6 5 4 3 2 1	[ ] I

2 Risk-taking orientation

6	Never act on anything before thinking things out carefully	7 6 5 4 3 2 1	
7	Always try to avoid risky decisions	7 6 5 4 3 2 1	
8	Don't take unnecessary chances	7 8 5 4 3 2 1	
9	It often pays to stick your neck out once in a while.	7 6 5 4 3 2 1	
10	Caution is the best policy	7 6 5 4 3 2 1	
11	Nobody got anywhere without taking a chance every once in a while	7 6 5 4 3 2 1	[ ] RA

3 Performance quality orientation

12	Even the simplest jobs should be done well	7 6 5 4 3 2 1	
13	Quality comes before quantity	7 6 5 4 3 2 1	
14	If a job is worth doing, it is worth doing well	7 6 5 4 3 2 1	
15	You should always take time to do things right	7 6 5 4 3 2 1	
16	Those who know their business well will succeed	7 6 5 4 3 2 1	
17	Always try to pursue a standard of excellence.	7 6 5 4 3 2 1	
18	Always try to be right	7 6 5 4 3 2 1	
19	Never settle for half measures when doing a job	7 6 5 4 3 2 1	[ ] PQ

4 Strategic planning

20	Treat rules as more important than ideas	7 6 5 4 3 2 1	
21	Always explore the alternatives before acting	7 6 5 4 3 2 1	
22	It is essential to think ahead	7 6 5 4 3 2 1	
23	A successful organization always knows where it is going	7 6 5 4 3 2 1	
24	Too much attention to planning can slow you down	7 6 5 4 3 2 1	
25	You can never spend too much time planning ahead	7 6 5 4 3 2 1	[ ] SP

B Interpersonal dimensions

1 Power orientated

26	You have to play politics to get on	7 6 5 4 3 2 1	
27	Successful people are those who are loyal to their boss	7 6 5 4 3 2 1	
28	You need to be firm and decisive to survive	7 6 5 4 3 2 1	
29	Subordinates should be hard-working and loyal	7 6 5 4 3 2 1	
30	Control is all-important	7 6 5 4 3 2 1	
31	People in authority have more clout	7 6 5 4 3 2 1	
32	You have to be hard and tough to get on.	7 6 5 4 3 2 1	[ ] P

2 Achievement orientated

33	Success comes to those who believe in getting the job done	7 6 5 4 3 2 1	
34	Personal commitment to attaining goals is of utmost importance	7 6 5 4 3 2 1	
35	Successful people take on challenging tasks	7 6 5 4 3 2 1	
36	Getting the right results comes first.	7 6 5 4 3 2 1	
37	Always strive for better ways of achieving goals.	7 6 5 4 3 2 1	
38	Be the first to reach your targets.	7 6 5 4 3 2 1	
39	Everyone likes a winner	7 6 5 4 3 2 1	[ ] A

3 Co-operation orientation

40	Success comes to those who get on with others	7 6 5 4 3 2 1	
41	You've got to look out for yourself first and foremost	7 6 5 4 3 2 1	
42	Always try to get on with your colleagues	7 6 5 4 3 2 1	
43	Working together is important	7 6 5 4 3 2 1	
44	Always look for constructive ways of overcoming problems.	7 6 5 4 3 2 1	
45	Teamwork comes first	7 6 5 4 3 2 1	
46	It doesn't usually pay to 'rock the boat'	7 6 5 4 3 2 1	[ ] C

4 Supportive orientation

47	Show concern for the needs of others	7 6 5 4 3 2 1	
48	Always try to help your colleagues	7 6 5 4 3 2 1	
49	Warmth among colleagues helps get the job done	7 6 5 4 3 2 1	
50	People are more important than things	7 6 5 4 3 2 1	
51	People should be told when they have done well	7 6 5 4 3 2 1	[ ] (S)

5	**Communication orientation**								
52	People at work need encouragement	7	6	5	4	3	2	1	
53	Ideas should flow freely	7	6	5	4	3	2	1	
54	Line management should take care over what they say to subordinates	7	6	5	4	3	2	1	
55	Open communication is best	7	6	5	4	3	2	1	
56	Everyone in an organization should be kept informed	7	6	5	4	3	2	1	
57	Communication needs to be carefully controlled	7	6	5	4	3	2	1	
58	Policy decisions should always be based on sound information	7	6	5	4	3	2	1	
59	Only communicate on a 'need-to-know' level	7	6	5	4	3	2	1	☐ (R/C)
6	**Rewards orientated**								
60	People need regular rewards	7	6	5	4	3	2	1	
61	Rewards should go to those who are committed to their work	7	6	5	4	3	2	1	
62	Promotion goes to those who wait	7	6	5	4	3	2	1	
63	People shouldn't always expect special rewards for doing their job well	7	6	5	4	3	2	1	
64	Rewards should follow quickly on performance	7	6	5	4	3	2	1	
65	Good workers deserve rapid promotion	7	6	5	4	3	2	1	
66	Rewards for effort should not be too easily given	7	6	5	4	3	2	1	☐ (R)
7	**Moral orientation**								
67	Happy workers are more productive	7	6	5	4	3	2	1	
68	A healthy team spirit is important to a successful organization	7	6	5	4	3	2	1	
69	Friendly managers seldom gain the respect of their subordinates.	7	6	5	4	3	2	1	
70	People are best motivated with friendliness	7	6	5	4	3	2	1	
71	An organization which takes care of its employees can expect them to work well	7	6	5	4	3	2	1	☐ (M)
C	**Individual-level orientation**								
1	**Autonomy orientation**								
72	Final decisions should always be checked with superiors	7	6	5	4	3	2	1	
73	It is best to give individuals the freedom to do things in their own way	7	6	5	4	3	2	1	
74	Good workers accept goals without question	7	6	5	4	3	2	1	
75	Strict management procedures build a tight ship	7	6	5	4	3	2	1	
76	Superiors should never be challenged	7	6	5	4	3	2	1	
77	Giving workers a major say in how they do their jobs improves performance	7	6	5	4	3	2	1	☐ (AU)
2	**Self-expression orientation**								
78	Always question others' decisions	7	6	5	4	3	2	1	
79	Be spontaneous	7	6	5	4	3	2	1	
80	Always try to improve your understanding of your job	7	6	5	4	3	2	1	
81	Employees should be helped to realize their full potential	7	6	5	4	3	2	1	
82	Workers should be encouraged to be enthusiastic about their work.	7	6	5	4	3	2	1	
83	Order and discipline are essential to business success	7	6	5	4	3	2	1	
84	Workers would normally do best to concentrate on the jobs they are given	7	6	5	4	3	2	1	☐ (SE)
3	**Diversity orientation**								
85	Employees should concentrate on mastering just a few clearly-defined duties and responsibilities	7	6	5	4	3	2	1	
86	Job variety builds a happy work-force	7	6	5	4	3	2	1	
87	Employees can benefit their organization by trying different jobs.	7	6	5	4	3	2	1	
88	Workers work best if they are given different things to do	7	6	5	4	3	2	1	
89	It is essential that work is interesting	7	6	5	4	3	2	1	☐ (D)
4	**Personal growth orientation**								
90	Employees need to explore ways of realizing their full potential	7	6	5	4	3	2	1	
91	It is only by stretching people that they become more effective	7	6	5	4	3	2	1	
92	A mature person is one who always strives to improve	7	6	5	4	3	2	1	
93	People should put the needs of the company ahead of their personal growth.	7	6	5	4	3	2	1	
94	A company can only grow if it allows its work-force the freedom to develop	7	6	5	4	3	2	1	☐ (PG)

Harrison's measure (1975)

Table 3.6 Scoring frame for Harrison's organizational ideology questionnaire

Sums of ranks	*Individual and group profiles*			
	Power orientation	*Role orientation*	*Task orientation*	*Self orientation*
Existing organization ideology				
Participant's preferred organization ideology				
Tally of lowest scores of the group members				
	Power orientation	*Role orientation*	*Task orientation*	*Self orientation*
Existing organization ideology				
Participant's preferred organization ideology				

Source. Harrison (1972) Reproduced by permission of publisher.

Diagnosing organizational ideology (Roger Harrison)

Organizations have patterns of behaviour that operationalize an ideology a commonly held set of doctrines, myths, and symbols. An organization's ideology has a profound impact on the effectiveness of the organization. It influences most important issues in organization life: how decisions are made, how human resources are used, and how people respond to the environment. Organization ideologies can be divided into four orientations: power, role, task, and self. The items below give the positions of the four orientations on a number of aspects of organizational structure and functioning and on some attitudes and beliefs about human nature.

Instructions. Give a '1' to the statement that best represents the dominant view in your organization, a '2' to the one next closest to your organization's position, and so on through '3' and '4'. This is a measure of the *existing* organization ideology. Then go back and again rank the statement '1' through '4', this time according to your desires in the preferred organization you would like to work in.

1 A good boss is:

(a) Strong, decisive and firm, but fair. He is protective, generous, and indulgent to loyal subordinates.

(b) Impersonal and correct, avoiding the exercise of his authority for his own advantage. He demands from subordinates only that which is required by the formal system.

(c) Egalitarian and capable of being influenced in matters concerning the task. He uses his authority to obtain the resources needed to complete the job.

(d) Concerned with, and responsive to, the personal needs and values of others. He uses his position to provide satisfying and growth-stimulating work opportunities for subordinates.

2 A good subordinate is:

(a) Compliant, hard-working, and loyal to the interest of his superior.

(b) Responsible and reliable, meeting the duties and responsibilities of his job, and avoiding actions that surprise or embarrass his superior.

(c) Self-motivated to contribute his best to the task and is open with his ideas and suggestions. He is, nevertheless, willing to give the lead to others when they show great expertise or ability.

(d) Vitally interested in the development of his own potentialities, and is open to learning and to receiving help. He also respects the needs and values of others, and is willing to help and contribute to their development.

3 A good member of the organization gives first priority to the:

(a) Personal demands of the boss.

(b) Duties, responsibilities and requirements of his own role, and to the customary standards of personal behaviour

(c) Requirements of the task for skill, ability, energy, and material resources
(d) Personal needs of the individuals involved.

4 People who do well in the organization are:
(a) Shrewd and competitive, with a strong need for power
(b) Conscientious and responsible, with a strong sense of loyalty to the organization.
(c) Technically effective and competent, with a strong commitment to getting the job done.
(d) Effective and competent in personal relationships, with a strong commitment to the growth and development of people

5 The organization treats the individual as:
(a) Though his time and energy were at the disposal of persons higher in the hierarchy.
(b) Though his time and energy were available through a contract with rights and responsibilities for both sides.
(c). A co-worker who has committed his skills and abilities to the common cause
(d) An interesting and worthwhile person in his own right.

6 People are controlled and influenced by the:
(a) Personal exercise of economic and political power (rewards and punishments).
(b) Impersonal exercise of economic and political power to enforce procedures and standards of performance.
(c) Communication and discussion of task requirements leading to appropriate action motivated by personal commitment to goal achievement
(d) Intrinsic interest and enjoyment to be found in their activities and/or by concern, and caring for the needs of the other persons involved.

7 It is legitimate for one person to control another's activities if:
(a) He has more authority and power in the organization.
(b) His role prescribes that he is responsible for directing the other
(c) He has more knowledge relevant to the task
(d) The other accepts that the first person's help or instructions can contribute to his learning power

8 The basis of task assignment is the:
(a) Personal needs and judgement of those in authority.
(b) Formal divisions of functions and responsibilities in the system.
(c) Resource and expertise requirements of the job to be done
(d) Personal wishes and needs for learning and growth of individual organization members

9 Work is performed out of:
(a) Hope of reward, fear of punishment, or personal loyalty toward a powerful individual
(b) Respect for control obligations backed up by sanctions and loyalty toward the organization of system
(c) Satisfaction in excellence of work and achievement and/or personal commitment to the task or goal
(d) Enjoyment of the activity for its own sake and concern and respect for the needs and values of the other persons involved

10 People work together when:
(a) They are required to by higher authority or when they believe they can use each other for personal advantage
(b) Co-ordination and exchange are specified by the formal system
(c) Their joint contribution is needed to perform the task.
(d) The collaboration is personally satisfying, stimulating or challenging.

11 The purpose of competition is to:
(a) Gain personal power and advantage.
(b) Gain high-status positions in the formal system
(c) Increase the excellence of the contribution to the task
(d) Draw attention to one's own personal needs

12 Conflict is:
(a) Controlled by the intervention of higher authorities and often fostered by them to maintain their own power
(b) Suppressed by reference to rules, procedures, and definitions of responsibility.
(c) Resolved through full discussion of the merits of the work issues involved.
(d) Resolved by open and deep discussion of personal needs and values involved.

13 Decisions are made by the:
(a) Person with the higher power and authority.
(b) Person whose job description carries the responsibility
(c) Persons with the most knowledge and expertise about the problem.
(d) Persons most personally involved and affected by the outcome

14 In an appropriate control and communication structure:
(a) Command flows from the top down in a simple pyramid, so that anyone who is higher in the pyramid has authority over anyone who is lower Information flows up through the chain of command.
(b) Directives flow from the top down and information flows upwards within functional pyramids which meet at the top. The authority and responsibility of a role is limited to the roles beneath it in its own pyramid Cross-functional exchange is constructed.
(c) Information about task requirements and problems flows from the centre of the task activity upwards and outwards, with those closest to the task determining the resources and support needed from the rest of the organization A co-ordinating function may set priorities and overall resource levels based on information from all task centres The structure shifts with the nature and location of the tasks.
(d) Information and influence flow from person to person, based on voluntary relationships initiated for purposes of work, learning, moral support, enjoyment, and shared values. A co-ordinating function may establish overall levels of contributions needed for the maintenance of the organization. These tasks are assigned by mutual agreement

15 The environment is responded to as though it were:
(a) A competitive jungle in which everyone is against everyone else, and those who do not exploit others are themselves exploited
(b) An orderly and rational system in which competition is limited by law and there can be negotiation or compromise to resolve conflicts
(c) A complex of imperfect forms and systems which are to be reshaped and improved by the achievements of the organization
(d) A complex of potential threats and support It is used and manipulated by the organization both as a means of self-nourishment, and as a play-and-work space for the enjoyment and growth of organization members

Zohar's measure (1980)

הטכניון — מכון טכנולוגי לישראל
TECHNION — ISRAEL INSTITUTE OF TECHNOLOGY

הפקולטה להנדסת תעשיה וניהול
FACULTY OF INDUSTRIAL AND MANAGEMENT ENGINEERING

SAFETY CLIMATE QUESTIONNAIRE

(Translated from Hebrew)

This questionnaire is designed to find out what workers think about safety and related issues at their workplace. Its objective is to describe the current situation and not to describe it as you think it ought to be.

The questionnaire includes descriptive sentences collected from various sources. All you have to do is indicate how much you agree or disagree with each such sentence. That means, how much is it true in your case.

In order to mark your response you have to circle the appropriate number as in the following example:

	highly disagree	disagree	not sure	agree	highly agree	not relevant
In this company every worker can do his job the way he thinks it ought to be done	1	2	3	(4)	5	0

You can mark the last category, titled "not relevant", when the sentence refers to things which do not exist at your workplace.

This questionnaire is absolutely anonymous and there is no way to identify you personally. We want you therefore to be completely honest

CABLES TECHNION, HAIFA 32 000 / TELEPHONE 230111

and respond as you really feel and think.

Thank you for your cooperation.

Dr. Dov Zohar,
Project Director.

SAFETY CLIMATE QUESTIONNAIRE

[1-2] Company name: ____________________ [ ][ ]

[3-4] Questionnaire No: ________________ [ ][ ]

		highly disagree	disagree	not sure	agree	highly agree	not relevant
[5]	1. When a member of the safety committee approaches a worker and warns him, it really affects his behavior..........	1	2	3	4	5	0
[6]	2. Workers who violate safety regulations aggravate their fellow workers even when no harm has resulted..........	1	2	3	4	5	0
[7]	3. The risk level of my job concerns me quite a bit.......	1	2	3	4	5	0
[8]	4. Workers who behave safely have a higher chance for promotion than those who don't.	1	2	3	4	5	0
[9]	5. I usually inform my supervisor about safety hazards because they appreciate it and try to correct it.	1	2	3	4	5	0
[10]	6. Our general manager is well informed about safety issues in this plant.	1	2	3	4	5	0

		highly disagree	disagree	not sure	agree	highly agree	not relevant
[11]	7. The investment of money and effort in safety training programs is a worthy investment because it improves workers' performance on the job.	1	2	3	4	5	0
[12]	8. The best guys in our department care about safety and they want other workers to behave according to the regulations.	1	2	3	4	5	0
[13]	9. Work under a premium system has nothing to do with accidents. There are simply safe workers and unsafe ones.	1	2	3	4	5	0
[14]	10. The safety officer has much influence on what's happening in our factory.	1	2	3	4	5	0
[15]	11. Plant management in this factory is willing to invest money and effort to improve the safety level in here.	1	2	3	4	5	0
[16]	12. My safety training really helps me both in my work and at home.	1	2	3	4	5	0
[17]	13. Reckless behavior results in a negative evaluation of supervisors towards that worker.	1	2	3	4	5	0

		highly disagree	disagree	not sure	agree	highly agree	not relevant
[18]	14. Our management is well informed about safety problems and it quickly acts to correct them.	1	2	3	4	5	0
[19]	15. My chance for being involved in an accident is quite large.	1	2	3	4	5	0
[20]	16. Because I am working under a premium system I do things so fast that I have no time to care for my safety.	1	2	3	4	5	0
[21]	17. The safety committee in our plant has a very positive effect on what is happening here.	1	2	3	4	5	0
[22]	18. Managers in this factory really care and try to reduce risk levels as much as possible.	1	2	3	4	5	0
[23]	19. I would like to become a member of our plant safety committee because it would give me more status.	1	2	3	4	5	0
[24]	20. When a worker violates safety regulations it has an adverse effect on his supervisor's evaluation of him even when no harm was caused.	1	2	3	4	5	0

		highly disagree	disagree	not sure	agree	highly agree	not relevant
[25]	21. Our managers view safety regulation violations very seriously even when they have resulted in no apparent damage	1	2	3	4	5	0
[26]	22. I am sure it is only a matter of time for me to get involved in an accident.	1	2	3	4	5	0
[27]	23. When the safety officer has a negative opinion of someone, it affects his supervisor's evaluation.	1	2	3	4	5	0
[28]	24. I think safety issues are assigned high priority in management meetings.	1	2	3	4	5	0
[29]	25. The efforts invested in organizing safety training programs really pay back to the company.	1	2	3	4	5	0
[30]	26. The safety problems in my job are very serious.	1	2	3	4	5	0
[31]	27. When a manager realizes that a hazardous situation has been found, he immediately attempts to put it under control.	1	2	3	4	5	0
[32]	28. Workers who work safely try to emphasize it and make sure others appreciate it.	1	2	3	4	5	0

		highly disagree	disagree	not sure	agree	highly agree	not relevant
[33]	29. Workers who take safety training courses are less involved in accidents than those who don't.	1	2	3	4	5	0
[34]	30. One of the main factors affecting workers' evaluation for promotion is whether they were involved in an accident.	1	2	3	4	5	0
[35]	31. Workers who use personal protective equipment are not considered to be cowards but rather good and tidy workers.	1	2	3	4	5	0
[36]	32. Department managers usually remember who were involved in an accident and take it into consideration.	1	2	3	4	5	0
[37]	33. Workers who take safety training courses have a better chance for promotion than those who don't.	1	2	3	4	5	0
[38]	34. Compared to other factories, I think this one is rather dangerous.	1	2	3	4	5	0
[39]	35. Being involved in an accident has an adverse effect on the worker's reputation.	1	2	3	4	5	0

		highly disagree	disagree	not sure	agree	highly agree	not relevant
[40]	36. Plant management in this factory is always willing to adopt new ideas for improving the safety level.	1	2	3	4	5	0
[41]	37. Workers who don't work under a premium system can work more carefully.	1	2	3	4	5	0
[42]	38. When a worker confronts a dangerous situation in his work environment he reports it to the safety officer.	1	2	3	4	5	0
[43]	39. Workers who take safety training courses are doing a better job than those who don't.	1	2	3	4	5	0
[44]	40. When the safety officer issues a safety regulation, we take it into consideration and behave accordingly.	1	2	3	4	5	0

41. Please fill in the following demographic data (if you feel that any of these data may identify you and you wish to remain anonymous, leave it blank):

[45-46] (a) Department: ____________________ ☐☐

[47-48] (b) Job title: ____________________ ☐☐

[49-50] (c) Age: ☐☐

[51] (d) Sex: Male ☐ ; Female ☐

[52] (e) Marital status: Single ☐ ; Married ☐

[53-54] (f) No. of years in this company: ☐☐

[55-56] (g) No. of years in your present job: ☐☐

42. In your opinion, what is the most important factor affecting the safety level of this plant?

____

43. Do you have any other comments which you wish to make, either about this questionnaire or any other safety-related issues? Please use the space below.

____

Thank you!

Broadfoot and Ashkanasy measure (1994)

Broadfoot & Ashkanasy

"Survey Measures of Organisational Culture"

23rd Meeting of Australian Social Psychologists

Cairns, April, 1994

ORGANISATION PROFILE

This survey asks for your views about various aspects of your organisation.

This is your opportunity to express your opinion and make observations that can be used to improve the organisation.

Please give your honest opinion. Your answers will be kept strictly confidential. To ensure confidentiality do not put your name on the survey form. Also none of the data you will be asked to supply will make it possible to identify any individual. When you have completed the survey form place it in the envelope provided and return it to ____________________________________ by ____________________. The results of this survey will be processed by researchers at ______________________ and the envelopes will only be opened by them.

There are 65 statements in the survey. Unless otherwise instructed, you are to decide if each statement is true for your organisation. There are no right or wrong answers, just give your opinion. You may have strong opinions on some statements, but not on others. Using the following scale, *circle* the number that best represents your opinion.

Please respond to each item independently and do not go back and change already completed items. However if you make a mistake please cross out your response and circle another. Please ensure you respond to each statement.

Please use the following guide when you complete this profile. Essentially, you are being asked to decide first whether or not you agree with each statement. Then you need to determine the strength of your agreement or disagreement. If you are undecided, then you are asked to indicate your inclination one way or the other. You should use the middle score (4) only if you are quite undecided, or if you consider the item to be irrelevant.

Strong disagreement = 1 Disagree, but not strongly = 2	Undecided, but inclined to disagree = 3 Quite undecided or item is irrelevant to you = 4 Undecided, but inclined to agree = 5	Agree, but not strongly = 6 Strong agreement = 7

Strong disagreement = 1 Disagree, but not strongly = 2	Undecided, but inclined to disagree = 3 Quite undecided or item is irrelevant to you = 4 Undecided, but inclined to agree = 5	Agree, but not strongly = 6 Strong agreement = 7

1.	By their actions, our senior management show that they put our clients first.	1 2 3 4 5 6 7
2.	Open and free exchange of information is encouraged here.	1 2 3 4 5 6 7
3.	This organisation regularly invests time and resources in developing its members.	1 2 3 4 5 6 7
4.	Our managers encourage their staff to give their views and are generally responsive to them.	1 2 3 4 5 6 7
5.	For me, this is the best of all possible organisations for which to work.	1 2 3 4 5 6 7
6.	Individual rewards are based on performance in this organisation.	1 2 3 4 5 6 7
7.	Individualism is respected in this organisation.	1 2 3 4 5 6 7
8.	It takes time for newcomers to settle in here.	1 2 3 4 5 6 7
9.	Members of this organisation are concerned about their personal and career development.	1 2 3 4 5 6 7
10.	Communications across all levels in this organisation tend to be extremely good.	1 2 3 4 5 6 7
11.	People in this organisation help each other with on-the-job and personal problems.	1 2 3 4 5 6 7
12.	I know what is expected of me as a member of this organisation.	1 2 3 4 5 6 7
13.	This organisation avoids risk.	1 2 3 4 5 6 7
14.	I really care about the fate of this organisation.	1 2 3 4 5 6 7
15.	Management keeps the organisation on course.	1 2 3 4 5 6 7
16.	I often find myself having to make decisions based on limited information.	1 2 3 4 5 6 7
17.	This organisation is rule oriented.	1 2 3 4 5 6 7
18.	Employees know what clients want from this organisation.	1 2 3 4 5 6 7
19	Organisational policies and procedures are helpful, well understood and up to date.	1 2 3 4 5 6 7
20.	It would take very little change in my present work circumstances to cause me to leave this organisation.	1 2 3 4 5 6 7
21.	This organisation regards the welfare of its employees as its first prioriy.	1 2 3 4 5 6 7
22.	The 'grapevine' is the best source of information about this organisation.	1 2 3 4 5 6 7
23.	Often I find it difficult to agree with this organisation's policies on important matters relating to its employees.	1 2 3 4 5 6 7
24.	This organisation provides opportunities for personal and career development.	1 2 3 4 5 6 7
25.	I have to ask my boss before I can do almost anything.	1 2 3 4 5 6 7
26.	I find that my values and this organisation's values are very similar.	1 2 3 4 5 6 7
27.	People here are encouraged to use their own initiative to develop better methods.	1 2 3 4 5 6 7
28.	I would accept almost any type of job assignment to keep working for this organisation.	1 2 3 4 5 6 7
29.	This organisation is successful in developing people for more challenging work within the organisation.	1 2 3 4 5 6 7
30.	This organisation keeps employees well informed on matters important to its employees.	1 2 3 4 5 6 7
31.	It is up to peers to teach new employees how things are done here.	1 2 3 4 5 6 7
32.	I could just as well be working for a different organisation if the type of work was similar.	1 2 3 4 5 6 7
33.	Social relationships are encouraged here.	1 2 3 4 5 6 7
34.	We really strive to follow the organisation's plans.	1 2 3 4 5 6 7
35.	We accept people who don't fit in, provided they produce results.	1 2 3 4 5 6 7
36.	Deciding to work for this organisation was a definite mistake on my part.	1 2 3 4 5 6 7
37.	This organisation emphasises the needs of the clients more than the needs of the employees.	1 2 3 4 5 6 7

-1-

Strong disagreement = 1 Disagree, but not strongly = 2	Undecided, but inclined to disagree = 3 Quite undecided or item is irrelevant to you = 4 Undecided, but inclined to agree = 5	Agree, but not strongly = 6 Strong agreement = 7

38.	I am proud to tell others that I am part of this organisation.	1 2 3 4 5 6 7
39.	The emphasis here is on achieving results.	1 2 3 4 5 6 7
40.	Overall this organisation is a harmonious place to work.	1 2 3 4 5 6 7
41.	This organisation has very clear goals.	1 2 3 4 5 6 7
42.	This organisation does not have a formal induction program.	1 2 3 4 5 6 7
43.	I am willing to put in a great deal more effort than normally expected to help this organisation be successful.	1 2 3 4 5 6 7
44.	New ideas are highly valued here.	1 2 3 4 5 6 7
45.	People are properly oriented and trained on joining this organisation.	1 2 3 4 5 6 7
46.	Participation in strategic planning is encouraged here.	1 2 3 4 5 6 7
47.	This organisation inspires the best of me in the way of job performance.	1 2 3 4 5 6 7
48.	I do not have enough training to do my job well.	1 2 3 4 5 6 7
49.	Progress towards meeting planned objectives is periodically reviewed here.	1 2 3 4 5 6 7
50.	Leaders demonstrate their own commitment to what this organisation is trying to accomplish.	1 2 3 4 5 6 7
51.	There is little to be gained by sticking with this organisation indefinitely.	1 2 3 4 5 6 7
52.	Members of this organisation are expected to follow orders even when they are wrong.	1 2 3 4 5 6 7
53.	I 'talk up' this organisation to my friends as a great organisation to work for.	1 2 3 4 5 6 7
54.	There are leaders in this organisation who symbolise its values and beliefs.	1 2 3 4 5 6 7
55.	Everyone in this organisation is aware of the importance of care for the client.	1 2 3 4 5 6 7
56.	This organisation has a defined plan to meet it's goals.	1 2 3 4 5 6 7
57.	Innovation and creativity are encouraged here.	1 2 3 4 5 6 7
58.	This organisation is regarded as taking a leadership role in relation to other similar organisations.	1 2 3 4 5 6 7
59.	The organisational structure limits the way we do things here.	1 2 3 4 5 6 7
60.	I feel very little loyalty to this organisation.	1 2 3 4 5 6 7
61.	This organisation responds quickly to external changes.	1 2 3 4 5 6 7
62.	There is a clear way of measuring performance in this organisation.	1 2 3 4 5 6 7
63.	Management in this organisation sets precedents for others.	1 2 3 4 5 6 7
64.	I am extremely glad that I chose this organisation to work for, over others I was considering at the time I joined.	1 2 3 4 5 6 7
65.	Members of this organisation care about and strive for excellent performance.	1 2 3 4 5 6 7

Thank-you for completing this questionnaire. Please remember to double check that you have responded to every statement. Finally, please complete the demographic data below. Two of the questions are optional, however a clearer statistical structure will be possible if they are completed. Note that the data collected from this survey is confidential. The survey forms will be disposed of by researchers at the University of Queensland after they are processed.

PERSONAL: Age................ years Gender: F / M
Education: Secondary / TAFE / University / Post-graduate / Other..............................

EMPLOYMENT

Position Title *(Optional)*..............................

Location *(Optional)*..............................

Number of years in organisation.............; Number of years in present position......................

Broadfoot & Ashkanasy
"Survey Measures of Organisational Culture"
23rd Meeting of Australian Social Psychologists
Cairns, April, 1994

Organisation Profile Scoring Key

Organisational Culture

1. Leadership	1	15	50	54	63
2. Structure	17	19	25	52	59
3. Innovation	<u>13</u>	16	27	44	57
4. Job performance	6	35	39	62	65
5. Planning	34	41	46	49	56
6. Communication	2	4	10	<u>22</u>	30
7. Environment	18	37	55	58	61
8. Humanistic	7	11	21	33	40
9. Development of individual	3	9	24	29	<u>48</u>
10. Socialisation of entry	8	12	<u>31</u>	<u>42</u>	45

Commitment

5 14 <u>20</u> <u>23</u> 26 <u>32</u> <u>36</u> 38 43 47
<u>51</u> 53 <u>60</u> 64

Scoring

Underscored items are reverse scored (Subtract from 8)

Appendix C: Items developed for the pilot version of the: Organisational Culture Measure, Organisational Culture Measure items by sub-scale

Items developed for the pilot version of the Organisational Culture Measure

The items highlighted in grey were retained for use in the Organisational Culture Measure used in the main study. To these items were added ten new items include in two new sub-scales; Leadership orientation and Degree of Structure. Items with a ◄ were based on the Furnham and Gunter Measure.

1. ◄ The organisation believes it is vital for business success to keep up with new developments.
2. ◄ The organisation believes that it should avoid doing things in the same, predictable ways.
3. ◄ The organisation believes successful organisations generally keep one step ahead of the rest.
4. ◄ The organisation believes new ideas and procedures are to be treated with caution.
5. ◄ The organisation believes people should look for new ways of solving problems.
6. The organisation seeks to develop and improve on procedures.
7. The organisation believes old ways and practices are always best.
8. Generally workers look for constructive ways of overcoming problems.
9. The organisation thinks very carefully before acting.
10. The organisation believes procedures can be produced as you go.
11. ◄ The organisation tries to avoid risky decisions.
12. ◄ The organisation does not take unnecessary chances.
13. ◄ The organisation believes it often pays to stick your neck out once in a while.
14. ◄ The organisation believes caution is the best policy.
15. The organisation believes regulations are the most important thing.
16. The organisation believes that nobody got anywhere without taking a chance every once in a while.
17. ◄ Even the simplest jobs are to be done well.
18. ◄ That quality comes before quantity.
19. ◄ The organisation believes if a job is worth doing, it is worth doing well.
20. ◄ Always take time to do things right.
21. ◄ The organisation believes those who know their business well will succeed.
22. ◄ The organisation believes in pursuing a high standard of excellence.
23. ◄ The organisation believes one should always try to be right.
24. ◄ Never settle for half measures when doing a job.
25. ◄ The organisation believes that alternatives should be explored before acting.
26. ◄ The organisation believes it is essential to think ahead.
27. ◄ A successful organisation always knows where it is going.
28. ◄ The organisation believes that too much attention to planning can slow you down.
29. ◄ The organisation believes that one can never spend too much time planning ahead.

30. Too much time is spent responding to emergencies.

31. Crises are rare around here.

32. Work is well organised.

33. The organisation believes training of the work force is important.

34. Order and tidiness are considered important.

35. Goal setting happens here.

36. ◄ You have to play politics to get on.

37. ◄ Successful people are those who are loyal to their boss.

38. You need to be firm and decisive to survive here.

39. ◄ Subordinates should be hard- working and loyal.

40. ◄ The organisation believes controlling people is all-important.

41. ◄ People in authority really are in control here.

42. ◄ You have to be hard and tough to get on.

43. There is a consultative atmosphere here.

44. People in this company like to manage

45. Mutual respect is promoted here.

46. A great distance exists between the work force and management.

47. First name terms are the norm throughout the organisation.

48. ◄ Success comes to those who believe in getting the job done.

49. ◄ Personal commitment to attaining goals is of utmost importance for people in this organisation.

50. ◄ Successful people in this organisation are the ones who take on challenging tasks.

51. ◄ Getting the right results comes first around here.

52. ◄ The organisation believes one should always strive for better ways of achieving goals.

53. ◄ The organisation believes one should be first to reach one's targets.

54. ◄ Around here everyone likes a winner.

55. Customers are the first priority around here.

56. People strive to improve in this organisation.

57. ◄ Success comes to those who get on with others.

58. ◄ You've got to look out for yourself first and foremost.

59. ◄ People get on with their colleagues around here.

60. ◄ Working together is important around here.

61. ◄ Teamwork comes first.

62. ◄ It doesn't usually pay to "rock the boat".

63. Managers are involved at the grass roots level during day to day operations.

64. Seeking advice is encouraged.

65. Everyone in this organisation is a customer of the other.

66. ◄ People around here show concern for the needs of others.

67. ◄ Workers generally try to help their colleagues.

68. ◄ Warmth among colleagues helps get the job done.
69. ◄ This organisation believes that people are more important than things.
70. ◄ People are told when they have done well.
71. Management helps workers do their jobs better.
72. Feedback is encouraged in the organisation.
73. Management are concerned only with outputs.
74. ◄ People at work need encouragement.
75. ◄ Ideas generally flow freely.
76. ◄ Management is considered guarded over what they say to the work force.
77. ◄ The organisation believes that open communication is best.
78. ◄ Everyone in an organisation is to be kept informed.
79. ◄ Communication is too controlled by management.
80. ◄ Around here policy decisions are always based on sound information.
81. ◄ Communication seems to happen on a "need- to-know" basis mainly.
82. This organisation is too hierarchical in its structure, with lots of layers of management.
83. It is difficult for one person to make the difference here.
84. Company goals and objectives are clearly communicated.
85. People can bypass their boss or go to someone else with a problem.
86. Problems can be taken to anyone in the organisation.
87. Senior management understand very well the work undertaken in the maintenance area.
88. Management are rarely seen on the shop floor.
89. ◄ The organisation believes that people need regular rewards.
90. ◄ Rewards go to those who are committed to their work.
91. ◄ Promotion generally goes to those who have been around for a while.
92. ◄ People are rewarded for doing their job well.
93. ◄ Rewards follow quickly on performance.
94. ◄ Good workers deserve rapid promotion.
95. ◄ Rewards for effort are appropriate.
96. The organisation punishes those who make mistakes.
97. ◄ The organisation believes happy workers are more productive.
98. ◄ A healthy team spirit is important to a successful organisation.
99. ◄ Friendly managers gain the respect of their subordinates.
100. ◄ The organisation believes people are best motivated with friendliness.
101. ◄ An organisation which takes care of its employees can expect them to work well.
102. Workers think conditions here are as good as anywhere in the industry.
103. Working here is very satisfying.
104. People like working here.
105. This work environment is stressful for most people.

106. People who work here generally think it is a positive work environment.

107. The organisation looks after the staff here.

108. ◄ Final decisions are generally checked with superiors.

109. ◄ It is best to give individuals the freedom to do things in their own way.

110. ◄ Good workers accept work targets without question.

111. ◄ The organisation believes that strict management procedures build a tight ship.

112. ◄ Superiors are never to be challenged here.

113. ◄ Giving workers a major say in how they do their jobs improves performance.

114. People are held accountable only for things for which they are responsible.

115. People are allowed to get on with their job here.

116. Supervision is excessive here.

117. Expression of ideas is encouraged.

118. ◄ Always question the decision of others.

119. ◄ The company promotes spontaneous and creative behaviour in work.

120. ◄ The organisation believes that employees should always try to improve their understanding of their job.

121. ◄ Employees are helped to realise their full potential.

122. ◄ Workers are encouraged to be enthusiastic about their work.

123. ◄ The organisation believes that order and discipline are essential to business success.

124. ◄ The organisation believes that workers would normally do best to concentrate on the jobs they are given.

125. ◄ Employees generally concentrate on mastering just a few clearly defined duties and responsibilities.

126. ◄ Job variety builds a happy work force.

127. ◄ Employees can benefit their organisation by trying different jobs.

128. ◄ Workers work best if they are given different things to do.

129. ◄ The organisation believes that work should be interesting.

130. ◄ Employees need to explore ways of realising their full potential.

131. ◄ It is only by stretching people that they become more effective.

132. ◄ A mature person is one who always strives to improve.

133. ◄ Employees put the needs of the company ahead of their personal growth.

134. ◄ A company can only grow if it allows its work force the freedom to develop.

135. People generally feel that training staff helps the company grow.

136. It's the dollar that speaks around here.

137. The company places a lot of emphasis on cost effectiveness.

138. Staffing levels have always seemed to be too low for the work to be done.

139. The organisation believes that turning a profit is the number one objective.

140. The costs involved in this operation are everyone's concern.

141. Most people are here because of their passion for the industry.

142. The organisation believes that the most successful companies in this business are the ones who believe in what they are doing.

143. People in this organisation are as enthusiastic as in any other organisation.

144. This organisation is the best at what it does.

145. The organisation believes it is important to be critical of itself and its performance.

146. This is a proud work force.

147. Cutting corners is fairly common here.

148. No matter what you do things will go wrong anyway.

149. This organisation will make do where it can.

150. It'll come right without interference.

151. This organisation believes that as long as it works out OK most of the time that's OK.

152. She'll be right.

153. This organisation really does all it can to meet its legal and moral obligations.

154. Rules and regulations are there for a good reason.

155. All levels of this organisation work hard to be in compliance with regulations.

156. All levels of this organisation take responsibility for everyone's safety.

157. This organisation will undertake to report all observed notifiable non-compliances, and non-conformances even if it reflects badly on the organisation.

158. Safety is the number one concern for this company.

159. Reviews of safety practices are taken seriously in the organisation.

160. Safety is given less priority than operational considerations.

161. Generally people believe the organisation should be safer.

162. Safety is not something the organisation is too concerned about.

163. The organisation believes rules and regulations are to be complied with.

164. Rules and regulations are seen as a normal standard to be attained.

165. How the company is perceived by others in the industry is of great importance.

166. Regulatory bodies are too involved with this company and have too much influence.

167. Generally, people in the organisation are not interested in the practice of other organisations.

168. Communication with other 'players' in the industry is a good thing.

169. Care is taken to ensure the company is aware of all legislative changes.

170. This company responds in a flexible way to the changing industrial environment.

Organisational Culture Measure items by sub-scale

Initiative-taking orientation vs conforming cultures

1 The organisation believes it is vital for business success to keep up with new developments.

2 The organisation believes that it should avoid doing things in the same, predictable ways.

3 The organisation believes successful organisations generally keep one step ahead of the rest.

4 The organisation believes people should look for new ways of solving problems.

5 The organisation seeks to develop and improve on procedures.

6 Generally workers look for constructive ways of overcoming problems.

Caution taking orientation

7 The organisation thinks very carefully before acting.

8 The organisation does not take unnecessary chances.

9 The organisation believes caution is the best policy.

Performance quality orientation

10 Even the simplest jobs are to be done well.

11 That quality comes before quantity.

12 The organisation believes if a job is worth doing, it is worth doing well.

13 Always take time to do things right.

14 The organisation believes in pursuing a high standard of excellence.

15 Never settle for half measures when doing a job.

Planning orientation emphasis

16 The organisation believes that alternatives should be explored before acting.

17 The organisation believes it is essential to think ahead.

18 A successful organisation always knows where it is going.

19 The organisation believes that one can never spend too much time

planning ahead.

20 Crises are rare around here.

21 Work is well organised.

22 The organisation believes training of the work force is important.

23 Order and tidiness are considered important.

24 Goal setting happens here.

Power orientation

25 You have to play politics to get on.

26 Successful people are those who are loyal to their boss.

27 Subordinates should be hard- working and loyal.

28 The organisation believes controlling people is all-important.

29 You have to be hard and tough to get on.

30 There is a consultative atmosphere here.

31 People in this company like to manage

32 A great distance exists between the work force and management.

Achievement orientation

33 Success comes to those who believe in getting the job done.

34 Personal commitment to attaining goals is of utmost importance for people in this organisation.

35 Successful people in this organisation are the ones who take on challenging tasks.

36 The organisation believes one should always strive for better ways of achieving goals.

37 Around here everyone likes a winner.

38 Customers are the first priority around here.

39 People strive to improve in this organisation.

Co-operation / supportive / affiliation orientation

40 Success comes to those who get on with others.

41 People get on with their colleagues around here.

42 Working together is important around here.

43 Teamwork comes first.

44 Managers are involved at the grass roots level during day to day operations.

45 Seeking advice is encouraged.

46 Everyone in this organisation is a customer of the other.

47 People around here show concern for the needs of others.

48 Workers generally try to help their colleagues.

49 Warmth among colleagues helps get the job done.

50 This organisation believes that people are more important than things.

51 People are told when they have done well.

52 Management helps workers do their jobs better.

53 Feedback is encouraged in the organisation.

Communication orientation

54 Ideas generally flow freely.

55 The organisation believes that open communication is best.

56 Everyone in an organisation is to be kept informed.

57 Around here policy decisions are always based on sound information management.

58 Company goals and objectives are clearly communicated.

59 People can bypass their boss or go to someone else with a problem.

60 Problems can be taken to anyone in the organisation.

61 Senior management understand very well the work undertaken in the maintenance area.

Rewards orientation

62 The organisation believes that people need regular rewards.

63 Rewards go to those who are committed to their work.

64 People are rewarded for doing their job well.

65 Rewards follow quickly on performance.

66 Rewards for effort are appropriate.

Morale orientation, satisfaction

67 The organisation believes happy workers are more productive.

68 A healthy team spirit is important to a successful organisation.

69 The organisation believes people are best motivated with friendliness.

70 An organisation which takes care of its employees can expect them to work well.

71 Working here is very satisfying.

72 People like working here.

73 People who work here generally think it is a positive work environment.

74 The organisation looks after the staff here.

Autonomy of work orientation

75 It is best to give individuals the freedom to do things in their own way.

76 Giving workers a major say in how they do their jobs improves performance.

77 People are held accountable only for things for which they are responsible.

78 People are allowed to get on with their job here.

79 Expression of ideas is encouraged.

Self-expression orientation

80 The company promotes spontaneous and creative behaviour in work.

81 The organisation believes that employees should always try to improve their understanding of their job.

82 Employees are helped to realise their full potential.

83 Workers are encouraged to be enthusiastic about their work.

Work diversity orientation

84 Job variety builds a happy work force.

85 Employees can benefit their organisation by trying different jobs.

86 Workers work best if they are given different things to do.

Personal growth orientation

87 Employees need to explore ways of realising their full potential.

88 A mature person is one who always strives to improve.

89 A company can only grow if it allows its work force the freedom to develop.

90 People generally feel that training staff helps the company grow.

Passion for industry

91 Most people are here because of their passion for the industry.

92 The organisation believes that the most successful companies in this business are the ones who believe in what they are doing.

93 People in this organisation are as enthusiastic as in any other organisation.

94 This organisation is the best at what it does.

95 The organisation believes it is important to be critical of itself and its performance.

96 This is a proud work force.

Avoidance or fatalistic culture

97 No matter what you do things will go wrong anyway.

98 This organisation will make do where it can.

99 It'll come right without interference.

100 This organisation believes that as long as it works out OK most of the time that's OK.

101 She'll be right.

Compliance with rules culture

102 This organisation really does all it can to meet its legal and moral obligations.

103 Rules and regulations are there for a good reason.

104 All levels of this organisation work hard to be in compliance with regulations.

105 All levels of this organisation take responsibility for everyone's safety.

106 This organisation will undertake to report all observed notifiable non-compliances, and non-conformance's even if it reflects badly on the organisation.

Relationship to outside environment

107 Communication with other 'players' in the industry is a good thing.

108 Care is taken to ensure the company is aware of all legislative changes.

109 This company responds quickly to the demands of the industry.

Leadership orientation

110 Senior people here demonstrate by example, their own commitment to the organisational goals.

111 The senior people here symbolise the values and beliefs of the organisation.

112 Managers in this environment set precedents that others follow.

113 Management keeps the organisation on course.

114 Generally the people who work here are clear about what is expected of them.

Degree of structure

115 The work environment is rule oriented.

116 Organisational policies and procedures are helpful well understood and up to date.

117 In this environment there are rules for everything that's done.

118 Rules are generally followed even when they are not sensible or wrong.

119 The work environment is very structured.

Appendix D: Software and supporting documentation

Copy of data collection software

Software development

The software development followed on from the development of a the paper based Organisational Culture Measure and Safety Culture Measure measures. The researcher approached a software consultant and provided a design brief which included the requirements for a graphic interface, randomisation of items within the questionnaires, error free operation so that the software could run in the absence of the researcher or supervisor, the provision of help screens, ability for the researcher to customise screens for the operator in question and to be easily used by persons with only rudimentary computer mouse skills. The researcher has a human factors and psychology background as was able to provided input on layout and use of the software, and monitored very closely the development of the product. This ensured that the end product was able to be used by the target population who in some cases had only very minimal computer skills. The development and trial of the software took place over approximately four months. The software was used successfully in the pilot study and the feedback on it's user friendliness was extremely positive.

Although the computer administration worked successfully within the pilot study. It proved impractical to use this within the larger aviation organisations, due to workload demands and availability of personal computers.

MASSEY
UNIVERSITY

A L B A N Y

DEPARTMENT OF PSYCHOLOGY

20 03 97

Dear Colleague

Re: Research in Ian Patterson, Massey University

Allow me to introduce myself. My name is Ian Patterson I am currently engaged in a nationwide research project with the aviation community in New Zealand. This work is attempting to address the difficult problem of; *how the culture and safety climate of organisations might influence the generation of aviation maintenance errors in these organisations*. Maintenance has for too long, been the neglected relative in aviation human factors research.

I am employed by the Open Polytechnic of New Zealand and 'am working on this project under the supervision of Massey University where I am engaged in doctoral studies. CAA New Zealand and a range of operators are already working with me on this project and management has agreed that I might approach the workforce to ask for cooperation in this project. This will provide information on how the organisation might assist the workforce in understanding what factors contribute to the generation of these maintenance errors

As a first step in this research I wish to take some baseline recordings of the current 'Organisational Culture' and 'Perceived Safety Climate' that exist in your organisation. Of course to do this I need your help, on this and on three other occasions over the next two years

Your involvement is of course voluntary, but you will be released in work time to make your contribution. Of course without your co-operation I will have no data.

So what is required?

You will be asked to sit a computer terminal on which will be displayed a series of statements to which you respond by clicking a button with a computer mouse. All that is required is that you read the statement and respond as you see fit. There are no right or wrong answers and your individual responses are not under examination, rather the data from you and your colleagues is pooled to give an overview of how the workforce see things in the organisation. Only I will have access to the data which will be held securely by me alone. I will prepare a report at the end of the study and interim reports will be available to all interested parties. The box below shows the first screen's text from the computer administration and gives a little more background.

Private Bag 102 904 North Shore MSC Auckland New Zealand
Telephone 0 9 443 9693 Facsimile 0 9 443 9732

WELCOME, to my research project which is looking at the measurement of organisational culture and safety climate of your work environment. This program is designed to gauge COLLECTIVE OPINION on the organisation in which you work. Your individual responses are therefore pooled with those of your colleagues to give an overall picture of how the workforce sees things.

Your opinions are valuable because it is you who know your organisation best.

The research is NOT being conducted by or for your company but as part of a nationwide postgraduate research project into aviation safety. Your responses will be seen only by me (Ian Patterson from Massey University), so please try to answer honestly even if it may reflect badly on your work environment.

When prompted for your name by the program, you may prefer to use a false name. However, I would prefer it if you did not, mainly because it may be appropriate to repeat this measure at a later stage, to see if opinion on the work environment has changed. You are also asked for your department or division. Please use the name of the management unit you are under for this question.

You will be given a short (four item) practice questionnaire before you begin the questionnaires proper.

Ian Patterson can be contacted at the following telephone numbers if you have any questions.

0800 507333,

04 560 5772 direct line or

04 5605727 fax.

I am happy to talk about this work if you have any queries or would just like to know more.

Scroll up or down to recap instructions.

Click on the 'start' button with the left mouse button to proceed.

It is assumed that if you complete these questionnaires you consent to taking part in this research. The questionnaires should take about 30 minutes to complete.

Many thanks for helping me with this study.

Ian Patterson.

I hope you will agree to become part of this research. It is my firm belief that good scientific research of this type is of great benefit to the aviation community. I am happy to talk to anyone on this matter or other human factors related issues.

Many thanks for your time thus far.

Ian R Patterson

Dear Participant, in the boxes below are the instructions that are contained within the software you are about to use. This paper copy may be referred to while you are working the questionnaires.

WELCOME, to my research project which is looking at the measurement of organisational culture and safety climate of your work environment. This program is designed to gauge COLLECTIVE OPINION on the organisation in which you work. Your individual responses are therefore pooled with those of your colleagues to give an overall picture of how the workforce sees things.

Your opinions are valuable because it is you who know your organisation best. The research is NOT being conducted by or for your company but as part of a nationwide postgraduate research project into aviation safety. Your responses will be seen only by me (Ian Patterson from Massey University), so please try to answer honestly even if it may reflect badly on your work environment.

When prompted for your name by the program, you may prefer to use a false name. However, I would prefer it if you did not, mainly because it may be appropriate to repeat this measure at a later stage, to see if opinion on the work environment has changed. You are also asked for your department or division. Please use the name of the management unit you are under for this question.

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Scroll up or down to recap instructions.

Click on the 'start' button with the left mouse button to proceed.
It is assumed that if you complete these questionnaires you consent to taking part in this research. The questionnaires should take about 30 to 40 minutes to complete.
Many thanks for helping me with this study.
Ian Patterson.

Organisational Culture Questionnaire
(adapted from Furnham and Gunter, 1993).

This questionnaire is about organisational culture. Organisational Culture is the commonly held beliefs, attitudes, and values that exist within an organisation. Put more simply, organisational culture in your organisation is, "the way we do things around here".

You will be presented with a series of statements about organisations. For each statement you are asked to consider;
to what extent does the work environment seem to promote each of the statements or to what extent is the behaviour described present in the organisation?

Please think in terms of your present work environment, and the expectations people have of you. What are the behaviours, views, beliefs, policies and practices, that you and work colleagues are expected to adopt?

Indicate your answer by clicking on your choice with the mouse or by using the numeric keypad.

For example: If you feel the work environment tends to promote the statement to a great extent you would click on button 7. If the work environment did not seem to promote the statement at all then you would click on button 1. You may think the work environment partially promotes the statement so you would click on a button in the middle range. Of course you may think that you have no opinion on the matter in which case click on that button, though we like you to use this sparingly if possible. Clicking on the 'previous' button allows you to go back to the previous question.

Try to remember, we are interested in how you think the organisation would see itself if it were a person and what characteristics it seems to possess, NOT how you think it should be.

If you have any queries ask the supervisor. Click on OK to proceed.

Personal Safety Climate Questionnaire
(adapted from Zohar 1980)

This question is designed to find out what workers think about safety and related issues at their workplace. It's objective is to describe the current situation and not to describe it as you think it ought to be.

Your input will contribute to aviation safety in New Zealand and more importantly, may influence the way things are done in your organisation.

The questionnaire includes descriptive statements collected from various sources. All you have to do is indicate how strongly you agree or disagree with each statement as it relates to your organisation and the work you do.

As you work through the questionnaire, relate the questions to your own personal safety and the chances that you might be personally involved in an accident.

Example:
If you strongly agree that the statement applies then you would click on button 7. If you strongly disagree, then you would click on button 1. Of course you may come in the middle somewhere so use the number you think is appropriate. If you think that the item is not relevant to your organisation please click on the not relevant button.
Clicking on the previous button allows you to go to the previous statement.
Please try to be honest and respond as you really think. Your organisation will not see your responses.

Thank you for helping with this work.

Ian Patterson

Appendix E: Sample documentation supplied to participants

MASSEY UNIVERSITY
A L B A N Y
DEPARTMENT OF PSYCHOLOGY

Information Sheet

Identity of the researchers

The principal researcher in this study is Ian R Patterson, Registered Psychologist, and Lecturer In Psychology. The research is being conducted in fulfilment of a PhD program. Ian is being supervised in this research by Dr Ross St George (Massey University) and Dr Carol Slappendell (ACC, Formerly of Massey University)

Contact details

Ian Patterson (04 560 5772, TOPNZ, Private Bag 31914, Lower Hutt)
Dr Hillary Bennett, (06 350 5194, 09 443,9700, Massey University, Psychology Albany Campus)
Dr Ross St George (04 560400, CAA, PO BOX 31441, Lower Hutt) #
Dr Carol Slappendell (04 498, 7718 ACC, PO BOX 242, Wellington) #

Formerly Senior Lecturers at Massey University

Aims of the study

The purpose of this research is to determine the influences that the safety climate and organisational culture (as assessed by computer administered questionnaires) within aviation organisations, affect the production of aviation maintenance errors. The researcher is interested in the pooled responses of the work force of which you are a member. I will not consider how you as an individual see things, rather, what are the collective views held by people in the organisation

As a participant in this research you are invited to fill in two computer based questionnaires that examine the organisational culture and safety climate of your organisation. Each questionnaire asks a series of short questions about an aspect of the organisation in which you work. You are not asked to comment on your own or anyone else's behaviour specifically and your responses are confidential to the researcher. The questionnaires should take approximately 40 minutes to complete

Your involvement in this research is voluntary and you have a right to decline to be involved and withdraw at any time, even if you previously agreed to take part. In this event your contribution will be destroyed

You will be briefed on the purpose of the study prior to your involvement in the data collection phase and you may ask questions at any time. The information you provide to the researchers will not (and cannot) be traced back to you by any other party

Summary reports will be available to you at the close of the study. Neither organisations nor individuals will be identified by name in these reports. Your

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contribution will not be identifiable from any published or written material arising from this research

Security of information

Data collected in this study will be held securely by the researcher

You have a right to

- decline to take part
- refuse to answer particular questions
- ask any questions about the study
- demand that your name is not used except when your express permission is given
- access to summary findings when the research is concluded
- agree to participate in the study under the conditions contained in this Information Sheet

Remember you have a right to withdraw from the study at any time and your contribution will be destroyed. Please ask any questions of the researcher that you wish, at any time.

Thank you for spending time to read this.

Ian R Patterson

Appendix F: Measure of agreement on the Safety Index Measure (SIM) across subsequent administrations of the measure

The McNemar test and computation of the measure of agreement for across subsequent administrations of the Safety Index Measure

The following shows a worked example of the measure of agreement calculation for the Safety Index Measure across subsequent administrations of the measure, using the McNemar test

An adaptation of the McNemar Test (Siegel, S. (1956), Non-parametric Statistics for the behavioural sciences, McGraw Hill, p.63-67) performed by D. Meyer, Massey University. (2000). Time A represents a time preceding Time B. For example Time 1 and Time 2, Time 2 and Time 3 and Time 1 and Time 3.

Table 45: Showing the method of calculation for measure of agreement for the Safety Index Measure.

Time A	YES	NO	NA	
Time B				
YES	X	X	X	N1
NO	X	X	X	N2
NA	X	X	X	N3
	M1	M2	M2	Total

N is the sum across rows. M is the sum down columns. X are number of observations in that cell. The measure of agreement (Ma) is given by:

Ma =

$$\frac{(Agreements - (E1 + E2 + E3))^2}{E1 + E2 + E3} - \frac{(Disagreements - (Total - (E1 + E2 + E3)))^2}{Tota - (E1 + E2 + E3)}$$

Where $Ei = \frac{Ni * Mi}{Total}$, for example; (using values from Table 46) $E1 = \frac{468 * 449}{680}$

Substituting the data from the SIM raw data.

Table 46: Showing agreements on Safety Index Measure items using data across Time A and B.

Time A	YES	NO	NA	
Time B				
YES	349	99	20	468
NO	79	95	13	187
NA	21	3	1	25
	449	197	34	680

The measure of agreement obtained is 38.59; the Critical value is 10.83, df 1. A copy of the spread sheet used to calculate this is shown below.

Table 47: Spreadsheet showing the calculation for measure of agreement for the Safety Index Measure.

SUMMARY CROSS TABS

Total data set

yy	yn	y na	ny	n n	n na	na y	na n	na na	
21	32	8	7	9	7	0	1	0	85
31	12	0	18	19	0	4	1	0	85
50	6	1	9	10	0	8	1	0	85
52	4	1	8	10	1	8	0	1	85
60	6	1	7	8	2	1	0	0	85
49	15	0	6	15	0	0	0	0	85
46	13	5	9	11	1	0	0	0	85
40	11	4	15	13	2	0	0	0	85
349	99	20	79	95	13	21	3	1	680

	y	n	na				
y	349	99	20	468	E11	309.0176	
n	79	95	13	187	E22	54.175	364.4426
na	21	3	1	25	E33	1.25	
	449	197	34	680			

Agreements on the diagonal =	445	
Total agreements possible	680	235
% agree between time A and time B is	65.44118	

measure of agreement obtained: 38.58988

1 Degree of freedom p level is 0.001 Critical value is 10.828

Table 48: Spreadsheet showing Pearson's r across subsequent administrations of the Safety Index Measure.

Pearson's r for SIM Administrations										
	Org1	Org1	Org1	Org2	Org2	Org2	Org4	Org4	Org3	Org3
	18 11 96	04 04 97	12 02 9	27 09 96	24 02 97	19 11 97	18 11 96	27 08 97	26 09 96	19 10 97
Sub-scale1	0.80	0.40	0.80	0.80	1.00	0.80	0.60	0.80	1.00	0.30
Sub-scale2	0.71	0.79	0.85	0.86	1.00	0.93	0.57	0.93	0.69	1.00
Sub-scale3	0.90	0.70	0.60	0.78	0.90	0.90	0.90	1.00	0.78	0.90
Sub-scale4	0.80	0.70	0.60	0.50	0.70	0.89	0.70	1.00	0.40	0.70
Sub-scale5	0.50	0.20	0.50	0.60	0.67	0.67	0.80	0.83	0.80	0.33
Sub-scale6	0.83	0.67	0.83	1.00	1.00	1.00	1.00	0.83	0.50	0.67
Sub-scale7	0.86	0.80	0.73	0.74	0.80	0.90	0.85	0.76	0.45	0.63
Sub-scale8	0.60	0.40	0.50	0.75	0.60	0.75	0.40	0.60	0.25	0.40
Sim scores	**79.00**	**67.00**	**72.00**	**75.00**	**84.00**	**88.00**	**76.00**	**87.00**	**0.57**	**0.65**
Org1	r		**Org 2**	r		**Org4**	r			**Org3**
Time 1 with 2	0.76	5 months	Time 1	0.73	5 months	Time 1 with 2	0.437	8 months	-0.10	11 months
Time 1 with 3	0.54	15 months	Time 1	0.54	14 months					
Time 2 with 3	0.54	10 months	Time 2	0.65	9 months					
Pairs of observations	0.79	0.67								
	0.79	0.72								
	0.67	0.72								
	0.75	0.84								
	0.75	0.88	pearso	**0.54**						
	0.84	0.88								
	0.76	0.87								
	0.57	0.65								

Appendix G: Human error cause codes on Civil Aviation Authority of New Zealand database

Table 49: Human error cause codes on Civil Aviation Authority Database.

Organisational factors (General Failure Types)	Code number assigned by C.A.A.N.Z.
Inappropriate goals or policies	1296
Organisation structural deficiencies	1297
Inadequate communications	1298
Poor planning	1299
Inadequate control and monitoring	1300
Design system deficiencies	1301
Inadequate defences	1302
Unsuitable materials	1303
Unsuitable equipment	1304
Poor procedures	1305
Poor training	1306
Poor coordination	1307
Inadequate specifications/requirements	1308
Poor decisions	1309
Poor resource management	1310
Poor work environment	1311
Inadequate regulation	1312
Other organisation factor	1313

Table 49 cont: Human error cause codes on Civil Aviation Authority Database.

Local error factors	Code number assigned by C.A.A.N.Z.
Task unfamiliarity	1315
Time shortage	1316
Poor signal : noise	1317
Poor human-system interface	1318
Designer user mismatch	1319
Error irreversibility	1320
Information overload	1321
Negative task transfer (habits)	1322
Task overload	1386
Risk miss-perception	1323
Poor system feedback	1324
Inexperience (not lack of training	1325
Lack of knowledge	1326
Task/education mismatch	1327
Poor instructions/procedures	1328
Inadequate checking	1329
Hostile environment	1330
Other environmental factor (e.g. weather)	1331
Interpretation difficulties	1332
Disturbed sleep patterns	1333
Fatigue - other	1334
Drugs/alcohol	1335
Visual illusion	1336
Disorientation/vertigo	1337
Physiological other	1338
Monotony/boredom	1339
Lack of confidence	1340
Poor attention span	1341
Psychological other	1342
Other error enforcing condition	1343
Task overload	1386

Table 49: Human error cause codes on Civil Aviation Authority Database.

Local violation factors	Code number assigned by C.A.A.N.Z.
Lack of safety culture	1345
Management/staff conflict	1346
Poor morale	1347
Poor supervision & checking	1348
Group violation condoning attitude	1349
Hazard miss-perception	1350
Lack of management care/concern	1351
Lack of pride in work	1352
Risk taking culture encouraged	1353
Complacency (i.e. it can't happen)	1354
Learned helplessness (i.e. who cares	1355
Perceived license to bend rules	1356
Age/sex factor	1357
Other violation enforcing condition	1358
Active failure factors	Code number assigned by C.A.A.N.Z.
Primarily structural / mechanical	1360
State change not detected "information"	1361
Inaccurate system "diagnosis"	1362
Inappropriate "goal"	1363
Inappropriate "strategy"	1364
Inappropriate "procedures"	1365
Poor procedure "action"	1366
Procedures not followed	1385

Appendix H: Safety Index Measure and Managers' Self-Report General Failure Types raw data for Organisation 7

Table 50: Calculation of Safety Index Measure Scores for Organisation 7 (Sites A and B).

Location	**Safety Index Measure**
Unit 1	0.9788
Unit 2	0.9176
Unit 3	0.8986
Unit 4	0.8689
Site A Mean	**0.9135**
Unit 1	0.8276
Unit 2	0.8133
Unit 3	0.8846
Unit 4	0.7674
Site B Mean	0.8232
Grand Mean Site A and B	**0.8697**
Org 7 SIM score as %	**87**

Table 51: Calculation of Managers' Self-Report General Failure Types for Organisation 7 (Sites A and B). Site A provided data from four sites. Site B from 6 sites.

	Site A	**Site B**
	45	36
	42	44
	53	53
	29	28
		22
		37
Total	169	222
Total possible score for site = 18*5*no of units contributing to score	18*5*4=360	18*5*6=540
Score as %	169/360*100=47	540/540*100=41

Mean FTman score Org 7= 47+41/2=44

Appendix I: Documentation to research progress review meeting

Ian Patterson

PhD Progress and Problems

My request

My supervisors and I are requesting that a critical analysis of the data quality and the direction of the research is given by persons not directly involved in the work. My concerns around what constitutes a PhD are germane. I am at the point where I am being forced to consider abandoning the PhD. I am reluctant to take this step as I have already spent a great deal of time to get to this point. My current supervisors have been very supportive in recent months in looking at the difficulties I am facing. They have only relatively recently become involved following the departure from Massey, of my two original supervisors.

Outline of the broad aims of the research

At the outset of the PhD the following was envisaged. The aim of the study was to determine if the organisational culture and safety climate, that exists within aviation maintenance organisations, could be used to indicate the types of human error that are generated by these organisations. **The original emphasis was to be on the Human Factors elements in human error, rather than organisational culture and safety climate per se.** The execution of the research has been ongoing for over three years now.

Five measures would be made in a number of aviation maintenance organisations.

Measures 1 to 4 would be made three times in each organisation (Data 1, Data 2 and Data 3). Measure 5 is ongoing. The Organisational Culture Measure and the Safety Climate Measure where computer administered in most organisations for the Data 1 collection. All other measures were paper based.

The measures were;

1. Organisational Culture Measure (OCM).
2. Safety Climate Measure (SCM).
3. Safety Index Measure (SIM).
4. Managers Self Report, General Failure Types.
5. Analysis of human or organisational errors collected on the Civil Aviation Data Base. This data is collected from the industry and all errors are coded. (More details on the measures are included below.)

1 and 2 are completed by all members of the maintenance workforce. 3 is completed by the Quality Assurance person and the researcher. 4 is completed by the Mangers in the organisation.

It was envisaged:

1. That the cultural profile (OCM) and climate profile (SCM) or scores might be related to measure 5, the pattern of recorded errors in the industry.
2. That measures 3 and 4 could be used to indicate how well the maintenance organisation was performing in terms of safety. And on the basis of this, and some other indicators, expert ranks on the level of safety, for that organisation, might be assigned. This would be used as the basis of a Discriminant Function Analysis.
3. That the OCM and SCM data might predict the rank for safety obtained in 2 above. The OCM and SCM being independent variable and predictor for safety rank, the dependant variable.

NB Indications from the OCM measure, the conceptual design of which has 20 sub scales, indicates that the culture in organisations is relatively stable. Profiles obtained at Data 1 and Data 2, for one operator at least where very similar, see Appendix A.

Number of participants

Five aviation maintenance organisations have taken part in the research, providing input on measures 1 to 5. The Civil Aviation Authority has provide input on measures 1,2 and 5.

Problems with the data and design

My major question, is there a Ph.D. in this? Despite considerable efforts 25 plus site visits and the promise of responses the data collected is not high. To me, with an examiners hat on, it seems there is a paucity of data. In speaking to John Podd however, he was of the opinion that there would be sufficient data though he wondered about the appropriateness of a multivariate approach and whether more simple descriptive statistics might be appropriate. My ignorance of PhD marking criteria may be at the root of my concerns.

I Data may not be favourable to a multi- variate approach.

- As the study has progressed it has become increasingly obvious that the amount of data, i.e. number of individuals responding to the OCM and SCM will decrease from the first data cut (Data 1). **Data 1 has yielded 149 respondents on the OCM and SCM.**
- The OCM is 119 items long . The item to case ratio (1:1.2) is not favourable to a multivariate analysis. One approach has been to reduce the number of items in the OCM by selecting a subset of items. This reduces the items to 40. A Principal Components Analyses on this produces a 4 factor structure that is similar in content to a principal components analyses with all 119 items included. This represents a item to case ratio of 1:3.7.
- The SCM is 49 items long this also seems to generate a four factor structure but again the item to case ratio (1:3) is not good.
- Dr Denny Meyer (Statistician) has been available at Albany for some consultation on the statistics side and seems to think the data is analysable using multivariate methods. Though it may involve manipulation of item numbers in the analyses. **This does not sit well with a scientific approach and I am aware that examiners may pick up on this.**

II Error data on Civil Aviation Authority Data Base is limited.

The Civil Aviation Authority database has identified around 175 errors, attributable to the organisations include in the study and taken over an 18 month period. By necessity this means that the human factors element in the Ph.D. must assume less priority. I have attached the various raw data files to the email that accompanies this word document.

Possible Solution to I

- **Approach other organisations for a Data 1**. Collect and look at patterns in a larger sample. There are other aviation maintenance organisation that might be approached. Abandoning Data 2 and 3.
- **Only collect Data 1 and Data 2.** Making a push for the Data 2 collection some of which is already in, or being collected.
- **A comparative study across industries.** A pilot study used to develop the OCM and SCM, used an Oil refinery where 151 participants filled in a longer version of the OCM and SCM (179 items). Some of the items are slightly different but most are the same. Common items could form the basis for a comparison between the oil industry and the aviation industry on these two measures. Both are maintenance oriented, have safety as a major goal and can be described as socio-technical. It is possible that data could be collected again in the refinery using the same measure as used in the aviation industry.

Possible Solution to II

- The collection of this data is not under the researchers control but the quantity and quality is likely to improve in the next few months, as more data is coded. Some of this data coding will be retrospective into the period in which Data 1 was collected. However, how much of an improvement is made is uncertain.

Appendix A

Brief description of the measures

The initial development of the measures 1 to 4 took place over a two year period and followed a review of the literature and some of the already existing measures in this field. The measures evolved through an iterative process, involving consultation with the aviation, oil industries and other experts. Measures 1 to 4 were available in paper form from August 1995. Industry feedback was canvassed during a Human Factors Conference at that time and via personal communications with the aviation industry. The measure were then subject to a pilot study in the oil industry. Following this initial development period the measures were fixed and only minor modifications occurred during the data collection period.

Organisational Culture Measure

OCM is designed to assess the culture that exists in an organisation at any given point in time. Culture is defined here as, the shared set of beliefs, values, attitudes and behaviours that tend to characterise the work environment. The OCM was developed to provide a measure of the degree to which a comprehensive range of beliefs, values, attitudes and behaviours, exist within an organisation. Development was begun in early 1994. At that time, literature searches yielded little in the way of validated measures of organisational culture suited to the needs of this research. However, an examination of some of these yielded a measure by Furnham and Gunter (1993) that was used as a starting point for the development of a more comprehensive measure geared to the needs of the present study.

There were several reasons for choosing Furnham and Gunter's measure as a starting point. It used current language, and provided a comprehensive range of items covering a range of sub-scales of culture. It also seemed to be assessing beliefs, values, attitudes and behaviours, matching the working definition of culture used in this research. Additional items were generated or taken from other measures to compensate for areas in which the Furnham and Gunter measure was weak. This involved consultation with aviation industry specialists, the Civil Aviation Authority, and a series of familiarisation visits to industry by the researcher, during which information was obtained on aspects of culture that are particular to the aviation maintenance environment. For example, the nature of checking and countersigning and the use of standard procedures which might reflect a 'supervision' or 'low in autonomy' culture. This process resulted in a final OCM questionnaire consisting of 172 items representing 21 identifiable sub-scales. (The original Furnham and Gunter measure contained 94 items.) This 172 item questionnaire was written up in paper form in August 1995 and used in computerised form for pilot study in the oil industry. A reduced a slightly adapted version of this measure was used in the aviation industry.

The Safety Climate Measure

The SCM used in this study was adapted from a 40 item safety climate questionnaire developed by Zohar (1980) at Technion University in Israel during the late seventies. The questionnaire had not been published but inquiries by the researcher yielded a copy of the questionnaire. Originally the questionnaire was designed for use within twenty Israeli factory work environments, consequently some of the items required re-wording for the New Zealand aviation environment. An attraction of Zohar's questionnaire' was that it seemed to be the only safety climate questionnaire that had some form of psychometric analysis available. Zohar (1980) had originally constructed the measure to have eight dimensions or factors though further work by Brown and Holmes (1986) identified only 3 factors within Zohar's original questionnaire, they were; 1) employees perception of management's concern for their welfare. 2) employees perception of how active the mangers are in the area of safety, and 3) employees risk perception. Vitrio (1991) using a modified version of the Zohar's original questionnaire finds the scale to be essentially uni-dimensional. Thus the factor structure within the measure is open to some debate. Not withstanding this, further development of Zohar's measure was undertaken to adapt it to New Zealand conditions. This was done in consultation with the aviation industry and by examination of the safety literature. This process generated an additional items, for inclusion in the revised questionnaire. The revised version (49 items) of Zohar's questionnaire was available in July

1995. Final feedback from industry groups was sought before the measure was adapted for computer administration and included in the pilot study. A paper version was also available.

Safety Index Measure

This pencil and paper measure was designed to provide an index of the safety level in the maintenance work place, for example the hanger floor or the workshop carrying out engine overhauls. No measure of this type existed for the aviation maintenance environment. Requirements were that it could be administered by the researcher and a confederate within the organisation, during site visits with minimal disruption to the work environment. It measures observable features in the maintenance environment, that are considered to be indicators of safety. This measure is made three time in each organisation at data 1, 2 and 3.

Managers Self Report General Failure Types

This is a paper and pencil measure that is designed to measure how well the management consider their organisation is performing with respect to the incidence of General Failure Types at the strategic management level. The purpose of this measure is to determine if there is any relationship between the managers', self reported, perceptions around the occurrence of these kinds of failures and the actual performance of the organisation, as measured by the quality and quantity of aviation maintenance errors. This measure is made three time in each organisation at data 1, 2 and 3.

Maintenance error incident analysis, error classification.

This measure could be more accurately described as, a 'process' by which aviation maintenance errors are captured, investigated and coded according to the human factors components that these errors contained. Maintenance errors generated by organisations were assigned a cause code taken from a hybrid classification system developed from the International Civil Aviation Organisation's coding system and the Latent Failure Model coding developed by the researcher and Civil Aviation Authority NZ. (Civil Aviation Authority NZ had previously been using the ICAO codes but this system had proved unusable. The researcher , working with Civil Aviation Authority NZ, had helped to produce a system that was felt to be more useable and had become involved in training program to help implement this new system). Civil Aviation Authority New Zealand is using this coding system to code errors that are advised to them by the industry or from their audit and safety investigation process.

Appendix J: Descriptive statistics

Table 52: Descriptive Statistics.

Items numbers in Organisational Culture Measure and Safety Culture Measure	N	Minimum	Maximum	Mean	Std. Deviation	Tolerance test values
CUL1	520	1.00	7.00	4.92	1.41	.371
CUL2	520	1.00	7.00	3.69	1.49	.530
CUL3	520	1.00	7.00	5.09	1.45	.332
CUL4	520	1.00	7.00	4.74	1.44	.373
CUL5	520	1.00	7.00	4.78	1.51	.298
CUL6	520	1.00	7.00	5.35	1.24	.462
CUL7	520	1.00	7.00	4.03	1.70	.310
CUL8	520	1.00	7.00	4.85	1.57	.380
CUL9	520	1.00	7.00	4.80	1.47	.364
CUL10	520	1.00	7.00	5.01	1.65	.305
CUL11	520	1.00	7.00	4.88	1.65	.220
CUL12	520	1.00	7.00	4.94	1.59	.193
CUL13	520	1.00	7.00	4.65	1.68	.278
CUL14	520	1.00	7.00	5.33	1.40	.270
CUL15	520	1.00	7.00	4.94	1.50	.261
CUL16	520	1.00	7.00	4.47	1.46	.320
CUL17	520	1.00	7.00	4.72	1.60	.230
CUL18	520	1.00	7.00	4.99	1.61	.345
CUL19	520	1.00	7.00	4.30	1.55	.379
CUL20	520	1.00	7.00	3.07	1.77	.417
CUL21	520	1.00	7.00	3.69	1.56	.264
CUL22	520	1.00	7.00	4.16	1.72	.339
CUL23	520	1.00	7.00	4.52	1.57	.355
CUL24	520	1.00	7.00	3.84	1.57	.404
CUL25	520	1.00	7.00	5.21	1.61	.395
CUL26	520	1.00	7.00	4.63	1.70	.510
CUL27	520	1.00	7.00	4.95	1.36	.530
CUL28	520	1.00	7.00	4.70	1.50	.404
CUL29	520	1.00	7.00	3.73	1.69	.403
CUL30	520	1.00	7.00	4.76	1.55	.509
CUL31	520	1.00	7.00	4.64	1.37	.575
CUL32	520	1.00	7.00	5.17	1.69	.362
CUL33	520	1.00	7.00	4.37	1.62	.370

Table 52: Descriptive Statistics.

CUL34	520	1.00	7.00	4.26	1.49	.427
CUL35	520	1.00	7.00	4.13	1.63	.366
CUL36	520	1.00	7.00	4.50	1.41	.265
CUL37	520	1.00	7.00	3.98	1.56	.468
CUL38	520	1.00	7.00	5.19	1.49	.435
CUL39	520	1.00	7.00	4.29	1.37	.378
CUL40	520	1.00	7.00	4.66	1.51	.523
CUL41	520	1.00	7.00	4.88	1.27	.355
CUL42	520	1.00	7.00	5.11	1.37	.260
CUL43	520	1.00	7.00	4.53	1.59	.323
CUL44	520	1.00	7.00	2.92	1.72	.382
CUL45	520	1.00	7.00	4.66	1.64	.307
CUL46	520	1.00	7.00	4.46	1.68	.428
CUL47	520	1.00	7.00	3.91	1.52	.331
CUL48	520	1.00	7.00	5.19	1.27	.288
CUL49	520	1.00	7.00	4.99	1.46	.358
CUL50	520	1.00	7.00	3.07	1.70	.266
CUL51	520	1.00	7.00	3.57	1.71	.287
CUL52	520	1.00	7.00	3.20	1.53	.196
CUL53	520	1.00	7.00	3.83	1.64	.224
CUL54	520	1.00	7.00	3.81	1.53	.231
CUL55	520	1.00	7.00	3.96	1.59	.228
CUL56	520	1.00	7.00	3.95	1.71	.343
CUL57	520	0.00	7.00	3.61	1.48	.238
CUL58	520	1.00	7.00	3.71	1.61	.336
CUL59	520	1.00	7.00	4.26	1.66	.432
CUL60	520	1.00	7.00	3.69	1.69	.321
CUL61	520	1.00	7.00	3.44	1.78	.358
CUL62	520	1.00	7.00	3.24	1.66	.264
CUL63	520	1.00	7.00	3.27	1.59	.276
CUL64	520	1.00	7.00	3.09	1.56	.149
CUL65	520	1.00	7.00	2.76	1.47	.200
CUL66	520	1.00	7.00	3.35	1.75	.371
CUL67	520	1.00	7.00	3.53	1.75	.288
CUL68	520	1.00	7.00	5.13	1.59	.357
CUL69	520	1.00	7.00	3.79	1.50	.320

Table 52: Descriptive Statistics.

CUL70	520	1.00	7.00	4.99	1.76	.321
CUL71	520	1.00	7.00	4.31	1.55	.198
CUL72	520	1.00	7.00	4.17	1.42	.176
CUL73	520	1.00	7.00	3.87	1.49	.180
CUL74	520	1.00	7.00	3.56	1.66	.237
CUL75	520	1.00	7.00	3.59	1.50	.399
CUL76	520	1.00	7.00	4.65	1.61	.303
CUL77	520	1.00	7.00	4.64	1.58	.447
CUL78	520	1.00	7.00	4.75	1.38	.351
CUL79	520	1.00	7.00	4.24	1.62	.195
CUL80	520	1.00	7.00	3.27	1.47	.281
CUL81	520	1.00	7.00	4.80	1.43	.308
CUL82	519	1.00	7.00	3.50	1.57	.233
CUL83	520	1.00	7.00	3.71	1.52	.227
CUL84	520	1.00	7.00	4.80	1.57	.276
CUL85	520	1.00	7.00	4.55	1.58	.300
CUL86	520	1.00	7.00	4.71	1.46	.265
CUL87	520	1.00	7.00	4.87	1.48	.279
CUL88	520	1.00	7.00	4.83	1.47	.368
CUL89	520	1.00	7.00	4.74	1.57	.265
CUL90	520	1.00	7.00	5.26	1.41	.375
CUL91	520	1.00	7.00	4.23	1.73	.449
CUL92	520	1.00	7.00	4.91	1.37	.364
CUL93	520	1.00	7.00	4.23	1.50	.356
CUL94	520	1.00	7.00	4.61	1.58	.320
CUL95	520	1.00	7.00	4.68	1.52	.345
CUL96	520	1.00	7.00	4.26	1.66	.276
CUL97	520	1.00	7.00	3.35	1.66	.519
CUL98	520	1.00	7.00	4.32	1.78	.369
CUL99	520	1.00	7.00	3.05	1.48	.444
CUL100	520	1.00	7.00	3.50	1.82	.292
CUL101	520	1.00	7.00	2.62	1.72	.296
CUL102	520	1.00	7.00	4.86	1.66	.306
CUL103	520	1.00	7.00	5.89	1.30	.288
CUL104	520	1.00	7.00	5.37	1.50	.232
CUL105	520	1.00	7.00	4.80	1.65	.221

Table 52: Descriptive Statistics.

CUL106	520	1.00	7.00	4.93	1.64	.343
CUL107	520	1.00	7.00	5.35	1.33	.375
CUL108	520	1.00	7.00	5.44	1.38	.325
CUL109	520	1.00	7.00	4.87	1.50	.323
CUL110	520	1.00	7.00	4.00	1.65	.208
CUL111	520	1.00	7.00	3.94	1.66	.200
CUL112	520	1.00	7.00	3.70	1.59	.241
CUL113	520	1.00	7.00	4.01	1.56	.208
CUL114	520	1.00	7.00	4.70	1.47	.325
CUL115	520	1.00	7.00	5.18	1.35	.482
CUL116	520	1.00	7.00	4.35	1.54	.374
CUL117	520	2.00	7.00	5.49	1.34	.402
CUL118	520	1.00	7.00	4.49	1.50	.546
CUL119	520	1.00	7.00	5.12	1.31	.415
ITEM1	520	1.00	7.00	4.97	1.10	.451
ITEM2	520	1.00	7.00	4.94	1.32	.488
ITEM3	520	1.00	7.00	5.21	1.56	.549
ITEM4	520	1.00	7.00	3.63	1.49	.336
ITEM5	520	1.00	7.00	5.19	1.29	.340
ITEM6	520	1.00	7.00	4.83	1.46	.281
ITEM7	520	1.00	7.00	4.50	1.51	.368
ITEM8	520	1.00	7.00	5.39	1.41	.404
ITEM9	520	1.00	7.00	5.00	1.35	.355
ITEM10	520	1.00	7.00	4.44	1.47	.340
ITEM11	520	1.00	7.00	4.41	1.62	.239
ITEM12	520	1.00	7.00	4.91	1.45	.344
ITEM13	520	1.00	7.00	4.67	1.55	.408
ITEM14	520	1.00	7.00	4.42	1.60	.217
ITEM15	520	1.00	7.00	4.83	1.58	.439
ITEM16	520	1.00	7.00	4.31	1.41	.283
ITEM17	520	1.00	7.00	4.56	1.49	.202
ITEM18	520	1.00	7.00	3.17	1.37	.420
ITEM19	520	1.00	7.00	4.27	1.43	.416
ITEM20	520	1.00	7.00	4.60	1.51	.327
ITEM21	520	1.00	7.00	3.73	1.67	.518
ITEM22	520	1.00	7.00	4.00	1.49	.253

Table 52: Descriptive Statistics.

ITEM23	520	1.00	7.00	4.89	1.42	.345
ITEM24	520	1.00	7.00	4.95	1.49	.220
ITEM25	520	1.00	7.00	4.74	1.56	.203
ITEM26	520	1.00	7.00	4.63	1.38	.345
ITEM27	520	1.00	7.00	4.57	1.34	.467
ITEM28	520	1.00	7.00	5.47	1.33	.474
ITEM29	520	1.00	7.00	3.36	1.36	.388
ITEM30	520	1.00	7.00	5.04	1.43	.290
ITEM31	520	1.00	7.00	4.03	1.47	.551
ITEM32	520	1.00	7.00	4.38	1.47	.248
ITEM33	520	1.00	7.00	5.02	1.37	.406
ITEM34	520	1.00	7.00	3.84	1.48	.363
ITEM35	520	1.00	7.00	4.79	1.33	.298
ITEM36	520	1.00	7.00	4.51	1.54	.261
ITEM37	520	1.00	7.00	5.50	1.25	.477
ITEM38	520	1.00	7.00	3.06	1.55	.465
ITEM39	520	1.00	7.00	4.26	1.55	.353
ITEM40	520	1.00	7.00	5.02	1.53	.351
ITEM41	520	1.00	7.00	5.02	1.51	.243
ITEM42	520	1.00	7.00	4.84	1.57	.214
ITEM43	520	1.00	7.00	5.17	1.40	.284
ITEM44	520	1.00	7.00	4.24	1.70	.247
ITEM45	520	1.00	7.00	4.96	1.34	.284
ITEM46	520	1.00	7.00	3.95	1.52	.341
ITEM47	520	1.00	7.00	4.81	1.46	.353
ITEM48	520	1.00	7.00	4.85	1.48	.251
ITEM49	520	1.00	7.00	4.39	1.47	.228

Table 52: Descriptive Statistics.

Safety Culture Measure Organisational Culture Measure	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	
Safety Culture Measure	520	2.04	6.59	4.58	0.79	
Initiative	520	1.33	7.00	4.76	0.97	
Caution Orientation	520	1.00	7.00	4.56	1.29	
Performance Orientation	520	1.00	7.00	4.96	1.30	
Planning Orientation	520	1.33	6.78	4.20	1.08	
Power Orientation	520	2.00	7.00	4.72	0.89	
Achievement Orientation	520	1.29	7.00	4.39	1.00	
Co-operation Support	520	1.50	7.00	4.21	1.00	
Communication Orientation	520	1.00	7.00	3.80	1.14	
Rewards Orientation	520	1.00	7.00	3.14	1.32	
Morale Orientation	520	1.00	7.00	4.17	1.15	
Autonomy	520	1.00	7.00	4.37	1.02	
Self Expression	520	1.00	7.00	3.82	1.24	
Work Diversity	520	1.00	7.00	4.69	1.32	
Personal Growth	520	2.00	7.00	4.92	1.18	
Passion for Industry	520	1.00	7.00	4.49	1.12	
Avoidance Orientation	520	1.00	7.00	3.37	1.21	
Compliance Orientation	520	1.00	7.00	5.17	1.23	
Relationship to Outside	520	1.00	7.00	5.22	1.11	
Leadership Orientation	520	1.00	7.00	3.91	1.41	
Structure Orientation	520	2.00	7.00	4.89	0.89	

Table 53: Correlations between safety behaviours/indicators.

		SCM	EFI	SIM	FTman
EFI	Correlation	0.29			
	Sig. (2-tailed)	0.58	.		
	N	6.00			
SIM	Correlation	-0.08	-0.50		
	Sig. (2-tailed)	0.88	0.32	.	
	N	6.00	6.00		
FTman	Correlation	-0.35	-0.26	-0.33	
	Sig. (2-tailed)	0.49	0.62	0.52	.
	N	6.00	6.00	6.00	
EFI/ FTman rank	Correlation	0.41	0.76	-0.12	-0.83
	Sig. (2-tailed)	0.42	0.08	0.82	0.04
	N	6.00	6.00	6.00	6.00

Appendix K: Factor Loading Matrices for the Organisational Culture Measure and the Safety Culture Measure

Table 54: Factor loading matrix for the principal axis factoring of the Organisational Culture Measure.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
CUL1	.26	.15	.46	.04	.06	.20
CUL2	.24	.09	.35	-.11	.02	-.05
CUL3	.20	.15	.45	-.06	.13	.16
CUL4	.24	.13	.51	-.03	.05	.00
CUL5	.39	.08	.56	.10	.11	.14
CUL6	.10	.13	.34	-.07	.33	-.01
CUL7	.40	.05	.48	.13	.13	.13
CUL8	.26	.04	.42	.13	-.05	.19
CUL9	.15	.05	.44	.03	.05	.20
CUL10	.12	.12	.59	.22	.22	.22
CUL11	.19	.13	.60	.22	.10	.20
CUL12	.29	.10	.66	.20	.13	.21
CUL13	.19	.13	.61	.18	.12	.15
CUL14	.21	.19	.62	.12	.11	.33
CUL15	.16	.20	.63	.10	.16	.23
CUL16	.36	.08	.53	.03	.09	.16
CUL17	.28	.11	.61	.07	.14	.25
CUL18	.23	.32	.27	.02	.14	.26
CUL19	.23	.15	.42	.01	.00	.25
CUL20	.29	.04	.34	.08	.07	.12
CUL21	.46	.03	.39	.18	.18	.28
CUL22	.51	.08	.29	.19	.10	.20
CUL23	.31	.11	.45	.08	.14	.25
CUL24	.43	.13	.37	-.01	.03	.22
CUL25	-.40	.01	-.14	-.44	-.07	.03
CUL26	-.06	-.04	-.09	-.41	.07	.10
CUL27	.09	.07	.09	-.33	.07	.14
CUL28	-.30	.02	-.02	-.57	-.05	.09
CUL29	-.11	-.05	-.09	-.55	-.05	-.06
CUL30	-.23	.14	-.11	-.26	-.05	-.04
CUL31	.06	.02	.10	-.29	-.03	.12
CUL32	-.54	.07	-.14	-.35	-.06	.04
CUL33	.43	.13	.19	-.08	.07	.04

Table 54: Factor loading matrix for the principal axis factoring of the Organisational Culture Measure.

CUL34	.34	.22	.31	-.21	.17	.06
CUL35	.43	.10	.25	-.12	.06	.03
CUL36	.48	.14	.51	-.06	.11	.08
CUL37	.42	.15	.13	-.18	.10	-.06
CUL38	.24	.14	.42	.00	.09	.10
CUL39	.46	.08	.33	-.05	.21	.07
CUL40	.25	.16	.16	-.19	.04	.00
CUL41	.27	.07	.10	.05	.61	.09
CUL42	.28	.19	.29	.04	.58	.11
CUL43	.29	.22	.33	-.01	.45	.04
CUL44	.61	.00	.18	.12	.16	-.05
CUL45	.46	.09	.38	.15	.29	.09
CUL46	.36	.21	.35	.00	.17	.09
CUL47	.48	.10	.13	.06	.44	.04
CUL48	.23	.09	.15	.01	.63	.09
CUL49	.22	.29	.10	-.08	.53	.09
CUL50	.67	.07	.21	.19	.16	.06
CUL51	.65	.12	.21	.09	.12	-.05
CUL52	.75	.07	.21	.15	.16	.09
CUL53	.68	.11	.32	.05	.07	.08
CUL54	.66	.09	.26	.10	.25	.02
CUL55	.66	.10	.28	.10	.19	.14
CUL56	.50	.19	.24	.11	.07	.19
CUL57	.57	.09	.35	.09	.12	.17
CUL58	.55	.05	.30	-.01	.05	.18
CUL59	.28	.13	.10	.02	.10	.11
CUL60	.45	.10	.15	.13	.21	.07
CUL61	.62	-.04	.10	.07	.09	.18
CUL62	.60	.24	.18	-.03	-.06	.10
CUL63	.63	.21	.15	-.01	-.01	-.02
CUL64	.74	.19	.15	.08	.02	.01
CUL65	.69	.20	.15	.04	-.01	.02
CUL66	.45	.28	.04	.12	.05	.07
CUL67	.63	.18	.17	.14	.04	.07
CUL68	.20	.54	.13	.07	.22	.16

Table 54: Factor loading matrix for the principal axis factoring of the Organisational Culture Measure.

CUL69	.61	.30	.13	.04	.12	.08
CUL70	.13	.63	.07	.12	.07	.15
CUL71	.53	.18	.13	.25	.34	.23
CUL72	.55	.17	.09	.26	.35	.24
CUL73	.63	.12	.17	.24	.33	.19
CUL74	.68	.11	.13	.19	.15	.23
CUL75	.23	.32	-.02	-.07	.18	-.20
CUL76	.20	.63	.13	.05	.14	-.06
CUL77	.23	.19	.17	.03	.13	.19
CUL78	.44	.20	.13	.08	.30	.24
CUL79	.64	.17	.30	.14	.19	.12
CUL80	.67	.15	.16	-.01	.07	.02
CUL81	.46	.18	.32	.04	.08	.25
CUL82	.67	.15	.26	.06	.04	.13
CUL83	.68	.16	.31	.05	.05	.08
CUL84	.11	.73	.12	.04	.08	.09
CUL85	.24	.63	.13	-.06	.02	.10
CUL86	.08	.70	.09	.00	.06	.07
CUL87	.10	.72	.14	.02	.07	.12
CUL88	.17	.58	.19	-.05	.01	.10
CUL89	.08	.75	.13	-.01	.01	.14
CUL90	.07	.55	.15	.00	.15	.13
CUL91	.38	.11	.08	.02	.30	.10
CUL92	.31	.33	.27	-.06	.11	.28
CUL93	.47	.13	.15	.04	.29	.24
CUL94	.39	.12	.31	.06	.17	.31
CUL95	.43	.14	.37	.10	.14	.29
CUL96	.48	.14	.21	.06	.33	.23
CUL97	-.07	-.04	-.08	-.30	-.20	-.11
CUL98	-.17	-.15	-.32	-.41	.07	-.16
CUL99	-.02	-.12	-.20	-.45	-.07	-.18
CUL100	-.11	-.11	-.37	-.48	.09	-.20
CUL101	-.13	-.12	-.36	-.39	-.06	-.32
CUL102	.32	.14	.28	.17	.01	.54
CUL103	.12	.32	.22	.24	.12	.50

Table 54: Factor loading matrix for the principal axis factoring of the Organisational Culture Measure.

CUL104	.28	.18	.30	.22	.07	.52
CUL105	.37	.12	.34	.14	.01	.42
CUL106	.33	.14	.30	.14	.00	.45
CUL107	.19	.51	.12	.10	.04	.28
CUL108	.23	.24	.22	.04	-.02	.55
CUL109	.36	.22	.28	.04	-.04	.41
CUL110	.63	.09	.21	.02	.08	.35
CUL111	.54	.02	.19	-.06	.14	.38
CUL112	.59	.04	.17	-.08	.07	.35
CUL113	.59	.06	.23	.03	.12	.39
CUL114	.43	.08	.28	.05	.19	.37
CUL115	-.01	.05	.14	-.16	.04	.44
CUL116	.32	.20	.21	.09	.12	.45
CUL117	-.07	.13	.19	-.03	.09	.51
CUL118	-.07	.02	.04	-.14	.11	.26
CUL119	.11	.06	.23	-.17	.04	.44
Expl.Var	19.60	6.91	1.39	3.54	3.96	5.84
Prp.Totl	0.16	0.06	0.09	0.03	0.03	0.05

Table 55: Factor loading matrix for the principal axis factoring of the Safety Culture Measure.

Variable	Factor 1	Factor 2	Factor 3
Item1	0.29	0.44	0.11
Item2	0.12	0.41	0.17
Item3	-0.14	0.43	0.07
Item4	0.26	0.05	0.55
Item5	0.36	0.49	0.01
Item6	0.70	0.19	0.10
Item7	0.53	0.14	0.16
Item8	0.12	0.57	0.17
Item9	0.33	0.57	0.22
Item10	0.54	0.29	0.21
Item11	0.72	0.13	0.09
Item12	0.24	0.57	0.24
Item13	0.34	0.19	0.23
Item14	0.78	0.11	0.09
Item15	0.44	-0.08	0.09
Item16	0.61	0.26	0.09
Item17	0.76	0.13	0.09
Item18	0.11	0.17	0.50
Item19	0.27	0.22	0.44
Item20	0.65	0.16	0.17
Item21	-0.28	0.20	0.06
Item22	0.68	0.15	0.19
Item23	0.24	0.57	0.26
Item24	0.74	0.30	0.12
Item25	0.78	0.14	0.12
Item26	0.25	0.49	0.36
Item27	0.09	0.37	0.38
Item28	0.24	0.30	0.24
Item29	0.12	0.06	0.67
Item30	0.69	0.13	0.08
Item31	0.03	0.13	0.30
Item32	0.74	0.05	0.14
Item33	0.42	0.43	-0.02
Item34	0.00	0.24	0.63

Table 55: Factor loading matrix for the principal axis factoring of the Safety Culture Measure.

Item35	0.61	0.22	0.14
Item36	0.78	-0.01	0.08
Item37	-0.20	0.38	-0.01
Item38	0.42	-0.16	0.25
Item39	0.59	0.01	0.20
Item40	0.56	0.23	0.15
Item41	0.70	0.22	0.09
Item42	0.77	0.13	0.06
Item43	0.67	0.22	0.05
Item44	0.71	0.07	0.19
Item45	0.63	0.16	0.14
Item46	0.55	0.22	0.24
Item47	0.45	0.37	0.09
Item48	0.70	0.17	0.17
Item49	0.77	0.09	0.16
Expl.Var	13.45	4.03	2.92
Prp.Totl	0.27	0.08	0.06

Appendix L: Classification success of Organisational Culture Measure discriminating safety group (Safety Culture Measure removed from independent (predictor) variable

Table 56: Classification matrix for the Organisational Culture Measure sub-scales predicting membership of high, medium and low ranked safety groups, based on Summed Safety Ranks. (Safety Culture Measure removed from independent (predictor) variable

Rows: Observed classifications Columns: Predicted classifications	Cases in each group	% correct	HIGH	LOW	MEDIUM
	.		p =.11	p =.06	p =.84
HIGH	55	12	3	0	52
LOW	28	43	0	12	16
MEDIUM	421	99	1	2	418
Total	504	86	4	14	486

Note: p (proportion) of cases that would be classified by chance alone.

Appendix M: Rotated Component Matrix for the Organisational Culture Measure and Safety Culture Measure items

Table 57: Rotated Component Matrix for the Organisational Culture Measure and Safety Culture Measure items.

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation Rotation converged in 3 iterations.

Item	Component 1	Component 2
CUL52	.749	
CUL55	.726	
CUL73	.723	
CUL79	.712	
CUL50	.701	
CUL54	.697	
CUL83	.697	
CUL74	.697	
CUL57	.685	
CUL53	.675	
CUL64	.667	
CUL69	.666	
CUL67	.664	
CUL82	.659	
CUL72	.659	
CUL71	.651	
CUL44	.650	
CUL51	.640	
CUL80	.630	
CUL65	.624	
CUL45	.615	
CUL21	.610	
CUL113	.596	
CUL110	.594	
CUL96	.591	
CUL22	.580	
CUL58	.578	
CUL61	.575	
CUL7	.575	
CUL95	.574	
CUL93	.572	

Table 57: Rotated Component Matrix for the Organisational Culture Measure and Safety Culture Measure items.

CUL36	.571	
CUL63	.570	
CUL32	-.567	
CUL78	.565	
CUL62	.562	
CUL56	.559	
CUL12	.555	
CUL81	.552	
CUL5	.549	
CUL112	.547	
CUL42	.547	
CUL39	.543	
CUL43	.541	
CUL47	.536	
CUL60	.536	
CUL111	.526	
CUL114	.520	
CUL16	.517	
CUL17	.510	.414
CUL46	.510	
CUL14	.505	.405
CUL94	.495	
CUL24	.490	
CUL25	-.478	
CUL66	.476	
CUL23	.473	
CUL15	.469	
CUL13	.468	
CUL10	.461	
CUL11	.459	
CUL1	.459	
CUL92	.456	
CUL102	.447	.414
CUL18	.445	
CUL116	.440	

Table 57: Rotated Component Matrix for the Organisational Culture Measure and Safety Culture Measure items.

CUL106	.433	.424
CUL33	.432	
CUL48	.429	
CUL91	.428	
CUL34	.427	
CUL68	.425	
CUL49	.424	
CUL35	.424	
CUL38	.422	
CUL41	.422	
CUL37	.418	
CUL20	.411	
CUL76	.408	
CUL19	.406	
CUL85	.406	
ITEM42		.764
ITEM41		.745
ITEM24		.736
ITEM36		.705
ITEM25		.700
ITEM49		.691
ITEM43		.690
ITEM30		.685
ITEM44		.675
ITEM48		.674
ITEM14		.671
ITEM20		.649
ITEM6		.647
ITEM45		.647
ITEM17	.401	.636
ITEM35		.629
ITEM16		.624
ITEM11		.611
ITEM46		.605
ITEM40		.603

Table 57: Rotated Component Matrix for the Organisational Culture Measure and Safety Culture Measure items.

ITEM22		.597
ITEM39		.591
ITEM32		.591
ITEM10		.590
ITEM47		.576
CUL105	.414	.560
ITEM9		.537
ITEM33		.530
CUL108		.516
CUL104	.436	.485
ITEM5		.481
ITEM12		.467
ITEM26		.455
CUL109	.429	.452
ITEM19		.448
ITEM7		.447
ITEM23		.439
ITEM15		.416
ITEM1		.414
CUL103		.409
ITEM13		.405
Items loading exclusively on component	81	41

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