The Application of Human Factors through the Assessment and Improvement of Behavioural Safety to Improve Safety Performance in Small to Medium Sized Enterprises

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In loving memory of William Walker Rose

ABSTRACT

User-friendly systems of human factors (HF) analysis are not presently available to the managers of small to medium sized enterprises (SMEs). It is therefore difficult for such professionals to assess the safety culture within their own workplaces without the assistance of externally sourced experts.

Large companies have implemented methods of HF analysis with a significant degree of success using HF experts. The aim of this research project was to confirm that SMEs could also benefit from these methods using in-house personnel with a specially-created HF assessment tool.

Human error is often cited as the cause of accidents and incidents. A system of HF analysis was created as part of this research project to allow the technique to be implemented by non-experts within SMEs to identify human-related risks and thereby to assist in improving safety culture and safety performance by implementing measures to minimise those risks through HF methods.

This research project found that potential collaboration partners that were initially keen to take part soon withdrew from the research project after realising what was involved in terms of required resources.

For those companies that participated, the workforce was surveyed to determine the workplace safety culture. Some positive results were obtained but the overriding findings of this research project were that, of the majority of SMEs that were keen to collaborate, they did not actually want to change their safety culture; rather, they were content to continue to implement safety by enforcement of rules & regulations (antecedents) with little scope for implementation of behaviour-based safety systems of control. Although most companies approached knew of the potential benefits it was clear that they had no desire to allocate the resources necessary to achieve those benefits.

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Acronym List

AAIB	Air Accident Investigation Branch
ABA	Applied Behaviour Analysis
ABC	Antecedents, Behaviours, Consequences
ALARP	As Low As Reasonably Practicable
ATEX	Atmosphere Explosible
ATP	Automatic Train Protection
BBS	Behaviour Based Safety
BSTG	Buncefield Standards Task Group
BTP	British Transport Police
CA	Competent Authority (HSE & EA & SEPA combined)
COMAH	Control of Major Accident Hazards
CNES	Centre National d'Etudes Spatiales (French Space Agency)
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
ERTMS	European Rail Traffic Management System
ESA	European Space Agency
FMEA	Failure Mode and Effects Analysis
FRB	Forth road Bridge
GDP	Gross Domestic Product
HEA	Human Error Analysis
HEART	Human Error Assessment and Reduction Technique
HMRI	Her Majesty's Railway Inspectorate
HSC	Health and Safety Commission
HFE	Human Factors Engineering
HSE	Health and Safety Executive
HSL	Health and Safety Laboratory
IHLS	Independent High Level Switch
KSC	Kennedy Space Centre
MMI	Man Machine Interface
NASA	National Aeronautics and Space Administration
NATS	National Air Traffic Service
NVQ	National Vocational Qualification
OBC	On Board Computer
OFCE	Open Flammable Cloud Explosion
ORR	Office of Rail Regulation

PFD	Probability of Failure on Demand
PSLG	Process Safety Leadership Group
RAIB	Railway Accident Investigation Branch
RBI	Risk Based Inspection
RCFA	Root cause failure analysis
RCM	Reliability Centred Maintenance
RSSB	Rail Standards and Safety Board
SA/SD	Strongly Agree / Strongly Disagree
SCT	Safety Culture Tool
SME	Small to Medium Sized Enterprise
SPAD	Signal Passed at Danger
SRB	Solid Rocket Booster
SRI	Inertial Reference System
TAL	Transoceanic Abort Landing
THERP	Technique for Human Error Rate Prediction
TOC	Train Operating Company
TPWS	Train Protection and Warning System
TESEO	Technica Empirica Stima Errori Operati

1.0 INTRODUCTION

UK transportation and heavy industries have endured much negative publicity in the past regarding poor service and reliability. Serious (including fatal) accidents and increasing costs to the consumer have all added to the *unenviable* position in which these industry sectors find themselves.

Safety has improved through better methods of risk assessment and control in the workplace, greater regulation and enforcement and better training for workers but the number of accidents is still unacceptably high.

In 1900 the proportion of manufacturing in the UK GDP was 28% and by the year 2000 this had reduced to 14% (Lindsay, 2000). At the present time, manufacturing output appears to be showing a small positive growth (but at a reduced rate from previous recent quarters) while the overall UK economic growth is still positive (following the recession of 2008 / 2009) it has also slowed recently. Recent data shows that the current manufacturing output is approximately 12.8% of GDP and growing (O'Grady, 2010). The service sector continues to grow as seen from the official government data (from 21% in 1900 to 32% in 2000) (Lindsay, 2003).

From the rich history of the UK industrial revolution it is disappointing to consider that, in the future, the UK could become totally dependent on the output of other countries for all manufactured products. This would be bad for the UK economy as a result of the lost jobs in the manufacturing sector (with the potential to lose the manufacturing know how and capability at the same time); however, it is highly likely that a degree of manufacturing will always remain, with the subsequent requirement to manufacture goods safely from design through to delivery to the consumer. This is especially true for products associated with civil defence and national security where the UK is at the forefront of many emerging technologies.

Clearly, transport system infrastructure and associated control and monitoring systems cannot be farmed out to other countries as they form part of the built environment around us but the operation and maintenance of all such systems will remain a core function of any operator in the sector. In contrast to this, a UK company (Alexander Dennis) has recently announced winning a new £25M contract to supply buses to New Zealand. The buses will be manufactured within the UK in kit form and will be assembled by a partner in New Zealand. It is clear that in some sectors at least, UK industry is fighting back to win contracts over the rest of the world and to improve cost efficiencies using the latest technology and methods to do so. Such companies cannot be at the forefront of such sectors without working safely and efficiently.

The continuous introduction of new or updated EU and national industrial legislation means that heavy industry is becoming more and more regulated as time goes on. Such trends mean that it is becoming even more important (and more difficult) for companies to seek new and more novel methods of improving safety, productivity and environmental performance. The application of human factors methods of risk reduction through improvements in safety culture / safety behaviour is one such method.

The UK HSE states that "Human factors refer to environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work in a way which can affect health and safety." (HSG48, 1999) They also state that "Human factors is a broad field and organisations may have viewed it in the past as being too complex or difficult to do anything about." This is in broad agreement with the attitude of companies as found during the period of this research project. Human factors is described in more detail in Chapter 3.

Agnew and Snyder (2008) describe the ABC model of behaviour-based safety methods of reducing risk. This is a model comprised of three elements: antecedents, behaviours and consequences (ABC). An antecedent is described as any person, place, thing or event that comes before a situation that requires a behavioural action. A behaviour is what is seen or done in carrying out work, tasks and actions. The consequences are the events that occur after or simultaneously with the behaviour. The consequences of the behaviour can affect the probability of the same behaviour being carried out in future depending on whether the consequences were favourable or unfavourable (irrespective of whether they were correct, incorrect or even inherently unsafe). This is one of the problems with human perception: a poor or unsafe behaviour is often rewarded with good consequences such as completing the task quicker or with less people or using less raw materials.

Management personnel can also be at fault for reinforcing this unsafe behaviour with positive encouragement for the good consequences that were achieved (even though they may have been achieved through potentially unsafe behaviour, including violations). Such encouragement serves to make those behaviours more likely in the future. Potentially unsafe behaviours will not result in undesirable consequences every time but will present the potential for undesirable consequences every time and may result in those consequences being realised under only slightly different circumstances.

The ABC model is shown in Figure 1.1 below. The feedback loop between consequences and antecedents is shown. Whatever consequences were achieved in previous tasks become indirect antecedents for future tasks.

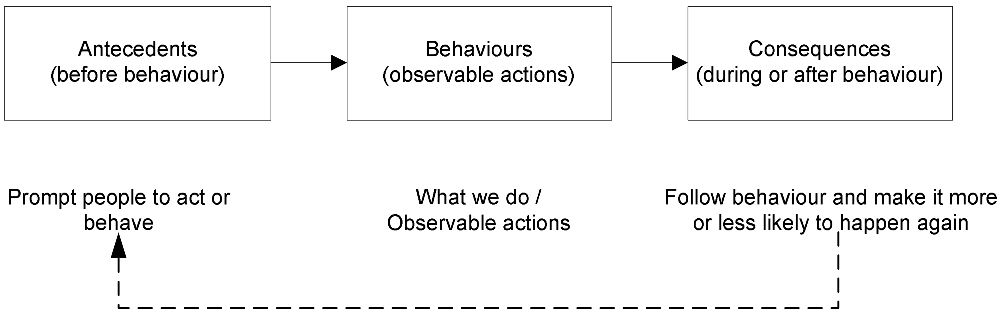

Figure 1.1: *ABC Model*

Roughton and Mercurio (2002) state that there is presently no documented texts offering a method of integrating behaviour based safety systems (BBS) of risk reduction into existing health and safety management systems and that many such methods “stand out like a sore thumb” when implemented alongside existing health and safety management systems. They also confirm that BBS is not able to solve all safety issues but that it is only one of the tools that a business can use in the aim of risk reduction. It is only capable of solving issues caused by potentially unsafe human behaviours and the other methods of risk reduction (antecedents) such as hazard recognition, inventory reduction, material substitution, procedures, training, etc. should all be implemented in combination with BBS methods.

It can be seen from the above that human factors / BBS methods of risk reduction do not directly affect the antecedent part of the ABC model but affect the behaviour part of the model and, indirectly, the consequences part of the model. The antecedents are the hazards that are present in the workplace and also the physical and organisational controls that are in place to control them such as training, risk assessment, procedures, rules, personal protective equipment, etc. The antecedent controls are not behaviour-based but are rule-based. They do still require personnel to follow the rules / procedures which means that they are still indirectly related to human behaviour. Any failure to follow those rules would be classified as a violation. There is a significant difference between errors and violations: errors can be prevented by providing better training, supervision and motivation whilst violations can only be prevented by changing the behaviours of the violators. Errors occur as a result of poor decisions (based on inadequate information, experience, competence or knowledge) while violations occur as a result of the person knowingly deciding to break the rules. Changing the behaviour of people can assist in preventing errors and violations from re-occurring. This statement forms the basis of the application of human factors in the workplace. The method is entirely concerned with the assessment and correction of the human decision-making process. The implementation of any antecedent measures within the workplace environment that assist in this can also be identified and implemented through human factors assessment.

A variety of legislative improvement initiatives have been introduced by the EU regarding industrial safety and public transportation systems such as Seveso (96/82/EEC, 1996) for workplaces with major accident hazards, ATEX (1999/92/EEC, 1999) for workplaces with flammable atmospheres, the EU machinery directive (2006/42/EC, 2006) and a common regulatory rail framework directive (2008/110/EC, 2008). Most of the legislation is reactionary, i.e. it has been introduced as a result of single catastrophic events or a series of smaller, less significant events. The key factor is that it is always introduced for the increased protection and safety of people, the environment and the infrastructure that surrounds us. The Seveso EU Directive was introduced after the massive explosion and dioxin chemical release that occurred in Seveso, Italy in 1976. The prevention of such disasters was not previously covered by any legislation and this directive was introduced to ensure that "high risk" chemical plants throughout the EU considered the major accident hazard risks and implemented measures to minimise all such risks not only to those within the operational plants but also to those in the surrounding area that may be affected by such events. Until that time all such incidents were prevented by self-regulation. In the UK the Seveso directive is implemented under the COMAH Regulations (SI1999/743, 1999).

Companies generally try to prevent such accidents from occurring under all foreseeable types of activity (for financial reasons if nothing else) but without regulation or some other method of ensuring that the control and safety measures are adequate, the prevention of undesirable outcomes from occurring is completely dependent on people acting correctly at all times. Individual and corporate competence is therefore at the forefront of the prevention of all such accidents.

A similar series of events resulted in the introduction of the ATEX User directive (1999/92EEC, 1999) (to promote safety in those work places containing potentially flammable or explosive atmospheres). This directive was implemented under the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) in the UK (SI2002/2776, 2002). DSEAR also implements the Chemical Agents Directive (CAD) (98/24/EC, 1998).

The railway industry is also undergoing change as a result of new EU legislation. As a means of harmonising the equipment and systems in use throughout Europe two EU directives for interoperability have been issued, one for high speed railway systems (96/48/EC, 1998) and the other for conventional systems (2001/16/EC). These directives seek to ensure that the technology and systems employed throughout the EU converge as time goes on, thereby enabling and promoting EU wide co-operation, sharing of knowledge and learning and cost minimisation.

The one thing that all such legislative measures have in common is that they are all intended to identify hazards and by doing so they provide a means of implementing risk prevention and mitigation measures. Many of the individual requirements of such legislation are focussed on the principles of promoting positive human behaviours, i.e. they clearly describe the type of activities that must be carried out in order to identify and reduce risk to a tolerable level. An example of this is DSEAR (SI2002/2776, 2002) which clearly describes the principles of explosion safety and informs those responsible for ensuring adequate safety is in place through analysis of the workplace, the materials handled and the activities carried out. It could be argued that highly capable and experienced personnel would always act correctly even without such legislation or guidance in place but not all personnel have the same capability or experience and without such legislation and guidance in place it is likely that there would be a much higher accident rate than at present, accompanied with the subsequent consequences to people, the environment and business. The main objective of all such legislation is therefore to identify the minimum requirements and to provide clear and unambiguous guidance on what must be achieved in order to meet those requirements. In the UK a core function of the Health and Safety Executive (HSE) is assisting people and companies to achieve the required objectives of legislation by direct consultation and by the issuing of approved codes of practice for legislation under their control. These are approved documents generally founded on industry best practice and guide operators in what they should be doing to achieve the minimum requirements of the legislation. Alternatively, if the operators do not heed the guidance provided, the HSE also have the power of enforcement through issuing improvement and prohibition notices to those companies or individuals that have not achieved the required standard and in extreme cases, by prosecuting offenders through the criminal justice system, either proactively or after an accident has occurred.

In the railway industry improvements have ranged from changes to management structure and lines of responsibility (especially following the collapse of Railtrack in October 2001) to improvements on the train systems and associated railway infrastructure. The benefits of some of these initiatives may not be seen or felt in their entirety for many years to come but they are no less desired by the public, train operators, track operators and the government through the regulatory bodies. Many of the benefits are not visible to the end user and they do little to boost consumer confidence in the ability of the companies concerned to provide a good service that meets their expectations, i.e. services running on time, with a seat always available, clean carriages, high quality refreshments, etc.

Whilst accident statistics are important, the consumer does not expect them to be a major factor in the quality of service provided as it is assumed by all stakeholders involved that public transportation accidents should not occur and that passenger safety is therefore the prime concern of everyone from traveller to train operating company (TOC) (RSSB, 2005). Many of the projects associated with providing and maintaining passenger safety come with a very high price tag. An example is Automatic Train Protection (ATP) which will cost billions to implement throughout the UK rail network. As a result of the complexity of the ATP system and the geographical position of the network infrastructure, such systems cannot be installed quickly or easily, especially on a network that must remain in operation throughout any such upgrade programme. In the interim period the effects felt by passengers of upgrade works on signalling systems and infrastructure are the inevitable delays and extended journey times. TOCs and the infrastructure operator are under immense pressure to improve service and safety levels whilst maintaining an acceptable level of service to the consumer. These time / operability pressures provide ideal conditions for high stress situations where the likelihood of human error is increased. Such errors can have a potentially dangerous effect on the railway network, either directly in the operation of the trains or indirectly through the inspection and maintenance of the railway infrastructure. Public perception is that poor track and infrastructure maintenance is one of the main causes for railway accidents / crashes (RSSB, 2005). Failure to follow strict operations, inspection and maintenance procedures can come at the expense of the lives of workers and passengers. Even the smallest and seemingly insignificant of errors can lead to an accident with a scale of effects that is completely indiscriminate to those it can affect and is often severely disproportionate to the root cause.

It is an unfortunate fact that railway accidents involving similar causes continue to occur showing that “lessons learned” have not in fact been learned at all or have been ignored or forgotten by those who need to know or should know better. The public perception of this fact is also uncannily accurate (RSSB, 2005), potentially as a result of the high profile media coverage given to such accidents. Examples of this are the Potters Bar and Grayrigg accidents – both caused by faulty points systems which had (allegedly) recently been inspected or maintained by the infrastructure operator. It is clear from preliminary reports that similarities exist between the two accidents and that the sense of public outrage at such accidents is even greater when corporate and personal negligence appears to be a factor time and time again when lessons should have been learned. Public perception shows that drivers and trains are generally trusted and considered to be safe but the management of the railway infrastructure is not trusted to the same degree (RSSB, 2005). Unfortunately a common factor in such accidents is the attitude and competence of humans and their ability to continuously perform their allotted tasks to the required degree of rigour under all conditions and with the independence necessary with which to ensure adequate safety is achieved at all times.

The global air transportation industry of the western world (northern hemisphere) has an excellent record in preventing accidents caused by human error and the UK railway industry is following in its footsteps in terms of accident investigation and shared learning through the Rail Accident Investigation Branch (RAIB) which is founded on similar principles to the Air Accident Investigation Branch (AAIB). Whilst there are international standards for operational activities such as air traffic control and aircraft maintenance procedures many countries and aviation companies fall short of these standards and are subsequently "blacklisted" from operating in the developed world until they can prove that they have met the required standards. An EU-wide system is operated which bans airlines from the entire EU area (EU Commission, 2011).

Public perception and sense of outrage is completely different between industrial and transportation accidents. An occasional (but all too frequent) industrial fatal accident rate (perceived low consequence) seems to be more tolerable to the UK public than a single incident leading to multiple fatalities (perceived high consequence) (Heath and Safety Commission, 2007). Even within the UK there appears to be differences between Scotland and the rest of the country in terms of the media coverage given to industrial fatal accidents where the perception in Scotland is that single fatalities are less tolerable to the public than elsewhere in the UK (Heath and Safety Commission, 2007). In the UK far more people are killed each year in industrial accidents than while using public transport but such accidents are not as well publicised and the sense of shock seems to be far greater when a higher number of people are involved in a single accident such as with train crashes. Another likely factor of this attitude is that of personal familiarity. Whilst most people can relate personally to a train crash as they will have used trains at some time in their lives, they will not normally have been involved in any specific area of industry in which an accident may have occurred and will feel therefore that such an accident couldn't possibly affect them or put them at risk as they consider themselves to be physically and geographically detached from the accident, its causes and its consequences.

Part of the reason for this attitude may be associated with the work ethics founded in the UK industrial revolution between the late 18th and early 19th centuries when the attitude towards safety was very much that "accidents happen" and that people could do nothing other than to accept this fact. This attitude has now largely given way to a more pro-active approach to safety awareness and risk reduction. Personal competence was still a factor in those days and apprentices learned how to work safely by copying the tradesman who taught them without the requirement for formal procedures.

The poverty and deprivation of that era meant that people relied heavily on their factory earnings and were not therefore empowered to enforce acceptable working conditions for fear of losing their jobs and income. Long term, debilitating illnesses (some fatal) associated with handling dangerous and harmful materials within industry were also commonplace and were accepted as a fact of life which could not be changed. A huge quantity of industrial legislation is now in place in the EU and the UK to promote better practices and to prosecute those who disobey the regulations. In the UK workplace injury and illness statistics show that there is still significant scope for improvement. In the year 2009/2010 152 people were killed while at work in the UK (Sweeney, 2010). For the same year, under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR), more than 121,000 reportable incidents occurred (Sweeney, 2010). Each one of these incidents represents an event that could cause life-changing injury or illness to workers (possibly even a fatality).

Many developing countries within the world do not have such rigorous legislation or workplace ethics and many preventable accidents and illnesses, as previously occurred in the UK, continue to occur in those places.

There are many examples of manufacturing processes being shut down in the UK and production moved elsewhere within the world for reasons of cost and efficiency. Whilst such developments provide an overall enhancement to the countries involved in terms of revenue generation and employment there will be unfortunate individuals that will suffer directly as a result of such policies as their right to a safe place of work is not equivalent to that of a worker in the EU. The author has consulted (albeit briefly) in the decommissioning of a manufacturing line based in Fife (Scotland) which was being moved in its entirety to a factory in India. There were a few key reasons for such a transfer of the line; namely:

- The manufacturing line did not comply with EU / UK machinery guarding and interlocking regulations and achieving compliance was deemed to be cost-prohibitive.
- The machinery guarding and interlocking regulations in India are far less prescriptive than in the UK meaning that only minimal investment in protective and safety devices was necessary.
- The UK labour costs associated with the operation of the line could no longer be supported for the value of the product being produced.
- As India is a rapidly developing country, it represented a huge market to the product being manufactured and such a move would clearly reduce the transportation costs of the finished product.

Although it was never stated directly, it was clear that one of the underlying factors was that there would be far fewer regulatory requirements with operating the line (in its current form) in India than in the UK. This situation suggested that the company involved placed less value on the life and well-being of an Indian citizen than that of a UK citizen which is clearly an ethical issue and one that may become more prevalent as time goes on. It is feasible that all such developments may eventually converge with EU legislation in terms of providing worker protection and well-being but the fundamental questions remain as to how long this will take and how many people will suffer unnecessarily before that time comes?

Whilst such economic development of countries is welcomed from all quarters it is debatable whether it should be carried out simply to make a profit potentially at the expense of the health and well-being of the workers involved. It is the author's experience, in working for a multi-national oil company and as an independent consultant, that most people have similar ethical values when it comes to protecting people and the environment from harm but that people are sometimes placed in difficult situations by their employers or by the situation and are often forced to make what could be considered to be unethical decisions as a result of the contributing factors involved.

There are people and corporate bodies that still do not live up to current laws and expectations in order to achieve the required degree of safety for themselves and others and as a result, EU and UK legislation is constantly being implemented and updated to close loopholes and to enforce better operating methods. The number of RIDDOR incidents (121,000) as noted for the year 2009 / 2010 clearly shows that it is essential to improve on our existing safety performance to minimise the number of injuries to personnel.

Whilst legislation enables prosecution of those who do not meet the required standards the most significant improvement in safety can be made by changing people's attitudes towards personal accountability, engineering integrity and personal competence rather than enforcing potentially uncomfortable and unfamiliar methods of working through antecedent measures. Some companies will continue to disobey the law simply because compliance will affect revenue too much (in their opinion). The operators of those companies are likely to find themselves in court at some point in time trying to defend their actions but they will only be there as a result of having put workers at risk without understanding the potential consequences of the tasks being carried out or worse; after bullying workers into performing tasks knowing that they are potentially dangerous.

Human factors is becoming more popular in industry as the incentives for its incorporation in project, operation and maintenance functions become more evident and as the level of understanding within the engineering community increases (Harvey, 2004). Human factors assessment and application of behavioural safety initiatives is one of the methods that can be used to improve on existing safety systems and reduce overall risk.

1.1 Research Project Scope

The scope of this research project was to investigate the application of HF in UK industry; specifically within small to medium sized enterprises (SMEs). The research covered aspects such as safety management, corporate and personal responsibility and competency, accident causation, HF case studies and proposed improvements to the way in which safety in UK industry is controlled and monitored.

Assessment of human factors within the workplace is often considered by industry managers as an additional (perhaps needless) operating cost and a complex method of risk reduction only achievable by using experts in the field. However, only by examining the attitudes of workers and identifying potentially unsafe behaviours will it be possible to change potentially unsafe behaviours. It is this behaviour modification that ultimately results in risk reduction through better safety culture / behavioural safety.

Historically, implementation of human factors methods in industry invariably involved the use of expert consultancies at significant cost to the client. The benefits are clearly much desired but the costs and human resource necessary to implement the methods of assessment and improvement may sometimes be seen as outweighing the benefits. It was an aspiration of this research project to bring human factors assessment capability to small to medium sized enterprises (SMEs) by methods which can be applied by non-experts. Clearly, such implementation may be considered by experts in the field to be a partial or incomplete implementation, compared to what an expert may be able to achieve with the same data and resources; however, this research project aimed to determine if such methods could be implemented by persons with little background or understanding of the methods to achieve measurable (and safe) results. It is possible that misunderstanding results and implementing safety or control measures incorrectly could lead to an increased level of risk to workers.

Implementing human factors methods of risk reduction in the workplace is no different from any other activity, i.e. it can take a lifetime to become an expert at doing something but in a very short time a person can achieve useful results using only a basic appreciation and background knowledge of the subject. There are many examples of this such as a person driving a car but who doesn't understand how the engine or gearbox function together to form a means of motive power. A person learning to ski will fall over often at the beginning but will quickly be able to descend down a hill, perhaps not at breakneck speed, but with sufficient speed and control with which to enjoy the experience. Human factors and health and safety engineering is not seen as being any different to this in that the perfect and thorough application by experts will identify all hazards and issues that present a significant risk to any particular workplace situation. In the vast majority of situations that present risk to workers, there are relatively simple actions that can be implemented to prevent an accident from occurring. This research project was carried out in order to investigate whether the methods of identifying these potential actions through human factors and behavioural safety assessment could be applied by non-experts and still achieve measurable (risk reducing) results.

For this research study, the basis of implementing human factors assessment in the workplace was a survey of workers' attitudes to the workplace. The outcome of the assessment would be a set of data that would guide the employer to elements of the workplace processes that could be changed in order to boost morale, improve behavioural safety (and usually efficiency) and improve safety culture within the workplace. The assessment and subsequent corrective measures should be directed at the most significant areas in which accidents can be prevented and would therefore provide a system of safety culture improvement for minimal cost and one that is based on prioritising the most significant issues and addressing these in order of importance as defined by employee perception and management priorities. Many systems of HF analysis, as provided by specialist external consultancies, utilise their own data gathering and analysis tools and involve carrying out extensive surveys and interviews of personnel to fill in their data fields. The data is then transformed into an action plan for implementation. The system of HF analysis created as part of this research project sought to obtain the same (or similar) data but, instead of creating another layer of safety management, would assist in making subtle changes to existing procedures and systems to ensure that HF was applied as part of existing processes and with existing resources.

1.2 Research Project Objectives

This first part of this research programme involved the review of the causation of high profile industrial and public transportation accidents and to hypothesize from the official findings whether the application of HF assessments could have prevented any of the accidents from occurring and how such application may be applied in order to maximise safety and minimise the likelihood of similar accidents occurring in the future.

It was confirmed in this project that small to medium sized enterprises (SMEs) often have little or no capability to implement such measures. All of the companies approached expressed a desire to participate in the research but none of them had any resources to do so. This included SMEs with a handful of employees and multi-national companies with thousands of employees.

This research project aimed to build upon the work and methods previously carried out in order to propose a system of HF analysis implementation which could be applied by SMEs and larger companies in a quick and efficient manner with minimum resources such that they can also reap the benefits of lower operating costs and lower risk.

This research programme sought out collaboration partners for the research study in terms of identifying existing practices and testing the implementation of the HF system in an industrial, transportation or manufacturing setting. The research therefore not only endeavoured to provide the means and methods by which HF implementation could be carried out by an SME but also intended to discover whether the professionally skilled engineer / manager could deploy such a system successfully, with little external assistance, to such an extent that real benefits could be achieved. The research would therefore not only add to existing knowledge but would also attempt to create less formal methods of utilising existing knowledge by opening up the application of HF to a far greater community of people.

The collaboration partners were chosen based on the original criteria listed below.

- Had employees in all grades of technical personnel, apprentice to chartered engineer;
- Handled dangerous or potentially explosive materials / substances providing for a significant level of real risk to workers;
- Didn't have any existing formal application of human factors methods of risk reduction;
- Had the requirement to design, install, operate, inspect and maintain safety-critical systems for provision of worker safety or that of the consumer (in terms of product safety) or the environment;
- Had in-house projects, maintenance and operations personnel;
- Preferably had less than 100 employees (technical, operational, supervisory and managerial).

At first glance, this may seem like a very restrictive list of criteria that would rule out most companies and SMEs in existence. However, through existing author/client relationships, 63 potential collaborators were identified as suitable. Several additional factors were used to determine which companies would be approached to consider collaboration in the research project. These were location, current relationship status and the author's perceived risk to the businesses by taking part in the research project.

The relationship status between the author and the collaborators was important. Some businesses only hire the services of the author because they have been forced to do so either by a threat of enforcement action from the enforcing authority (HSE) or actually having been served improvement or prohibition notices already. It is the author's experience that companies falling into this category usually have some underlying (but obvious) reason for their apparently poor safety record. This can usually be attributed to several key factors: inadequate competence of the personnel employed in positions of responsibility; an autocratic management style that forces people into compliance with the company rule (whether it is best, safest or otherwise) under threat of losing their jobs or status and also the refusal of management to provide the necessary level of resources present (to maximise profit margin).

Inadequate competence of personnel in positions of responsibility is a clear failure of management to understand the hazards and risk associated with their own businesses. Alternatively, by putting such people in place the management may be acutely aware of the weaknesses of those people and may use this as a means of ensuring their hard-line policies are implemented without question. In most cases those subordinates will have been chosen for their compliance with management style rather than for their ability to assess and control risks. This could present a highly dangerous and volatile situation: for the supervisor and for the shop floor operatives. With corporate manslaughter laws in force there is no hiding place for such managers but the unfortunate outcome in this situation is that it is the shop floor workers who invariably get hurt. Companies fitting this description were identified in the list of potential collaborators and were also approached to take part in the research. The response from those companies was predictable. No companies classified as such participated.

The collaboration partners were required to complete an initial survey in order to provide a baseline measurement of employee attitudes to safety, competence, operability and decision making processes within their company. In addition to this a critique of existing safety processes and procedures was carried out to identify other unrelated issues that may be present. All data was then analysed and presented to the companies to enable them to identify where maximum benefit could be gained from the application of corrective measures to improve safety based on the outcome of the HF assessment. The companies were then assisted in the application of HF methods and the subsequent safety culture and behavioural safety performance monitored over an extended period. On completion of the monitoring trial period the companies were then re-surveyed to determine what improvements (perceived and actual) had been achieved. The original intention of the research was then to determine what modifications could be carried out to the HF assessment system or what strategy could be changed in order to improve the scoring and performance of the survey elements. Due to the difficulties associated with the collaborators it was not possible to create a robust, fully tested HF assessment and analysis system. The reasons for this are discussed throughout this thesis.

It was a key requirement of this research programme that the system of HF analysis had to be such that it could be embedded in existing company safety and operational processes. Such a method of application was essential to avoid cynical attitudes such as the familiar “change for change’s sake” and to ensure that the modifications to company processes were minimised, substantially covert, and above all, easily implemented by making a number of small changes to existing systems rather than implementing “yet another” risk assessment process over all the others without provision of any additional resource. In the manufacturing industry, it is an unfortunate fact that this is a common attitude towards such methods and this attitude must be overcome if successful application of HF is to be achieved. “Substantially covert” means that the corrective measures or behaviour modification methods employed are built into the normal activities of all personnel in everything that they do at work, i.e. where a robust safety culture is developed in which people want to do things in a safe manner without the need for continuous enforcement. This would be a self-regulating workforce that is capable of setting its own standards and improving upon them because it is the right thing to do. Such a situation would rely on ethical standards supporting this attitude.

An excellent quote for this type of process comes from a manager in the sporting environment: Sir Clive Woodward; who said that “My philosophy is about doing 100 things 1% better.” In other words, to get the best out of any process, it is not feasible or possible to make any process 100% better. Instead, it is necessary to examine every aspect of every activity carried out and to determine how each aspect can be improved and optimised in order to make many minor changes to the way in which activities are carried out. In isolation each improvement would be insignificant but in combination the overall outcome becomes significant and assists in achieving the desired goals.

2.0 BACKGROUND

2.1 Societal Expectations

In today's society, people have come to expect ever-increasing levels of service and safety. The days of people treating injuries at work or in public transportation systems as inevitable and expected are long gone. However, it is a generally accepted fact that in potentially dangerous environments such as heavy industry and public transportation systems, with the significant sources of stored energy involved, it is inevitable that accidents will happen.

The industrial revolution was magnificent for the UK as a world leader in showing how things could be done on a grand scale for yield and profitability but the number of work-related injuries and diseases of that time is nothing to be proud of.

Similar attitudes to safety can also be found in industry today where some companies attempt to maximise profits by not complying with regulations if they believe they can get away with it, irrespective of the risk of being caught or of the harm that their actions may cause to individuals or society as a whole. Such cases are routinely prosecuted by the UK HSE. This attitude is no different to what happened in the UK industrial revolution or what can be seen happening today in real work situations in countries all over the world in their own modern day industrial revolutions. In places like India and China, people are commonly working for very low wages, in poorly regulated and poorly controlled factories where safety is clearly not the highest priority. The poverty and desperation that the workers find themselves in allows the factory owners to disregard their safety and wellbeing, knowing that, if someone is killed or injured, there are many more ready and willing to take their place. The workers only have two choices: to put themselves in danger or starve and be destitute. The industrial laws concerning such issues in developing countries do not appear to be as robust as those in the western countries.

In industry where, despite the years of gradual and continuous improvements in safety and control have been implemented (or enforced), an unacceptable number of injuries still continue to occur. In order to continue operating to the greatest level of safety possible, the best companies are looking to improve their safety performance through new methods, such as human factors, while at the other end of the scale those companies with the poorest safety records continue to perform badly, barely achieving the minimum requirements through lack of resources and an unwillingness to change existing practices. Revenue generation appears to be more important to the owners of those companies than the safety and welfare of their employees.

It has become clear that business owners need to be convinced of the benefits of the application of human factors before they will voluntarily authorise resources for such risk reduction schemes. Companies may be guided towards HF methods but it is up to each to determine how they will improve their own situation. It is fair to say that the best results are always achieved when people have a desire to change rather than having change enforced upon them. An example of this is described below.

Discouraging people from using personal vehicles in favour of more environmentally friendly modes of transport such as walking, cycling or using public transport will be an uphill struggle until it can be shown that an adequate level of service and safety is provided.

Figure 2.1 shows that the number of passenger miles travelled is increasing year on year as the population is growing and people become more mobile.

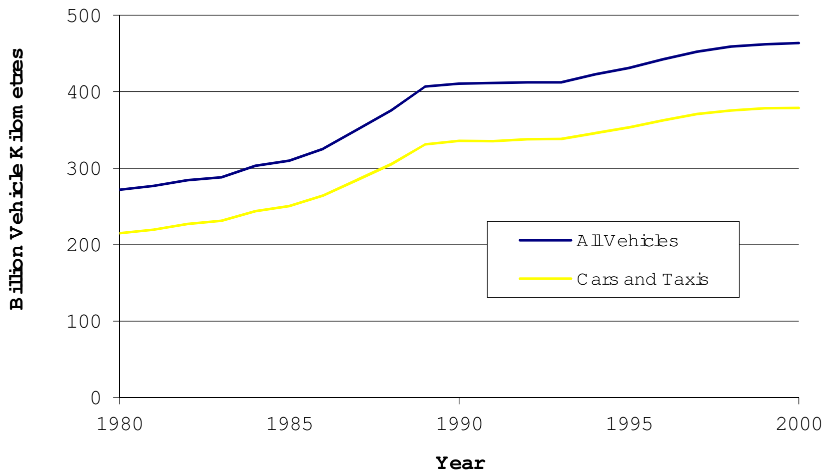

Figure 2.1: *UK Vehicle Usage*

One of the problems with such a desire to shift people's attitudes towards travel and commuting lies with the ability of the public transport operating companies to provide a safe and adequate service such that people have confidence of arriving at their destination on time and in one piece.

Statistically, road travel is more dangerous than rail travel (NTSB, 2004) but people feel more in control of their own destiny in a private vehicle and they perceive that they lose all such control on public transport. Data from the UK suggests that rail travel is 20 times safer than car travel but this value is highly dependent on how the statistics are compared and measured (RSSB, 2007). The key point is that rail travel is safer than car travel; to what degree is arbitrary. Coach travel lies somewhere between the two.

As the societal risk increases with an increase in the number of people using the service, it will become even more important for existing safety standards and system reliability to be enhanced to maintain present risk levels.

The application of human factors is one of the tools which can be used to assist in fulfilling this expectation and its application within industry is the main focus of this research project.

2.2 Human Failings - The Root Cause of Accidents

Consideration of the type of faults or errors to be detected and prevented is crucial if procedural controls and risk reduction systems are to be effective.

The classification of human error has been attempted by many people. Rasmussen & Jensen (1974) cited by Reason (1990) devised a framework for the categorisation of human errors based on the performance level of the activities being carried out. The three performance levels are skill-based, rule-based and knowledge based and these are discussed in detail in section 3.3.

Dekker (2006) defines the cause of human error as being in “the head” or “the world” and describes the old and new views of attributing human error to the cause of an accident. The old method simply attributed the cause of an accident to human error without further assessment which brought closure of the accident investigation. The new view may still define human error as a cause but instead of an investigation ceasing on the discovery of a human error it will then examine the workplace situation in much more detail to determine what other factors may have been present that caused the error to occur. This research project and the assessment tool created was fundamentally concerned with the identification of such factors being present within the workplace prior to them contributing to an accident.

Stranks (2007) also uses the three performance levels in his categorisation of human error in the same way as Reason (1990).

There are older texts that use different classification criteria such as Green (1982) in which the main classification of human error is defined by the activity (and hence the person or group in which the root cause of the error is founded), i.e. operation, maintenance, design or test after which the cause and nature of the contributing factors need to be investigated further. This method of classification is not considered to be ideal in this research study as it is primarily interested on the type of activity rather than the type of error.

The method of classifying human error in three performance levels has been at the forefront of the field for a considerable period of time. For the purposes of this research project the three performance level model as defined by Reason (1990) has therefore been used.

2.3 Equipment Failings

Revealed faults in equipment are relatively straightforward to deal with as they are easily detected and can be corrected as required before a real hazard is allowed to exist. They will inevitably cause loss of service but with little additional direct risk. The analysis and modifications processes implemented under HF can be used to prevent future recurrences.

Covert faults (functional or systematic) are the most likely to cause accidents, being revealed only when the consequences of the failure have caused an undesirable or unplanned event. Functional safety standards such as IEC 61508 and tools such as human factors / safety culture assessments can be used in the identification and prevention of systematic errors and covert faults.

2.4 Major Accident Statistics

Accident statistics of various sectors have been examined and these are shown below.

2.4.1 UK Railway Industry

The Annual Safety Performance Report (ASPR) produced by the Rail Safety and Standards Board (RSSB) details the safety performance of the UK railway network. It identifies the causes of all accidents and injuries on the railway network. The data also includes assaults, suicides, trespass, etc.

The latest report (2010) shows that, overall, the risk level to all people that interface with the railway network in any form is reducing. There are many reasons for this, most significantly the work being carried out by the operators in terms of reducing accident rates (train crashes and occupational risks) and providing better security arrangements for passengers.

The charts below show the breakdown of the causes of fatal accidents by person type and location (reproduced from the ASPR 2010 report – RSSB, 2010).

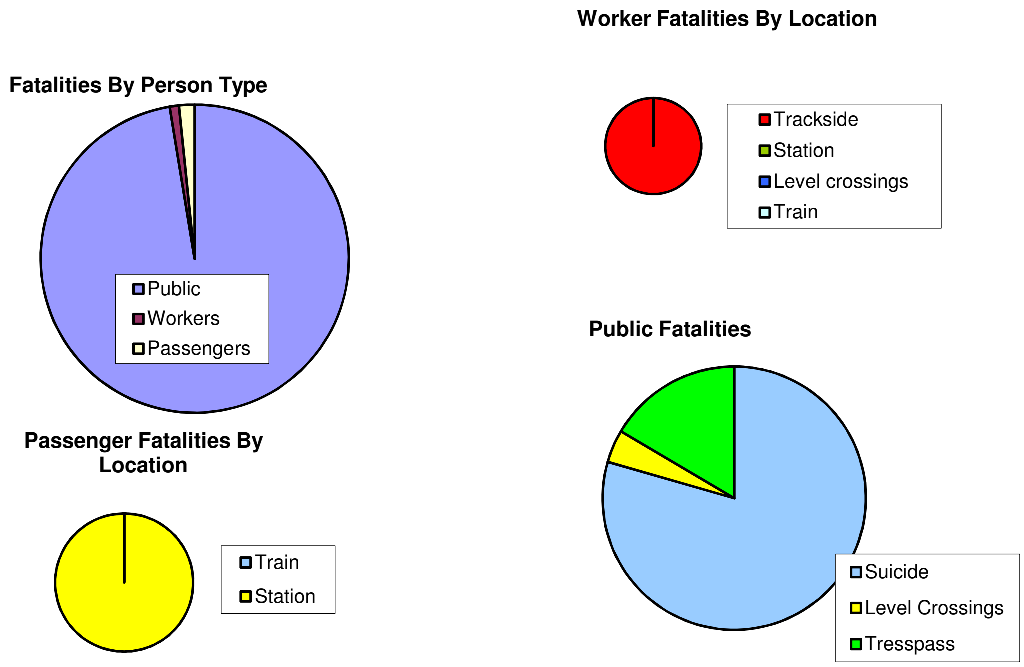

Figure 2.2: *Railway Industry Fatalities (by people and location breakdown)*

It can be seen that the public appear to be most at risk based on the accident statistics, however the 97.4% which comprises all public fatalities also includes suicides which accounted for 236 out of 306 fatalities while trespass accounted for another 49 thereby leaving a residual 13 fatalities: 12 of these were at level crossings and one was as a result of a fall onto the track. It can be seen therefore that the risk to the general public is much lower than the charts initially suggest.

These figures show that HF assessment of the workforce is unlikely to provide any reduction in fatal accidents to the public as most of the accidents detailed in the statistics are beyond the direct control of railway workers as they are violations of existing rules and regulations. It would appear that only more antecedents would serve to reduce such accidents by way of physical prevention measures such as better security preventing people gaining access to the line and perhaps better safety / hazard awareness campaigns to reiterate the dangers. Figure 2.3 shows the trend for reduced fatalities since 1945.

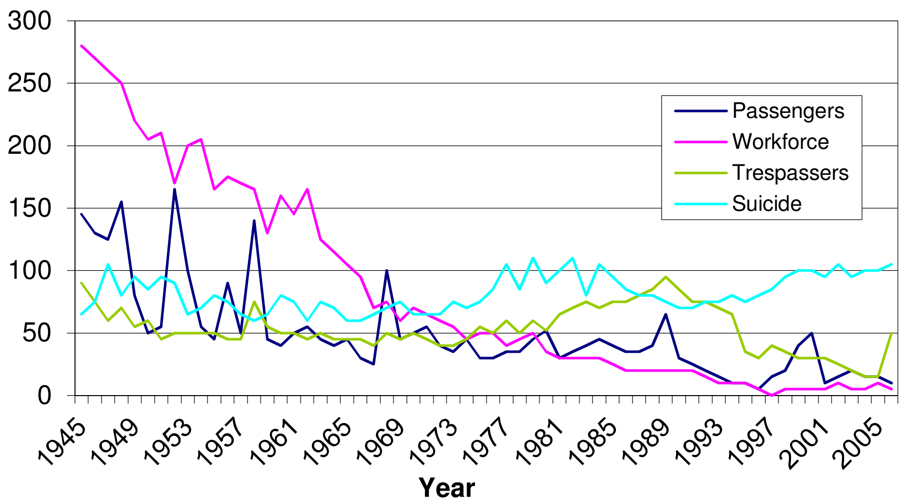

Figure 2.3: *Railway Industry Annual Fatalities*

The trend shows that worker fatalities have reduced by a huge margin in the last few decades. This is clearly a welcome trend for all concerned and one which can be used to show that the many new antecedents employed to improve worker safety are and have been effective in reducing the rate of fatalities. As the trend flattens out it will cost more per head to reduce the fatality rate still further. The aspiration for all people and corporate bodies involved in the railway industry must be to prevent any fatalities from occurring at all. A single fatal accident in any year is an unacceptably high accident rate and the prevention of any fatal accidents must be an aspiration for all concerned.

It is interesting to note that until the mid-1970s the suicide and trespass rates had a downward trend but that they both underwent a relatively steep increase simultaneously from around 1974. This was a time when inflation was high and unemployment was increasing. Strikes and industrial action were rife which meant that the country even suffered power cuts as a result of the poor state of the country's industry. The trend for suicides on the railway industry has remained relatively unchanged for decades and it is an unfortunate fact that there is probably little that can be done from within the industry to reduce the prevalence of such events. The trespass rate has decreased significantly which is a result of increased surveillance technology on the railway network, better vigilance and maintenance of the security systems employed around the network such as barriers and fences and also as a result of high profile media campaigns to educate the young population (the majority of cases) about the dangers present on the railway. It can be seen that the reduction in fatal accidents caused by trespassing has been achieved by changing people's behaviour, i.e. by the application of human factors assessment combined with appropriate prevention measures.

Figure 2.4 below shows the trend for the number of fatal train accidents.

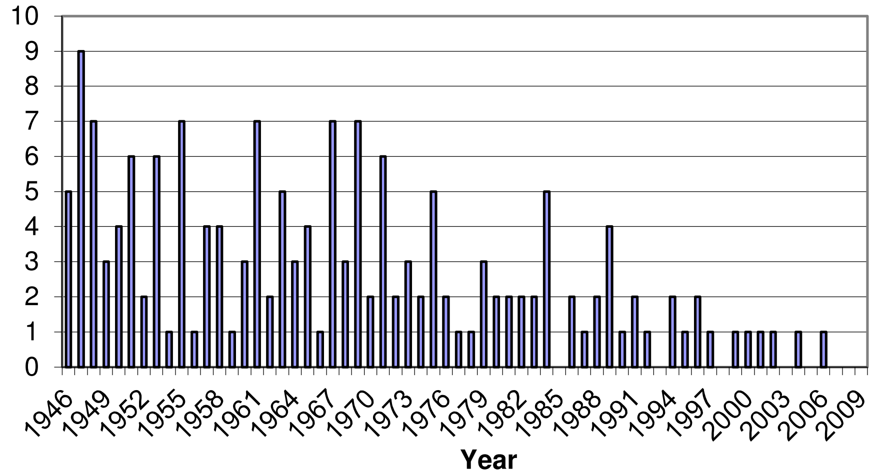

Figure 2.4: *No of Fatal Railway Accidents / Crashes*

It can be seen that there is a downward trend of the number of fatal accidents occurring each year but there is no scope for complacency as recent accidents such as the one that occurred at Grayrigg has shown.

2.4.2 UK Industry

The HSE promotes and enforces health and safety legislation in the UK and as part of their statutory functions to government they also monitor the health and safety performance of UK companies and produce reports of the corresponding statistics. The report for year 2009/2010 (HSE Statistics, 2009/10) reveals that over 1.3 million people within the UK were suffering from work-related illnesses, 152 people were killed while at work and over 121,000 people received serious injuries significantly affecting their lives.

The "Total Employed" data shown in Figure 2.5 below was derived from Craig (2003), ONS (2001), ONS (2002), ONS (2006), ONS (2010) and ONS (2011). It can be seen that the ratio of employed to self-employed remained significantly similar for the period shown.

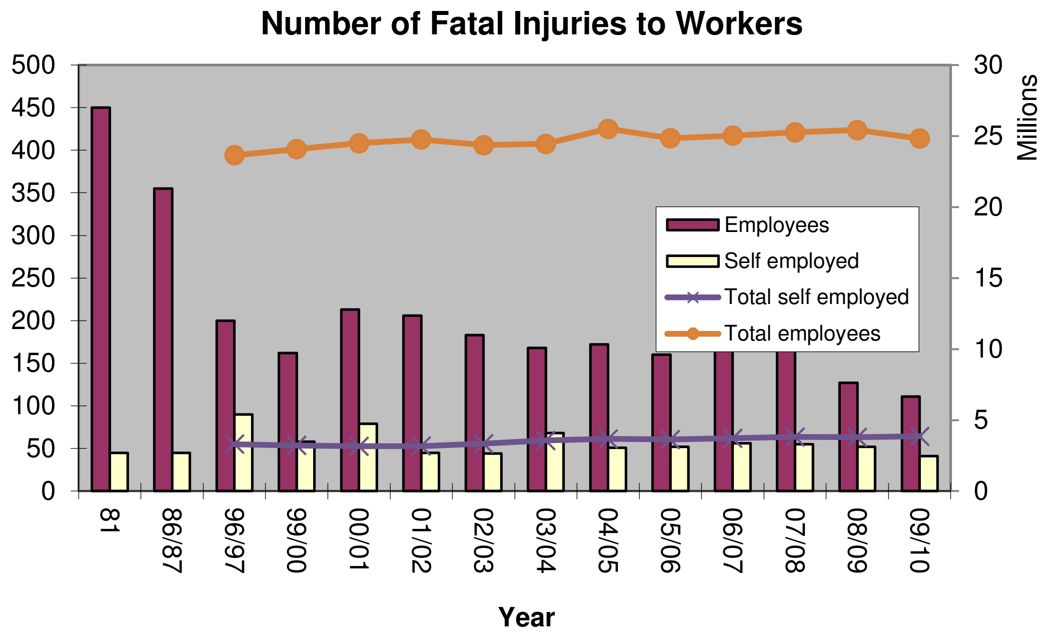

Figure 2.5: *Fatalities in UK Industry*

This chart provides a clear picture of UK industry in that despite a significant amount of resources being spent on reducing such accidents, the number of fatalities per year has remained relatively unchanged since the mid-1990s. Given that heavy industry and manufacturing is generally in decline within the UK (ONS, 2010) this number of accidents may also mean that the fatality rate is actually increasing within those sectors. The workforce has increased by around six million since 1981 while the number of fatalities has reduced which means that overall the fatal injury rate is improving. The number of people who are self-employed has remained relatively static as has the number of fatalities in that group. It is clear that a different approach is required if the rate of fatal accidents is to be reduced further. Human factors assessment is one such method of achieving this.

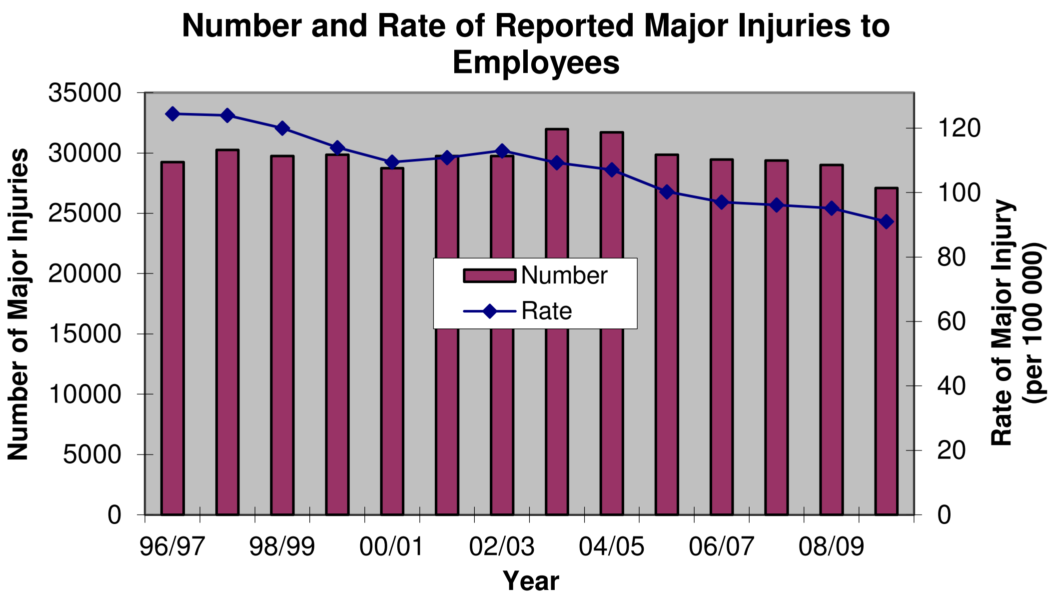

Figure 2.6: *Major Injuries in UK Industry*

Figure 2.6 above shows those injuries in UK industry that are potentially life-changing by way of permanent disability or disfigurement. As most accidents occur as a result of a series of factors coming together at the same time a minor change in behaviour at any point in the process or activity can result in the prevention of that accident. In contrast, a minor change in behaviour or associated conditions of the task may also result in a number of these accidents turning out to be fatal if the change in behaviour is for the worse.

2.5 Case Studies

It is an unfortunate fact that there are many high-profile accidents available for analysis and research. This research project examined several accidents to highlight any common human factors aspects between them in order to seek out methods of identifying any of the combination of factors which could have prevented the accident.

When applied effectively human factors assessments should be capable of identifying potential HF issues from the highest level of management down to operational levels of personnel.

With the assistance of collaborative companies, the aim of this research project was to propose solutions / answers to some key questions such as those listed below.

- To what extent do human factors (or lack of their consideration) play a part in accident causation?
- Where accidents have occurred, how difficult (or easy) would it have been to prevent the accident had an appropriate human factors assessment system been in place?
- At what level or levels (technician, supervisor, engineer, and manager) would changes in behaviour have been required in order to prevent the accident?
- Is there any correlation between perceived and proven competence of responsible persons?
- To what extent is competency testing and assurance carried out and how is competence measured?
- Is there any evidence to suggest that any one group of personnel are responsible for the majority of accidents, e.g. operatives, managers?
- Do all levels of personnel have the same perception of what or who is the common cause of accidents or errors?
- If any one group is predominantly associated with the causation of accidents, has an investigation taken place into why this is so? Was the investigation conclusive and what actions have been put in place since? As all people are not the same there is likely to be some correlation between their role and the training or procedures associated with their role, i.e. there must be common factors for this group of personnel that make them (or their role) more susceptible to causing accidents.
- Are existing safety management systems capable of identifying such potential issues? It is a fact that no two people are the same and, as a result, the application of human factors assessment in the workplace can only change some human behavioural traits. Undesirable behaviours or work methods that cannot be changed directly must be manipulated through systematic application of procedural and physical methods, i.e. antecedents. Some people are more easily influenced than others and the application of human factors methods must enable a minimum standard to be achieved.

- It is the author's experience that no-one knowingly intends to design a poor system or operate industrial processes badly, but what happens when such a system is in operation? Is there a management process for implementing change and does it take account of the human factors issues? Is there a review process to bring about improvement? Is it used and enforced simply as means of achieving management targets or is there a genuine desire to do the right thing?
- Is there any one particular type of equipment that contributes to a significant amount of accidents? Is the equipment fail-safe? Are there override facilities that can be applied to disable such safety systems? Are they used correctly and properly authorised through written procedures? What other factors of safety are built in to the equipment in order to ensure that systematic faults (physical and procedural) can be designed out at an early stage?
- Is there any evidence of motivational or training issues that can be associated with previous accidents or incidents? How are such issues brought to the surface? Are there processes in place with which personnel can have their say or is it down to the management style of individuals to bring about change for the better?
- What type of systems can be put in place such that even the least motivated or qualified person can still perform their duties safely?
- What design processes are used to ensure that even with worst performance criteria, the automatic safety systems will take over at the appropriate time and carry out the corrective safety actions?
- Were incorrect assumptions a factor in the causation of any accidents? Were the assumptions so long ago that they were out of date, i.e. could a design / operational review process have uncovered the issue prior to an accident occurring?
- Have there been any indisputable cases of incompetence or neglect that led to an accident? How can these be prevented in future? How were they dealt with at the time?
- Are accident / incident statistics trended such that they could have indicated that the likelihood of an accident occurring was increasing?

- Are good safety behaviours praised or reinforced or is it only negative situations that promote discussions about safety?
- Is there enough internal or external safety auditing carried out? What determines "enough"? How are audit results handled?
- Are safety issues dealt with promptly or are they placed on work lists or to do lists for the future? How are they prioritised and by whom? Is the prioritisation system effective? Are there any cases where high priority issues have been incorrectly assigned a low priority?
- What systems and methods are in place to highlight safety issues? How do the management (or the workforce) judge if these systems are adequate?
- Is the information system adequate? How do management know that the personnel are fully up to date with all the required knowledge and training?
- How is human factors applied in all these soft issues?

Many of these questions formed the basis of this research project by working with the collaborative companies in determining their current situation in terms of the application of human factors (whether intentional or not).

2.6 Case Study 1 – Forth Road Bridge Suspension Cable Corrosion

The Forth Road Bridge (FRB) was opened in 1964 when the heaviest single load allowed on UK roads was 25 tonnes. The UK heavy goods vehicle weight limit is now 40 tonnes with the possibility that it may be raised even further in line with continental Europe (44 tonnes).

The main suspension cables of the FRB are required to support the 13,800 tonnes of load placed on them by the bridge structure. The loading and safety factors built into the FRB's design mean that it is still safe to operate today but only after recognition some time ago that the main supporting towers required strengthening to cope with the increasing demands placed on them by increasing vehicular weight limits. The volume of traffic has also increased well beyond that for which the bridge was designed. The theoretical capacity is placed at 30,000 vehicle crossings per day. In 1976 there were approximately 12,500 crossings per day whilst in 2004 this figure was closer to 32,000. Projected figures include for steady growth between 2% and 3% (Forth Estuary Transportation Authority, 2011).

When the FRB was built it cost £11.5 million to construct (Forth Estuary Transportation Authority, 2011).

As a result of on-going inspection and maintenance work significant corrosion issues have been identified in the main bridge support suspension cables. This has been caused by moisture ingress but other contributing factors (under investigation), potentially dating back to when the bridge was constructed, may also include poor workmanship, inadequate construction procedures or techniques and inadequate supervision and control of construction methods.

The costs of halting further degradation or repairing the structure are immense in comparison to the costs associated with preventing such degradation in the first place. A 15-year programme of upgrade and maintenance projects is currently underway totalling £98 million. This involves extensive consultation on the most effective method of correcting the current issues, i.e. replacement or augmentation of the main support cables and how such a project can be carried out with minimal disruption to the bridge traffic and the country as a whole. The costs associated with such assessment studies are significant and could well have been avoided had better notice been taken of all relevant factors during construction. Another indirect solution to the problem is the creation of a completely new crossing (now approved) but the requirement for such a drastic measure should have been entirely preventable had appropriate measures been in place during and since construction.

There are many examples of similar bridges throughout the world that have far less corrosion than that being measured on the FRB and with far fewer broken wires within the main suspension cable pile. All bridges undergo some deterioration and this is one of the problems associated with the operation of such a structure; as soon as construction is completed the task of preventing it falling down begins. Suspension bridges are invariably above salt water and are therefore likely to be subject to accelerated rates of corrosion as a result of the harsh conditions of the salty atmosphere.

The Golden Gate Bridge in San Francisco recently had a survey carried out to determine the scale of corrosion on its main suspension cables. The report stated that the cables required stripping back and recoating along their entire length as the existing paint system "had surpassed its useful life".

Following the discovery of the cable corrosion on the FRB the Highways Agency commissioned a similar investigation on the Severn Bridge (built in 1966 and of a similar construction to the FRB). The corrosion detected on this bridge was found to be more severe than the FRB and similar analysis and corrective measures are now being carried out. Vehicle restrictions were put in place immediately; contrary to the FRB where restrictions are not yet necessary but remain under continuous review.

As such public structures are vital to the country, it is essential that a high degree of safety and operability are maintained and that all factors of the original design are kept under review to maintain the conditions and purpose for which they were originally designed and constructed. This is no different to public transportation systems or industrial plants where safety, operability and efficiency must remain under constant review to maintain safety and effectiveness.

2.6.1 Case Study 1 Analysis

Direct implementation of human factors assessments is unlikely to have been used to any great extent during the design and construction of the bridge. It is likely that the best available engineering methods would have been in place as the UK was good at this type of project. When the bridge was built, the country had come through the Industrial Revolution, two world wars, and appeared to be leading the world in terms of manufacturing quality and methods. There would have been no significant reasons during the bridge construction to question the construction methods in use or quality of personnel and materials used. It was not known at the time but a significant proportion of the country's manufacturing heritage was to end in ruin in the few short years that followed: British Leyland, Triumph, deep coal mining, British Steel and more recently The Rover Group to name a few; all of which were industries associated synonymously with the industrial heritage of the UK but all of which had underlying faults that the UK government was no longer willing to support. The same underlying faults with those industries may have contributed to the problems now being encountered on the FRB, i.e. lack of motivation (possibly associated with a union movement with too much influence), lack of foresight, judgement and inadequate experience, training and supervision.

Given the passage of time it is impossible to determine the level of supervision and procedural compliance during construction. Anecdotal evidence suggests that some of the bridge span cable wires were run during the worst weather of the year to keep up with construction schedules and that it was during these periods that the seeds of the degradation now evident were planted, i.e. through rule-based mistakes (if adequate competence was present), knowledge-based mistakes (if adequate competence was not present) or violations (if the procedures were not followed). There is also anecdotal evidence that the wires that make up the pile of the main cables were not properly laid when reeled out between the anchor points at each end and that wire crossovers had occurred. The evidence suggests that these had been ignored completely or incorrectly disregarded as an insignificant issue i.e. errors potentially attributable to knowledge-based mistakes or violations. Crossovers would provide small air gaps and pockets between the wires that could retain moisture and promote corrosion. Clearly, the prevention of such situations is far more desirable than the present predicament of trying to limit the degradation many years later. The current programme of inspection and maintenance on the bridge cables is centred on detection of new wire breakages (by acoustic methods) and also in fitting de-humidification equipment in an attempt to remove moisture and thereby limit or prevent further corrosion / degradation. At time of writing approximately 100 single wire breakages have been detected from a total present in the cable pile of 11,618. The FRB management board therefore believe that the overall extent of the problem has been uncovered but on-going acoustic monitoring will confirm the situation.

It is highly unlikely that personal competency assessment of the bridge construction operatives at the time would have been anything other than an informal interview between supervisor / manager and prospective employees. The type of work carried out by such personnel relies more on material selection, design and supervision than in the operative skill set. It is therefore postulated that the professionally graded personnel involved in the construction team are the most likely group to have been able to prevent the current situation from occurring. This would represent errors caused by lack of judgement and inadequate competence or experience, i.e. knowledge-based mistakes.

Should these theories prove to be correct the present situation may be partially attributed to pressure being applied as part of tight construction schedules or perhaps as a means of achieving higher bonus payments, i.e. skill-based errors, rule-based mistakes or even violations induced by motivational issues. The original cause is somewhat arbitrary as the most important factor now is to prevent further degradation of the structure to ensure that safety is maintained. Now that the issue has been identified much greater attention to detail is in place and experts are assessing the situation daily.

At the design stage, critical assumptions of the cable wire ambient conditions would have been made in terms of specifying the correct grade and type of steel to be used. These assumptions would have been based on other similar structures around the world in terms of likely corrosion rates and bridge loadings. As a result of the increased rate of corrosion it is clear that these assumptions were either incorrect or based on incorrect or absent data, i.e. knowledge-based mistakes.

2.6.2 Case Study 1 Conclusion

It is impossible to say at this time if personnel responsible for design displayed any incompetence or neglect but clearly several factors have come together over time resulting in the huge and costly task of preservation. The current situation with the FRB is well publicised and is likely to assist in the maintenance and care of other such structures in the future (as detailed for Severn Bridge). Better technology in terms of design methods, construction methods, material composition / selection and personal competence and responsibility are now in place and such a situation is less likely to occur in the future. Acoustic monitoring and de-humidification systems are now being included in new bridges around the world in order to prevent such issues from occurring.

The Health and Safety at Work Act now enables prosecution of company directors and new / modified legislation (Corporate Manslaughter and Corporate Homicide Act) is in place to make corporate bodies responsible (through the justice system) for their actions where neglect of duty has been proven to be a contributing factor to an accident. All such measures clearly make the adoption of personal competence assessment and assurance a worthwhile exercise for those companies involved in safety-critical projects. Thus the prevention of errors attributable to inadequate competence (skill and knowledge-based) has been addressed at high level and companies involved in such construction projects must ensure that they have adequate competency assessment systems in place.

As each day passes the roads are becoming more congested and transportation systems are becoming more important. The travelling public are now more vocal and less tolerant of the disruption associated with such issues. It is likely that government agencies and corporate bodies responsible for such issues will be held to account in future as better methods of control, supervision and traceability are now in place.

Human factors assessment can play a major part in such projects by ensuring that potential issues are detected and addressed to ensure public safety is maintained, that personnel are competent for their allotted tasks and that adequate systems of monitoring are in place to ensure that not only are people performing their duties correctly but that they are able to build upon the foundations of the safety management systems in place to bring about the best possible solutions available by the prevention of errors and bad practices creeping in or being disregarded without due analysis.

Had the potential effects of moisture in the cables been adequately considered in terms of future corrosion rates it is likely that some kind of assessment would have been carried out at the design phase to determine what actions were necessary at the construction phase. Such hypothetical questions are not easily answered decades later.

The selection of project design and construction personnel is an important part of any project as the individual experience and competence of each person in the team contributes to the overall project team capability. Bale and Edwards (2000) found that more than 50% of companies did not verify qualifications or experience of their contract employees. This clearly represents an intolerable risk to any organisation responsible for employee and public safety and could be judged as criminal neglect. Human factors assessment can be used to assist in ensuring that personnel employed on such high profile projects have the required skills and competences. This is not achieved directly but through the implementation of antecedent procedures and processes designed to ensure that the selection and monitoring processes take account of all such issues.

Over time it would appear that some safety-critical assumptions have been made regarding the integrity of the bridge structure. The present situation shows that an inadequate inspection and maintenance strategy was in place. Human factors assessments may have prevented this situation by identifying issues earlier but it is doubtful if it could have prevented the issues given that the root cause appears to have occurred during construction when such methods were not commonly available.

This case study was selected specifically to show that human error (including covert latent errors) within industry, transportation and civil engineering applications can be detected through many different methods including regular inspection and maintenance (as in this case). The lack of such systems can be identified with the aid of tools such as the safety culture survey.

Risk reduction can also be achieved by building a better safety culture through implementing a human factors assessment system to detect any existing human factor issues not yet identified or appropriately addressed. In this case the potential corrosion issue (and any other latent problems with the structure) may have been identified at an earlier stage had a structured assessment of all people, work processes and systems been implemented. The HF assessment system may have identified weaknesses requiring further investigation through the competence management, my role and my manager sections of the proposed safety culture questionnaire.

The UK HSE (HSG48, 1999) states that "careful consideration of human factors", i.e. the implementation of a better safety culture through human factors assessment, as proposed within this research project, "can reduce the number of accidents and cases of occupational ill health." Therefore, through better training and detection of potential HF issues the likelihood of human error (skill-based, rule-based and knowledge-based errors caused by inadequate judgement, competence and inexperience) can be reduced.

Whittingham (2004), states that violations (rule-based motivational errors) can be prevented through a system of training, robust procedures, workplace auditing and ensuring that all violations are thoroughly investigated and addressed in accordance with the company procedures, i.e. implementing and building a better safety culture. Whittingham (2004) also notes that not investigating every violation can appear to the workforce that such behaviour is condoned. This would have the effect of promoting unsafe (violating) behaviour thereby developing a poor safety culture.

2.7 Case Study 2 – Challenger Space Shuttle Disaster

The Challenger space Shuttle disaster on 28th January 1986 was a tragic culmination of issues, events and problems that were known about by many people and those problems had been communicated to personnel in overall charge of the launch process but yet the decision necessary to prevent the accident from occurring wasn't taken for several reasons: none of which (in hindsight) are considered important enough at the expense of a single human being: far less an entire crew of seven. The fact that Challenger also had two members of the public on board made the situation even worse. They were not career astronauts but had been specially trained for the mission as payload specialists.

The Rogers Commission Report (Rogers, 1986) found that no single person involved in the decision making process to launch felt that they had been put under pressure to approve the launch against their best judgement.

By the time the Challenger explosion occurred there had been 24 successful space flights with a remarkable safety record (on the surface) and very little to report in terms of problems encountered during any of the missions. Any problems that had occurred had been dealt with in such a manner that they were not considered to be serious or did not present a high risk. The confidence placed in the Space Shuttle system by NASA, and the world as a whole, was very high, but to a select few that were involved in the safety and engineering management of the Shuttle system there were problems and they were known about. It would be extremely unfair to say that the problems were ignored as they had been discussed at great length but, with the advantage of hindsight, they were not given an adequate risk ranking and the tragic results were there to see for all shortly after the Challenger launch was authorised to proceed. It is clear that the issues were not discussed at the appropriate levels within the organisations involved.

Rogers (1986) found that the potential problems with the solid rocket booster (SRB) seals at low ambient temperatures were not known about or understood by all the people responsible for the decision-making process to authorise launches.

Circumstances surrounding the STS51L launch were incredibly unlucky. The mission had been delayed twice due to operational delays with mission STS 61C. Weather conditions at the Transoceanic Abort Landing (TAL) site in Dakar, Senegal enforced a third delay. The Cassablanca TAL was then chosen for the next available launch window but this meant changing to a morning launch rather than a night launch. This resulted in a further delay as Kennedy Space Centre (KSC) launch processing could not be made ready for the morning launch in time. Predicted bad weather at KSC then enforced another delay of 24 hours. Operational problems with an entry hatch door assembly enforced another 24 hour delay. On the 28th January a further delay of 2 hours was caused by a component failure in the Shuttle fire detection system. During all of this time discussions were being held within NASA regarding the abnormally low ambient temperatures being encountered on the launch pad. No missions had previously been launched in such low temperatures and genuine concerns had been expressed from employees of the solid rocket booster (SRB) manufacturer (Morton Thiokol) and NASA that the Shuttle had not been designed to launch in such conditions and that without further analysis it was not recommended to proceed with the launch.

The ambient temperature was lower than the SRBs had been designed for but this situation was clouded further by different interpretations of the original

SRB specification. In hindsight the delays encountered for the STS51L launch gave a much greater timescale and more opportunities than normal to postpone the launch but to no avail. Rogers (1986) found that the seal problems with the SRBs had been known about for years but the issue had not been adequately resolved. Launches in low ambient temperatures were simply avoided. Recent launches had been "signed off" at lower levels of authority such that the senior levels of launch personnel were not formally aware of the detail and risk with the SRB seals and that, provided they had signed authority from the systems people at lower levels, they could proceed with a launch.

The Rogers Commission Report identified failure of the aft field seal of the right SRB as the prime cause of the accident caused by:

> "faulty design unacceptably sensitive to a number of factors. These factors were the effects of temperature, physical dimensions, the character of materials, the effects of reusability, processing, and the reaction of the joint to dynamic loading."

The conditions on the launch pad prior to launch did not help. Approximately seven inches of rain had fallen in the time that the Shuttle assembly was on the launch pad. A previous mission (STS9) had shown that water ingress to the SRB seals could occur as this was detected when stripping down and making ready for the next mission. The cold conditions of the launch day provided for the possibility that water in the SRB aft joint could have frozen, thereby restricting the ability of the O-ring seal to adequately perform its intended function (prevention of high pressure combustion gases leaking from anywhere other than the rocket nozzles). The launch pad temperature on launch day was 9℃ (15℉) lower than any previous mission (Rogers, 1986). The resilience of the seal had been proven (in subsequent extensive testing) to be such that it could give rise to the leakage rates displayed during the launch of STS51L in the conditions encountered. The temperature of the joint at the area where the first leakage of propellant gases occurred was estimated to be minus 2℃ (28℉) while at the side facing the sunlight the temperature was estimated to be 10℃ (50℉) (Rogers, 1986). The pressure increases induced on the SRB section seals on rocket motor start up caused the tang and clevis of the joint to "open up". The O-ring seals are in place to prevent leakage during such conditions. The right SRB aft section seal under the conditions of launch was potentially incapable of responding to the load conditions quickly enough as a result of the temperature-induced reduced resilience and a leak occurred resulting ultimately in the destruction of the Shuttle. Another factor of the right SRB was that during assembly there was a significant “out of roundness” observed between the two sections of the SRB at the aft joint. Procedures were in place for such situations and it was thought that these were adequate.

2.7.1 Case Study 2 Analysis

Human factors assessment is a huge issue for NASA and space exploration as a whole and substantial resource (over $183 million in 2008) is spent on human related issues associated with the space exploration programme to ensure that the technical, personnel and operational systems are up to the task (NASA, 2008). Although beyond the scope of this research project, there are many other factors detailed in the Rogers Commission report that suggest internal and external politics also played a major role in the decision to launch but, irrespective of this, the report findings stated that no person felt that they were under any internal or external pressures to make the decision to launch.

There are conspiracy theories (Maxon, 2011) surrounding the accident that suggest that the mission was testing some other advanced propulsion / rocket system or was carrying some other secret device for military purposes. As all such theories are purely speculative with little or no hard evidence they are not considered further within this report.

It is clear that human factors played a significant part in the causation of the accident. Many of the people involved in the decision to launch were not fully aware of the issues and risks associated with the O-ring seals on the SRBs. Rogers (1986) found that the decision-making chain of events that led to an authorisation for launch was founded on:

> “incomplete and sometimes misleading information, a conflict between engineering data and management judgments, and a NASA management structure that permitted internal flight safety problems to bypass key Shuttle managers.” (Rogers, 1986, pp.20.)

A diagram of the flight readiness planning is shown in Figure 2.7. The Level 1 flight schedule is initiated at approximately two weeks prior to launch with the commencement of Level 4 flight readiness activities. Each successive flight readiness level then follows the programme outlined in the initial Level 1 schedule.

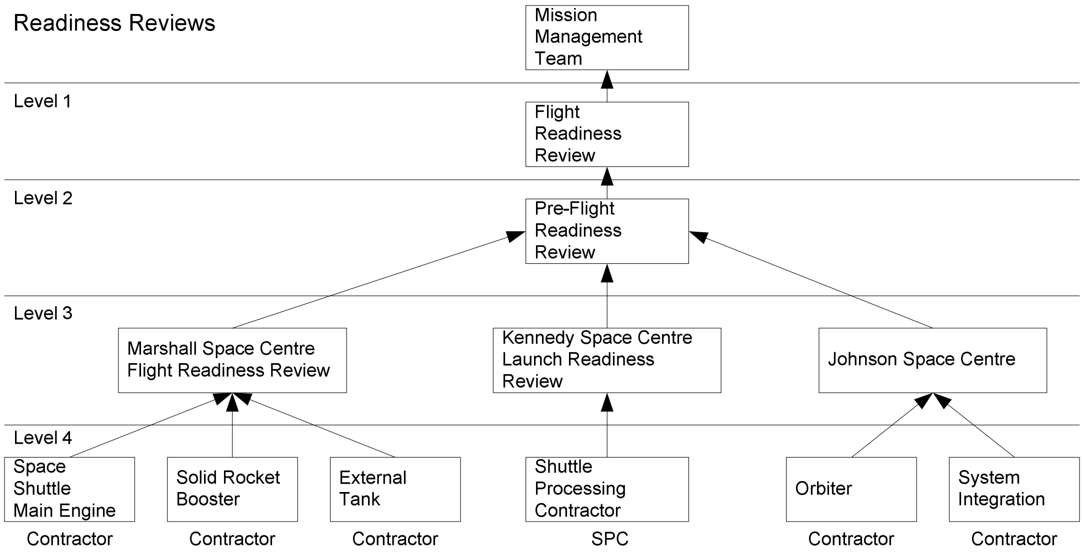

Figure 2.7: *NASA Flight Readiness Structure*

Reproduced from the Rogers Commission Report – 1986.

Rogers (1986) found that the SRB seal problems had been known about since 1982. A "Criticality 1" flight constraint had been put on the seal problem which meant that loss of life or vehicle was a credible risk. The personnel involved in discussing these issues were involved at Level 4 and Level 3 of the flight readiness programme. Since mission STS51B (where it was found that a seal had failed) 6 waivers had been issued for the seal problems from mission STS51F onwards. The theory seems to have been that as each successful mission passed the likelihood of catastrophic failure diminished and the people responsible for issuing or signing for the waivers had become complacent.

A leak check carried out on the SRB seals was the key factor for signing off flight readiness (at Level 3) but this check did not adequately take account of the ambient conditions and dynamic loadings associated with a launch in very cold temperatures. A tele-conference was held between senior Level 3 personnel from all relevant parties prior to launch and the testimonies of the personnel involved were key to the Rogers Commission report. The engineers responsible for the integrity of the SRB seals at Morton-Thiokol were not happy with a low temperature launch as the data they had from previous missions suggested a higher probability of seal failure under those conditions. Their data was incomplete but they had enough to recommend a delay to launch at least until the temperature at the launch pad had risen to at least the lowest temperature of any previous successful launch (11.6℃ / 53℉). It was stated that they felt that the tone of the recent meetings and tele-conference held to discuss the issue was such that they felt they were under pressure to prove that there was a problem rather than the more normal situation when they would be under pressure to prove that all systems were functioning correctly and therefore ready for flight. They were being asked to prove that they weren't ready for flight instead of being asked to prove that they were ready for flight. This must have been a very difficult decision for the SRB manufacturer management to be in as they didn't have clear and unambiguous evidence that the SRB would fail and hence could not prove conclusively that they weren't ready. The SRB engineers felt exasperated that they had done all they could to postpone the launch but the management decision to launch based on the fact that they could not prove that the SRB seal would fail prevailed. Commercial and/or political pressures had dominated the decision-making process.

None of this information was passed to Level 2 or Level 1 flight readiness. The outcome of all the discussions was simply that any problems had either been rectified or had been signed off. To the Level 1 and Level 2 flight readiness personnel it looked like they were ready to launch.

The key findings of the Rogers Commission Report in terms of the systems and management failings were as follows.

- There was a serious flaw in the decision-making process that could have been prevented had a structured safety assessment system been in place with which all such problems could be flagged to all levels of personnel. (Rogers, 1986, pp.105.)
- Launch waivers and constraints were not required to be informed to all flight readiness levels. This created the possibility that flight system faults (potentially fatal) could still be in place when launch occurred. (Rogers, 1986, pp.105.)

- The Space Shuttle design, planning, construction and flight operations programme workload was shared between several NASA establishments. The Marshall Space Flight Center (sic), responsible for main engines (SRBs) was found to be trying to resolve all its own issues internally without passing notification of these forward. The Space Shuttle is a combination of many sub-systems and it was considered essential by the commission that all such items of importance should be shared for a full and adequate assessment to be made by all involved parties. Poor communications was not conducive to operating the system effectively and with maximum safety. (Rogers, 1986, pp.105.)
- Morton-Thiokol was found to have reversed its decision to launch after receiving considerable pressure from Marshall Space Flight Center (sic) to do so. The Commission found that this decision had been made against the advice of its engineers and was more associated with an unwillingness to upset a client than to ensure the safety and integrity of the crew and Shuttle vehicle system. (Rogers, 1986, pp.105.)

Hawkins (1987) extract contained in Flin, O'Connor & Crichton (2008) also cites fatigue as a potential contributing factor in the Challenger explosion through sleep loss, excessive duty periods and disturbed circadian rhythms of those involved in the discussions surrounding the ambient temperature and its effect on the SRB seals. Some of the personnel involved in making the decision to launch had been discussing the issues in great detail for a number of days and it is postulated that their judgement may have been adversely affected by fatigue. Rogers (1986) noted that the managers involved had "several days of irregular working hours and insufficient sleep" while engaged in the discussions. Rogers (1986) also noted that fatigue, caused by excessive duty periods and shift rotas, was a contributing factor in a potentially serious incident that occurred prior to launching mission 61-C in early January 1986.

The official findings show that, even in multi-billion dollar projects with few limits on the resources available, commercial pressures can still affect the way that safety-critical decisions are made. The decision making processes in place were clearly flawed but the overriding factor in the decision to launch was that a highly influential partner (Marshall) had exerted commercial pressure (indirectly or otherwise) on another partner (Morton-Thiokol), who clearly did not want to be the cause of any further delays to the programme. The resultant accident was therefore inevitable, if not with STS51L then with a later flight, until the root cause of the problem was identified and rectified as detailed within the Commission report findings.

2.7.2 Case Study 2 Conclusion

It is clear that human factors played a significant part in the accident. The initial SRB seal design was flawed and this was realised from analysis of used SRBs by the SRB manufacturer engineers. The engineers acted responsibly by highlighting the potential issues as soon as they became apparent but the issues were not heard at the appropriate levels of the Shuttle launch programme as a result of commercial pressures. Had a different group of people been in charge with slightly different ethics or backgrounds it is feasible that the decision to launch by Morton-Thiokol might not have been reversed and the Challenger and its crew would still be here today. The decision making process was found to be reliant not only on highly developed systems of control and analysis but also on personal competencies, ethics, experience and responsibilities to such a degree that people were able to short circuit the system to their own ends thereby providing a path (or drift) to failure which could not be stopped once it had commenced. A well-developed decision-making safety management system making better use of human factors assessments and auditing may have served to seek out and remove all such possibilities.

The workload during the launch preparation stage including the launch delays has been highlighted as a potential cause of fatigue which may have resulted in a degraded ability of the management personnel involved to make good decisions, i.e. the root cause of the explosion may be attributable to judgement errors (knowledge-based performance level). Additionally, some cause may be attributed to motivational issues on the part of the Marshall personnel who appeared to have lost focus on safety and were instead more concerned with keeping up with the programme (rule-based mistakes and potentially violating behaviour). Dekker (2005) describes the potential for "drift" into a potentially unsafe situation through a "slow, incremental movement of systems operations toward the edge of their safety envelope." Such a situation may have been present in this example where some "blow by" past the O-ring seals was observed on several previous launches and that issuing a waiver for this had almost become routine, irrespective of the prevailing ambient conditions.

Since the Challenger accident the Space Shuttle programme has suffered a further disaster with the loss of the Columbia orbiter in 2003 when it broke up on re-entry to the earth's atmosphere. This was caused by a piece of foam insulation from the main fuel tank breaking away some 81 seconds after lift-off and damaging the thermal protection of the orbiter's left wing. This damage was critical and was found to be the root cause of the loss of the orbiter due to excessive thermal load on the structure through the damaged wing on re-entry to the earth's atmosphere. A similar investigation to the Challenger accident was held with a similar outcome. The summarised findings of the Columbia Accident Investigation Board include the statement:

> "The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human space flight. Cultural traits and organizational practices detrimental to safety were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements); organizational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules." (NASA, 2003, pp.9.)

It is clear that there were striking similarities to the issues deep rooted in the Challenger accident and that those lessons had clearly not been learned by all concerned to the degree necessary with which to prevent future system failures.

Such failures in an organisation with almost limitless resources serve to show how difficult it can be for the wider engineering community with far less resources available but fortunately usually with far less risk.

2.8 Case Study 3 – Ladbroke Grove Rail Disaster

On the morning of 5th October 1999 two trains collided practically head on at Ladbroke Grove, approximately 2 miles west of Paddington Station (Cullen, 2002, Part 1 Report). 31 people lost their lives in the accident, including the two train drivers. 400 others were injured either directly as a result of the collision or by the effects of fire and smoke that occurred after the collision.

Lord Cullen was requested by the Health and Safety Commission to investigate the root causes of accident. The inquiry was carried out in two parts: Part 1 which was primarily concerned with the causes and circumstances of the crash and Part 2 which was concerned with an investigation into the management of safety on the railways.

The two trains that collided were a 3-car Turbo type-165 train operated by Thames Trains (TT) and a High Speed Train (HST) operated by First Great Western (FGW). The FGW train was an eight car train with a diesel power car at either end, i.e. substantially heavier. It was travelling at approximately 90mph and therefore held much more momentum than the TT train.

The TT train had left Paddington station at approximately 08:06 and the collision occurred two miles west of Paddington approximately three minutes later with a combined speed of approximately 130mph (Cullen, 2002, Part 1 Report).

2.8.1 Case Study 3 – Analysis

The inquiry found that the crash occurred directly as a result of the outbound TT train passing through a red signal (SN109) which ultimately led it into the path of the inbound FGW train.

Train interlocking and control system records from the associated Slough control centre showed that the signalling systems were proven to be functioning correctly prior to the crash. The TT train had been traversing its route and (through subsequent expert analysis) was shown to have previously passed a double yellow aspect followed by a single yellow aspect and then finally the red aspect of SN109. The SN109 signal was at red to hold the TT train in position until the FGW train had passed, at which time the points and signalling systems would have been set for safe progress of the TT train. A double yellow aspect means that a train is occupying the line 2 signals ahead and that the next signal is currently displaying a single yellow. A single yellow aspect means that the next signal is currently at red, i.e. a train is occupying the next section of line ahead of the red signal (Rowbotham, 2001).

The brakes of both trains were applied immediately prior to the crash but such was the closing speed of the trains that by the time both drivers would have realised what was about to occur the braking time would have had an insignificant effect on energy of the crash. The crash occurred immediately beyond the points through which the TT train had switched lines just beyond SN109.

Cullen (2002, Part 1 Report) found that there were several key factors that affected the likelihood of those involved to survive such an event. These are summarised below.

- Design of the carriages in terms of resistance to impacts / crashes and their ability to absorb energy by remaining intact rather than breaking up.
- Driver training procedures and competency assessment.
- SPAD management in terms of preventing and thoroughly investigating all occurrences.
- Signal sighting capabilities of drivers and the subsequent positioning and monitoring of the signals under all conditions from all types of trains.
- Fitment of train cab communications systems.
- Fitment (and operation of) automatic train protection systems.
- Modification of safety-critical signalling systems and the lack of subsequent monitoring or adequate training updates.
- The lack of a cohesive safety management and investigation system to respond to on-going signalling system and operational safety issues.

Carriage Design

Although there is scope for improvement, the FGW train was effective in maintaining a good degree of safety in terms of maintaining a survival space as its carriages were substantially intact after the crash. Its design was such that a significant amount of plastic deformation took place near the ends of the carriages although this design feature was not an original intent of the designer (Cullen, 2002, Part 1 Report). In contrast, the TT carriages did not fare so well where instead of absorbing the crash energy by plastic deformation; they broke up to a large extent thereby exposing the occupants to far greater danger from the surrounding infrastructure as a result of being ejected from the train or being struck by flying debris. The TT train was a more modern construction but was built using substantially lighter materials and methods of construction. The reason that the TT carriages broke up rather than deforming was that the structural welds of the carriage were weaker than the surrounding material and these gave way on impact (Cullen, 2002, Part 2 Report).

New trains now include crumple zones similar to those found in road vehicles. Extensive testing has shown that they clearly assist in absorbing energy of impacts thereby reducing the likelihood or extent of injury to anyone inside. Newer designs also include anti-overriding devices which reduce the risk of one carriage going up and over the other at impact. Whilst a welcome development, it was shown that in this crash, crumple zones would not have changed the outcome significantly as the kinetic energy in the crash amounted to approximately 400MJ whilst the crumple zones presently fitted to new trains are designed to absorb around only 1MJ (Cullen, 2002, Part 1 Report).

Driver Training

Thames Trains had previously been audited regarding their procedures and processes for driver training and these were found to be inadequate. Some recent progress had been made prior to the crash but the findings and recommendations of the audits were not implemented in an expeditious manner. No direct fault or error was attributed to the TT driver as there were several other contributing factors most notably training and signal sighting issues in combination with an unacceptable number of SPADs that had been occurring at the signal involved. It was clear that safety management within Thames Trains was not all it should have been. The safety culture within the company (and the industry as a whole) was found to be lacking.

Part 2 of the inquiry concentrated on safety management and heard (from one of the expert witnesses) that in general approximately 90% of all industrial accidents are caused by changes in human behaviour rather than functional or systematic failures (Cullen, Part 2 report, 2002).

The Cullen Inquiry also found that while there was no evidence to suggest that safety was compromised (or improved) as a result of privatisation, communications between the fragmented companies made it more difficult to form a cohesive industry-wide approach to managing safety and creating a common safety culture for all involved.

The Inquiry was presented with evidence suggesting that railway system performance had been given a higher priority than safety as its business targets were predominantly measured by delays and timetable compliance (driven no doubt to a certain extent by the need to minimise the hype and associated backlash supported by or caused by the media). The management and board level of the operators perceived this situation differently from the front line employees in that they did not feel that this was the case while workers at the front line were persistently aware of the safety issues but were not of the opinion that sufficient resources were allocated to correct them. Cullen (2002) found that management even attempted to lay some blame on the Government in terms of enforcing and encouraging the setting of performance targets at the expense of safety. It is most likely that such a view was a gross misunderstanding of expected values and targets.

It is likely that if passengers were given a choice the vast majority of them would quite rationally choose to arrive at their destination a little late in favour of risking not arriving at all. Recent research carried out by RSSB confirms this position (RSSB, 2005).

It is clear that management personnel in overall charge of any kind of safety-critical system must remain strong in terms of maintaining focus on the real targets and not be influenced by external pressure to concentrate on false targets likely to detract from the real issues. In hindsight it is clear that taking some criticism for missing performance targets is significantly more preferable to being at the centre of an accident such as that which occurred at Ladbroke Grove. Safety culture must be developed as the overall most important business requirement and only when that is functioning correctly can other less important issues be tackled successfully.

SPAD Management

When the Ladbroke Grove accident occurred SPADs were occurring at the rate of approximately 56 per month across the network (HSE, 1999). Not all such recorded incidents were significant in terms of the capability of causing a major accident; the majority only resulting in the train stopping in the overlap region just behind the signal. However, approximately 5% of the SPADs that occurred did have the potential to cause damage or injury.

The areas around Paddington had previously been subjected to a special investigation as a result of the high number of SPADs that had occurred in the area (Cullen, 2002, Part 1 Report). Signal sighting issues were a concern and these were being "dealt with" by Railtrack (the infrastructure operator). Signal SN109 had a history of eight previous SPADs over the preceding five years. HMRI had investigated the high frequency of SPADs in the area and had taken a slightly relaxed attitude to enforcement action as a result of the promises it had received from Railtrack that they were being addressed. As it turned out the promises were not fulfilled (Cullen, 2002, Part 1 Report). HMRI accepted the criticism from the Inquiry that had it issued improvement notices irrespective of what they were being told by the operator, there was a high probability that the corrective measures would have been implemented in a more timely fashion and perhaps would have prevented the accident from occurring at all. A specific investigation was held into a previous SPAD at SN109 which occurred on 4th February 1998. The timescale for the investigation and subsequent corrective actions was criticised by the Inquiry as it could have been carried out much more quickly and efficiently and thereby would have had the potential to prevent the crash from occurring. HMRI cited lack of resource, lack of vigour in pursuit of issues and placing too much trust in the operators as their reasons for their apparent lack of influence and regulation (Cullen, 2002, Part 2 Report).

The Inquiry evidence therefore shows that not only was the railway industry not enforcing and building an adequate safety culture, it was clear that the regulator (HMRI) was also suffering from similar issues and that a relaxed culture had taken over where it was incorrectly assumed that everyone in the industry was doing their best and that as long as this was the case there was no need to rock the boat any further by introducing formal measures such as improvement notices.

Since the crash many measures have been put in place to prevent SPADs and to handle SPAD investigations. Senior railway personnel have been trained in root cause failure analysis (RCFA) and also in the methods of conducting SPAD investigations. Human Factors specialists are also now involved in the investigations into the causation of SPADs (Cullen, 2002, Part 1 Report).

Another recommendation of the inquiry was that signal sighting processes and procedures required to be improved in order to improve the likelihood that issues are discovered prior to an accident occurring. The Office of Rail Regulation (ORR) has now formally taken over responsibility for Health and Safety in the railway industry from HSC and HSE and co-ordinates all such matters (including accident investigation through the RAIB). As it is a body independent from the HSE / HSC its resources should be easier to manage than in the previous multi-role HSE set up and thereby provides scope for better and more consistent regulation. The HF issues of the regulator have therefore been recognised and corrected.

Signal Sighting

Signal sighting is considered to be a greatly important issue as it is becoming clear from SPAD investigations that issues with drivers misunderstanding or not being able to see track side signals quickly enough or for long enough to enable them to carry out their jobs safely and effectively is a significant factor in the causation of SPADs.

Following the Southall crash in 1997 the requirement for carrying out signal sighting was greatly increased (Cullen, 2002, Part 1 Report). The procedures and methods of signal sighting or the baseline on which systems were judged against were not considered to be adequately documented. Most decisions on the need for improvement or modification of a signalling system were based on the vast experience of a relatively small community of people. The Inquiry recommended that the signal sighting community was subjected to a review in terms ensuring that an adequate number of personnel were in place and that those personnel were subjected to a systematic review of competence and capability (Cullen, 2002, Part 1 Report).

As this is such a highly specialised safety-critical task the personnel involved had previously been self-regulating. The Inquiry found that the responsibility for initiation of the formation of a signal sighting committee for investigative purposes was not always clear and therefore these were not always carried out under the terms of the group standards (GK/RT/0037, GO/RT/3252) in response to SPADs occurring (Cullen, 2002, Part 1 Report).

It is clear that the individuals were well respected and they seemed to be capable of performing their tasks to the required degree of competence and integrity but that resources or internal politics were so restrictive that the safety management system was not conducive to initiating signal sighting activities when required.

Cab Communications

A new system of GSM-R communications is currently being designed and trialled across certain areas of the network. The system requires £1.2 billion of investment and is expected to be fully operational by 2013. The system is massive and requires a huge amount of co-ordination in what is a very difficult and dangerous operating environment. It is recognised that there are more important and immediate issues such as building an industry-wide safety culture, TPWS+, ATP, etc.

The trials are being monitored for all issues of concern including human factors issues.

Automatic Train Protection (ATP)

The ATP project for UK railway infrastructure will be implemented as part of the European Rail Traffic Management System (ERTMS). Waboso (2002) asserts that the primary reason for such a system (as proposed for the UK) is to prevent signals passed at danger (SPAD); the cause of several fatal rail crashes in the UK. Risk assessments and cost benefit analysis suggest that ATP installed as part of the European Rail Traffic Management System (ERTMS) would not provide a significant increase in safety for the costs involved over the presently installed system: Train Protection and Warning System (TPWS); currently estimated to prevent approximately 80% of ATP-preventable crashes (Waboso, 2002). The immediate need for ATP has therefore been much reduced and the massive spend required for ERTMS/ATP has been shown to be unjustified at this time.

ERTMS not only provides an ATP system but also enables compliance with the EC interoperability directives. The system will provide several key requirements: EU-wide interoperability, increased capacity and increased safety.

ERTMS is being implemented on several different levels. Level 1 and Level 2 specifications are in place and there are systems in operation already across Europe. There are different grades of implementation in each level with each providing different levels of capacity and safety improvements. The higher grades of Level 2 are not yet fully designed or implemented.

Waboso (2002) asserts that the most rapid method of migration to Level 1 would require a huge amount of work; would need to retain existing signalling equipment and would substantially reduce existing capacity. The migration would also likely cause significant disruption to services. The ERTMS final report also shows that this disruption and reduction in capacity is likely to cause people to migrate to using road transport thereby exposing them to greater theoretical risk with a subsequent increase in the likely number of injuries and fatalities on the road network as a result.

The HSC have previously accepted that the original timescale proposed by Cullen / Uff (2001) was not viable (Jones, 2003). A more measured and achievable approach is therefore being developed that allows a gradual migration to ERTMS. When the changeover occurs it envisaged that it will be to Level 2 which will dispose of the requirement for the majority of line-side signalling equipment. This means that the risk to track workers will also have been substantially reduced in the interim period and for the future as there will be far less equipment to maintain and inspect that is located in the trackside danger zone. Much of the ERTMS equipment will be based on radio communications (GSM-R) between the signalling system and the train cab to provide cab signalling (as fitted to systems such as the Eurotunnel / Eurostar) where line-side signalling is not present or minimal. This means that higher speeds are possible as the driver no longer needs to be able to sight external signals as all such signalling information will be displayed in the cab on the HMI (human machine interface).

The ERTMS review project has taken account of the direct and indirect risks and has recommended the most effective way forward in terms of reducing overall risk to all concerned. Contrary to the implementation timescales recommended in the Cullen / Uff Joint Report (2001) the ERTMS project has found that the best implementation method is not the quickest and that the quickest implementation of ERTMS does not provide for the greatest overall reduction in risk.

Where equipment is being replaced in the future as part of the maintenance or planned end of life programmes it is expected that ERTMS-ready equipment and components will be installed in order to ease the transfer to the new systems at some later date. Waboso (2002) asserts that the TPWS system has a design life of 15 years but as with modification and replacement of all such high-tech large scale systems it is likely that this will be extended as required prior to implementation of ERTMS.

System Modifications / Management of Change

Gantry 8 at Ladbroke Grove which contained SN109 had been modified in a recent upgrade of the signalling system. A signal sighting committee had not been convened after this modification contrary to internal procedures and also to the advice of HMRI following a post modification inspection (Cullen, 2002, Part 1 Report). As discussed under the signal sighting section above these committees lacked ownership and were rarely convened as and when they should have been. Procedures and processes were in place to ensure such committees met when required but they were not followed. There did not appear to be any auditing or monitoring system in place which was capable of detecting such failures. This can be considered as a systematic procedural failure and one which could easily have been corrected had an effective HF monitoring and review system been in place.

As there was no formal meeting of signal sighting committees there was also a lack of committee output such as training update requirements and safety notices to drivers. This is clearly a high risk strategy which should not have been allowed to continue unchecked. This highlights a major failing of the safety management system, indicative of the safety culture of that period.

Driver Training / Safety Management

Cullen (2002, Part 1 Report) found that there was an inadequate safety management system on the part of the infrastructure and of the TOCs. The Inquiry made recommendations concerning communications between drivers and their managers, specifically to discuss any safety-related issues as a priority.

Cullen (2002, Part 1 Report) recommended that driver competence was tested every three years to ensure that performance was at the required high level and also that the effectiveness of competence testing systems were reviewed at a similar frequency. It was also recommended that a central driver licensing system was created perhaps with a NVQ style of training and on-going certification.

Cullen (2002, Part 1 Report) also recommended that a safety culture promoting effective communication without fear of recrimination was developed. This implies that a certain amount of blame culture existed prior to the crash. Such a culture is not conducive to getting the best (or safest) out of the whole team.

Cullen (2002, Part 2 Report) found that there was a culture of tolerance to unsafe acts and such behaviour only breeds further contempt for the safety systems and procedures in place. Agnew & Snyder (2008) state that when operatives see management showing such behaviours it is usually the case that they too will copy those behaviours. It is imperative therefore that where safety-critical systems are involved, management must lead by example and show by their actions that breaking the rules will not be tolerated.

SN109 had a history of SPADs which should have prompted a review of the causes but this did not take place. This is a case of management failing to lead by example. Cullen (2002, Part 2 Report) found that a great majority of SPADs that occurred within the railway network were too often attributed simply to driver error and as such the incidents were not subjected to a full review to discover whether any underlying issues were present (as was proven to be the case at SN109).

The Inquiry conclusions to the safety management culture were that higher safety standards required to be set through clear leadership, good two-way communications, better adoption of best practice in operations and learning processes, better training of all employees from drivers' duties through to incident management and response of associated train personnel, a new focus on the concerns and aspirations of the customers and a new ethos of communications within the industry.

Clearly the issues noted above relate entirely to promoting the good behaviours of humans while minimising the prevalence and effects of less desirable behaviours, i.e. designing out the HF-induced issues.

2.8.2 Case Study 3 – Conclusions

It is clear that since the occurrence of the major accidents that involved driver error, signal sighting issues and SPADs, a huge amount of work has been completed by the industry and the regulatory authorities in terms of correcting the procedural and behavioural failings that once existed. The number of SPADs is reducing and training, monitoring and reporting methods have been vastly improved. TPWS has now been installed over the entire network (Office of Rail Regulation, 2010) and is producing positive results as can be seen in more recent SPAD reports (RSSB, 2007).

By analysis of the physical, procedural and technical systems involved, it has been shown by the UK railway industry that by designing and implementing appropriate systems of safety management, control and monitoring that the safety culture, even in a highly complex organisation, can be improved to such an extent that results previously thought to be unachievable can be realised to the benefit of all who use and work in the railway system.

Cullen (2002, Part 1 Report) found that the direct cause of this accident was that the TT train driver drove through a red light but also that it would be unfair to attribute all blame to him as there were other situational aspects that contributed to this accident occurring. Signal sighting issues (poor design), driver training (skill-based and knowledge-based errors), motivational errors (violations), inadequate SPAD detection safety systems and poor communications channels (motivational and competence issues) all contributed the accident occurring. Driver inexperience may also have been a contributing factor given the driver's recent qualification to operate. Cullen (2002, Part 1 Report) found that the signalling system designers did not provide the drivers with best available information at Gantry 8 / SN109. Also, the issues with signal SN109 were not investigated and rectified expeditiously. Existing issues were not communicated adequately to new staff such as the TT train driver who had only qualified two weeks prior to the accident occurring. Although deemed to be fully competent, having passed all necessary theory and practical examinations, putting a new driver on a route with a history of signal sighting issues was noted by Cullen (2002 Part 1 Report) to be a less than acceptable situation. The training programme was subjected to an audit and was found to be lacking in terms of practical experience on the exit from Paddington with respect to passing SN109. The training programme was subjected to an independent review by Prof. John Groeger (University of Surrey) which revealed that in certain parts of the programme (route learning) there were no clear pass / fail criteria with which the driver trainers could assess the trainees against. Additionally there was no definition of how many times or how accurately the trainee had to complete an activity for the trainer/observer to deem them competent. Such a situation may occur as a result of many factors but clearly they must include motivational issues, competence issues and judgement errors on the part of the management and driver training personnel, i.e. knowledge-based mistakes and rule-based mistakes. The review noted this situation to be a weakness and specific recommendations were made to rectify this situation.

There were other human factors present such as fatigue as a result of the working / commuting arrangements of the TT driver. The driver rose at 03:00 to get to Paddington in time for his first journey of the day (approximately 05:30). The driver had requested to operate out of Reading which was much closer to his home but this request was not granted. Minimising commute times and maximising rest / sleep periods would have helped to reduce stress and the likelihood of fatigue occurring. This is considered to be a management judgement error and a motivational issue (knowledge-based mistakes) as the management appeared to be unsympathetic to the driver's request and may not have realised the potential outcome of the decision.

2.9 Case Study 4 – Ariane 5 Flight 501 Failure

The Ariane 5 rocket launcher system was designed and built by a pan-European consortium of companies known as the European Space Agency (ESA). It was designed as a heavy lift system of delivering payloads into orbit such as commercial communications satellites. Although fundamentally a European system it is launched from Central America (Kourou in French Guiana). This location is near to the equator which minimises the flying distance to achieve weightlessness, thereby minimising the quantity of fuel required to do so.

The maiden launch of the system was heralded as a new chapter in the space industry as Europe became a more considerable commercial force with the Ariane 5 heavy lift system.

Lions (1996) found that on the day of the launch (04/06/1996) there were no major issues of concern affecting the launch schedule. Visibility was such that the launch time was postponed for a short period but weather on the whole was suitable. After the countdown sequence the main Vulcain engine and solid rocket boosters (SRBs) all ignited normally and were fully operational in flight until at approximately T+36 seconds when the launcher suddenly veered off course and spectacularly broke up and exploded as a result of the dynamic forces encountered and the resultant safety self-destruct systems deployed. The launcher exploded into thousands of pieces showering an area east of the launch pad of approximately $12km^2$ with the debris. Some of this debris presented a danger to people and the environment as a result of the flammable and toxic materials released during the explosion.

At T+36 seconds the back-up inertial reference system failed followed immediately by the active system. These failures caused the engine nozzles to swivel to the extreme position of their operating envelope resulting in the sudden veering that was observed.

An independent Inquiry Board was set up under instruction by the Director General of ESA and the Chairman of the French Space Agency (CNES) to investigate the accident.

As a result of the nature of the failure it was quickly determined by the Board that their initial investigations would be centred on the flight control systems. Extensive telemetry data was available and this was analysed by experts for the purposes of attaching a verifiable time line to the analysis.

Several other anomalies occurred during the short flight but, after preliminary investigation, these were ruled out as contributing factors to the accident. It was acknowledged that they required to be rectified for future launches but that they would not lead to such an accident as observed on the maiden flight.

Despite the difficult terrain and ground conditions of the area (mangrove swamp and savannah), the inertial control systems components were recovered and sent off for analysis.

The flight control system of Ariane 5 was based on the same system fitted to Ariane 4; an earlier and highly successful ESA launch system (Lions, 1996). The system includes an Inertial Reference System (SRI) with its own internal computer which calculates angles and velocities based on information from the laser gyros and accelerometers fitted to the launcher. The data from the SRI is fed to the launcher on board computer (OBC) which executes the flight control program and controls the engine directional thrust nozzles by hydraulic actuator systems. Redundant systems are employed to improve reliability. One SRI is “active” while the other is in “hot stand-by” mode and the units are identical. OBCs are also duplicated. When the OBC detects a failure of the active SRI it automatically switches to the hot stand-by unit (if operational). The SRIs fitted to Ariane 5 were the same as those fitted to Ariane 4 in all respects (including software).

The accident was caused when the active SRI (SRI2) developed a software operand exception error followed by automatic shutdown of the unit processor thereby enforcing the OBC to switch to the other unit (SRI1). Under normal circumstances this would enable the launcher to continue its flight but in this case the hot standby had also failed for exactly the same reason during the previous data cycle (72ms earlier). This meant that the OBC could no longer compute any real flight control data and the flight was doomed from that point. As both the SRIs had ceased to function the OBC was computing flight control actions based on an erroneous diagnostic string pattern value interpreted as genuine flight data (Lions, 1996).

The software routine that contained the error was associated with the alignment of the strap-down inertial platform and only computes meaningful results prior to take-off. It is used as a means of detecting the position of the launcher with reference to earth and space. After lift-off the software routine is essentially redundant as the in-flight systems take over. The software routine operates for approximately 50 seconds (9 seconds before and 41 seconds after lift-off). This sequence was derived from the Ariane 4 launcher and was not changed for Ariane 5. The times are associated with the procedures involved in halting and restarting countdowns and to enable the ground systems to re-gain control of flight systems from the launcher after countdown cessation. There was no requirement for the Ariane 5 alignment system software to continue after lift-off but the same times set for Ariane 4 were still in place.

The Ariane 5 alignment / lift off preparation sequence was different to the Ariane 4 sequence to such an extent that the software routine was not applicable in terms of the time required to re-align the systems after a countdown hold. For reasons of commonality and unnecessary software modification this routine was not modified for the Ariane 5 launcher. This may be perceived as a knowledge-based judgement error at several levels within the organisation.

The Board found that the reason for the operand exception was that during a conversion of an operand value in the alignment routine from 64-bit floating point form to 16-bit integer form the floating point number had a greater value than could be represented by the integer value. The operand was found to be the horizontal bias value (BH) as measured by the strap-down inertial platform (containing the laser gyros and accelerometers). The software code for the SRI relating to this value was exactly the same as Ariane 4 including timings and values. The flight path of Ariane 5 has a greater horizontal velocity than Ariane 4 thereby causing the operand exception error to occur. The code was therefore unsuitable for the Ariane 5 launcher. Error trapping for this operand value was not in place. Six other similar measurements were used in the software with four of them having error trapping routines in place. The assessment of the three values that did not have software error trapping showed (incorrectly) that there was insignificant risk associated with these values and that to achieve the processor workload target of 80% these values could remain unprotected. This was a valid assumption for Ariane 4 but not Ariane 5 (Lions, 1996). The classification of risk associated with this value was incorrect. The inquiry report does not attribute blame to any single person or group but the errors appear to be caused by inexperience, judgement and competence by several persons or groups.

The issue with the BH parameter was that assumptions were made that the value was physically limited or that there was a large margin of safety; both of these assumptions were incorrect for Ariane 5 as found by the Board. Such assumptions clearly show a lack of knowledge (competence) or judgement by a number of personnel involved.

The testing regime of the launcher system did not include physical testing of the SRI systems under launch conditions and the Board concluded that had it done so, the flaw in the guidance system would have been discovered. This failure may be attributed to a lack of competence as a result of the personnel involved not appreciating the requirement for more thorough testing of the flight control software and associated systems to be carried out. This is not likely to be an issue with a root cause directly associated with the personnel involved but is more likely to have a root cause in the training, development and competence assurance programmes within ESA, i.e. judgement and competence errors associated with the personnel at a higher level within the organisation. This is the type of issue that the safety culture questionnaire and assessment tool has been designed to detect.

The Ariane 5 trajectory data was not programmed into the SRIs but instead the Ariane 4 data remained. As a result of the assumptions made at an earlier stage of the development process this was not perceived to be an issue at the testing phase, i.e. inadequate competence or judgement errors.

The SRI specification required the processor to be shut down when a software exception occurred. The Board found that this was also a major factor in contributing to the accident. The type of software errors accounted for were solely in place for the purpose of detecting random hardware failures for which a hot stand-by system was considered as adequate mitigation. However, the type of failure that occurred was systematic and was not therefore adequately protected against by the stand-by systems in place, i.e. there was a failure to detect the latent error through inadequate competence, inexperience or judgement.

The Board found that the system performed as designed, i.e. the exception error was detected and the stated action was carried out (processor shut down). It was the specification that was incorrect in that the SRI should not have been shut down on an exception occurring. The Ariane programme had an overall view that software should be considered as correct in all such error handling situations until it could be shown that it was at fault. The Board had the opposite view in that all software should be considered to be faulty until all best practice methods of testing and analysis have proven it to be otherwise.

The Board stated their view was that mission-critical software should be subjected to the same level of exhaustive testing and analysis procedures as any hardware component and that back-up / stand-by systems must take account of software failures when considering the system failure modes.

Equipment testing and qualification procedures for Ariane 5 are similar to that of the Space Shuttle. The process is noted below.

1. Equipment Level: Each item of equipment is confirmed as being in conformance with specification (including software).
2. Stage Integration Level: Integration testing is carried out to ensure that all equipment functions correctly as part of the subsystems to which it is connected.
3. System Validation Testing Level: Validation testing is where entire systems are tested, e.g. the flight control system where all subsystems are either present for the tests or are simulated.

The Board found that the test programme did not include a test being performed to verify that the SRI would function correctly when subjected to the countdown sequence in combination with the expected Ariane 5 flight trajectory data. The Board concluded that had such a test been carried out the accident would not have happened as the underlying software fault would have been discovered. The specification for the Ariane 5 SRI did not contain reference to the functional requirement to include actual Ariane 5 flight trajectory data. The Ariane 4 data therefore remained.

The SRIs were considered to be fully qualified at equipment level and all subsequent higher level testing of the associated sub-systems was carried out by simulation of the SRI signals and data.

2.9.1 Case Study 4 Analysis

The main findings of the board were that the loss of the vehicle was caused by total loss of the guidance and attitude systems and that this failure was caused by inadequate analysis and testing of the SRI and the complete flight control system, i.e. judgement, competence and potentially inexperience errors (knowledge-based, rule-based and skill-based errors).

It is clear that human factors played a significant part in the cause of this accident where assumptions were made that were not correct and those assumptions had not been fully analysed to determine the potential effects on the whole system. As with NASA, the Ariane project employs a huge number of highly intelligent and specialist personnel easily capable of detecting such a fault in the design given the appropriate procedures and processes with which to carry out their duties.

The Board made 14 key recommendations based on their findings. They are summarised below.

- Disable the alignment system after lift-off and ensure only software functions necessary for flight are operated during flight.
- Prepare an adequate testing facility.
- Do not disable any sensor from sending best effort data.
- Provide a specific qualification review of each item of equipment containing software and ensure that all critical software is classified as a Configuration Controlled Item (CCI).
- Review software functions specifically for the effects of assumptions, the range values possible under all conditions and to ensure that a review is carried out by external experts.

- Improve software exception handling and back-up capabilities.
- Improve quantity of telemetry data available.
- Reconsider the definition of critical components (including software).
- Include external experts review of specifications, software and justification documentation.
- Include trajectory data in specifications and test requirements.
- Review existing test coverage of all existing equipment.
- Improve software change control procedures and justification documentation.
- Set up a team of experts for ensuring the software qualification is carried out to the necessary degree of rigour.
- Provide a more transparent system of co-operation between all Ariane 5 partners.

As can be seen, there were no issues of a highly technical nature identified in the recommendations. All recommendations were either relatively simple statements of making straightforward changes as to how certain flight systems operated or they were recommendations for how the testing, analysis and system verification was carried out and by whom, i.e. they were recommendations based on removing human factors issues.

2.9.2 Case Study 4 Conclusions

Whilst the fixes necessary to implement the recommendations may have been highly complex, the identification of the required fixes was relatively straightforward.

It is postulated that had an effective HF policy been in place then the type of actions highlighted in the recommendations made by the Board would have been identified as part of the normal administrative review process.

The personnel responsible for the safety-critical systems had such a tight scope of responsibility that they were not focussed on the wider issues (or were prevented from doing so by their limited breadth of responsibility). This need not be an issue of great importance provided that someone else or some other team is in overall control but in the case of Ariane 5 this was not the case, hence how the software error was built into the launcher.

The testing and qualification procedures were found not to be of adequate rigour so as to enable all such errors to be discovered and that in this case the fault that led to the destruction of the launcher passed undetected. In such a large organisation it is unlikely that the same team would be responsible for writing the hardware / software specifications and also that of the test specifications. For independence and integrity reasons it would clearly be unwise for such a situation. The international functional safety standards such as BSE 61508 and BSEN 61511 require such rigorous practices for safety-critical systems where independence must be designed into the system from conception to decommissioning and this must be adequately documented.

The testing programme did not consider the need for a full test of the systems under simulated launch conditions. Ordinarily the software routine that caused the failure does not directly affect flight control after lift-off but was still capable of shutting down the processor that measured critical flight control parameters and passed data to the OBC. This indirect ability to cause the accident seems to be an inexcusable oversight on behalf of all personnel involved. The communications system within the organisation was not set up such that the width and scope of reviews carried out were visible to all partners to the same degree; a very similar situation to that in the NASA accidents. This type of error falls into several categories: judgement, competence and inexperience, i.e. knowledge-based and skill-based errors. Also, the inexperience does not relate to the experience of those personnel working in their field of expertise but their experience of appreciating the bigger picture of all potential issues.

As the recommendations show, many of the issues were easily resolved and the Ariane 5 launch system has since carried out 56 successful missions (up to mid-2011 but also with one further failure during this time). It is a point worth noting that the system is not designed for carrying personnel into space. Had it been so then it is most likely that additional review and testing stages would have been included in the procedural requirements and again the fault would almost certainly have been discovered prior to flight. The Board's report does not go into detail about the competence of personnel but it is clear that there were such issues given that the error was not detected.

It is widely accepted that all software contains errors and whilst the error in the software code was a credible occurrence, as with all other such software errors, it should have been detected through the test specification and actual systems testing programme. It is clear therefore that the software fault was not the only contributing factor.

The type of error that caused the Ariane 5 accident shows that there were failings not only at the engineering level but also in safety engineering and management levels in terms of not providing adequate systems of review, control and communication, i.e. judgement, competence and potentially inexperience errors (knowledge-based).

In the petrochemical industry it is normal to include specialist safety engineering personnel at all stages of the design and testing programme in order to assist in identifying such issues. While those personnel may not be useful in terms of providing solutions to issues raised they may have brought the issues to the fore such that the technical and managerial personnel could have addressed them as necessary.

2.10 Case Study 5 – Buncefield Explosion

The Buncefield fuel storage and distribution depot serves the south east of England. The depot is used for the storage and transportation of all types of hydrocarbon fuels to the surrounding area via road tankers and also by direct pipe line connections (jet aviation fuel) to Gatwick and Heathrow airports. The depot receives its fuel in batches via three cross-country pipe lines: one from Lindsay Refinery in North Humberside, one from Stanlow Refinery in Cheshire and the third from Coryton Refinery in Essex (Buncefield Major Incident Investigation Board, 2008).

A series of explosions occurred at the depot in December 2005. This occurred after a gasoline tank had been inadvertently overfilled and the released liquid formed an extensive vapour cloud at ground level. It is postulated by the investigation team that the vapour cloud was ignited by a piece of electrical equipment within the fuel depot. The main explosion caused catastrophic damage to the facilities at the depot and also in the buildings in the immediate vicinity. The blast wave destroyed several houses and business premises adjacent to the depot and severely damaged many others. It was extremely fortunate that no one was killed as a result of the explosion. Over forty people were injured as a direct result of the explosion but these were not life-threatening injuries.

The explosion caused widespread disruption to people (domestic and businesses) in the surrounding area by the implementation of road closures for several months afterwards to allow the emergency response and site clean-up teams to access the site safely and to keep people away from the danger present in the aftermath of the explosion. People had to be evacuated from their homes and businesses for their safety: some for several months. Several businesses went into liquidation as a result of the disruption and many buildings had to be knocked down as a result of the blast damage being irreparable. Damage to buildings was recorded up to 2km away from the depot: an area much larger than previously thought possible for open flammable cloud explosions (OFCE). Subsequent investigation revealed that a detonation-type explosion must have occurred to have caused the level of damage present and the energy released in the explosion was found to have been equivalent to an earth quake with a magnitude of 2.4 on the Richter scale (Buncefield Explosion Blast Wave Energy, 2010). Under normal conditions OFCEs do not give rise to detonations. These usually only occur when a degree of confinement or turbulence is present with which to propagate a flame front more efficiently through the unburned mixture of flammable material and air. Whilst deflagrations still present a danger to life and infrastructure, the explosion energy involved with a deflagration is much lower than with a detonation because the explosion occurs over a longer time period and does not reach such high explosion blast wave pressures. A detonation is an impulse-type explosion with very short positive phase blast wave pressure rise and fall times while a deflagration develops much slower because it is unconfined. It is therefore a much less energetic explosion with lower maximum pressure and longer blast wave pressure rise and fall times as shown in Figure 2.8 below.

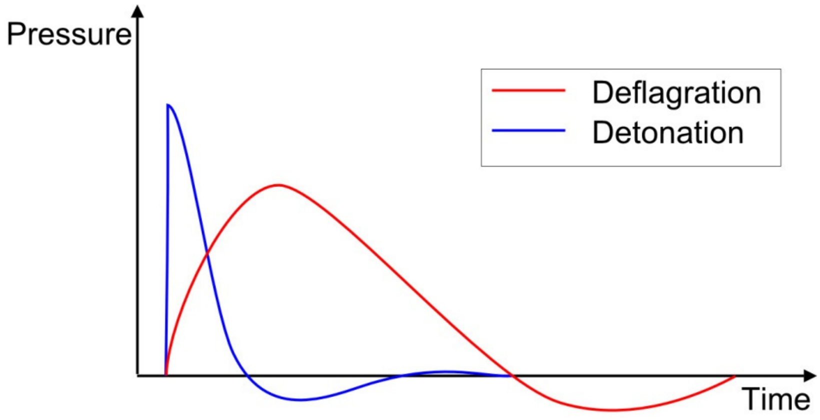

Figure 2.8: *Typical Blast Wave Pressure / Time Curves*

In the aftermath of the explosion and the subsequent fire fighting efforts it became apparent that a significant environmental incident had also occurred (Buncefield Major Incident Investigation Board, 2008). The fire water, mixed with hydrocarbons and fire fighting foam compounds was not retained within the site as it should have been and found its way into the surrounding groundwater system. This also contaminated an aquifer which many surrounding domestic and commercial businesses use for abstraction. The local water utility company also used this as a source of potable water.

A major investigation was carried out by a specially formed team from the HSE and the Environment Agency (known as the Competent Authority for COMAH purposes). They examined all aspects of the site from normal operation up to the point of the explosion occurring. The findings of the investigation led to several successful prosecutions of those held responsible.

2.10.1 Case Study 5 Analysis

The main causes of the explosion are listed below (MacDonald, 2011). These were used as the basis for the subsequent prosecution of those at fault.

- Simultaneous failure of the automatic tank gauging (ATG) instrument and independent high level switch (IHLS).
- The IHLS was of a design that was potentially unsafe.
- An inadequate attitude to equipment maintenance was prevalent.
- Tank filling procedures were inadequate and poorly enforced.
- The flow rate to the tanks (from other sites) was controlled by the feed plants and the availability of information on flow status was poor.

- Throughput had increased as a result of the adjacent depot closing down.
- The combinational effects of these factors resulted in a stronger focus being placed on production than safety, leading to a poor safety culture.

ATG / IHLS Failure

The tank level is monitored on a computer screen in the control room. The computer system receives the tank level information from the ATG instrument located on the tank. The ATG had developed a fault which meant that it could no longer track the level in the tank. It had become stuck thereby also leading to a "stuck" displayed level. The tank was being filled from the previous evening from one of the three supply pipe lines. It would appear that the operator did not notice that the tank being filled was no longer showing that it was filling; a potential operator competence issue (in this case a skill-based error) but also potentially one of a poorly designed level display equipment and alarm system. Issues with how the tank level information was displayed on the screen meant that this fault was not obvious. Additionally, the alarms that could be set up in the tank gauging system for monitoring tank operations were not operational. The software alarms that could be configured allowed for multiple high and low levels as well as tank movement alarms, i.e. to sound an alarm when a tank starts to show filling or emptying when it should be static and vice versa. Access to the software system to change the alarm set points was not restricted and this meant that the alarms could effectively be disabled, i.e. an unapproved modification (or violation) to what is essentially a safety system. The issues with the level display system were numerous. There were clearly issues associated with operator training, level monitoring and alarm system ergonomics, motivation of level system installer/maintainer, motivation of operators, inexperience of operators (potentially as a result of poor training) and clearly an overall lack of control and supervision from the site management team, i.e. competence, judgement, and motivational failings (rule-based, knowledge-based and skill based errors).

IHLS Design Flaw

The IHLS had a design flaw that had not been identified to the switch installation contractor or the site operator. This fundamentally affected the safety of the installation. The switch was fitted with a lever which is used to test the functional operation of the device. The lever is fitted with a means of padlocking it in the inactive position. If not padlocked it is possible for the lever to be in the wrong position which would have prevented the switch from initiating a tank overfill protection shutdown. This is believed to have been a major contributing factor to the explosion occurring. Since installation no padlocks had been fitted to any of the IHLSs at the site. The IHLS manufacturer was criticised (and ultimately convicted and fined) for not providing sufficient information to the installation contractor in order to maintain safety with their switches installed in a safety-critical application. This is a motivational type of error on the part of the switch designer (rule-based mistake or violation) but also one of inexperience and judgement on the part of the installer/maintainer (knowledge-based mistake compounded by the knowledge-based mistake of the supplier).

Inadequate Maintenance

The level gauge had failed several times prior to the explosion occurring but the root cause of the failures had not been identified. Only cursory checks and quick fixes had been applied to rectify the situation each time but the root cause was not identified and the fault kept occurring. This is clearly an error associated with inadequate competence, experience and judgement (knowledge-based and skill-based mistakes). The maintenance of the ATG system was contracted out to the ATG manufacturer with little contractual control. The site operator simply trusted the ATG manufacturer to provide an adequate service level but without actually ensuring that such a level of service was in place and maintained. The maintenance contractor clearly had motivational issues present as a result of the structure of the maintenance contract potentially rewarding the contractor for each visit necessary with little or no auditing to ensure that faults were being properly rectified. This is also indicative of serious judgemental and competence errors being present (rule-based and skill-based mistakes). A lack of experience or understanding of the issues present also contributed to the issue. In safety-critical applications the investigation team stated that this was not good enough and the site operator was ultimately fined for not providing a safe place of work and for endangering people not at work (the public). The site operators were fined a total of more than £4million in addition to costs also totalling over £4million.

The failure of the ATG should not have resulted in the tank overfilling as best practice would have required the operators to manually check the tank level during the filling process. This does not appear to have been adequately carried out. This situation was made more complex as a result of how the pipe line systems were operated. Failure to manually check tank level is likely to be a motivational error on the part of the operators as operating procedures would include such measures ordinarily, i.e. a likely violation of existing procedures. If such procedures were not in place then there would also be competence, judgement and inexperience issues present on the part of the management team, i.e. knowledge-based mistakes.

Tank Filling Procedures

The filling of the tanks was often not under the direct control of the site operators. The inquiry found that the depot was run with a frame of mind that placed too much emphasis on keeping pipe lines available and with a far lower emphasis being placed on safety. As the flow could be turned on and off remotely and the depot could draw from the tank at the same time as it was being filled it was often difficult for the operators to accurately determine what the filling rate was.

Throughput Increase

One of the adjacent site operators had recently closed down its operations and the resultant gap in supply was taken up by the Buncefield site. This change appears to have been implemented without formal analysis of the effects on the operability of the depot and without due consideration of the workload of the operators and supervisors responsible for its operation. This was clearly a failing of management to fully understand the situation, i.e. a knowledge-based or rule-based mistake or violation (if management of change procedures were in place) but this also suggests that the competence of those involved was also questionable. Inexperience may also have been a factor in the review / decision process to increase throughput without properly examining the process safety implications.

2.10.2 Case Study 5 Conclusions

A human factors assessment (as described in this thesis) may well have identified the contributing factors leading to the occurrence of this explosion. However; even if it had identified the most significant issues prior to the explosion occurring, it is not a foregone conclusion that the site management would have addressed the findings given the attitudes and production requirements in place at the time. The system (including humans) had been pushed beyond its capability and the explosion that occurred was the result.

It is clear from the investigating team reports that the underlying causes of the incident were predominantly related to inadequate control and management of the site, i.e. inexperience, judgement, motivation and competence issues (knowledge-based and rule-based mistakes). Attention to detail was lost in the need to keep the depot running at maximum capacity and too much freedom and trust was afforded to the contractors engaged to install and maintain the site equipment to a sufficient degree of rigour. The site personnel were not qualified or sufficiently experienced to ensure such measures were being adequately applied and the management did not put sufficient measures in place.

2.11 Human Factors as a Solution

Modern engineering methods in design, construction and operation can do much to improve safety and reliability while inadequate control of these aspects may mean that the associated engineering outcomes remain susceptible to influencing factors such as poor motivation and training of those personnel in positions of safety-critical responsibility.

Influencing the behaviour of those in responsible positions by the consideration of human factors in their routine activities and responsibilities can introduce benefits in cost, safety and performance (Harvey, 2004). An example of this has recently been implemented by the National Air Traffic Service (NATS) where all personnel in safety-critical positions such as air traffic controllers and support services / maintenance personnel are now required to undergo rigorous requirement-driven competence testing and analysis and the overall assessment is carried out on a risk-based analysis of the level of competence required (Bush, 2007).

Harvey (2004) has shown that increased effort in human factors assessment at the design stage of any safety-critical system results in that system being more efficient and having fewer problems throughout its life cycle and it is likely that such a system will therefore be inherently safer and more reliable as a result, though such assumptions are clearly related more to the *quality* of the HF assessment work carried out and not the *quantity*.

Kubie (2001) writes that there can be cases where “one safeguard too many” can actually induce greater risk as a result of people becoming complacent. An example presented is that of improved safety and technology in the motor car by the introduction of mandatory seatbelt use in the UK (1983). Since introduction there are now fewer fatalities in the UK as a result of crashes but there are more crashes occurring (Kubie, 2001). People seem to be paying less attention to their surroundings, perhaps as a result of being enveloped in their cell of safety and feeling detached from the real risk that exists not only outside the vehicle but also within the vehicle. There are now a multitude of distractions available such as SatNav, CD players and mobile phones and these too will no doubt have a contributing factor to the accident rate. There are also more vehicles on the road today than were present in 1983. Legislation has also been brought in to make using such equipment while driving an endorsable offence but not everyone complies with such laws. Clearly this is an unacceptable situation but one which cannot be corrected in a state where people are essentially free to move around in whatever transport they desire and however they choose to do it – until they have been caught and dealt with through the judicial system. Even then, the system does not seek to improve behaviour but simply imposes fines or driving bans. For the worst offenders such as drink drivers, rehabilitation schemes are in place whereby offenders can elect (or be ordered) to attend rehabilitation programmes to assist in preventing such future behaviour. These schemes seek to change the behaviour that causes the offenders to break the rules and take unacceptable risks in the first place thereby maximising the likelihood of future prevention of such errors and unacceptable behaviour. The assessment of human factors in the workplace and in public transportation systems seeks to apply exactly the same methods by which the behaviour of people can be changed for the better.

It is essential for the continuous improvement of public transportation safety that all available technology is considered at the design stage but in contradiction to this, in safety-critical control systems, such as those in use in transportation and industry, it is often more appropriate to include tried and tested technology in the final design. An example of this is the automated control and safety shutdown systems fitted to commercial nuclear reactors. Whilst the shutdown systems in place contain the most up to date high-integrity, high-reliability and high-tech equipment they also contain tried and tested technology such as 1950s design electro-mechanical relay-based systems. Such systems are not only designed to be fail-safe (for predictable equipment failures) but they also make use of redundant systems using a different means of detection, initiation and executive action to minimise the probability of failure to operate on demand (PFD) through the removal of common mode failures in the protection systems.

Human factors in addition to other safety management and risk reduction tools such as risk assessment, reliability centred maintenance (RCM), risk based inspection (RBI), failure mode and effect analysis (FMEA), can be used to minimise and mitigate the risk associated with any new methods or technology being employed. Huge leaps forward in engineering technology and practice, such as the invention of the compound steam engine in1869 (Compound steam engine invention, 2010) or the jet engine in 1937 (Jet engines history, 2010) are now rare events: the norm now being many small steps, discoveries and developments which collectively form an overall improvement over an extended time frame. Human factors engineering can be used to bring about many of these small changes and can influence many aspects in the design and operation of any transportation or industrial control system.

For older safety-critical systems being upgraded, such as those in the UK railway industry, human factors can and does play a significant part in the development and design process to optimise the final solution prior to implementation and also to minimise the disruption to passengers in the interim. It is essential that all available data is assimilated and considered to ensure that the most effective system is designed. Missing data can be critically important to the design of any system and can result in a system with inherent covert design flaws. This must be prevented for all such safety-critical systems and requires obtaining real evidence and information from all sources and from all levels of personnel from technician through to manager from all personnel actively involved in managing such assets (maintenance operation, etc.) to ensure that all relevant data has been addressed.

Transfer of human factors assessment knowledge and methods into industry from other sectors such as air and sea transportation where it has already been proven useful should be possible as it is a generic tool that can be applied to all aspects of engineering and operational activities.

The method of HF assessment proposed as part of this research project is capable of being implemented in a similar way for all sectors and includes several key stages of implementation; namely: think, plan, consult, do, review; implying that human factors assessment should be applied to the entire lifecycle of any project, equipment or system and that it needs to be an iterative process. It is therefore no different to any other engineering or project management process founded on good behaviours with a systematic approach. Whilst an isolated application of human factors assessment to any one stage or aspect of a project may provide improvements over no application at all, it is unlikely to achieve all potential benefits of applying it to the entire system or lifecycle.

Roughton and Mercurio (2002) describe a method of developing an effective safety culture in a planned and structured way including the specific stages of developing policies (thinking and planning), communicating policies (consulting), developing and establishing goals and objectives (doing), reviewing achievements (reviewing and improving existing arrangements).

Tainsh (2004) describes the process of human factors integration within the defence sector. The process includes several key stages: concept, development, production, utilisation, support and retirement. As described above, this process can also be made to fit the think, plan, consult, do, review process proposed as part of this project.

Figure 2.9 below shows that the implementation process should not be considered as circular but more of a spiral with decreasing risk for each iteration.

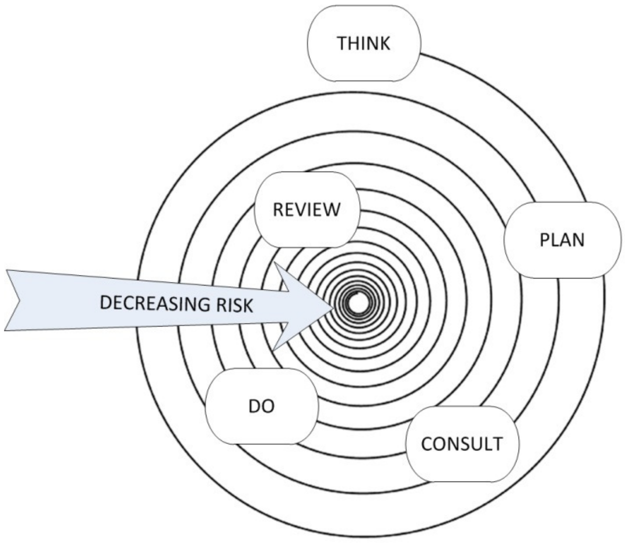

Figure 2.9: *Iterative HF Application Process*

Lester (2007) defines the project lifecycle for general project management as containing 8 key stages: concept (think), feasibility (plan, consult), evaluation (plan, consult), authorisation (consult, do), implementation (do), completion (do, review), operation (do, review) and termination (do, review)

As noted (in brackets) these key project lifecycle stages can also be made to fit the model proposed within this research project.

2.11.1 Implementation Stage 1: Think

By assessing potential human factors issues at the conceptual stage of a project, the foundations can be laid for a fully and correctly specified project. This research project has investigated how human factors can be applied in real situations within industry by exploring what information is required and how it can be used to optimise the operation of workplaces. In terms of human factors, this research project investigated (by analysis of data from collaborative companies) what requirements should be specified and how the requirements can be defined and incorporated into existing systems of control and monitoring. This preliminary stage of the implementation of human factors is very much associated with the provision of specifications such that the entire scope of requirements is covered and confirmed as such. The scope clearly needs to take account of external factors such as any legislative constraints or other constraints of any type and their likely effect over the lifecycle of the project / system.

2.11.2 Implementation Stage 2: Plan

The planning stage of the implementation of human factors assessment of a project or system should include a full appraisal of the overall project strategy. Isolated or spurious application of the technique will provide benefits but the most effective application will be when the entire project or system lifecycle is subjected to a full and rigorous application of the technique.

This research project has investigated, through collaboration, the application of human factors assessments to determine what benefits are expected or achievable and how project timescales or resource burden may be affected by the application of HF assessments and how the operation of the process systems may be affected in terms of efficiency and safety.

2.11.3 Implementation Stage 3: Consultation

The consultation process should be applied at all levels and to all stages of a project in order to maximise the quality and quantity of the data and information that is available to the personnel responsible for the system design and operation. This consultation described does not refer to hiring external experts (though it does not discount this) but refers instead to consultation between all relevant personnel involved. It is essential to consider what group of personnel the data came from and to analyse what personnel provide the most useful data in terms of assisting in improving the safety integrity of any existing or proposed system.

An accident is a coming together of several undesirable factors at the same time, with undesirable consequences. The UK HSE defines an accident as:

> "any unplanned event that results in injury or ill-health to people, or damages property, plant or equipment". (Health and Safety Executive, 2010)

Near misses are defined as:

> "an unplanned event which does not cause injury or damage, but could have done so." (Health and Safety Executive, 2010)

The accidents caused by the errors or omissions of humans can be split into two main types: those which are caused by truly genuine errors or misunderstandings and those which are a direct result of neglect (violations). In the former, genuine errors are often the result of inadequate competence or experience of the personnel involved; such personnel having done their best but unfortunately not possessing the breadth of experience and competence required with which to make good and balanced engineering judgements. The case can easily be argued that this is not a failing of the individual but a failing of the individual's management or its safety management system to recognise the competency or experience gap present. External influences causing distractions can also have an adverse effect on people's performance. This may be down to the type of person, i.e. how easily they are distracted in any situation requiring a high degree of concentration or it may be as a result of a poorly designed workplace in which constant distractions prevent the required degree of concentration ever being achieved. The latter type of accident (neglect or violation) is caused by human incompetence, where personnel clearly neglect their professional duties and responsibilities and even more importantly that they are aware of the risks and the potential consequences to themselves and others.

Human factors assessments can be used to assist in designing out these incompetence factors by incorporating protection against them at the design stage of a project lifecycle. The difficulty is in recognising such factors during analysis to be able to design them out. It is essential therefore that an adequate competence assessment system is in place and this project aimed to provide a system of assessment that can be used to gauge when a company has an adequate system as part of the implementation of HF assessments in an industrial setting.

One of the most important considerations in engineering is determining what information is unknown rather than what is known and also what measures can be put in place to mitigate the unknowns by estimating the likely scale of the worst case event that may occur. The assessment of human factors should endeavour to answer this fundamentally important question for all activities.

2.11.4 Implementation Stage 4: Do

An effective safety and management strategy is essential for modern transportation systems and industrial processes or manufacturing systems but it must be used effectively at all levels of the organisation if it is to be successful and more importantly, if it is to be safe. Inadequate enforcement of safety could be considered tantamount to promoting accidents. This research project has investigated who must be involved in the analysis, how their competency and experience is assessed or measured, and by whom, and what is the degree of certainty associated with competency measurement? A list of criteria which can be combined to give an assessment of a person's competence was defined by Bale and Edwards (2000) based on extensive industry experience and benchmarking. This project investigates published accident and incident reports/statistics to seek out correlations in the data between the systems and processes involved and the HF assessment input (or lack of input) that went into the design of the system.

2.11.5 Implementation Stage 5: Review

It is essential to continuously monitor and review the effectiveness of any safety related process or system to maintain or improve upon design and operability as operating experience increases. The review process also has benefits in being fed into the design process of new systems. Passenger movements and lifestyles are continuously changing and transportation systems must be able to adapt to such changes quickly, economically and safely. Process plants are often reconfigured for the purposes of making slightly different products or enhancing the quality of existing products. There is a clear need for management of change procedures to be in place. Several high profile accidents can be attributed directly to failings in such procedures as highlighted by Bale and Edwards (2000).

3.0 LITERATURE REVIEW

This chapter provides an overview of literature concerning human factors, safety culture and behavioural safety in the context of its application in industry.

The purpose of this research project was to potentially answer several key questions (as described below) and from those answers to consider how to implement suitable methods of analysis to determine significant issues present within SMEs and hence implement the most appropriate corrective measures.

- What is human factors?
- What methods of assessing human factors are available?
- Why do people make mistakes and violate safety rules?
- What methods can be employed to prevent mistakes and violations?
- How do ethical values (personal and corporate) affect safety culture?

3.1 What is Human Factors?

Many texts have been written that deal with human factors assessment systems and methods. A considerable number of them refer specifically to those aspects of human factors associated with ergonomics and design of man-machine interfaces (MMIs). This is not the area of interest of this research project. This project is concerned with the assessment of why people do the things they do, whether those actions are correct or not and how those individual decisions can be manipulated by the health and safety management systems in place to ensure that the number of correct decisions far exceeds the number of incorrect decisions, i.e. a system that is heavily weighted to promote safe behaviours and discourage unsafe behaviours.

Meister (1971) describes human factors as:

> "...those elements which influence the efficiency with which people can use equipment to accomplish the functions of that equipment. The most important of these elements are the following:

Meister (1971) then goes on to define those elements as equipment, environment, task and personnel.

The environment, task and personnel are the elements that can affect the performance of humans in the safe operation of any process within the workplace and this is considered in more detail throughout this text.

The environment in which a person works, among many other factors, is important in terms of ensuring that workers are not put under too much stress as a result of the surrounding conditions. People need to be able to carry out their tasks with a certain minimum level of concentration in order to achieve and maintain safety.

Analysis of the task being carried out is also critically important to ensure that all possible conditions and situations have been assessed. Such analysis serves to remove as much of the safety-related decisions from the operatives as possible and to implement work processes and procedures that provide the safest possible environment and work methods. Only abnormal conditions or events would then require a decision from the operative to determine the appropriate action to be taken. This method of working can present a potential risk to the business by designing processes and systems to be automated to such an extent that operatives may lose their skills of judgement and analysis and may become bored in their roles thereby increasing the likelihood of an error occurring.

The personnel selected for any particular task must be capable of performing that task to a defined minimum level of rigour and safety. This description essentially means that personnel must be competent to carry out their allotted duties. If safety-related decisions are part of those duties then the personnel must have sufficient knowledge and must have received sufficient training and experience with which to be able to make those decisions.

Dekker (2006) also provides his definition of what human factors is. "Human factors is not just about humans, just like human error is not just about humans. It is about how features of people's tools and tasks and working environment systematically influence human performance." As can be seen from this definition, it is broadly similar to that described by Meister in that human factors must take account of the human issues as well as the working environment, the task in hand and the capabilities of those people performing the tasks.

Reason & Hobbs (2003) state that "human errors do not emerge randomly, but are shaped by situation and task factors that are part of the environment in which the person is functioning." In consideration of why errors occur they state "Error-producing conditions in the workplace are commonly referred to as local factors, meaning that they are present in the immediate surroundings at the time of the error." These local factors are the same as the human factors as described above, i.e. they describe any conditions present that can affect how the human performs in the tasks that are to be carried out. This is the essence of what this research project is all about: the assessment of those factors that can affect the human decision-making process that determines whether good behaviours or potentially unsafe behaviours are carried out.

Reason (1997) discusses the principles of proactive process measurement which involves making an assessment of three key factors: unsafe acts, local workplace factors and organisational factors. Reason (1997) asserts that the measurement or assessment of unsafe acts is extremely difficult as the number of unsafe acts actually carried out in any workplace is almost impossible to ascertain. Unsafe acts do not always result in immediate undesirable consequences other than indirectly promoting unsafe behaviours in the future and when this happens they may not be reported. It is stated by Reason (1997) that "Errors are essentially information-processing problems" while violations "have their origins in motivational, attitudinal, group and cultural factors, and need to be tackled by countermeasures aimed more at the heart than the head." The assessment of these factors therefore leads to a potential range of corrective measures that can be applied in order to reduce the likelihood of unsafe behaviours occurring and thereby reduce risk within the workplace.

Local workplace factors (as defined by Reason) such as environment, process and machinery hazards, etc. are relatively straightforward to assess, given an adequate quantity and quality of information regarding the tasks to be carried out.

Organisational factors are described by Reason (1997) as the upper level parent failures that cause child failures further down the organisation, i.e. those issues that become apparent at the shop floor level but with their root causes in the management system. A good system of upper level management and control is therefore critically important if the risk associated with the work carried out on the shop floor is to be minimised.

Komaki et al. (2000) describe the applied behaviour analysis (ABA) method of human factors assessment. They state that:

> "The ABA approach has three features which distinguish it from other motivation theories: (a) its emphasis on the consequences of performance; (b) its pinpointing and direct sampling of relevant behaviours or outcomes; and (c) its insistence on the evaluation of effectiveness."

From the description detailed above it can be seen that behaviours and consequences are again at the forefront of the methods they describe.

Komaki et al. (2000) state that the consequences of our behaviour "..are thought to have a powerful impact on what we do from day to day." This means that behaviour can be conditioned as a function of its consequences. The ABA method relies on the feedback provided to workers on the behaviour that is carried out. Komaki et al. (2000) discuss antecedents such as "training, the setting of goals and the communication of company policy" which all precede performance (or behaviours) and also consequences "such as the providing of feedback, recognition, and incentives which usually follow performance and take place after the behaviour." It is noted by the authors that the antecedent measures are important but that consequences have a stronger effect on people in terms of changing future behaviours by providing motivational encouragement to do the right thing for the right reasons. ABA is therefore dependent on the reaction to and learning from the delivery of consequences which provide positive reinforcement for correct and appropriate behaviours and negative (but still preferably safe) consequences for inappropriate (or unsafe) behaviours.

Dhillon (2007) describes human factors as "the body of knowledge concerned with human abilities, shortcomings, and so on." and splits human factors into four separate categories of objectives (fundamental operational, reliability and maintainability, user and operator and miscellaneous).

Helander (2006) describes human factors as:

> "Considering environmental and organizational constraints, use knowledge of human abilities and limitations to design the system, organization, job,

machine, tool or consumer product so that it is safe, efficient and comfortable to use."

It can be seen that this description encompasses all aspects of human interaction in the workplace from objects to organisations and that it is entirely concerned with the design process, whether that design refers to procedures (antecedents) to control how work is (or should be) carried out or whether the design refers to objects or equipment that the workers use to achieve some goal. This is a good description of what human factors means in the context of this research project.

The UK HSE (HSG48, 1999) note that human error is often cited as the primary cause of many industrial and transportation accidents. The real situation is never this simple though (unless sabotage is a factor and this would not be classified as an error but would be an act of safety violation, potentially with criminal intent). In all such cases where human error is cited as the cause of an accident there are always other factors present which contribute to the accident occurring. The common link in the chain of most accidents is the human and it is because of this that the human is often blamed for the accident. It is often found that the human is not the major cause of the accident but that some other cause related to design, operation and maintenance is the major contributing factor. Often, a single individual is blamed for an accident in such situations but it is usually true that the same accident would have occurred to some other equally competent individual at some other point in time when the same contributing factors came together. In those cases human error may be to blame for the accident but not invariably the human that is present at the time. The root cause of many accidents is often a latent error inherent in the design that was not discovered until a certain series of circumstances contrived to cause the accident.

3.2 What methods of assessing human factors are available?

Many of the methods of assessing human factors in the workplace and designing the associated behaviour-based correction measures appear to be very similar in how they are implemented. Some methods only refer to the likelihood of human error while others are specifically centred on promoting safety culture.

3.2.1 TESEO

Technica Empirica Stima Errori Operati (TESEO) is a method that assigns values to five key factors of an activity as listed below.

- Type of activity
- Temporary stress factor (routine activities)
- Operator qualities
- Activity anxiety factor
- Activity ergonomic factor

This method is described by Wong (2002) as a simplistic method of assessing the likelihood of human error applicable to control room operators.

Values are provided in a table for assigning to each factor based on the type of activity being carried out. When all factors have been assigned a value the overall probability of human failure can be estimated by multiplying all factors together.

3.2.2 Behaviour Based Safety (BBS)

As described by Agnew and Snyder (2008) this is a method of assessing the presence of unsafe behaviours and implementing corrective measures to prevent them occurring in future. The corrective measures are the consequences of the behaviour; generally negative for unsafe behaviours. Behaviours are observed and recorded, often by using small purpose-designed checklists, and are reinforced immediately by the observer. Positive reinforcement occurs when a person is observed to be doing the right thing and negative reinforcement is provided when unsafe behaviours are observed. Safe behaviour associated with a small task or sub-task can be encouraged and positively reinforced by an action (behaviour) as simple as a thumbs up signal from a distance between colleagues while unsafe behaviour may result in a thumbs down. Both types of observation would be formally recorded and eventually included in the site behavioural safety statistics. Potentially serious unsafe behaviours can be stopped immediately by anyone. Authorised intervention is therefore a key requirement of the operation of this method of reducing risk. All personnel must feel empowered to be able to intervene for the right reasons and they should be encouraged to do so.

The method relies on encouraging people to think about safety in all that they do and to encourage the desired behaviours in colleagues to the extent that they become habits, i.e. to make safe behaviour the behaviour of choice with little or no thought given to doing the task in any way other than with the desired safe behaviour.

The BBS method of implementing human factors assessment and correction relies on activities being observed and good behaviour being positively reinforced immediately by the observer and negative behaviour being prevented or stopped from occurring in future by applying undesirable consequences such as a reprimand or having a safety discussion about what standard of safety is required and how that wasn't achieved. The system is therefore based on continuous observation and feedback in which workers are involved in the observations and are continuously discussing with each other how to encourage safe behaviours and discourage unsafe behaviours. The system works best when all levels of staff actively participate in the administration of the system and if several key behaviours are selected for people to concentrate on such as applying safe methods of lifting objects, wearing PPE, keeping to pedestrian walkways, etc. Once a particular behaviour has been assessed as becoming a habit, through auditing (no observed non-conformances for a certain period of time), it can be removed from the watch list and new behaviours introduced. These events can be treated as a reason for a more significant positive reinforcement such as an extra reward for each worker. This could be as simple as an extra tea break, a free cake at the works canteen, an early finish on the last day of the week, etc. Agnew and Snyder state that the rewards work best when the whole team is involved in the enjoyment of the reward, i.e. a team building opportunity.

Workers are actively encouraged to assist in the administration of the system by selecting behaviours to be monitored and the targets to be achieved. By doing so everyone has a sense of ownership and everyone has the opportunity to make a difference. This means that the method is an inclusive system from shop floor to management with none of the traditional barriers such as the "them and us" attitude.

Observation records created are anonymous and they can be carried out by shop floor workers observing senior staff and vice-versa. People are not expected to specifically stop their task to go off and do some observing but are expected to do this while carrying out their normal tasks. A simple tally record of what was observed and where is sufficient so that analysis can be carried out by the system administrator when all records have been assessed and counted.

Such a system fundamentally requires good working relationships to be in place for it to work effectively. People need to be able to listen to each other without taking offence when some negative reinforcement is given and to use such events as learning opportunities. Companies with industrial disputes or poor relationships between management and shop floor are unlikely to realise real benefits from such a system as it is founded on trust and co-operation between management and shop floor.

This type of system is clearly designed to improve overall safety by reducing risk in those activities known to present high risk. Through persistent observation and feedback (reinforcement) a better safety culture is developed.

Reason (1997) describes a good safety culture as something that "emerges gradually from the persistent and successful application of practical and down-to-earth measures." and that "Acquiring a safety culture is a process of collective learning, like any other." Reason (1997) also asserts "It is made up of a number of interactive elements, or ways of doing, thinking and managing that have enhanced safety health as their natural by-product." What Reason describes here is a way of working and operating a business that inherently includes and promotes safe behaviour at all levels of the company as part of normal operation. Every positive action carried out adds to the overall safety culture of the business and every negative action carried out is a learning opportunity (provided it is observed and correctly reinforced) and also assists in reducing risk. His definition describes the process detailed by Agnew and Snyder (2008).

Reason (1997) highlights the importance of the business to be honest in reporting all accidents and near misses in order to obtain realistic data that can be used to reduce risk in the long term. He identifies four key elements of a safety culture as listed below:

- Reporting culture
- Just culture
- Flexible culture
- Learning culture

These four elements come together as a safety culture. In order to achieve a good safety culture all four elements must be in place. Reason asserts that the business activities can be engineered in order to ensure that the four elements are adequately addressed.

Reporting must be encouraged to a high degree. Reason asserts that humans are not good at owning up to errors and that the number of accidents and near misses reported will always be less than the actual number of incidents that occurred. BBS attempts to get around this by ensuring that all filed reports are anonymous which serves to remove any accusations of a blame culture being present by recording only the number of safe and unsafe observations and no personal data. The trust that such a reporting system develops is essential in order to maximise the number of near misses recorded. It is debatable whether human nature would allow for this level of reporting to be achieved if there was no evidence (or consequences) of an accident or near miss occurring. It is likely that the individual involved will learn from the experience without necessarily passing on the potential learning to others.

A just culture is described as a culture that does not offer total immunity to people who blatantly carry out unsafe acts (violations) but serves to ensure that such acts are discouraged by ensuring that appropriate and immediate action is taken to rectify the situation and to prevent recurrence.

A flexible culture is engineered by the careful assessment of peak demands and normal demands on the workforce and by implementing suitable controls to be able to respond at peak times. The whole system must be arranged such that it can cope with changes through flexible, tried and tested (but safe) operating methods.

Every organisation must be able to learn from its incidents and accidents. If it is incapable of doing so then near misses and accidents will continue to occur at a higher than acceptable frequency.

The four elements noted by Reason (1997) require people who are willing to co-operate in building a better culture. It is clear that if people are unwilling to participate in this co-operation then they may not be suitable for a business operating such methods. The safety culture is only as good as its weakest person and if that person does not show any willingness to comply then it would be in the best interests of the business if that person was not present. This is one of the most difficult aspects of human factors as it requires total dedication from all employees for it to be most effective.

Many methods of assessing human factors rely on carrying out a safety culture survey of the workforce (as carried out in this project). These systems rely on the returned data to highlight any particular aspects of the operation that personnel feel unhappy about and that require to be addressed if safety culture is to be improved. The methods of doing so vary between different systems but all essentially require changes in behaviour to be implemented. In some cases more antecedent measures will be appropriate, while in others it may be preferable to reinforce behaviour by ensuring that the consequences of behaviours are used as a means of promoting the correct behaviours.

Of all the literature read as part of this project there does not appear to be an assessment system that would enable small to medium sized enterprises to assess human factors (or safety culture) using in house personnel. The aim of this research project was to fill this gap by provision of a safety culture survey assessment tool that would highlight potential safety culture issues thereby enabling SMEs to develop suitable corrective measures whether they be antecedents or consequence-based to reduce risk.

3.2.3 Human Error Assessment and Reduction Technique (HEART)

The HEART method of human error prediction serves to assess the likely failure rates of humans to do the right thing when required. The system was developed in 1985 but is still valid and being taught today. It is a relatively technical method of estimating the likelihood of human error for the type of activity being carried out (and under what conditions). The method serves to calculate the probability of the human to complete the task without error.

As with the TESEO method, several factors are taken into account to calculate the overall value of probability. The system takes account of error-producing conditions (EPCs) (their relevance and number of EPCs present), and the generic task type. Over 800 academic papers were examined by Williams in order to assimilate information on human reliability and error rates and these were used to create the HEART system of analysis. The assessment system defines the values to be used for each type of task and EPC present.

Reason (1997) also references an assessment system proposed by Williams (1997) that estimates the probability of a violation being committed. The violation-producing condition factor (VPC) is derived from a table of potential VPCs (as repeated in Table 3.1 below). It is interesting to note that a factor exists specifically for male operatives. This is because the data used to create the table of values shows that males are more likely to violate safety rules and procedures than females.

By identifying the most likely causes of human-related failure for any activity it is possible to concentrate corrective resources on those high risk aspects. As a result of the technical aspects of the method it would not be easily applied in all small to medium sized enterprises without adequate training and experience.

Table 3.1: *Williams' Violation-Producing Conditions*

Violation-Producing Condition	**Factor**
Perceived low likelihood of detection	x 10
Inconvenience	x 7
Apparent authority or status to violate, disregard, or override advice, requests, procedures or instructions	x 3
Copying behaviour	x 2.1
No disapproving authority figure present	x 2
Perceived requirement to obey 'authority figure'	x 1.8
Gender (males)	x 1.4
Group pressure (per each individual encouraging deviation / violation: maximum 5)	x 1.07

3.2.4 Technique for Human Error Rate Prediction (THERP)

THERP was created primarily for the US nuclear industry but can be applied to any high-risk, safety-critical processes (Whittingham, 2004). It is based on the error rates for specific tasks on equipment present in the 1960's and 1970's. It can be argued therefore that the intrinsic data within the system may now be out of date given the vast changes to control room equipment that have occurred since that time, i.e. from panel mounted three-term process controllers to modern computerised distributed control systems but the system is still in use.

3.2.5 Fault Tree Analysis / Event Tree Analysis

This is a method of assessing the sequence of events that can lead to an accident occurring. At each stage of the assessment the likelihood of success or failure of that element can be calculated and the overall likelihood of failure or success can be assigned a value (probability). Event trees are good for visually displaying the routes / decisions to failure.

3.2.6 Keil Centre Accident Investigation Human Factors Assessment

Lardner and Scaife (2006) identify methods of human factors analysis in accident investigations to determine what behaviours may have contributed to the accident occurring. The method enables the investigator to define those behaviours and to assist in designing changes to the process, procedures or activities to prevent recurrence in the future. They describe how the ABC method (Komaki et al., 2000) was used to analyse intentional behaviours while for unintentional behaviours, human error analysis (HEA) was used. In the human error assessment system four key factors are analysed; perception, memory, decision and action. These are the four elements that a human carries out for any cognitive action or decision process. The paper acknowledges that the method could also be developed into a proactive system of accident prevention. The method is not conducive to being implemented within SMEs using in-house personnel.

3.2.7 Health and Safety Laboratory: Safety Culture Tool

The Health and Safety Laboratory (HSL) has recently created a Safety Climate Tool (SCT) that enables companies to assess the safety culture within the workplace. It is also based on an employee survey and uses a series of forty multiple choice statements with a Likert scale of answers. The statements are spread over eight different topics.

The tool is relatively complex in how it operates and is a standalone application. The graphical functions of this package are excellent and many varied graphs can be produced to represent the data collected during the survey. The review of the tool reveals that perhaps an element of information overload may be present and picking out the most important and salient aspects of the analysis may be time consuming and difficult for a layman. In comparison to the assessment tool created in this research project, it has less than half the number of statements and does not actually provide an overall safety culture rating that can be compared to previous surveys or other departments. The data necessary for this is available but not in a form that makes it easy for the assessor to find quickly or easily.

The depth of questioning in the HSL SCT is less than that within the assessment tool created in this project as a result of there being fewer statements. The additional analysis using "quality factors" within the assessment tool produced in this research project provide added weight and depth of analysis of the surveys individually and as a group from each survey. The tool created by this research project is therefore deemed to be more user friendly than the HSL SCT. The SCT presently has much more graphing capability but this too could be built into the tool created as part of this project as it is implemented using a spreadsheet with excellent graphing capabilities.

3.2.8 HSE CRR430/2002

This document, written by the Keil Centre (M Fleming and R Lardner) and commissioned by the UK Health and Safety Executive describes the ABC method of implementation as described previously. Figure 3.1 below shows the implementation of a behavioural safety programme using the ABC process as described therein.

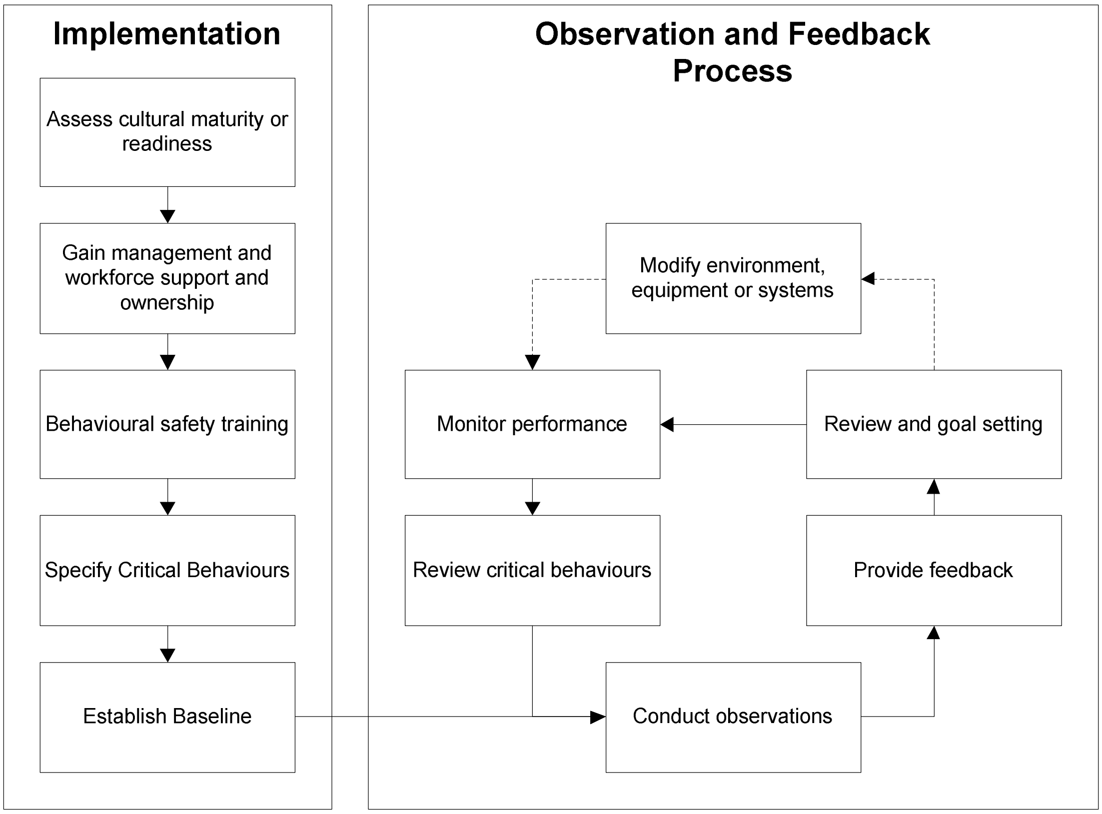

Figure 3.1: *ABC Implementation*

Carrying out a baseline survey of safety culture of the company is important as it determines how well an ABC (or BBS) system of risk reduction is likely to be received and implemented. If appropriate attitudes and safety culture are already present then it will be much easier to get all personnel to participate in the ABC system. If there are any significant issues of distrust or industrial disputes between management and frontline personnel then it will be much more difficult to implement.

3.3 Why do people make mistakes and violate safety rules?

Reason (1990) asserts that there are three types of human error as noted below:

- Skill-based slips and lapses
- Rule-based mistakes
- Knowledge-based mistakes

The skill-bases slips and lapses occur when the immediate actions carried out deviate from the intended actions due to execution or storage failures, i.e. the task is simply not carried out correctly or certain aspects of the task (or parts of it) were forgotten.

Mistakes are defined as those errors that occur when the plans and procedures are carried out correctly but, as a result of the plans and procedures containing inherent faults, a deviation from the expected outcome occurs.

Skill-based slips and rule-based mistakes occur as a result of the person carrying out the tasks with inadequate attention, precision or cognisance of the rules and procedures to be followed. They can be modelled using a feed-forward mechanism, i.e. the means to prevent errors are detailed prior to the task commencing based on sufficient knowledge and experience being present when the task was appraised.

The knowledge-based mistakes can be modelled using only feedback mechanisms, i.e. such mistakes are error-driven and may be embedded within any task at the stage when people with inadequate information, experience, competence and knowledge have detailed how such a task is to be carried out. Only when some future activity is in progress and the intended outcome is not achieved will the mistake become evident, thereby providing more knowledge and the ability to implement corrective measures.

A "Generic Error-Modelling System" is proposed by Reason (1990) (as shown in Figure 3.2 of the printed version of this thesis).

Figure removed due to publisher copyright assertion.

Figure 3.2: *Generic Error-Modelling System*

The generic error model commences at the start of the task and finishes at the successful completion of the task and includes all three types of error and mistake that can be addressed while the task is on-going. The model depends on the person recognising that there is actually a problem (within the rule-based level) and then carrying out subsequent corrective measures (or attempted measures). It can be seen from the model that the actions of solving a problem are divided into two areas: those that precede the detection of the problem (skill-based errors) and those that follow it (rule-based and knowledge-based mistakes). The model shows that the first decision after detection is to ascertain if the problem is familiar and to consider the application of previously attempted solutions to the current problem. Reason (1990) asserts that this is a normal human trait to seek out familiarity and patterns before contemplating a move to the knowledge based level of problem solving, even though this may be where the root cause of the problem is to be found.

Masked problems such as those associated with knowledge-based mistakes may be present long before a task commences but are only detected when the problem manifests itself in some form while the task is being carried out.

Reason (1990) lists the types of error that can occur at each performance level: slips and lapses, rule-based mistakes and knowledge based errors (as noted in Figure 3.3 of the printed version of this thesis).

Figure removed due to publisher copyright assertion.

Figure 3.3: *Performance Level Failure Modes*

Reason (1990) provides a detailed explanation of the different types of errors and mistakes (not included in this version of the thesis as a result of publisher copyright assertion).

Flin, O'Connor & Crichton (2008) state that human errors are caused by deficiencies in either technical skills (as defined for slips and lapses by Reason (1990)) or non-technical skills. These non-technical skills are defined as the "cognitive, social and personal resource skills that complement technical skills, and contribute to safe and efficient task performance." They cite seven key skills that are discussed throughout their book as noted below:

- Situation awareness (slips, lapses, rule-based)
- Decision-making (rule-based, knowledge-based)
- Communication (rule-based, knowledge-based)
- Teamwork (rule-based, knowledge-based)
- Leadership (rule-based, knowledge-based)
- Managing stress (slips, lapses, knowledge-based)
- Coping with fatigue (slips, lapses, knowledge-based)

Formal training can now be provided to assist people in improving these skill sets. Previously, in the aviation sector, these aspects of pilot training were not covered formally but were instead taught and handed down by existing incumbents as part of the hands-on practical training process (similar to an apprenticeship). It can be seen that non-technical skills errors can also be attributed to the three error types described by Reason (1990) and as added in brackets above.

The authors state that their findings are derived mainly from the aviation industry but that the same non-technical skill set is applicable to all safety-related tasks within any industry. Deficiencies in any of the skills listed above can lead to an error occurring. It is noted by the authors that a workplace employing assessment of such skill sets to minimise the risk of human error occurring should also have other measures in place such as procedures, training, physical protection measures, etc., i.e. the antecedent measures. They also acknowledge that the working environment, organisational demands and behaviours of others can also have an effect on the overall safety of any situation as a result of the influence on the people involved.

Reason (2008) asserts that the main cause of all human errors is under-specification. Violations are described as “deliberate but non-malevolent deviations from safety procedures, rules and regulations.” Sometimes violations are implemented through a formal process of approval such as operating outside the normal procedures or operating envelope but with alternative safety measures in place. The other type of violation refers to those occasions where personnel do not have such formal approval and where alternative safety measures have neither been examined nor implemented. Small violations are carried out frequently at the skill-based level of activity and the tasks are completed more often than not with a successful outcome. This is unfortunate because, as described in the ABC system of assessment, such an outcome (or reward) is likely to promote the same behaviour in the future thereby increasing future exposure to risk if violations do not result in a negative reinforcement (or punishment) (Reason, 2008). Minor changes to the task conditions may result in a much less desirable outcome due to the workplace environment, task timing, simultaneous operations, etc. It is stated that the violators choose to violate for three main reasons: illusion of control, illusion of invulnerability and the illusion of superiority (Reason, 2008). "Habitual violators feel powerful and overestimate the extent to which they can govern the outcome of a risky situation." Violators also "underestimate the chances that their rule-breaking will lead to adverse consequences." Violators have a sense of "being more skilled" than everyone else. When people carry out violations they do not do so with the intent of causing harm to anyone or any company: they simply weigh up the likely outcomes and decide using their own judgement and previous experience of similar situations whether to follow procedures or not. As stated above, any previous positive reinforcement of violations will tend to encourage similar behaviour in the future. A common factor with people violating procedures and rules is that the procedures are inadequate. In such cases people will violate the procedures in order to get the job done (unless prevented from doing so by a rigorous system of discouraging such behaviour). It is stated that managers must be able to determine the appropriate level of rule-based procedures in order to ensure that frontline workers still have the required degree of "intelligent wariness necessary to recognise inappropriate procedures and avoid mispliances" (Reason, 2008). In other words, violations are still not acceptable and should not be carried out but if the need arises to highlight such issues then the workers can be trusted to identify them as they occur and to propose options for rectification and approval by management.

Whittingham (2004) asserts that "most violations have an underlying cause." and that "unless this cause is properly addressed it is probable that future violations will occur." Whittingham defines an error as "an unintended or unknowing act or omission with the potential for an undesired consequence." while violations are defined as an act where "there was some level of intention in violating the rule." and also that "there was prior knowledge of the rule being violated." There is a clear difference of intent between errors and violations even though the consequences of both may be exactly the same. As stated previously, violators (as a general rule) do not intend to cause harm to anyone by violating a procedure or safety rule but this is sometimes what happens because of the violator's failure to fully assess the possible consequences of their actions. In any business, a violation may result in severe consequences for the violator such as termination of employment while an error is likely to result in the erroneous person being retrained or mentored in order for them (and the business) to learn from the error and to prevent recurrence.

Reason (1990) provides similar definitions for violations and uses intentionality to classify each type. If there was no intention to commit the violation then it can be classified as erroneous or unintentional. If it was deliberate then it is stated to be necessary to determine if there was an intention to cause damage to the system or harm to people (sabotage). The violations that remain make up the majority, intended to some extent but with no intended malice. Reason classifies all such violations as "routine" or "exceptional". Routine violations occur on a habitual basis due to humans "taking the path of least effort" and operating in an "indifferent environment, i.e. one that rarely punishes violations or rewards observance."

3.4 Methods Available to Prevent Mistakes and Violations?

Agnew and Snyder (2008) confirm that errors and violations can be prevented by implementing behaviour-based systems of control where all errors or violations are dealt with swiftly by provision of continuous monitoring and feedback. The system is focussed more on positively reinforcing good (safe) behaviours but for violations this feedback can also include punishment. The authors describe the difference between punishment and penalty: punishment is when a person receives something they would rather not have; such as a reprimand and a penalty is when a person loses something they would rather have kept, such as freedom to operate autonomously. Both are valid means of correcting behaviour but the punishment method is more likely to produce a more positive outcome than a penalty. Deploying penalties by removing privileges from workers never goes down well under any circumstances and may lead to resentment and perhaps even distrust. This scenario would not be conducive to creating a good safety culture. A punishment such as a safety discussion (or reprimand) to highlight the error and discuss its potential consequences is an opportunity for a swift rectification of the unsafe behaviour and a means of ensuring that it is not repeated. If delivered in a positive and professional way with no resentment on a personal level then it is an effective method to rectify the problem and build a better safety culture. It is noted by Agnew and Snyder (2008) that punishment can only be used if the unsafe act is actually observed first hand and that it must be delivered immediately to be effective. Agnew and Snyder (2008) note several issues with punishment and penalties as listed below:

- Effectiveness is often temporary unless the punishment is immediate, certain and severe.
- It is not certain what type of behaviour will replace the unsafe behaviour.
- Punishment is useless with lone workers.
- Overuse leads to negative side effects.

It would appear then that punishment should only be used if absolutely necessary and that perhaps this would fit more reasonably with violations rather than errors. It is also clear that punishment is not an effective tool for preventing unsafe behaviours as it can only be used after unsafe behaviours have occurred, i.e. it is a lagging control measure rather than a leading control measure or reactive rather than pro-active. Positively reinforcing good behaviours that prevent accidents and near misses is much better.

It is the author's experience within multi-national and SME businesses that safety discussions and mentoring have a far greater effect than receiving a punishment, i.e. as recommended by Agnew and Snyder (2008). It is also the author's experience that the vast majority of people want to work safely for all the right reasons and are happy to discuss safety if and when it is appropriate to their tasks or roles. Intentional violations are rare in most workplaces and therefore punishments are not ordinarily required to be handed out on a frequent basis. Agnew and Snyder (2008) recommend that positive means of promoting safe behaviours are far more desirable than negative means of reinforcement. This involves determining why the person had the opportunity to make a bad choice and by implementing changes to the workplace or its antecedent measures to remove that situation for the future.

Torner (2008) asserts that behavioural-based safety programs should concentrate on changing the behaviour of managers primarily as they have the most influence on how work is carried out. Any behaviour change by managers tends to be replicated by the subordinates due to copying behaviour which means that what managers do has a much stronger impact on subordinates than what they say.

Whittingham (2004) asserts that control of violations is relatively straightforward once the nature of the violation has been assessed. The root causes for its occurrence must be determined and then rectified through redesign of the workplace systems causing the violation to occur. In the absence of any measures to completely remove the conditions giving rise to the violations occurring then rectification may be down to the implementation of procedures, rules and training along with workforce self-governance (Whittingham, 2004). Supervisory auditing processes must be in place but they cannot (for reasons of practicality) be present for the whole time. The setting of rules and procedures establishes the minimum corporate safety performance requirements and clearly demonstrates the requirements of workers to perform their tasks safely.

For the correction of errors Whittingham (2004) asserts that three conditions must be met: the error must be detectable, recoverable and there must be time and opportunity to effect the recovery. Errors at this stage of the process have already occurred and only mitigation is possible, i.e. minimising the scale of effects of the error.

Reason & Hobbs (2003) state that the first priority of addressing human error is to capture all the available data in terms of near misses and “free lessons” as well as actual accidents. From this data, reliable predictions and trends can be formed. To get this data (and the potential benefits) the whole workforce must be prepared to submit truthful accounts of all such incidents. This is where the BBS method proposed by Agnew and Snyder (2008) can achieve this as all such data is anonymous thereby ensuring that no person can be singled out for punishment from the data alone. In an accident or near miss situation where there are no witnesses it may be argued that reporting may not occur as desired. A good safety culture must be present (with trust) and the system must be convenient to use in practice for all such incidents to be reported.

Reason (1997) asserts that human errors are not the cause of accidents but are consequences that lead to accidents. Errors are "shaped and provoked by upstream workplace and organizational factors." Reason describes a blame cycle that is self-perpetuating and destructive unless a significant effort to break free from the cycle is made. Reason (1997) asserts that several key facts must be understood to achieve this primarily associated with error causation / root cause.

List of four key facts removed due to publisher copyright assertion.

As a result of the difficulties in addressing all potential human failings it is postulated by Reason (1997) that situational issues are easier to remedy than people issues for several reasons.

List of reasons removed due to publisher copyright assertion.

There are various methods of error prevention available and these can be directed at either the human or the situation in which the human is placed. The actual complexity of the situation may make it an obvious choice on where best to direct error prevention resources. However, in the absence of an obvious choice between the two, the error prevention / risk reduction measures must be applied taking cognisance of the human and situational conditions present. This may involve a combination of human error assessment techniques, application of rules and procedures, physical protection measures, training, etc.

The texts reviewed show that consequence-based prevention methods have the greatest potential for removing error producing conditions in terms of attempting to ensure that humans make the right choices for the right reasons.

3.5 How Do Ethical Values Affect Safety Culture?

A corporate body must have a clear system of ethical values in place in order to set minimum standards for the employees to align themselves to. As the ethical values of individuals may be different from that of the company, it is necessary for all people within a business or organisation to have a clear understanding of what is acceptable to the business and what is not. Whitbeck (1998) asserts that such measures only set "the minimal standards for ethical practice." These minimal standards can assist in "distinguishing malpractice from acceptable practice but are not much help in differentiating good or responsible practice from minimally acceptable practice." In a technically challenging field such as engineering it is clear that such minimal standards must be complemented by the ethical values of the people and the businesses for which engineers provide professional services. Ethics therefore need to be applied at the personal and the corporate level and should be set such that the health and safety of all who may be affected by the engineering decision-making process are kept safe from harm.

Fleddermann (2008) asserts "No duty of the engineer is more important than her duty to protect the safety and well-being of the public." Engineers are required to design safe systems and objects. One of the issues facing an engineer is the question "How safe is safe enough?" Safety is described by Fleddermann as a "very precise and a very vague term" as it requires to be measured to determine what level of safety has been achieved but also, at face value, it needs to be determined simply whether a design is safe or not safe. Subjective decision making in such assessments are susceptible to the ethics of the people and corporate bodies involved. Fleddermann cites four requirements for an engineer to work safely as noted below:

- a design must comply with the local laws and regulations for safety;
- it must meet accepted engineering practice;
- alternative, safer designs must be explored;
- potential misuse must be examined to determine failure modes expected under those conditions.

The ethical values of the engineer's decision-making process are built into the design by consideration of the safety of the design throughout the design, building and testing of the product or system.

Nijhof and Rietijk (1999) state that we should think of "ethical decision making as the central "Behaviour" and explore all factors in the meaning of "Antecedents" and "Consequences". They provide an example of where a company implements an improved packaging line in a manufacturing plant.

The line was unreliable and adversely affected production. A new line was designed and installed but this had a severe effect on the workforce. They no longer needed to work a five-shift system (meaning a reduction in salary for those affected) and the new packaging line needed less than half the previous number of personnel. The decision to install the new line was taken based on business needs, i.e. the line was installed and personnel no longer required were compensated accordingly. The business need is far more important in such cases as this is why the business exists. It does not exist to provide employment but exists to support the business activities in the generation of revenue for the minimum costs possible. The authors postulate that carrying out an ABC analysis of the situation can assist in the ethical decision-making process.

Robinson et al. (2007) describe the ethical relationships that must be present between engineers and the people or groups who may be affected by the engineer's work such as employers, the public and professional bodies. They state that the virtues of an ethically aware engineer are "temperance, justice, courage, hope, respect, integrity, wisdom and empathy". An engineer must therefore be aware of the world around them and be able to translate the effects of their work into that arena. It is clear that for an engineer to be ethically aware and effective, their employer must also be aware of and be in agreement with the ethical values required (or desired) and must be willing to support those values as part of its business model. Any conflicts between engineer and employer are likely to end in disagreement and ultimately relationship breakdown as a result of the engineer being forced to operate under ethical values they consider to be lower than their own. This would not be conducive to building a good safety culture and would instead build barriers and distrust.

Dekker (2007) describes the ethics of reporting near misses and incidents. He asserts that it is essential for all such events to be reported and analysed if the organisation is to learn from the events and prevent recurrence. If a person fails to report such events they have allowed their ethical values to slip to such an extent that self-preservation has become more important than the protection of those who may be at risk if a similar event were to occur again at some future time.

Dekker asserts that reporting might be a risk to the reporter for the reasons listed below:

- Fear of supervisor/manager response.
- Uncertainty of the rights and obligations of the reporter.
- Will the information reported stay confidential (including the reporter's identity)?

Dekker (2007) asserts that people fail to report near misses and potential accidents because of the fear of the consequences and not because they want to be or are actually dishonest. People can become apathetic when they feel that even if they did report an incident that the employer would do little or nothing in response. Such feelings can only come from a history of similar experiences with the employer. This would not be a good safety culture that promotes learning and continuous improvements to safety but would instead be a culture that shows little care, respect and empathy for its own employees. It is clear from such ethical dilemmas that procedures and policies must be in place (antecedents) that specify what the reporting process entails and what employees can expect from the employer in return for honest and frank reporting. Punishment may be an option for such a process but the most important and overriding factor is that the risk is eliminated or reduced to a tolerable level. The setting of personal and corporate ethical values are essential if a trusting relationship between employee and employer is to be nurtured for the benefit of risk reduction. As described by Agnew & Snyder (2008), anonymous reporting is clearly a workable method of removing the blame factor from the reporting process and hence, a high degree of analysis and accident prevention is the potential result. Dekker (2007) asserts that feedback from the reports to the relevant people on what was reported and what has been changed as a result of the reports helps to build trust and shows that the reporting process is worthwhile and merits continuation and support. As stated by Agnew & Snyder (2008), when people see the consequences of the safe behaviour such as positive reinforcement they are encouraged to promote that behaviour in the future.

Dekker (2007) discusses the options for a theoretical line to be drawn between "acceptable and unacceptable behaviour." This imaginary line signifies the difference between being culpable or innocent in any situation that arises. The difference between the two sides is the difference between the types of error that causes the accident, i.e. errors or violations. In all such situations errors are described as normative or technical. Normative errors include negligence, violations, etc. while technical errors occur as a consequence of a person's inadequate training, knowledge and experience, i.e. competence.

Part of the ethical considerations of an engineer must be an awareness at all times of whether they are operating beyond their own competence or capabilities. All such fears must be formally highlighted to their managers if they are to remain on the lawful side of this imaginary line.

Buara (2006) recommends that technical competence is considered for all activities carried out by an engineer. If an engineer feels that their expertise is not sufficient for the task then they should acknowledge this as a means of protecting the public or client from the potential effects of errors. There can be few actions more positive than an engineer taking such a stand as it means that they have placed the safety of others before their own interests.

Armstrong, Dixon & Robinson (1999) discuss the responsibilities of an engineer stating that they must "take responsibility for ethical dilemmas and work through the ethical decision-making process – avoiding any denial of responsibility."

It can be seen that ethical decisions and dilemmas faced by engineers can be complex and often conflicting between safety and other corporate factors. Engineers therefore have the ability to protect people from harm by ensuring that risks are properly assessed and rectified as appropriate based on their personal and corporate ethical values.

3.6 Literature Review Conclusion

None of the literature examined has described how the results of a safety culture survey can be interpreted. This interpretation is one of the most important aspects of any such risk reduction methods if small to medium sized enterprises are to implement them using in-house personnel.

The methods of defining antecedents, behaviours and consequences are relatively straightforward within a business and as soon as people commence working with the ABC method risk can be reduced immediately when that organisational intervention takes place but successful implementation relies on the first stage of the process (the safety culture survey) being completed with a high degree of assurance that it is actually correct and representative. Any misinterpretation of survey results could lead to costly errors in terms of incorrectly addressing non-issues (encysting) or; much worse, by not addressing a latent issue that later turns out to be a contributing factor to an accident where someone is hurt (thematic vagabonding). The safety culture survey presents a significant quantity of data that can be used to identify many things in terms of all the different aspects of safety culture within any business but, most importantly, it should be able to identify those major causes of concern within the workforce that can be assigned a higher priority for corrective action.

4.0 RESEARCH METHODOLOGY

4.1 General

The purpose of this research project was to create a means of assessing the safety culture of businesses such that a uniform system of human factors assessment and implementation could be carried out by small to medium sized enterprises in-house. The assistance of collaborating partners was therefore critically important to the overall success of the project.

Most of the identified potential collaborating companies were chosen as a result of the nature of the hazards present on their sites, i.e. they use or produce materials and substances with the potential for gas, vapour and dust cloud explosions to occur. Such hazards present a real and measurable threat to the safety of people and manufacturing / production processes. The list of potential collaborators was created based on the author's experience of those companies through existing professional relationships.

4.1.1 Collaborator Participation

Companies were approached to determine whether they would be interested in taking part in the research project and a presentation was made to those companies that were potentially interested and wanted to hear more about what would be involved (as detailed in Appendix A). The presentation showed the background to the research, what was expected to be gained from participating and how the research programme might benefit their companies in their own long term strategy for risk reduction and prevention of accidents and incidents that have the potential to cause harm to people, the environment and company's profitability.

4.1.2 Project Methodology

The research project involved assessing the safety culture of each collaborating company in a logical step by step process as listed below.

1. Carry out a baseline survey of the workforce
2. Analyse results to highlight potential human factors issues
3. Present results to collaborating companies and decide on particular aspects to be targeted as part of the risk reduction process
4. Company implements corrective measures and monitors performance against targets

5. Carry out final safety culture survey
6. Analyse results to establish what improvements have been achieved

The corrective measures implemented at stage 4 of the process are critically important to the success of the application of human factors as a means of risk reduction. The application of human factors in the workplace is centred on identifying risks created by potentially unsafe behaviours or situations and implementing methods of ensuring that those behaviours and situations are corrected, preferably by changing the way people think or alternatively by implementing antecedents to prevent or discourage unsafe behaviours.

4.2 Safety Culture Survey

The method of assessing a company's safety culture was to carry out an employee multiple choice safety culture survey.

The statements in the survey were formed from several donor assessment surveys. They were derived from the reference documents RR365, HSE (1999), OTR 1999/063, HSE (2001), and the Gap Analysis Tool, Step Change in Safety (2007). Statements were also inserted by the author based on empirical findings from working with SMEs for over eight years. Once the master list of statements was finalised the statements were analysed and categorised into nine topics listed below based on the subject content and intent of each statement. This sub-division of statements allowed each topic to be assessed as a group for comparison and analysis.

The survey topics are entitled:

- Safety Culture;
- Organisational Measures;
- Incident Management
- Competence Management;
- Influencing Factors;
- My Role;
- My Manager;
- Communications;
- The Organisation.

The survey was laid out in a multiple choice Likert scale format and required respondents to tick the box that represented their feelings of the subject that they were being questioned about. The answer choices were: strongly agree; agree; neither agree nor disagree; disagree and strongly disagree.

The RR365 source for survey statements did not have a Likert scale type of response. This document and the described method of carrying out the employee safety culture survey is based on open questioning of respondents requiring the interviewer to record the responses. The statements were therefore manipulated in order to make them suitable for use with a Likert 5-point scale.

The statements derived from the OTR 1999/063 reference document were predominantly from donor surveys also made up using Likert five-point scale responses. Reliability data of the donor statements was not available but it is stated within the document that the original questionnaires had been properly validated by their creators. Reliability analysis of the survey created for this research project has been carried out and is reported in section 5.

The Gap Analysis Toolkit document used a three-point Likert-type scale with Yes / No / Part responses. The statements were also manipulated in order to make them suitable for use with a Likert 5-point scale.

The Likert scale of answers used in the survey appears to be simple but it presents a few issues in terms of the middle value (neither agree nor disagree). This value may be selected by a respondent wishing to express an actual indifferent response but selection of the middle value may also signify that the respondent simply may not have understood the statement in the first place. This type of survey response can therefore mask issues that may be present if the meaning of the survey statements has not been made clear enough. Throughout this document the middle value is defined as an "indifferent" response.

As the questionnaire created for this research project combines statements from several independently validated questionnaires along with new statements not previously subjected to validation, it was necessary to also validate this questionnaire using inferential statistical methods. This is discussed further in sections 5.0, 7.0 and 9.0.

The front sheet of the survey provided instructions for the respondents to explain how the survey should be completed. All surveys were filled in anonymously and the company for which they worked was not shown anywhere on the survey documentation. Completed surveys were logged by the company letter designation (A, B, C, etc.) in the lower left corner of the survey.

Emphasis was placed on answering the survey “carefully and frankly”. The instructions also stated that completing the survey should take around 15 to 20 minutes thereby implying that the respondents should not spend too much time thinking about the answers as it was their first impressions and immediate perception of their own feelings of what answer fits best that was to be recorded.

Some of the statements in the survey are present specifically to estimate whether a respondent’s answers can be trusted to a high degree. Although all statements appear to have subjective answers, the subject matter is asked in such a way that for certain statements within the survey, there can only be one correct way to answer the statement by virtue of the systems and processes known to be in place within the company. The evidence of the correct answers to these statements is to be found within the company’s health and safety management system and this can be easily substantiated. These statements should provide unequivocal results as they are so obvious, i.e. either 100% agreement or 100% disagreement. The results of these statements are discussed in more detail in the analysis of each company’s results.

The intent of each statement is described in appendix B.

4.3 Research Study Partners

The author has carried out work in a professional capacity for most of the companies detailed below. This was predominantly consultancy work associated with the health and safety aspects of operating safely in workplaces containing potentially explosive atmospheres. The work carried out for these companies provided an intimate insight into the safety management systems and business activities of the companies involved and thereby assisted in determining whether the companies would be suitable and likely to take part in the research project.

The one thing that all the identified potential collaborators had in common was that they all had significant (life threatening) hazards in their workplaces.

Agnew & Snyder (2008) believe that every workplace can benefit from the application of behavioural based safety as a means of improving safety culture and thereby reducing risk but it has been shown by this project that not every business is receptive to such methods.

Such behavioural based safety systems (BBS) operate by considering the antecedents, behaviours and consequences (ABC) in the workplace. The method is reliant on the workplace implementing antecedents that the workers must comply with. These are the rules, procedures and physical aspects and objects of the workplace that the workers interface with. Behaviours are what people do in response to the workplace situations and antecedents. After the behaviour has taken place the consequences become apparent and they can be good or bad. It has been shown that people learn quickly from consequences, especially bad ones.

Taking human factors into consideration is not an antecedent type of measure but is a behavioural measure, i.e. it seeks to improve safety by encouraging people to think safer and to perform their tasks in a safer or better way. While some businesses strive to reduce accident rates and accident severity through continuous improvement it is also the case that other businesses are satisfied to implement only the antecedent measures such as procedures, rules, training, etc. and are content with the residual baseline accident rate that is produced as a result of implementing only those measures. The antecedent measures are essentially the minimum required in accordance with the health and safety legislation in place. Whilst there are formal requirements to reduce risk to as low as reasonably practicable (ALARP) this is a subjective term and the views and opinions of the business health and safety manager and the regulator may differ significantly. Whilst the antecedents can be considered as the legal requirements, other measures such as implementing consequence based behavioural safety methods (i.e. human factors) are optional. The ethics of managers, resources available, production deadlines and financial constraints of each business are all significant factors that have a bearing on whether a business is likely to attempt an implementation of such methods.

A dominant factor of whether a company would participate in such research has been found to be the attitude of the senior manager responsible for health and safety management. It has been found, as noted below, that some managers were keen to get involved because of the potential benefits while others seemed to be keen to participate because they were being offered something for free but without first giving any thought of assessing the resources required.

With the knowledge of the hazards and activities associated with each business and a good working relationship with the management personnel of those businesses a basic assessment of each company was carried out to determine whether human factors could be successfully applied in the business and to determine whether a formal approach to the business was likely to result in their agreement to participate.

As a result of client confidentiality the companies involved are simply referred to as Company A, Company B, etc. throughout this thesis.

4.4 Large Businesses

Several multi-national companies were contacted regarding collaboration in this research project. These were not the intended benefactors of the intended outcome of this research project but they were approached to take part. The companies all have hazards within their workplaces that can give rise to major accidents such as fires and explosions.

Such companies invariably have large budgets for ensuring that health and safety is given adequate priority within the business and they have come to learn that the provision of a safe place of work where employees are valued can also pay dividends in terms of production, employee absence rates, employee morale, business development and overall business continuity. Even though such large businesses are currently operating in an increasingly tight regime of budgetary controls, they usually have the funds available to implement safety improvement methods such as human factors and safety culture analysis.

Of the list of potentially suitable collaborators, ten companies were in this classification but only two companies agreed to take part. This was somewhat disappointing given the hazards associated with those businesses, the number of employees involved and the overall level of professionalism in terms of health and safety compliance previously observed.

It was an assumption of the author that the data gathered from such large companies would still be useful for the development of a human factors assessment system that could be used in smaller companies.

4.5 Small Businesses

Small businesses with similar hazards and risk as the larger companies were also contacted to take part in this research project. It was with these companies in mind that this research project was initiated. Unlike the multi-nationals, these companies do not have vast numbers of safety professionals or the budgets with which to implement such methods with the aid of human factors experts. Such companies have limited budgets and resources and must make every penny of revenue count towards the bottom line.

Of the list of suitable businesses identified, eight companies were classified as small and were contacted to take part in this research programme: with low success, i.e. none of the companies approached participated in the research.

4.6 Non-Transportation Companies

4.6.1 Company A (Large Business)

When first approached regarding collaboration in this research project, this company was positive from the start. Such an assessment of safety culture attitudes and perception of safety culture was seen as a means of gauging the status of the health and safety management system of the business and also the attitudes and views of their employees towards the business. As the survey was to be reviewed and assessed by someone independent from the company it was felt by their HSE manager that it would be more likely to get an honest response from the employees than an in-house survey.

Company A is a company that manufactures petroleum dispensers for use in garage forecourts throughout the world. Although it is a multi-national company with many different departments and business streams, only a specific section of the dispenser manufacturing plant took part in the research: the paint shop department, where a significant quantity of flammable and potentially explosive materials are in use at all times. Flammable dust hazards are also present within the department. All of these hazards require employees to strictly follow compliance with explosion prevention measures at all times. A small societal risk is also present as the main flammable materials storage area is in a locked container located outside the manufacturing plant.

The department contains approximately 20 employees in a two-shift system. Activities such as spray painting (solvent based), powder coating and screen printing are carried out on a continuous basis.

The company issued the survey for employees to fill in (results as detailed in Appendix B). The survey responses were entered (and double checked) into an assessment system based on a spreadsheet created specifically for this project.

4.6.2 Company B (Small Business)

Company B was a small business with around 15 employees. The company specialised in the manufacture and maintenance of hydraulic systems used throughout industry. The company had a particular expertise in serving businesses involved in explosives manufacture. They also provided a systems integration service which is the design, creation and implementation of human / machine interfaces using programmable logic controllers (PLCs) coupled to supervisory control and data acquisition (SCADA) systems. This company clearly fitted the main collaborator selection criteria.

Initially, the business owner was keen to get his company involved but, as a result of the recession and other business factors, this company soon withdrew from the research project. It later transpired that the vast majority of its employees had left en masse leaving the owner to fulfil existing contracts almost single-handedly.

Analysis of this situation was not carried out but it would appear that such a mass exodus of employees would suggest that either a better offer for the employees came in from elsewhere or that there was something fundamentally wrong with the operation of the business that the employees were not satisfied with. Human factors assessment may have been able to identify such risks prior to the situation developing but unfortunately it came too late for this business to take part.

4.6.3 Company C (Large Business)

Company C is another multi-national business. They manufacture silicon wafers for use in the semiconductor manufacturing industry. As found with Company A, this company was keen to get involved as soon as they heard about the project.

They wanted to take part for similar reasons to Company A, i.e. to gauge the present situation in terms of safety culture and to determine if they could do anything better. They also felt that as it was a survey being carried out independently they would be more likely to get a better response from the workforce than from a similar in-house survey.

The company identified three different departments that they wanted to take part in the research project. Each department is considered as an autonomous business unit within the site and in terms of the number of employees in each they could be defined as small businesses within the overall company structure. The health and safety management system is common to all three departments but its implementation is variable in each area as a result of how each department manager operates their area.

The three departments are, slicing (C1), polishing (C2) and facilities management (C3).

The facilities management team are responsible for all ancillary systems around the plant. This includes the process gas storage and distribution systems, building ventilation systems, gas detection systems. The process gases used in wafer manufacture are potentially explosive (hydrogen) and some are also pyrophoric (silane). With the pyrophoric gases it is almost inevitable that ignition will occur on release to the atmosphere. These hazards show how important the management of safety is within the plant as errors could lead to catastrophic events.

The quantity of materials stored and used at the site means that the business is a registered COMAH site, i.e. it has fundamental safety requirements imposed upon it by the HSE to ensure safety is maintained, not only for their own benefit but also for the people and the environment beyond the plant perimeter: the societal risk.

The slicing team are responsible for cutting the raw silicon blocks into wafers using specialist machines. There are approximately 30 people working in this area. Many of the tasks in this area are automated but still require a degree of machine supervision to ensure that the process runs smoothly. The process fluid hazards within this part of the manufacturing process are not as dangerous as the other parts of the plant but the machines are capable of causing severe injury to personnel from entrapment and entanglement. It is important for this part of the manufacturing process to be run efficiently for the plant to be successful. Any hold ups in production in this part of the process affects all subsequent processes.

The polishing area takes the rough cut silicon wafers and flattens then polishes them in special machines to specified tolerances measured in nanometres. There are approximately 45 people working in this area. Similar hazards to the slicing area are present (machinery safety) and a similar level of automation is fitted to the machines.

4.6.4 Company D (Small business)

Company D is involved in the provision of asset management services to companies all over the UK. They have around 10 employees and provide and configure software for client maintenance management systems. They also provide consultancy services in workplaces containing potentially explosive atmospheres. It is necessary for some of the workers in the company to carry out client site visits and many of their clients have major accident hazards present. Working safely is therefore a critical requirement for its employees.

This company were positive when approached and agreed to collaborate but later withdrew as the managing director felt that human factors assessment “was not applicable and he couldn’t see the long term benefit” to it. Given the potential risk to employees whilst on client sites, this was a surprising attitude. This was discussed with the MD and following these discussions it is the author’s opinion that he did not fully understand the benefits to his business but perhaps, more worryingly, didn’t realise or understand the risks that his employees were subjected to whilst carrying out site survey work. There was no acceptance by the MD that human factors could be applied to the whole business as a means of improving efficiency, safety culture and behavioural safety throughout the workforce. This is an attitude that has been encountered frequently during the course of this research project.

4.6.5 Company E (Large Business)

Company E is a company heavily involved in supplying field personnel to the North Sea oil industry. They are also involved in the supply of industrial procurement services throughout the whole of the UK. They have several offices and employ approximately 200 people (around half of which are directly involved in the North Sea activities).

Field personnel are predominantly skilled to technician level and are responsible for oil rig equipment inspection and maintenance activities. In such situations they are clearly operating in workplaces with potentially high risk.

When this company was approached to take part in the research it was positive and expressed a willingness to do so, however, they never actually did.

Their employees are usually embedded within the workforce of other companies (rig operators) and are required to follow all their procedures and work methods. It is clear that such personnel may not be able take part in the research as a result of those working arrangements. The practicalities of taking part were therefore deemed to be too difficult (by the company) to be overcome.

4.6.6 Company F (Large Business)

Company F is a multi-national company that provides engineering, procurement and construction (EPC) services. In the UK this is primarily in the water industry (clean and waste). This company were positive when first approached but were not responsive thereafter. They have since lost out on some major contracts and have downsized considerably as a result of this and the overall cessation of public spending on the water infrastructure system.

Since being approached this company has developed its own behavioural safety improvement system.

The timing of this research project was not ideal for this company and they therefore declined to take any further part in the project.

4.6.7 Company G (Small Business)

Company G is a company that provides services similar to that of Company E but on a smaller scale. They have approximately 40 employees operating mainly in land-based workplaces containing major accident hazards. Their work involves equipment installation work as well as maintenance and inspection.

This company agreed to take part in the research but showed no further interest once they got a better understanding of what was going to be involved in terms of resource and time. Despite repeated attempts to convince them of the potential benefits they declined any further involvement.

4.6.8 Company H (Small Business)

Company H is an aerosol manufacturing company that agreed to take part following discussions and having seen the presentation of the project. The company employed approximately 60 people at the time of approach. The safety culture survey was duly issued but no returns were forthcoming. When queried on this they failed to respond. When the presentation was made (in their premises) they expressed their desire to take part but also utilised the time on site to discuss some other consultancy services at the same time. This was provided as requested. Repeated efforts to contact the business to ascertain collaboration status failed to get a response.

Approximately one year later, long after their participation had been written off by the author, the company made contact once again to enquire about taking part in the research. A meeting was arranged to discuss this (on an urgent basis at their request) at which it soon became obvious that the company was not interested in the research and had merely used the HF project as an excuse to procure the author's professional opinion on several serious and fundamentally dangerous plant issues that posed a potential threat to the business at that time. Following the meeting, despite repeated attempts to clarify the situation with respect to the research project collaboration status, no further communications were received.

It is disappointing that the business did not eventually take part as the survey results may have provided an excellent case study in corporate competence, ethics and working relationships between management, shop floor and external bodies.

It was clear during the last site visit that the recently promoted health and safety manager was also still carrying out his previous role and was clearly in a position that required more time than was available. Senior management had put this person in a position of responsibility and for which there simply was not enough time to carry out the task properly (or safely). There are many human factors issues in play here that would benefit from a realistic appraisal of the actual risk involved.

It was made known that a visit by the HSE was about to take place and that the company was desirous of ensuring that everything was in order in terms of potentially explosive atmospheres legislation. This assurance could not be given and would not be possible until some major changes to the organisation and the processing equipment were made. In order to ensure the safety of workers and the public it was recommended that the new production line be shut down and all identified issues rectified prior to re-commissioning.

No further communications have been received from the company. The situation described simply would not occur in an organisation that had a good safety culture. Equipment would not be commissioned until it was proven to be safe for operation. People would be trained in its operation and essential safety equipment would not have been removed because “it didn’t work correctly” but would have been rectified to ensure that a safe situation was maintained. This type and size of business is exactly the type of business that should be taking part in such research programmes in order to determine how new methods of risk reduction could benefit the business by providing a safer place of work. There are clearly some fundamental issues regarding personnel selection that the senior management probably knew about but opted to continue in the hope that everything would be ok. Hope is not something that safety should be founded on.

4.6.9 Company I (Small Business)

Company I is a company employing approximately 30 people. They are a whisky bottling company. The health and safety manager expressed a desire to take part in the research but, like the others described above, decided not to proceed after she had been issued with the survey.

4.6.10 Company J (Small Business)

Company J is a small business with approximately 15 employees. The company manufactures machines and conveyance systems for manufacturing plants all over the world. They also provide systems integration services by designing and constructing PLC control systems. When first approached to take part in the research they expressed some interest but eventually decided not to participate.

4.6.11 Company K (Large Business)

Company K is a specialist printing company manufacturing and printing high quality packaging items such as those used for cigarettes and chocolates. The business employs approximately 250 people in this location. The business also operates similar plants all over the world. The printing inks used in the process at this plant are solvent based, thereby presenting an explosion risk in many of the printing processes carried out. When first approached to take part in the research this company also expressed an interest in participating but they but they opted not to do so in the end.

4.6.12 Company M (Large Business)

This is a multi-national pharmaceutical company with a vast number of personnel operating throughout the world. The factory approached to take part in the research has an employee count of approximately 300. The factory contains significant explosive, toxic and chemical hazards. Meetings were held with the HSE manager responsible for the site and they agreed to take part in the collaboration as it fitted in with their policy of continuous improvement. After several meetings a schedule was agreed and the survey was officially issued to the business. At this point the company decided that it would no longer like to participate in the project. Other than resourcing issues, no reason was given for the sudden withdrawal and despite efforts to reverse the decision this was the end of their collaboration.

4.6.13 Company N (Small Business)

This is a company that makes high specification acrylic baths. The processes used at the manufacturing plant use potentially explosive chemicals (including potentially unstable oxidising agents). The hazards are well understood by the plant personnel and good systems of control and monitoring are in place within the factory. The company employs approximately 80 people and they agreed to take part in the research firstly to get a better understanding of where they thought they were in terms of safety culture and secondly because they would receive this work free of charge. On agreeing to participate and then receiving the survey the company withdrew without formally giving a reason. Whilst the operations director of the company saw the potential benefits, it would appear that the other directors did not agree and the employee survey never took place.

4.6.14 Company O (Large Business)

This is a multi-national company and employs approximately 80 people in the location approached. The company manufactures refractory components made from carbon fibre in a highly specialised and potentially dangerous process. The hazards on site are numerous and include the potential for dust explosions, chlorine gas releases, natural gas explosions, waste gas explosions, solvent based paint spraying, high temperatures (> 1000℃), toxic and corrosive chemicals and asphyxiant gases.

It can be seen that without adequate controls in place this workplace would present a significant risk to employees within the factory and also to those people beyond its perimeter.

The business has professionally qualified health, safety and engineering personnel and holds several quality accreditation certificates including those for product quality and environmental management.

There was evidence (which became clear whilst engaged to carry out previous professional consultancy work) that some of the processes carried out on site were not fully understood by all personnel affected. These processes were potentially hazardous and had caused near misses previously. Root cause analysis had been carried out but this did not lead to any significant learning within the current workforce. The personnel that knew and understood the processes had moved on to other employment.

When approached about taking part in the research project the managers responsible for health, safety and engineering within the business agreed to collaborate. When they sought approval from the board of the business it was also agreed that the company would collaborate but with a major caveat: all surveys would have to be handed out not by the company but directly by the author and that all such administration concerning data collection and employee information would also be carried out by the author.

Given the shift working systems employed within the factory (making data collection extremely difficult) and the complete lack of involvement of the business on the part of explaining to employees what the survey is about and why it should be filled in it was decided by the author that these conditions would make data collection very difficult and unreliable given the geographical location of the factory. The conditions imposed suggest that the follow up work would also receive little support from the business. It appeared that the business expected a magic wand to be waved in order to define and correct any issues identified. From this it was clear that this business would not be a suitable collaborator and no further participation was sought.

4.6.15 Company Q (Large Business)

This company manufactures lithographic plates used in printing processes. The process involves the use of a large quantity of solvents and other dangerous chemicals. Approximately 300 people are employed within the factory.

When approached, the Engineering Manager and Health and Safety Manager of the company agreed to participate in principle but had to seek approval from the board. A presentation of the research project was subsequently made to the board and when permission to participate had later been approved it came with similar conditions to those applied by Company O. They wanted only a few people from their workforce to participate (to be selected by them) and they would not fill in survey forms but would be interviewed by the author in the presence of a senior company representative. This was clearly not an open process that could be used to estimate the overall safety culture of the business. Negotiations with the company to remove those conditions were unsuccessful and the company would not agree to carry out the employee survey as first proposed.

As described with Company O above, the survey is only the start of the human factors assessment process and it was difficult to see how this company could achieve real benefits from such methods when they were unwilling to have a full workforce survey carried out to establish baseline safety culture. It appeared that the company executives were either afraid of what the survey might reveal (to the author and more importantly to themselves) or that they didn't want to see this information formally recorded.

Given the likely outcome of such an assessment process under those restrictive conditions the author opted not to progress collaboration with this company any further.

4.6.16 Company R (Small Business)

Company R employs approximately 110 people. They operate a fuel oil depot that contains bulk fuel oil and LPG tanks. They also operate their own fleet of fuel tankers that deliver fuel to client premises (commercial and domestic). The effects of an explosion occurring at the depot would be potentially catastrophic. All personnel at the company receive formal training in ignition prevention measures. The fuel tanker drivers are provided with formal training and must pass the course exams in order to be certified as competent for operating fuel tankers.

This company was keen to participate in the research project but on carrying out a trial survey with a small number of their employees they found that the employees had too many questions of their own regarding the meaning of some of the statements. The managing director and the operations manager estimated the likely outcome of the survey by their own experience and by the responses from their own small survey and decided not to proceed with participation as they felt that the administration of issuing the surveys, collating responses and answering queries from employees would be too much of a burden on their resources.

The company's operations are already highly regulated by antecedents such as training and procedures and the company has an excellent safety record in terms of driver safety and road crash statistics. The senior management of the business did not therefore believe there to be significant value to the business from collaboration as a result of the long history of no major accidents and there being no obvious significant safety issues that required to be addressed.

4.7 Transportation Companies

It was an aspiration of the author that this research project would include several public transportation companies as a means of identifying how human factors methods of risk reduction could be applied to public transportation systems. Attempts were made to encourage some of these companies to take part but it quickly became evident that they would not be doing so. None of the transportation companies approached were previous clients of the author which made meeting the correct people within the organisations difficult and almost impossible to build a trusting relationship with them.

Several options for seeking out collaboration companies in the transportation sector were examined. Mail shots to all bus and train operating companies was considered but, given the low rate of success with such communications and not having a guarantee of the letter arriving on the decision maker's desk, it was decided to make a targeted approach to specific companies. Two multinational public transportation companies were contacted both of which have headquarters in Scotland.

4.7.1 Company L (Large Business)

Company L operates public transportation systems throughout the world and they employ more than 130,000 staff. This company put forward their HQ HSE manager directly to discuss collaboration.

This company was easy to contact and to make arrangements with to discuss the project in terms of what collaboration would mean for them. A presentation and meeting was held at their headquarters and they agreed to take part in the project. It was agreed that all personnel in their local office and bus depot would take part and that other depots could also be approached and take part if they so desired. Shortly afterwards, it became clear that this company, though positive at first, seemed to have lost all interest and took no further part in the research project.

Despite numerous attempts to ascertain what the status of their collaboration was they did not respond to any further requests for meetings and discussions.

It was noted (from national media) that the company was going through a phase of industrial action such as work to rule, overtime bans, etc. as part of the unionised collective bargaining process. In such a climate of uncertainty and distrust between employees and management, it is debatable whether an employee survey of safety culture within that depot would have given a true and realistic indication of safety culture.

4.7.2 Company P (Large Business)

This company preferred to refer all enquiries regarding health and safety to their communications branch. The director responsible for health and safety was named in the company's annual report but it was found to be impossible to contact him directly. After many phone calls, waiting on hold, failed call transfers and subsequent referrals to other people or offices throughout the organisation, it became clear that this company had no intention of speaking to anyone outside the group with respect to health and safety performance or assessing the safety culture of the business.

It would be unfair to say that this company is not interested in promoting health and safety as the subject receives considerable coverage in the group annual report and also in its marketing of the business. Some of its most important key performance indicators are founded on the safety of its passengers and its employees. It was found to be impossible to actually reach the decision maker within the business that would authorise or even discuss participation in the project.

Collaboration with transportation companies was therefore not progressed any further.

4.8 Collaborator Participation Issues

It can be seen from the examples detailed that the research has been hindered by the continuous problem of collaborator recruitment and subsequent withdrawal. Not one single company that agreed to participate and then subsequently withdrew explained in definitive terms why they did not want to continue. This was somewhat disappointing as the author had built up good working relationships with those companies (and continues to do so).

At one point, it was beginning to look like the survey may be at fault for scaring off potential collaborators. Although none of the companies ever admitted this, it is the author's belief that the probing and detailed nature of some of the statements may have been the cause of the companies to withdraw from the research having previously agreed to take part. If this is the true reason then it suggests that the companies were not in a position of strong leadership and were unwilling to face up to the true opinions of the workforce in terms of safety culture within the organisation. It would appear that, even if they thought they knew what the real situation was, they did not want to see it written down in black and white. Such an attitude is not one of a business with a mature safety culture but is one that is still developing (or perhaps even stagnant) with little scope for improvement until the attitudes of those in overall control are changed. These companies are relying on the old way of doing things, i.e. implementing and monitoring antecedents but doing little to change behaviours or assessing and using the potential consequences of unsafe behaviours as a means of reducing risk.

It is interesting to note that all collaborators were pleased to state that they would take part when they were first approached about the research project. It was clear from the discussions with each company that they all had a broadly similar view to the research and that was that anything that could potentially improve safety by reducing risk must be a good thing. It is feasible that the most likely reason for their withdrawal was the realisation that human factors assessment and implementation in the workplace was not a magic fix-all method that could be implemented instantaneously with little or no resource but that it was a method of risk reduction that requires a considerable degree of resource and dogged determination to implement and maintain in order to achieve the potential benefits. Those benefits are achieved through changing people's behaviour and this is a process that can take a considerable period of time and resource to achieve. The most important factor in the application of such methods is that the senior management must be willing to invest the time and resources required to achieve measurable results.

The application of human factors ultimately involves changing the way things are done in order to remove or modify poor behavioural safety practices and to implement good behavioural safety practices in their place. This is the difficult part of applying human factors assessment methods of risk reduction and it is the author's view that this realisation was the primary reason for the majority of the businesses withdrawing from the research project.

5.0 SAFETY CULTURE SURVEY ASSESSMENT TOOL

The aim of this research project was to produce a human factors assessment system that could be used by non-specialists to assess the safety culture of their own workplaces. This information would then be used to prioritise those aspects that scored lowest with a view to implementing corrective measures as a means of reducing risk.

A safety culture survey was created (as described in section 4) to assess the workplace safety culture and to detect potential human factors issues present.

An assessment tool was created specifically for the purpose of analysing the responses from the safety culture surveys filled in by the participating companies' employees. The tool was created using spreadsheet software and is unique to the survey statements (as shown in Appendix B).

It was a requirement to ensure that the majority of the safety culture survey analysis was incorporated into the assessment tool to enable non-experts to use it even though they may have little knowledge of human factors assessment or behavioural safety assessment systems.

The tool provides no assistance to companies in determining how those low-scoring aspects of the safety culture survey can be modified or improved. This can only be carried out with further detailed analysis of the business and its activities. The output of the safety culture assessment tool is therefore only the start of the process of identifying potential HF issues as a risk reduction measure.

5.1 Assessment Tool Response Values

The survey uses a Likert scale of answers for each of the statements. The assessment of the returned surveys is substantially automated by the tool by transposing each response on the Likert scale to a numerical value.

The values used for the responses are shown in Table 5.1 below. Each response is assigned a primary value from 1 to 5 (or blank). This is then converted to a secondary value depending on whether the statement should have a positive or negative response to show a good safety culture. The secondary value ranges between 0 and 1.0 with intermediate values of 0.1, 0.25, 0.5 and 0.75. Blank responses receive a secondary value of 0.

In the table below, and hereafter, statements requiring an agreeable response for a good safety culture are designated as positive statements and those requiring a disagreeable response for a good safety culture are designated as negative statements.

Table 5.1: *Survey Response Values*

Response	**Primary Value**	**Secondary Values**	
		Positive statement	Negative statement
Strongly agree	1	1.00	0.10
Agree	2	0.75	0.25
Neither agree nor disagree	3	0.50	0.50
Disagree	4	0.25	0.75
Strongly disagree	5	0.10	1.00
No response		0.0	0.0

Two example statements from the safety culture survey are listed below to show how the statement scoring system functions.

Table 5.2: *Example Statement Response Scoring*

	Strongly Agree (1)	Agree (2)	Neither agree nor disagree (3)	Disagree (4)	Strongly disagree (5)
1. Permit forms and procedures are clear, unambiguous and easy to use.	✓				
2. The Permit to work system is a way of covering people's backs.				✓	

In statement 1 the “strongly agree” tick box is assigned a primary value of “1”. In this case it is a strong favourable response and is therefore assigned a secondary value of 1.0 (as shown in Table 5.1). Had a “strongly disagree” response been selected then the primary value would have been “5” and the secondary value assigned would have been 0.1 (unfavourable).

In statement 2 the “disagree” tick box is assigned a primary value of “4”. This is a negative statement and a disagree response is favourable. As it is not a strong response it only merits a value of 0.75. Had the agree tick box been selected the primary value would have been "2" and the secondary value would have been 0.25.

5.2 Assessment Tool Quality Factors

The twenty three quality factors listed below are used to highlight any particular aspects of the safety culture survey that require further investigation. The values returned by these factors are not definitive responses to each statement but are a measure of the consistency of the answers provided by each respondent on each aspect of the safety culture survey. The quality factors are not therefore intended to be a measure of the reliability of the survey tool but are a measure of the quality of the responses from each respondent.

In a similar way to the nine topics derived for the 98 statements the quality factors were derived by examining methods of assessing the quality of each survey. The creation of the quality factors was an empirical process, i.e. they were derived by manually examining the returned responses to detect any potential issues and to determine how those issues may be enumerated. With further analysis there are likely to be more elements of the responses that could be used to determine the quality of each response.

In anticipation of foreseeable issues and the need to evaluate the quality of each response, most of the quality factors were created after the main statement master list had been finalised. Some of the quality factors were created only after the participating companies returned their baseline surveys when it became apparent that there were some potential issues that needed to be addressed that had not been foreseen. The factors falling into this category were "number of indifferent responses", "motivation", "training", "strongly disagree/strongly agree ratio" and "consecutive 3s". A description of the intent and calculation of each factor is provided below.

Each quality factor is assigned a maximum value of 10 based on the number of positive and negative responses for each factor's set of statements. The twenty three quality factor values are summated to give an overall rating with a maximum value of 230. The arithmetic mean of these values is calculated and is used in the creation of a value representing the overall safety culture.

The quality factors are calculated for each respondent. The average of all quality factors is used in the overall assessment of safety culture.

5.2.1 Survey Response Quality

A basic quality measurement of each returned survey is determined by examining the responses to S35, S38 and S87. Based on the knowledge of the health and safety management systems of the companies that participated these are all statements that should return a very high number of agree or strongly agree responses as it could be shown by the companies that the measures described by these statements are in place and strictly adhered to. Any survey returned that did not have such a response to all three statements may require further analysis in terms of the reliability of the answers to the other statements.

The statements used for this quality factor may be changed to suit the company taking part in the survey. These statements can be selected from any section within the survey; the only criteria being that they should guarantee a positive and unequivocal response.

Each response is allocated a secondary value as shown in Table 5.3 below.

Table 5.3: *Survey Quality*

Response	Quality Factor
All strongly agree	10
All agree	6
Some agree	3, 2
All neither agree nor disagree	1
Some disagree	0.5

To show the scoring system by way of example, assume a person has responded “strongly agree” to S35 & S38 but has provided an indifferent response to S87. The scoring for this situation would be as follows:

S35 and S38 would have been assigned secondary values of 1.0 (maximum) while S87 would only have been assigned a secondary value of 0.5. The total score would therefore be 2.5. For this quality factor, a score of 3 is required to receive a maximum quality rating of “10” (three statements in this quality factor). The “all agree” score of “6” is achieved when all respondents answer favourably, i.e. secondary values of 0.75 for each statement with a total score of 2.25. The formula in the assessment tool assigns a quality factor value of "6" if a score of greater than 2.24 is achieved. The next lowest scores of "3" and "2" are achieved if one or more of the statements are answered with a less than favourable response. If all statements are answered indifferently (total score of 1.5) then the secondary value assigned will be 1.0. The tool assigns a value of 1.0 for scores greater than 1.49. The tool assigns a value of 0.5 for any total scores lower than 1.5.

The analysis of the three statements is achieved by way of "IF" statements examining the total score of the summation of the secondary values assigned for each statement. The "IF" formula for this quality factor is shown below.

```
=IF(S35+S38+S87=3,10,IF(S35+S38+S87>2.24,6,IF(S35+S38+S87>1.99,3,IF(S35+S38+S87>1.74,2,IF(S35+S38+S87>1.49,1,IF(S35+S38+S87<1.5,0.5,0.5))))))
```

Other quality factors in the tool have a greater number of statements associated with them but the scoring system remains the same, i.e. all strongly agree, all agree, etc. are assigned as shown in the associated tables. The numerical values in the formula change depending on the number of statements being examined.

5.2.2 Survey Thoroughness

This factor is based on the number of statements answered in the returned responses Table 5.4 below shows the values allocated. A total of 101 responses are required from each respondent (including the base data on the front page of the survey.

Table 5.4: *Survey Thoroughness*

Response	**Quality Factor**
> 96 statements answered	10
> 94 statements answered	6
> 92 statements answered	3
> 90 statements answered	2
> 88 statements answered	1
< 88 statements answered	0.5

5.2.3 Negative Response Statements (Disagrees)

A number of statements throughout the survey require a negative response to signify that the safety culture is good. This quality measurement is an estimate of how willing people are to actually select the strongly disagree box, even when it is the correct thing to do (i.e. a positive response in the presence of a good safety culture). Statements 13, 14, 20, 26, 29, 30, 37, 50, 51, 53, 59, 76, 84 and 98 are used for the assessment of this value. Table 5.5 below shows the values allocated.

Table 5.5: *Negative Responses Quality Factor Allocation*

Response	Quality Factor
All strongly disagree	10
All disagree	6
Some disagree	3, 2
All neither agree nor disagree	1
Some agree	0.5

5.2.4 Blame Culture

Three statements (S4, S22 and S23) within the survey specifically seek to determine whether a blame culture is perceived to be present. The allocation of values is as shown in Table 5.6 below.

Table 5.6: *Blame Culture Quality Factor Value Allocation*

Response	Quality Factor
All strongly agree	10
All agree	6
Some agree	3, 2
All neither agree nor disagree	1
Some disagree	0.5

These values apply to all factors except where specifically noted otherwise.

5.2.5 Colleague Trust

An estimate of the trust in terms of safety compliance and performance that people place in their colleagues is measured by five statements (S7, S8, S59, S63 and S65). Statement 59 is a negative statement and may have a negative impact on this factor if people are minded not to select the disagree responses.

5.2.6 Intervention

The willingness of people to intervene when unsafe behaviours occur or when they feel they have ideas on how to improve safety within the workplace is estimated using this factor. The answers to S3, S9 and S80 are examined to estimate the level of intervention displayed by each respondent.

5.2.7 Communications

Several statements throughout the survey refer to the communications processes within the workplace. This factor determines a score based on the consistency of answers to statements related to bi-directional communications between management and shop floor. Statements 28, 70, 75, 77, 78, 79, 81, 82, 83, 84, 86 and 87 are all examined to calculate this factor.

5.2.8 Incident Management

The response to incidents is a measure of the safety culture of an organisation. In a company with a good safety culture the response will be positive and will concentrate on determining root cause as a means of eliminating future occurrences. The process will feedback the information to affected personnel as a means of ensuring learning points have been adequately addressed. In a poor safety culture (with blame being a prominent factor in any investigation) such learning and future recurrence is unlikely to occur to any significant degree. This factor uses the answers to statements 21, 23, 25, 28 and 32.

5.2.9 Competence

The response to statements 34, 35, 36, 41, 64 and 65 are used to determine the respondents' perception of how their company deals with personnel and corporate competence requirements within the business.

5.2.10 Roles and Responsibilities

The response to statements 34, 37, 40, 42 and 67 are used to determine the respondents' perception of how their company ensures that personnel are aware of their individual and corporate roles and responsibilities. This factor contains one negative statement (S37).

5.2.11 Safety Culture

The perceived safety culture of the company is estimated based on the answers to statements 2, 6, 45, 47, 68, 72, 76, 88, 89, 90, 92, 93 and 94. As there are so many statements in this quality factor the potential effects of each negative response will have a lesser effect on the overall score achieved than for factors with fewer statements.

5.2.12 Organisational Measures

The response to statements 11, 12, 16, 17, 48 and 52 are used to determine the respondents' perception of the organisational measures related to safety within the business.

5.2.13 Employee Empowerment

In a company with a good safety culture employees will feel empowered to intervene when they see unsafe behaviours that could result in an accident. They will also be encouraged to communicate issues and concerns to senior management and will be forthright in communicating their views and opinions on any proposed modifications to how work is carried out. The response to statements 3, 5, 8, 54, 56, and 62 are used to determine the respondents' perception of the degree of empowerment they have.

5.2.14 Procedural Awareness

In a company with a good safety culture employees will be aware of all the operational procedures relevant to their particular tasks and they will have been trained in those procedures. Refresher training will be carried out and regular site audits will confirm procedures are being applied. The response to statements 9, 11, 12, 14 and 15 are used to determine the respondents' awareness of the procedures in place.

5.2.15 Management Pressure / Stress

The level of pressure or stress imposed on the workforce is estimated by analysing the responses to statements 45, 47, 49, 50 and 51. Two of these are negative statements (S50 & S51).

5.2.16 Employee Value / Worth

The degree of value or worth felt by each respondent was estimated using the responses from statements 10, 55, 57, 72, 85, 91 and 94. Some of these statements relate to the management seeking the involvement of the shop floor workers in key management decisions and developments.

5.2.17 Safety Promotion

The company's approach to encouraging the promotion of safety is estimated by analysing the responses from statements 18, 56, 66, 69, 71, 73, 74, 80, 85, 88 and 93. A good safety culture will encourage employees to support the safety initiatives and the management to positively reinforce them in all possible situations.

5.2.18 Resources

The company's approach to the provision of adequate resources is estimated using the responses to statements 27, 46 and 96. A good safety culture will always provide enough resources to ensure the minimum level of safety is maintained. There may not always be sufficient resources for production requirements and when conflicts occur the safety of personnel should be the prime concern.

5.2.19 Number of Indifferent Responses

As described in section 4.2, an indifferent response is defined as the middle value of the Likert scale within the survey, i.e. "Neither agree nor disagree".

As a means of detecting (and possibly rejecting) poor quality surveys spoiled by a high number of indifferent responses this quality factor assesses the number of indifferent responses from each returned survey and allocates a quality value as shown in Table 5.7 below.

A high number of indifferent responses in any one survey adds very little to the overall assessment of the safety culture within a workplace other than indicating what may be an inadequate attitude on behalf of the respondent towards the safety improvement and risk reduction methods that their employer is attempting to implement. It was shown in the analysis of results that a significant number of indifferent responses did not adversely affect the overall outcome of the assessment.

Table 5.7: *Indifferent Responses*

Response	Quality Factor
Less than 10 indifferent responses	10
Less than 15 indifferent responses	6
Less than 20 indifferent responses	3
Less than 25 indifferent responses	2
Less than 30 indifferent responses	1
Less than 35 indifferent responses	0.5

A wholly indifferent response may well be a valid representation of a respondent's perception of the workplace but this is considered to be a highly unlikely and unrealistic situation given the clear statements and topics and the variety of positive and negative responses expected throughout.

In workplaces with the potential for high risks such as explosions and with a highly skilled and trained workforce a survey with a high number of indifferent responses would be disappointing and possibly even unacceptable to the employer. It is conceivable that support operatives such as cleaners, security staff, canteen workers, etc. may not have strong attitudes towards the activities carried out on the shop floor as they may have little knowledge of what hazards and activities are actually present. The base data on the front page of the survey serves to determine the job role of the respondents to take account of such situations.

An indifferent response may also be produced if respondents have been asked to complete the survey during their own time or if they were not given enough time to complete it during their normal working hours. An overbearing management style or an apathetic attitude of the respondent may be indicated by such a response under those conditions.

Indifferent responses need to be assessed on balance with the other responses taken at the same time. If such a response occurs in isolation then it will be evident that any issues present are more likely to lie with the respondent rather than with the management style or procedures.

Employers' reasons for implementing HF methods include safety performance improvements, productivity improvements and better operability of the plant and equipment through increased reliability and better (safer), more efficient maintenance methods. Less obvious reasons are also present such as teambuilding, procedures compliance, self-preservation and empathy for others' safety. An indifferent attitude to filling in the survey would indicate a respondent with a mind-set that would not be receptive to development in terms of changing the way that work activities are planned and carried out and may prevent effective implementation of such measures.

A largely indifferent response does not necessarily show that the person submitting it does not care about safety; more likely that they don't care enough. A person with such an attitude is likely to have a dampening factor on any new initiatives for risk reduction. It has to be kept in mind that the respondent may well have a wholly inadequate attitude to safety.

Any surveys that have an unacceptable number of indifferent responses are highlighted within the tool for further examination and to determine whether those results should be discarded from the analysis.

5.2.20 Employee Motivation

This factor estimates the degree of motivation within the workforce for doing things in a safe manner and for the correct reasons. The statements serve to determine what factors the employees use in their own decision making processes, i.e. production requirements, safety, perceived line manager attitudes, etc. In a good safety culture the procedures will reflect the working arrangements and short cuts and safety-related decisions should not ordinarily be required. There should be no conflicts between safety and production that shop floor operatives feel pressurised to choose between. The level of line management support in place should always be adequate for such decisions to be made by line management. Workforce motivation was estimated using the responses to statements 14, 43, 44, 50, 51, 53, 76 and 97. Four of these statements are negative statements (S50, S51, S53 & S76).

5.2.21 Training

This quality factor estimates how the respondents feel about the level and quality of training received for the tasks that they are required to carry out. The responses to statements 19, 20, 24, 33, 39, 40, 60, 61 and 87 are used to generate this quality factor. The statements relate to how training is updated following plant or procedure modifications, how people are trained in order to deal with incident investigations, how people are trained in basic risk analysis techniques, whether their training requirements are periodically reviewed and whether there is a coaching programme in place to deal with poor performers.

5.2.22 Disagree / Agree Ratio

This quality factor attempts to determine the willingness of a respondent to answer with a strongly disagree response to signify a good safety culture as well as a strongly agree response when appropriate. There are 14 negative statements and 84 positive statements. The quality factor is assigned as shown in Table 5.8 below.

Table 5.8: *Disagree / Agree Ratio*

Disagree / Agree Ratio	Quality Factor
> 0.167	10
> 0.142	6
> 0.119	3
> 0.095	2
> 0.071	1
< 0.071	0.5

5.2.23 Consecutive Indifferent Responses

The maximum number of consecutive indifferent responses is calculated for each returned survey. It is conceivable, though unlikely, that a whole section of statements may prompt an indifferent response, especially for those support personnel not directly involved with the main production areas or the business activities carried out. The trigger level for this quality factor is therefore set at 13 (the maximum number of statements in any one section) and the factor value reduces thereafter as noted in Table 5.9 below.

Table 5.9: *Consecutive Indifferent Responses*

No of Consecutive Indifferent Responses	Quality Factor
< 13	10
< 20	6
< 25	3
< 30	2
< 35	1
< 40	0.5

5.3 Survey Analysis

5.3.1 Safety Culture Assessment Value

A safety culture ranking of the company is assigned by calculating the arithmetic mean of the mean quality factors and the mean response totals from each safety culture survey carried out. The safety culture is assigned a value between 0 and 10 as shown in Table 5.10 below.

Table 5.10: *Safety Culture Value*

Safety Culture Ranking Value	Safety Culture Rating
0-2	Very poor
2-4	Poor
4-6	Average
6-8	Good
8-10	Very good

The role of each respondent is taken into consideration to ascertain if there are any significant differences between management and non-management personnel.

5.3.2 Individual Survey Total

In the assessment tool the response to each statement is assigned a primary and secondary value as shown in Table 5.1.

The secondary responses (maximum value of 1.0) are summated to provide an overall total for each respondent for the ninety-eight statements in the safety culture survey. As the number of statements in each section varies, the total for each section is normalised to a maximum value of ten. The totals from each of the nine survey sections are then summated and used as one of the factors to calculate the overall safety culture value.

The arithmetic mean of all responses for each safety culture survey carried out is calculated and assigned a ranking value as noted in Table 5.11 below.

Table 5.11: *Ranking of Survey Secondary Value Total*

Mean Response Total	Mean Total Ranking
0-20	Very poor
20-40	Poor
40-60	Average
60-80	Good
> 80	Very good

5.3.3 Maximum Summated Secondary Values Total

The maximum summated secondary values total is determined for each safety culture survey carried out to ascertain from what group of personnel the maximum value comes from (manager, technician, etc.).

5.3.4 Quality Factors Mean Value

The arithmetic mean of the summated quality factors is also used in the calculation of the overall safety culture value. The ranking of the summated quality factors value is assigned as shown in Table 5.12 below.

Table 5.12: *Mean Quality Factors*

Mean Response Total	Mean Total Ranking
0-11	Very poor
11-22	Poor
22-44	Average
44-66	Good
66-132	Very good
> 132	Excellent

5.3.5 Maximum Summated Quality Factors Total

The maximum summated total is determined to ascertain from what group of personnel the maximum value comes from. This information is useful in forming a trend with the other results available from the assessment tool to determine what group of people have the strongest perception of a good safety culture being present.

5.3.6 Determination of High Priority Issues

As a means of maximising the effect of available resources to address any potential issues identified by the assessment tool, the lowest scoring section of each returned survey is determined. This will assist the company in determining what aspects of the workplace are in need of improvement. It is acknowledged that the lowest scoring section of the safety culture survey may not actually be the most vulnerable or most likely to give rise to an accident occurring. Careful analysis of the assessment tool output is therefore necessary in order to ensure that correct decisions are made concerning corrective measures to be applied. Once a plan of action has been determined the corrective measures can be applied in the workplace in order to reduce the potential risks that may be present. These may be antecedent-type measures such as the provision of adequate equipment, rules and procedures or behaviour-based measures such as those expected to be in place with a fully trained and competent workforce.

The results of all surveys are compared and the modal and mean values are determined. The low scoring modal value is the survey section with the greatest number of lowest scores. The lowest scoring mean value is the section with lowest mean score of all sections and all surveys returned.

It is possible that the mode and mean may return different results hence why both are determined. In addition to the lowest-scoring sections the highest scoring sections are also determined.

5.3.7 Quality Factors Average Values

The mean of each of the quality factors is also calculated to provide an overall estimate of how well each factor is scored throughout the workforce. These values are then ranked from highest score to lowest score and the lowest score is determined. As stated above, identifying those factors with the lowest scores assists the company in determining where best to use available resources for the purposes of making improvements to the workplace and thereby reducing risk associated with that aspect of the assessment.

5.3.8 Maximum Individual Safety Culture Value

The maximum safety culture value from each set of surveys returned is determined to ascertain from what group of personnel the return comes from.

5.3.9 Survey Average Values

The mode and arithmetic mean is determined for each of the statements in the returned responses for each company. These 'average' values serve to ascertain what the most common response to each statement is, thereby providing an overall estimate of the workforce's perception of that aspect of the workplace. The arithmetic mean provides a measure of the strength of feeling for a statement, i.e. the higher or lower the value the stronger the feeling for that response.

The spread of responses for each statement is also calculated to provide a direct comparison of the response to each statement in the baseline and final safety culture survey results and to provide a graphical representation of the spread of results.

5.4 Safety Culture Survey Sections Reliability Analysis

Reliability analysis of the safety culture survey questionnaire has been carried out using the SPSS statistical software package. Cronbach's alpha coefficient was derived for each of the safety culture survey sections and the relevant quality factors. Dewberry (2004) states that the minimum acceptable value for the coefficient is 0.7. Pallant (2007) sates that measurement of the coefficient in scales with less than ten items may report low values of the alpha coefficient and that using the inter-item correlation values may be a better measurement of reliability; with values between 0.2 and 0.4 being acceptable. Dewberry (2004) states that a minimum value of 0.32 is required for inter-item correlation. The minimum number of items in each scale (or section) being examined in this survey questionnaire was ten. Such issues were not therefore expected.

5.4.1 Safety Culture Section (S1 to S10)

The Cronbach's alpha coefficient for the "Safety Culture" section of each of the surveys carried out is shown below. An example of the complete analysis is shown for the Company A baseline survey in Appendix F.

The values show that the series of statements in this section appear to be reliably measuring the respondent's view to safety culture within the workplace.

It can be seen that the Company C3 baseline survey returned a coefficient of 0.508 which falls below the acceptable threshold. Statements 2, 3 and 9 (if deleted) all returned higher coefficient values (0.603, 0.670 and 0.613 respectively) but still not an acceptable value. Manipulation or deletion of these statements may be required to raise the alpha coefficient to an acceptable level. However, given the high values achieved for other surveys, the low coefficient is more likely to be indicative of an issue with the low number of respondents (7) in this case.

Table 5.13: *Safety Culture Section Cronbach's Alpha Coefficient*

	Company A	Company C1	Company C2	Company C3
Baseline	0.852	0.875	0.853	0.508
Final	0.766	0.886	0.901	0.802

Factor analysis has been carried out for this section of the safety culture survey and Table 5.14 below shows which statements are associated with each identified factor. Dewberry (2004) states that the item loading on a factor is good when it is greater than 0.55. The table shows items (or statements) with loadings greater than 0.55 in **bold** type. The remaining statements with loadings of greater than 0.32 are shown in normal type.

Table 5.14: *Safety Culture Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4
Company A baseline	S1, **S2, S3**, S7, S8, **S9**	S1, S3, **S4, S6, S8**, S9	S1, S3, **S5, S7, S10**	N/A
Company A final	**S1, S4, S6, S9**	**S3, S8, S9, S10**	**S3, S5, S7,** S8	**S2**
Company C1 baseline	**S2, S3, S4, S5, S6, S8, S9**	**S1**, S4, S5, S6, S8, **S10**	S2, **S5, S7**, S10	N/A
Company C1 final	**S1, S2, S3, S5**, S6, **S7, S8, S9, S10**	S2, S3, **S4, S6,** S9, S10	N/A	N/A
Company C2 baseline	S1, S3, **S4, S5, S6, S9, S10**	S1, **S7, S8**, S9, S10	S1, **S2, S3,** S9	N/A
Company C2 final	S3, **S4, S5, S6, S7, S8,** S9, S10	**S1, S2, S3**, S6, S8, **S9, S10**	N/A	N/A

Company C3 baseline	**S1, S2, S3,** S5, **S7, S8, S10**	**S2, S5, S9**	**S4, S6**	N/A
Company C3 final	**S1**, S4, **S7, S8,** S9, **S10**	**S2, S3**, S5, S7, S8, **S9**	**S4, S5, S6,** S7	N/A

The results show that although four factors were identified they are all interlinked with statements common to each and cannot therefore be easily separated into three different constructs with completely different statements in each. When the loading values are taken into consideration it can be seen that there may be a good separation between factors as there is little duplication of highly loaded statements in each factor.

The results show that statement 2 had a significant effect on the Cronbach's alpha coefficient and there may be scope for removing this statement from the survey or rewording it to provide better, more reliable results.

Dewberry (2004) states that a minimum sample size of 300 is necessary to give "a good factor solution". This size of sample is unlikely to be achieved in SMEs. The results from factor analysis must therefore be treated with caution until the reliability of the survey tool can be proven by using a greater sample size such as with large businesses.

5.4.2 Organisational Measures Section (S11 to S20)

The Cronbach's alpha coefficient for the "Organisational Measures" section is shown in Table 5.15 below.

Table 5.15: *Organisational Measures Section Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.509	0.597	0.438	0.546
Final	0.601	0.422	0.708	0.393
Baseline S13 deleted	0.517	0.657	0.590	0.576
Baseline S20 deleted	0.698	0.602	0.648	0.468
Final S13 deleted	0.688	0.503	0.701	0.453
Final S20 deleted	0.713	0.659	0.860	0.625

The values show that the statements in this section are not reliably measuring the respondent's view to organisational arrangements within the workplace as most of the alpha coefficient values are less than 0.7. The "value if deleted" analysis shows that (for most surveys) statements 13 and 20 are adversely affecting the reliability.

An issue with statement 13 was detected when it became evident that some people did not know that the acronym PTW meant permit to work. This is likely to have adversely affected the response to this statement. An improved questionnaire would remove all such acronyms to improve clarity. Rewording (or deleting) statement 20 to a less ambiguous form is also considered to be essential.

Factor analysis has been carried out for this section of the safety culture survey and is shown in Table 5.16 below. Again, it can be seen that there are more factors identified than would be ideal.

Table 5.16: *Organisational Measures Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4
Company A baseline	**S11, S12**, S13, S15, **S16, S17**	S17, **S18, S19, S20**	**S13, S14**, S17, **S19**	S13, **S15,** S17
Company A final	S11, **S16, S17, S18, S19**, S20	**S11, S12**, S13, **S15**, S16	S12, **S13, S14, S20**	N/A
Company C1 baseline	S12, **S13, S19, S20**	S12, S13, **S14, S15,** S18	**S11, S12, S16,** S20	S13, **S17, S18**
Company C1 final	**S12, S15, S16, S17,** S19, S20	S11, S12, S15, **S16, S18, S19**, S20	S12, **S13, S14,** S20	N/A
Company C2 baseline	**S15, S16, S18, S19, S20**	**S11, S12, S13**, S16	**S14, S17,** S19, S20	N/A
Company C2 final	**S11, S12, S15, S16, S17, S18, S19, S20**	S11, **S13, S14**	N/A	N/A
Company C3 baseline	**S12, S14**, S16, **S18, S19**	**S16, S17, S19, S20**	**S11, S13**, S14, S16, S17, S19	**S15, S18**
Company C3 final	**S11, S12, S19**, S20	**S15, S17, S18, S19**, S20	**S13, S16**, S17, S18, S20	**S14**, S15, **S20**

As found in the previous section the factors identified are largely interlinked with statements common to each and cannot therefore be easily separated into different constructs.

5.4.3 Incident Management Section (S21 to S32)

The Cronbach's alpha coefficient for the "Incident Management" section for is shown in Table 5.17 below.

Table 5.17: *Incident Management Section Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.710	0.799	0.747	0.463
Final	0.440	0.598	0.844	0.664
Baseline S26 deleted	0.742	0.845	0.817	N/A
Baseline S28 deleted	0.739	0.756	0.699	0.231
Baseline S30 deleted	0.721	0.805	0.749	0.502
Baseline S31 deleted	0.747	0.798	0.764	0.595
Final S26 deleted	0.580	0.724	0.853	0.729
Final S28 deleted	0.284	0.539	0.825	0.702
Final S30 deleted	0.617	0.598	0.828	0.644
Final S31 deleted	0.450	0.667	0.907	0.650

Acceptable results in both the baseline and final surveys were achieved only with Company C2. Examination of the "value if deleted" analysis showed that statements 26, 28, 30 and 31 were having an adverse effect on the alpha coefficient. The most significant of these were statements 26 and 31.

The information referred to in statements 28 and 30 would not normally be available or known to all people within a business and these statements may therefore promote a degree of unreliability as found in the analysis. These statements could also be reworded to improve clarity. Using a statement such as "I am aware of a formal communications process being in place…" in place of "A formal communications process is in place…" may help to bring these statements more into line with the intended functionality of the section and to remove any ambiguity of the intended meaning of the statement.

Factor analysis has been carried out for this section of the safety culture survey and Table 5.18 below shows which statements are associated with each identified factor. It can be seen that there are more factors identified than would be ideal.

Table 5.18: *Incident Management Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Company A baseline	**S21, S22, S25, S27,** S31, **S32**	**S23,** S28, **S29, S30,** S31	S25, **S26, S28**, S31	**S23, S24**, S28, S31	N/A
Company A final	**S21, S22, S28,** S30, **S32**	S23, S25, **S26, S30**	**S24, S27**	**S21, S23, S29**	**S25, S31**
Company C1 baseline	**S21, S22,** S23, **S25, S27, S28,** S32	S22, **S23, S24**, S25, **S26, S29**, S32	S25, **S27,** S29, **S31,** S32	S24, **S30,** S32	N/A
Company C1 final	**S21, S22, S25,** S27, **S28, S31**	S21, **S23, S26**, S28, **S29, S30**, S31	S22, **S24,** S27, S29, **S32**	N/A	N/A
Company C2 baseline	S21, **S22, S24, S25, S27,** S30, S32	S21, S22, **S23,** S25, **S26, S28, S29,** S32	S23, S29, **S30, S31, S32**	N/A	N/A
Company C2 final	**S21, S22, S23,** S24, **S25, S27, S28,** S29, S30, S32	S23, S25, S26, S27, **S29, S30, S31**	**S24, S25, S26,** S29, S32	N/A	N/A
Company C3 baseline	N/A	N/A	N/A	N/A	N/A
Company C3 final	**S21, S22, S23,** S24, **S26, S29, S32**	S25, **S27, S28,** S29, S32	**S25,** S26, **S30,** S31	S22, **S24,** S27, **S31,** S32	

The factors identified in the analysis for this section are largely interlinked with statements common to each and cannot therefore be easily separated.

5.4.4 Competence Management Section (S33 to S42)

The Cronbach's alpha coefficient for the "Competence Management" section is shown in Table 5.19 below.

The poor result in Company C3 baseline survey has been attributed to the low number of responses (7). It was noted from the "value if deleted" analysis that statement 37 had an adverse effect on most surveys. This statement needs to be deleted or modified to be less ambiguous.

Table 5.19: *Competence Management Section Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.890	0.734	0.854	0.542
Final	0.918	0.801	0.865	0.759
Baseline S37 deleted	0.927	0.750	0.879	0.396
Final S37 deleted	0.928	0.788	0.869	0.758

Factor analysis has been carried out for this section of the safety culture survey and is shown in Table 5.20 below. It can be seen that there are more factors identified than would be ideal.

The factors identified in the analysis for this section are interlinked with statements common to each and cannot therefore be easily separated into different constructs.

Table 5.20: *Competence Management Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4
Company A baseline	**S33,** S34, **S35, S36, S37,** S39, **S40, S41,** S42	**S34,** S36, **S37, S38, S39, S42**	N/A	N/A
Company A final	S32, **S33,** S34, **S35, S36, S37,** S39, **S40, S41,** S42	**S33,** S34, S35, **S37,** S39, **S40,** S42	N/A	N/A
Company C1 baseline	**S35, S36,** S37, **S40,** S41	S33, S36, **S39,** S41	S37, **S38, S42**	**S33, S34,** S37
Company C1 final	**S33,** S36, **S37,** S38, **S40, S42**	**S34, S36, S38, S39,** S40, S42	**S35,** S36, S39, S40	**S34, S41**
Company C2 baseline	**S35, S36, S38, S39,** S40, **S41**	**S33, S34,** S35, **S36, S39, S40,** S41	**S37,** S40, **S42**	N/A
Company C2 final	**S33, S35, S36,** S37, **S39,** S40, **S41**	**S34,** S35, S36, S39, **S40,** S41	S35, **S38, S42**	N/A
Company C3 baseline	**S34, S35, S37, S38, S42**	S35, **S39, S40, S41**	**S33, S34, S36,** S39	N/A
Company C3 final	S33, **S36,** S39, **S40, S41**	S33, **S34,** S35, **S37,** S40, **S42**	S33, **S35, S37, S38,** S39, S40	N/A

5.4.5 Influencing Factors Section (S43 to S53)

The Cronbach's alpha coefficient for the "Influencing Factors" section is shown in Table 5.21 below.

Table 5.21: *Influencing Factors Section Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.917	0.926	0.869	0.593
Final	0.926	0.673	0.892	0.431

It can be seen that the Company C3 survey appears to be a poor result in comparison with the others.

The "value if deleted" analysis did not identify any significant statements common to all surveys that were having a detrimental effect on the overall result. Statement 53 in the Company C1 final survey was noted to raise the alpha coefficient value to 0.715 if deleted. Deletion or improving the clarity of this statement may therefore be an appropriate solution.

Factor analysis has been carried out for this section of the safety culture survey and is shown in Table 5.22 below.

Table 5.22: *Influencing Factors Section Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Company A baseline	**S43, S44, S45, S46, S47, S48, S49, S50, S51,** S52, S53	S48, S49, **S52, S53**	N/A	N/A	N/A
Company A final	**S43, S44, S45, S46, S47, S48, S52,** S53	S47, **S48, S50, S51, S53**	S43, **S49,** S52	N/A	N/A
Company C1 baseline	**S43, S44, S45, S46, S47, S49, S52,** S53	**S43,** S44, S45, S46, S47, **S48, S51,** S52	S44, S45, S46, S47, **S50,** S51, **S53**	N/A	N/A
Company C1 final	**S44, S45, S46, S47, S48**	**S45, S49,** S50, **S52**	**S43, S50, S51**	S50, **S51, S53**	N/A
Company C2 baseline	**S43, S44, S46, S47, S48, S49, S52**	S44, **S45,** S46, S47, **S50, S51, S53**	N/A	N/A	N/A
Company C2	**S44, S45,**	S45, **S46,**	**S49, S52**	**S43,** S50	N/A

final	S46, **S47, S48,** S51, **S53**	**S50, S51, S53**			
Company C3 baseline	S43, **S44, S45, S47, S48,** S50	**S43, S46, S50, S52**	S47, S48, **S52, S53**	**S43, S44, S49**	S50, **S51**
Company C3 final	**S44, S45, S46, S47, S48**	**S43, S44,** S47, **S51, S52, S53**	S44, S48, **S50,** S52	**S49,** S52, S53	N/A

The factors identified in the analysis for this section are interlinked with statements common to each and cannot therefore be easily separated into different constructs. It is noted that factor 1 contains many statements common to each survey which suggests that this section is closer to a good solution than the previous sections analysed.

5.4.6 My Role Section (S54 to 66)

The Cronbach's alpha coefficient for the "My Role" section is shown in Table 5.23 below.

Table 5.23: *My Role Section Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.931	0.910	0.828	0.847
Final	0.596	0.864	0.757	0.767
Baseline S59 deleted	0.951	0.911	0.858	0.885
Final S59 deleted	0.731	0.891	0.740	0.851

It can be seen that statement 59 appears to have a detrimental effect in all surveys. This statement needs to be reviewed or deleted.

Factor analysis has been carried out for this section of the safety culture survey and is shown in Table 5.24 below. It can be seen that there are more factors identified than would be ideal for a construct with only one intended measurement and twelve statements. The factors identified are interlinked with statements common to each and cannot therefore be easily separated into different constructs.

Table 5.24: *My Role Section Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Company A Baseline	**S54, S55, S56, S57, S58,** S59, S60, **S62, S63, S64, S65, S66**	S57, S58, **S59, S60, S61,** S62, S63, **S64,** S66	N/A	N/A	N/A
Company A final	S55, S59, **S62, S63, S64, S65, S66**	**S56,** S59, **S60,** S61, S62, S64	**S55, S57,** S65	S55, **S58, S59,** S61	**S54,** S60, S61, S65
Company C1 baseline	**S54, S55, S56,** S57, **S61, S62, S64, S65, S66**	**S57, S58, S59, S63**	S57, S58, **S60, S62,** S65	N/A	N/A
Company C1 final	**S54, S55, S56, S58, S60, S61, S65**	**S59, S60,** S61, **S63, S64**	**S55,** S56, **S62,** S64, **S65, S66**	**S57, S58,** S63	N/A
Company C2 baseline	**S54, S55, S56,** S57, **S59**	S56, **S57, S58, S60,** S63, **S66**	S57, **S61, S62, S63**	S58, **S64, S65,** S66	N/A
Company C2 final	**S56, S57, S58, S60, S61, S62**	**S54, S55, S63**	S55, **S64, S66**	S57, **S59, S65**	N/A
Company C3 baseline	**S54, S55,** S58, **S61, S62,** S63, **S65**	**S55,** S57, **S59, S60, S63**	**S56, S58,** S61, **S62, S63**	S54, **S57, S64**	
Company C3 final	**S54, S55, S56,** S59, S60, S61, **S62, S63,** S64, **S66**	S54, **S58, S59, S60, S61,** S62, **S64, S65**	**S57,** S60, S61	N/A	N/A

5.4.7 My Manager Section (S67 to S76)

The Cronbach's alpha coefficient for the "My Manager" section is shown in Table 5.25 below. The values show that this section appears to be reliably measuring what people think about their manager.

Reviewing the "value if deleted" analysis shows that statement 73 had a detrimental effect in all surveys. Modification or deletion of this statement is therefore required.

Table 5.25: *My Manager Section Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.818	0.843	0.843	0.764
Final	0.854	0.838	0.731	0.749
Baseline S73 deleted	0.936	0.940	0.903	0.908
Final S73 deleted	0.844	0.880	0.853	0.859

Factor analysis has been carried out for this section of the safety culture survey and is shown in Table 5.26 below.

The factors identified in the analysis for this section are also interlinked with statements common to each and cannot therefore be easily separated into different constructs. It is clear that there are generally two strong factors identified in each survey with one or two weaker factors. The second factor does not appear to contain a regular pattern of statements but instead contains a mixture of statements in each survey.

Table 5.26: *My Manager Section Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4
Company A baseline	S67, S68, **S69, S70, S71, S73, S76**	**S67, S68,** S69, S70, **S72,** S73, **S74, S75**	N/A	N/A
Company A final	**S69, S71, S72, S74,** S75	**S67, S68,** S72, **S76**	**S67,** S72, **S73, S75**	S68, **S70**
Company C1 baseline	**S68,** S69, **S70, S71, S72, S73, S74, S76**	**S67, S69,** S70, S71, S73, S74, **S75**	N/A	N/A
Company C1 final	**S67, S69, S70, S71, S72, S74,** S75	S67, **S68,** S72, S74, **S76**	S70, S73, **S75**	N/A
Company C2 baseline	S67, S68, **S69, S70, S71, S72, S74, S75, S76**	**S73, S76**	N/A	N/A
Company C2 final	**S67, S68,** S69, **S70, S71, S72, S73, S74, S76**	**S67, S69,** S70, **S71,** S72, **S73, S75, S76**	N/A	N/A
Company C3 baseline	**S67, S70, S71,** S72, **S74, S75, S76**	**S67, S68,** S70, **S71, S72, S73,** S74, S75	**S69,** S72	N/A
Company C3 final	**S67,** S68, **S69, S71, S72, S73, S74, S76**	S72, S73, **S74, S75,** S76	**S68, S70**	N/A

5.4.8 Communications Section (S77 to S86)

The Cronbach's alpha coefficient for the "Communications" section is shown in Table 5.27 below. The values suggest that this section is reliably measuring people's perception of communications within their workplace.

Table 5.27: *Communications Section Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.918	0.943	0.869	0.833
Final	0.849	0.877	0.908	0.828

Factor analysis has been carried out for this section of the safety culture survey and is shown in Table 5.28 below.

The factors identified in the analysis for this section are interlinked with statements common to each and cannot therefore be easily separated into different constructs. The factors do not appear to contain a regular pattern of statements but instead contain a mixture of statements in each survey.

Table 5.28: *Communications Section Factor Analysis*

	Factor 1	Factor 2	Factor 3
Company A baseline	**S78, S80, S81,** S82, **S83, S84, S85, S86**	**S77, S78, S79,** S80, S81, **S82,** S85	N/A
Company A final	**S77, S78,** S79, **S85, S86**	**S79, S80, S81, S82,** S83	**S82, S83, S84**
Company C1 baseline	**S77, S82,** S83, **S84,** S85, **S86**	**S78, S79, S80, S85,** S86	S77, **S80, S81, S82, S83**
Company C1 final	**S77, S78, S79, S80, S81, S83, S85**	S79, S80, **S82,** S83, **S84, S86**	N/A
Company C2 baseline	S77, **S78, S79, S80,** S81, S82, **S83, S85**	**S77, S79,** S80, **S81, S82, S83, S84**	N/A
Company C2 final	**S77, S78, S79, S80, S81, S82, S83, S85**	S78, S79, S80, **S84,** S85, S86	N/A
Company C3 baseline	**S77,** S79, **S80, S81, S82, S83**	S77, **S79,** S80, **S81,** S82, S83, S84, **S85, S86**	**S78, S83, S84**
Company C3 final	**S77, S80, S81, S82, S85, S86**	**S78, S79,** S82, **S83,** S84	N/A

5.4.9 The Organisation Section (S87 to S98)

The Cronbach's alpha coefficient for the "Organisation" section is shown in Table 5.29 below. The values suggest that this section is reliably measuring people's perception of communications within their workplace.

The "value if deleted" analysis showed that a small improvement could be made with the deletion of statement 97.

Table 5.29: *The Organisation Section Reliability Analysis*

	Company A	**Company C1**	**Company C2**	**Company C3**
Baseline	0.872	0.738	0.839	0.901
Final	0.885	0.855	0.931	0.836
Baseline S97 deleted	0.916	0.879	0.882	0.912
Final S97 deleted	0.909	0.911	0.955	0.854

Factor analysis has been carried out for this section of the safety culture survey and is shown in Table 5.30 below.

Table 5.30: *The Organisation Section Factor Analysis*

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
Company A baseline	S87, **S88, S91, S92, S93, S94, S95, S96**	S87, S88, **S89, S90,** S91, **S92, S96**	**S87, S97, S98**	N/A
Company A final	**S87, S89,** S90, **S95, S96, S98**	**S88,** S91, S92, **S93, S94, S96**	S89, **S90,** S91, S92, S93, **S97,** S98	N/A
Company C1 baseline	S88, S89, **S90,** S91, **S92, S95, S97, S98**	S88, **S90, S91, S93, S94,** S98	**S87, S89,** S91, **S96,** S97, S98	N/A
Company C1 final	**S87, S88,** S89, S91, S92, **S93,** S94, **S95, S96**	**S89, S90, S91, S92, S94,** S96, **S98**	S87, S92, S94, **S97, S98**	N/A
Company C2 baseline	**S88, S89, S90,** S91, **S92, S93, S94**	S89, S90, **S91, S95, S97, S98**	**S87, S88,** S95, **S96**	N/A
Company C2 final	**S88,** S89, **S90, S91, S92, S93, S94, S95, S96, S98**	**S87, S88, S89, S90,** S91, S92, **S97, S98**	N/A	N/A
Company C3	**S87, S88,**	**S87, S88,**	S88, **S89,**	N/A

baseline	**S91,** S92, S94, **S95, S96,** S97	**S92, S93, S94, S98**	**S90,** S91, S92, S93, **S97,** S98	
Company C3 final	**S88,** S89, **S90, S91, S92, S93**	**S87,** S92, **S95, S98**	S92, **S94, S97**	S88, S90, S91, **S96**

The factors identified in the analysis for this section are interlinked with statements common to each and cannot therefore be easily separated. Further manipulation of the statements is therefore necessary to bring the result more in line with the intent of this section.

5.5 Safety Culture Survey Quality Factors Reliability Analysis

5.5.1 Survey Response Quality Quality Factor (S35, S38, S87)

The Cronbach's alpha coefficient for the "Survey Response Quality" quality factor is shown in Table 5.31 below. The values are generally lower than 0.7. As there were only three statements in this factor this may have had an adverse effect on the alpha coefficient. Pallant (2007) states that a minimum of ten items is required to provide an accurate alpha coefficient measurement.

The statements included in this factor are not necessarily linked by their subject but are chosen based on a specific analysis of the company, its activities and systems to ensure that the statements selected deliver a certain response. The alpha coefficient is not therefore suitable for measuring this factor as the statements selected may not be linked at all and that the descriptive analysis is more suitable. A negative alpha value is indicative of the measurement being invalid (as noted below for Company C3).

Table 5.31: *Survey Response Quality Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.731	0.193	0.583	-2.2
Final	0.859	0.427	0.443	0.642

Factor analysis has been carried out for the "Survey Response Quality" quality factor and is shown in Table 5.32. It can be seen that the statements chosen for measurement of "survey response quality" are generally contained within the same factor.

Table 5.32: *Survey Response Quality Factor Analysis*

	Factor 1	Factor 2
Company A baseline	**S35, S38, S87**	N/A
Company A final	**S35, S38, S87**	N/A
Company C1 baseline	**S38, S87**	**S35**
Company C1 final	**S35, S38, S87**	N/A
Company C2 baseline	**S35, S38, S87**	N/A
Company C2 final	**S35, S87**	**S38**
Company C3 baseline	**S35, S38, S87**	N/A
Company C3 final	**S35, S38, S87**	N/A

5.5.2 Blame Culture Quality Factor (S4, S22, S23)

The Cronbach's alpha coefficients for the "Blame Culture" quality factor are shown in Table 5.33 below. As can be seen, the values are generally less than 0.7 and this is attributed to the measurement factor only containing three statements.

Table 5.33: *Blame Culture Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.301	0.803	0.718	0.295
Final	0.612	0.780	0.776	0.769

Factor analysis has been carried out for the "Blame Culture" quality factor and is shown in Table 5.32 below. It can be seen that the statements chosen for the measurement of "blame culture" are generally contained within the same factor but this is possibly related more to the low number of statements being assessed. The Company C3 result is different but this is attributed to the low sample size in that survey.

Table 5.34: *Blame Culture Factor Analysis*

	Factor 1	Factor 2
Company A baseline	**S4, S22, S23**	N/A
Company A final	**S4, S22, S23**	N/A
Company C1 baseline	**S4, S22, S23**	N/A
Company C1 final	**S4, S22, S23**	N/A
Company C2 baseline	**S4, S22, S23**	N/A
Company C2 final	**S4, S22, S23**	N/A

Company C3 baseline	**S4, S23**	**S22**
Company C3 final	S4, **S22, S23**	S4, **S22, S23**

5.5.3 Colleague Trust Quality Factor (S7, S8, S59, S63, S65)

The Cronbach's alpha coefficients for the "Colleague Trust" quality factor are shown in Table 5.35 below. Most of the values are lower than the acceptable 0.7 threshold. The "value if deleted" analysis also provided for poor results with all statements. The poor results are attributed to this measurement factor containing only five statements.

Table 5.35: *Colleague Trust Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.684	0.732	0.542	0.245
Final	-0.010	0.540	0.698	0.298

Factor analysis for the "Colleague Trust" quality factor is shown in Table 5.36 below. It can be seen that the statements chosen for measurement of "colleague trust" are generally split between two factors. The statements between the two factors are not the same each time which suggests that the statements used for this factor require to be reviewed in order to improve the measurement.

Table 5.36: *Colleague Trust Factor Analysis*

	Factor 1	Factor 2
Company A baseline	**S7, S8, S63, S65**	**S59**
Company A final	**S8, S59, S63, S65**	**S7**
Company C1 baseline	**S7, S59, S65**	**S8, S63**
Company C1 final	**S7, S8, S65**	**S59, S63**
Company C2 baseline	**S7, S8, S65**	**S59,** S63
Company C2 final	**S7, S8, S63**	S59, **S65**
Company C3 baseline	**S7, S8, S65**	**S59, S63**
Company C3 final	**S7, S59,** S65	**S8, S63**

5.5.4 Intervention Quality Factor (S3, S9, S80)

The Cronbach's alpha coefficients for the "Intervention" quality factor are shown in Table 5.37 below. The "value if deleted" analysis provided poor results in most cases which are attributed to this measurement factor containing only three statements.

Table 5.37: *Intervention Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.843	0.802	0.640	0.233
Final	0.381	0.613	0.865	0.339

Factor analysis for the "Intervention" quality factor is shown in Table 5.38 below. It can be seen that the statements chosen for measurement of "intervention" appear to be closely related and are reliably measuring the same thing; however there being only three statements this result may be optimistic.

Table 5.38: *Intervention Factor Analysis*

	Factor 1	Factor 2
Company A baseline	**S3, S9, S80**	N/A
Company A final	**S3, S9**	**S80**
Company C1 baseline	**S3, S9, S80**	N/A
Company C1 final	**S3, S9, S80**	N/A
Company C2 baseline	**S3, S9, S80**	N/A
Company C2 final	**S3, S9, S80**	N/A
Company C3 baseline	**S3, S9, S80**	N/A
Company C3 final	**S3, S9**	**S80**

5.5.5 Communications Quality Factor (S28, S70, S75, S77, S78, S79, S81, S82, S83, S84, S86, S87)

The Cronbach's alpha coefficients for the "Communications" quality factor are shown in Table 5.39 below. All values are greater than 0.7 which shows that the statements have good correlation and can be considered to be reliably measuring the same thing.

Table 5.39: *Communications Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.920	0.924	0.876	0.814
Final	0.859	0.843	0.837	0.803

Factor analysis for the "Communications" quality factor is shown in Table 5.40 below. It can be seen that the statements chosen for measurement of "communications" are split between four factors. The statements in each of the factors were not repeatable between surveys which suggests that the statements used for this factor require to be reviewed in order to improve the measurement.

Table 5.40: *Communications Factor Analysis*

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
Company A baseline	**S75,** S78, **S81,** S82, **S83, S84, S86, S87**	**S70, S75, S77, S78, S79, S81, S82**	**S28,** S70, S78, **S82**	**N/A**
Company A final	**S75, S79, S81, S82, S83,** S87	**S28, S77, S78, S81,** S86	**S70,** S78, **S86, S87**	S79, S81, S83, **S84**
Company C1 baseline	**S28, S75, S78, S79,** S86, **S87**	**S70, S77,** S78, **S81, S82, S83**	**S77, S82,** S83, **S84, S86**	N/A
Company C1 final	S28, **S77, S78, S79, S81, S83**	**S28,** S77, S79, S81, **S84**, S86, S87	S28, **S70, S75, S78,** S83	S79, **S82,** S83, S84, **S86**
Company C2 baseline	S28, **S70, S75,** S77, **S79,** S81, **S82, S83,** S84	S77, S78, S79, **S81,** S83, **S86,** S87	**S28,** S78, **S84**	N/A
Company C2 final	**S70,** S77, **S78, S79, S81, S82, S83,** S84	**S70,** S75, S77, S78, S79, **S84, S86, S87**	**S75, S77, S81**	**S28,** S70, S78, S79, S87
Company C3 baseline	S70, **S75, S77, S81, S82, S83,** S87	**S28,** S70, **S79,** S81, **S86,** S87	S70, **S78, S83,** S86, **S87**	S28, **S70,** S75, **S82, S84,** S86
Company C3 final	S28, **S70,** S81, S82, **S84, S87**	S28, **S77, S81,** S82, **S86,** S87	**S28, S78,** S79, **S83**	**S75, S79,** S84, S87

5.5.6 Incident Management Quality Factor (S21, S23, S25, S28, S32)

The Cronbach's alpha coefficients for the "Incident Management" quality factor are shown in Table 5.41 below. All values are greater than 0.7 which shows that the statements appear to have good correlation and can be considered to be reliably measuring the same thing. The positive result may not be accurate due to the low number of statements in use to measure this factor.

Table 5.41: *Incident Management Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.583	0.840	0.825	0.698
Final	0.763	0.681	0.838	0.389

Factor analysis for the "Incident Management" quality factor is shown in Table 5.42 below. The statements selected for measurement of "incident management" are split between two factors and were not repeatable between surveys which suggests that the statements used for this factor require to be reviewed in order to improve the measurement.

Table 5.42: *Incident Management Factor Analysis*

	Factor 1	Factor 2
Company A baseline	S21, **S25, S28, S32**	**S21, S23,** S28
Company A final	**S21,** S25, **S28, S32**	S21, **S23, S25**
Company C1 baseline	**S21, S23, S25, S28, S32**	N/A
Company C1 final	**S21,** S23, **S25, S28**	S23, S25, S28, **S32**
Company C2 baseline	**S21, S23, S25, S28, S32**	N/A
Company C2 final	**S21, S23, S25, S28, S32**	N/A
Company C3 baseline	**S21,** S23, **S28, S32**	**S21, S23, S25**
Company C3 final	**S21, S23, S32**	**S25, S28**

5.5.7 Competence Quality Factor (S34, S35, S36, S41, S64, S65)

The Cronbach's alpha coefficients for the "Competence" quality factor are shown in Table 5.43 below. Many values are less than 0.7 which shows that the statements do not have good correlation and may not be considered to be reliably measuring the same thing. It was noted that the "value if deleted" analysis showed that minor improvements in the alpha coefficient could be achieved by deleting S34 and S64 but these were minimal and would not achieve the value of 0.7.

Table 5.43: *Competence Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.861	0.647	0.741	0.698
Final	0.838	0.682	0.355	0.202

Factor analysis for the “Competence” quality factor is shown in Table 5.44 below. It can be seen that the statements chosen for measurement of “competence” are split between three factors. The statements in each of the factors were not repeatable between surveys which suggests that the statements used for this factor require to be reviewed in order to improve the measurement.

Table 5.44: *Competence Factor Analysis*

	Factor 1	Factor 2	Factor 3
Company A baseline	**S34, S35, S36, S41, S64, S65**	N/A	N/A
Company A final	S34, **S35, S36, S41,** S65	**S34, S64, S65**	N/A
Company C1 baseline	**S41, S64, S65**	**S34, S35, S36,** S41	N/A
Company C1 final	**S34, S41, S64, S65**	S34, **S35, S36**	N/A
Company C2 baseline	**S34, S35, S36, S41,** S65	**S64, S65**	N/A
Company C2 final	**S34, S35, S36, S41, S64**	**S65**	N/A
Company C3 baseline	S34, **S35, S41**	S34, **S36, S64,** S65	**S34, S65**
Company C3 final	**S36, S41,** S64, S65	S34, **S35,** S64	N/A

5.5.8 Roles & Responsibilities Quality Factor (S34, S37, S40, S42, S67)

The Cronbach’s alpha coefficients for the “Roles & Responsibilities” quality factor are shown in Table 5.45 below. Most values are less than 0.7 which shows that the statements do not appear to have good correlation and may not be considered to be reliably measuring the same thing. It was noted that the “value if deleted” analysis showed that minor improvements in the alpha coefficient could be achieved by deleting S37 but these were minimal and would still not achieve the value of 0.7. The poor result is primarily attributed to there being only five statements in this factor.

Table 5.45: *Roles & Responsibilities Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.775	0.438	0.658	0.649
Final	0.841	0.815	0.636	0.547

Factor analysis for the "Roles & Responsibilities" quality factor is shown in Table 5.46 below. It can be seen that the statements chosen for measurement of "roles & responsibilities" are split between two factors. There appears to be good correlation between S34, S40, S42 and S67. This also suggests that S37 may be adversely affecting the reliability and accuracy of this quality factor. The statements in each of the factors were not repeatable between surveys which suggests that they require to be reviewed and modified in order to improve the measurement.

Table 5.46: *Roles & Responsibilities Factor Analysis*

	Factor 1	Factor 2
Company A baseline	**S34, S40 S42, S67**	S34, **S37**
Company A final	**S34, S40 S42, S67**	**S37,** S40 S42
Company C1 baseline	**S37,** S40 S42, S67	**S34, S37,** S40
Company C1 final	**S34, S37, S40, S42, S67**	N/A
Company C2 baseline	**S40, S42, S67**	S34, **S37, S42**
Company C2 final	**S34, S37, S40 S67**	**S42**
Company C3 baseline	**S34, S37, S42,** S67	**S40, S67**
Company C3 final	**S34, S37, S42**	**S40, S67**

5.5.9 Safety Culture Quality Factor (S2, S6, S45, S47, S68, S72, S76, S88, S89, S90, S92, S93, S94)

The Cronbach's alpha coefficients for the "Safety Culture" quality factor are shown in Table 5.47 below. All values are greater than 0.7 which shows that the statements appear to have good correlation and may be considered to be reliably measuring the same thing.

Table 5.47: *Safety Culture Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.919	0.946	0.875	0.915
Final	0.907	0.915	0.951	0.832

Factor analysis has been carried out for the "Safety Culture" quality factor and is shown in Table 5.48 below. It can be seen that the statements chosen for measurement of "safety culture" are split between four factors and were not repeatable between surveys which suggests that they require to be reviewed and modified in order to improve the measurement and reduce the number of factors present.

Table 5.48: *Safety Culture Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4
Company A baseline	**S6, S45, S47,** S68, S72, **S88,** S92, **S93, S94**	**S2,** S68, **S72,** S88, **S89, S90, S92, S94**	S47, **S68,** S72, **S76**	N/A
Company A final	S2, S76, **S88, S90, S92, S93, S94**	**S2,** S45, **S68, S72, S76**	S2, **S6, S68,** S72, **S89, S90,** S93	**S45 S47,** S88, S92
Company C1 baseline	S2, S45, **S47, S68,** S72, **S76, S88, S90, S92**	**S2, S6, S45,** S47, S68, **S72,** S88, **S89,** S92, S93	**S45, S68,** S88, **S90, S93, S94**	N/A
Company C1 final	**S47, S68, S72, S88,** S89, S92, **S93**	**S6, S45,** S47, S68, S88, **S89,** S90, **S94**	**S2,** S68, **S72, S76,** S89	S76, **S89, S90, S92,** S93, S94
Company C2 baseline	**S6,** S45, **S47, S68, S72, S88, S90, S92, S93, S94**	**S45, S76, S89,** S90, S93	**S2,** S45, **S88,** S89	N/A
Company C2 final	**S45,** S47, S68, **S72, S76, S88, S89, S90,** S92, S93	S6, S45, **S47, S68, S72,** S76, **S88,** S90, **S93, S94**	**S2, S6,** S45, S47, **S92, S93,** S94	N/A
Company C3 baseline	**S6, S45, S47, S68, S72, S88, S90,** S92, S93	**S2, S45, S47,** S72, **S76, S88, S89, S92, S94**	S47, S68, S72, S89, **S93,** S94	N/A
Company C3 final	S45, **S88, S89, S90, S92, S93**	**S6, S45, S47, S72, S76,** S92	S2, S45, S47, S89, S90, S93, **S94**	S2, S47, **S68,** S90

5.5.10 Organisational Measures Quality Factor (S11, S12, S16, S17, S48, S52)

The Cronbach’s alpha coefficients for the “Organisational Measures” quality factor are shown in Table 5.49 below. It can be seen that Company C3 has produced a poor result. This is attributed to the low sample size and also that there were only six statements in this factor.

Table 5.49: *Organisational Measures Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.807	0.749	0.756	0.189
Final	0.851	0.759	0.822	0.662

Factor analysis for the "Organisational Measures" quality factor is shown in Table 5.50. It can be seen that the statements chosen for measurement of "organisational measures" are split mainly between two factors. Company C3 has again provided a poor result. The statements in each of the factors were not repeatable between surveys which suggests that the statements used for this factor require to be reviewed and modified in order to improve the measurement.

Table 5.50: *Organisational Measures Factor Analysis*

	Factor 1	Factor 2	Factor 3
Company A baseline	**S11, S12, S16, S17**	S11, **S48, S52**	N/A
Company A final	S11, **S16, S17, S48, S52**	**S11, S12,** S16	N/A
Company C1 baseline	**S11, S12, S16,** S48	**S17, S48, S52**	N/A
Company C1 final	**S11, S12,** S17, **S48**	S12, **S16, S17, S52**	N/A
Company C2 baseline	S11, **S12, S17, S48**	**S11,** S12, **S16,** S48, **S52**	N/A
Company C2 final	**S12, S16, S17, S52**	**S11, S12, S16, S48**	N/A
Company C3 baseline	**S11, S16, S17, S48, S52**	**S12, S16**	N/A
Company C3 final	**S11, S12, S48,** S52	**S17, S48**	**S16, S52**

5.5.11 Empowerment Quality Factor (S3, S5, S8, S54, S56, S62)

The Cronbach's alpha coefficients for the "Empowerment" quality factor are shown in Table 5.51 below. It can be seen that Company C3 has produced a poor result. This is attributed to the low sample size and also that there were only six statements in this factor. Whilst the other values are greater than 0.7 these may not be valid as a result of the low number of statements being assessed.

Table 5.51: *Empowerment Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.877	0.824	0.800	0.246
Final	0.619	0.805	0.719	0.916

Factor analysis for the "Empowerment" quality factor is shown in Table 5.52 below. It can be seen that the statements chosen for measurement of "empowerment" are split mainly between two factors. Company A and Company C3 provided poor results. Factor 1 appears to be very strong in most surveys and exclusive in three surveys. The result shows that the series of statements selected appear to have strong correlation and are reliably measuring the intended factor.

Table 5.52: *Empowerment Factor Analysis*

	Factor 1	Factor 2	Factor 3
Company A baseline	**S3, S5, S8, S54, S56, S62**	N/A	N/A
Company A final	**S3,** S5, **S8,** S56, **S62**	**S5, S56,** S62	**S54,** S62
Company C1 baseline	**S3, S8, S54, S56,** S62	**S5,** S54, **S62**	N/A
Company C1 final	**S54, S56, S62**	**S3, S5, S8**	N/A
Company C2 baseline	**S3, S5, S8, S54, S56, S62**	N/A	N/A
Company C2 final	S3, S54, **S56, S62**	**S3, S5, S8,** S54	N/A
Company C3 baseline	**S3,** S8, S54, **S56**	S8, **S54,** S56, **S62**	**S5, S56**
Company C3 final	**S3, S5, S8, S54, S56, S62**	N/A	N/A

5.5.12 Procedural Awareness Quality Factor (S9, S11, S12, S14, S15)

The Cronbach's alpha coefficients for the "Procedural Awareness" quality factor are shown in Table 5.53 below. It can be seen that most surveys have produced a poor result. This is attributed to the low number of statements (five) in this factor. Also, it is noted that negative alpha values have been produced by the Company C3 analysis which is indicative of there being poor reliability. This may also be as a result of the low sample size in this survey (seven). Descriptive methods are therefore considered to be more suitable for such situations when the statistical analysis provides a non-robust analysis.

Table 5.53: *Procedural Awareness Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.545	0.727	0.684	0.214
Final	0.405	0.747	0.651	0.447
Baseline S14 deleted	0.725	0.752	0.771	-0.317
Final S14 deleted	0.378	0.834	0.709	0.555

Factor analysis for the "Procedural Awareness" quality factor is shown in Table 5.54 below. It can be seen that the statements chosen for measurement of "procedural awareness" are split mainly between two factors. The result shows that the series of statements selected for this factor produced a strong Factor 1 with weaker second and third factors. The analysis shows that the statements selected are reliably measuring the intended factor.

Table 5.54: *Procedural Awareness Factor Analysis*

	Factor 1	Factor 2	Factor 3
Company A baseline	S9, **S11, S12, S15**	**S9, S14**	N/A
Company A final	S11, **S12, S15**	**S9,** S11, S12	**S11, S14**
Company C1 baseline	**S11, S12, S14, S15**	**S9,** S11, S14	N/A
Company C1 final	**S9, S11, S12,** S15	S9, **S12, S14, S15**	N/A
Company C2 baseline	**S9, S11, S12,** S15	**S14,** S15	N/A
Company C2 final	S9, **S11, S12, S15**	S9, **S11, S14**	N/A
Company C3 baseline	**S9, S11, S12, S14, S15**	N/A	N/A
Company C3 final	**S11, S12,** S15	**S9, S15**	**S14**

5.5.13 Management Pressure / Stress Quality Factor (S45, S47, S49, S50, S51)

The Cronbach's alpha coefficients for the "Management Pressure / Stress" quality factor are shown in Table 5.53 below.

Table 5.55: *Management Pressure / Stress Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.873	0.820	0.774	0.706
Final	0.827	0.584	0.784	0.119

It can be seen that most surveys have produced an acceptable result showing that the intended aspect is being reliably measured but as there are only five statements being assessed this measurement may not be reliable even though the alpha coefficients may suggest otherwise. Company C3 has produced a poor result in the final survey.

Factor analysis for the "Management Pressure / Stress" quality factor is shown in Table 5.56 below. It can be seen that the statements chosen for measurement of "management pressure / stress" are concentrated within Factor 1 which suggests that the intended factor is being reliably measured.

Table 5.56: *Management Pressure / Stress Factor Analysis*

	Factor 1	Factor 2	Factor 3
Company A baseline	**S45, S47. S49, S50, S51**	N/A	N/A
Company A final	**S45, S47. S49, S50, S51**	N/A	N/A
Company C1 baseline	**S45, S47. S49, S50, S51**	N/A	N/A
Company C1 final	**S45, S49, S50**	**S45, S47**	**S50, S51**
Company C2 baseline	**S45, S47. S49, S50, S51**	N/A	N/A
Company C2 final	**S45, S47. S50, S51**	**S49, S50,** S51	N/A
Company C3 baseline	**S45, S47. S50,** S51	**S49, S51**	N/A
Company C3 final	**S45, S47**	**S45, S51**	N/A

5.5.14 Employee Value Quality Factor (S10, S55, S57, S72, S85, S91, S94)

The Cronbach's alpha coefficients for the "Employee Value" quality factor are shown in Table 5.57 below.

Table 5.57: *Employee Value Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.867	0.840	0.860	0.866
Final	0.723	0.872	0.892	0.818

It can be seen that most surveys have produced an acceptable result showing that the intended factor is being reliably measured but as there are only seven statements being assessed this measurement may not be reliable even though the alpha coefficients may suggest otherwise.

Factor analysis for the "Employee Value" quality factor is shown in Table 5.58 below. It can be seen that the statements chosen for measurement of "employee value" are split between two factors. The statements in each of the factors were not repeatable between surveys which suggests that the statements used for this factor require to be reviewed and modified in order to improve the measurement.

Table 5.58: *Employee Value Pressure / Stress Factor Analysis*

	Factor 1	Factor 2
Company A baseline	**S55,** S57, **S72, S85, S91, S94**	**S10,** S55, **S57,** S94
Company A final	**S10, S55, S57, S85**	**S72,** S85, **S91, S94**
Company C1 baseline	**S55,** S57, **S72, S85, S91,** S94	**S10, S57, S72, S85, S94**
Company C1 final	S10, **S55,** S72, **S85, S91, S94**	**S10, S57,** S72
Company C2 baseline	**S10, S55,** S57, **S72, S85, S91, S94**	N/A
Company C2 final	**S10, S57, S72, S85, S91, S94**	**S55, S85**
Company C3 baseline	**S55,** S57, **S72, S85, S91, S94**	**S10, S57, S94**
Company C3 final	**S10, S57, S85,** S91, **S94**	**S55, S72, S85, S91**

5.5.15 Safety Promotion Quality Factor (S18, S56, S66, S69, S71, S73, S74, S80, S85, S88, S93)

The Cronbach's alpha coefficients for the "Safety Promotion" quality factor are shown in Table 5.59 below.

Table 5.59: *Safety Promotion Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.822	0.850	0.846	0.658
Final	0.859	0.880	0.820	0.765
Baseline S73 deleted	0.910	0.935	0.896	0.820
Final S73 deleted	0.853	0.910	0.900	0.869

It can be seen that most surveys have produced an acceptable result showing that the intended factor is being reliably measured. The "value if deleted" analysis showed that statement 73 was having an adverse effect on the overall analysis. This statement also had an adverse effect in the "My manager" section of the questionnaire and should be deleted or modified.

Factor analysis for the "Safety Promotion" quality factor is shown in Table 5.60 below. It can be seen that the statements chosen for measurement of "safety promotion" are split between four factors. The statements in each of the factors were not repeatable between surveys which suggests that the statements used for this factor require to be reviewed and modified in order to improve the measurement.

Table 5.60: *Safety Promotion Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4
Company A baseline	S18, **S66, S69, S71, S73,** S74, S80	**S55, S56, S74, S80,** S88, **S93**	**S18,** S69, S71, S80, **S85, S88,** S93	N/A
Company A final	**S69, S71, S74,** S80, **S88,** S93	**S56, S73, S80,** S93	**S18,** S56, **S85,** S93	**S66,** S80
Company C1 baseline	**S56, S66, S69, S71,** S73, **S74, S80, S85, S88,** S93	**S18,** S69, S73, S74, S85, **S88, S93**	N/A	N/A
Company C1 final	**S66,** S71, **S74, S80, S85, S88,** S93	**S18, S56, S69, S71,** S88, **S93**	S18, **S73**	N/A

Company C2 baseline	**S18, S56, S66, S69, S71,** S73, **S74, S80,** S85, S88	**S73,** S80, **S85,** S88	N/A	N/A
Company C2 final	**S56, S69, S71,** S73, S74, **S80, S85, S88, S93**	**S18, S66,** S73, S74, S80, **S85,** S88, **S93**	N/A	N/A
Company C3 baseline	**S66, S71, S73, S74,** S88	**S74, S80, S85, S88, S93**	**S18, S56, S73,** S80	**S18, S69,** S80
Company C3 final	S18, S69, **S71, S73, S74, S80, S85,** S93	**S56, S66, S69, S71, S73,** S74	**S18**, S71, S85, **S88,** S93	N/A

5.5.16 Resources Quality Factor (S27, S46, S66)

The Cronbach's alpha coefficients for the "Resources" quality factor are shown in Table 5.61 below. It can be seen that most surveys have produced an unacceptable result but this is attributed primarily to the low number of statements being analysed. Descriptive methods or inter-item correlations are therefore more suitable.

Table 5.61: *Resources Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.795	0.624	0.445	0.250
Final	0.609	0.555	0.809	0.591

Factor analysis for the "Resources" quality factor is shown in Table 5.62 below. It can be seen that the statements chosen for measurement of "resources" were exclusively contained within one factor. This to be expected in a factor with only three statements.

Table 5.62: *Resources Factor Analysis*

	Factor 1
Company A baseline	**S27, S46, S96**
Company A final	**S27, S46, S96**
Company C1 baseline	**S27, S46, S96**
Company C1 final	**S27, S46, S96**
Company C2 baseline	**S27, S46, S96**
Company C2 final	**S27, S46, S96**
Company C3 baseline	**S27, S46, S96**
Company C3 final	**S27, S46, S96**

5.5.17 Motivation Quality Factor (S14, S43, S44, S50, S51, S53, S76, S97)

The Cronbach's alpha coefficients for the "Motivation" quality factor are shown in Table 5.63 below. It can be seen that most surveys have produced an acceptable result showing that the intended factor is being reliably measured.

Table 5.63: *Motivation Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.492	0.423	0.679	0.143
Final	0.817	0.397	0.752	-0.27
Baseline S97 deleted	0.722	0.689	0.784	0.360
Final S97 deleted	0.873	0.566	0.857	-0.160

The "value if deleted" analysis showed that statement 97 was having an adverse effect on the overall analysis. This statement also had an adverse effect in the "The Organisation" section of the questionnaire. The statement should therefore be modified or deleted from the survey instrument.

Factor analysis for the "Motivation" quality factor is shown in Table 5.64 below. It can be seen that the statements chosen for measurement of "motivation" are split between four factors. The statements in each of the factors were not repeatable between surveys which suggests that the statements used for this factor require to be reviewed and modified in order to improve the measurement.

Table 5.64: *Motivation Factor Analysis*

	Factor 1	Factor 2	Factor 3	Factor 4
Company A baseline	**S43, S44, S50, S51,** S97	**S14,** S50, S51, **S97**	**S53, S56**	N/A
Company A final	**S43,** S50, S51, S53, **S76**	S14, **S43, S44, S76**	**S14,** S44, S76, **S97**	N/A
Company C1 baseline	S14, **S43, S44,** S51, **S76, S97**	S14, S44, **S50, S51 S53,** S76, **S97**	N/A	N/A
Company C1 final	S43, S51**, S53, S76, S97**	S14, **S43, S50, S51**	**S14, S44,** S51, S76	N/A
Company C2	**S14, S50, S51,**	**S43, S44,** S53,	N/A	N/A

baseline	**S53, S76,** S97	S97		
Company C2 final	**S44,** S50, **S51, S53, S76**	S14, **S50, S53, S76, S97**	S14, **S43,** S50	N/A
Company C3 baseline	**S14, S53, S97**	**S43, S44**	S44, **S50, S76**	S50, **S51,** S97
Company C3 final	**S14, S44, S51, S53**	S44, **S51, S76**	N/A	N/A

5.5.18 Training Quality Factor (S19, S20, S24, S33, S39, S40, S60, S61, S87)

The Cronbach's alpha coefficients for the "Training" quality factor are shown in Table 5.65 below. It can be seen that most surveys have produced an acceptable result showing that the intended factor is being reliably measured.

Table 5.65: *Training Reliability Analysis*

	Company A	Company C1	Company C2	Company C3
Baseline	0.655	0.419	0.694	-0.395
Final	0.775	0.743	0.743	0.754
Baseline S20 deleted	0.826	0.702	0.849	-0.565
Final S20 deleted	0.824	0.824	0.883	0.845

The "value if deleted" analysis showed that statement 20 was having an adverse effect on the overall analysis. As discussed previously, in the "Organisational Measures" analysis section, the survey instrument would have a greater reliability value if S20 were to be deleted.

Factor analysis for the "Training" quality factor is shown in Table 5.66 below. It can be seen that the statements chosen for measurement of "training" are split between three factors. The statements in each of the factors were not repeatable between surveys which suggests that the statements used for this factor also require to be reviewed and modified in order to improve the measurement and reduce the number of factors.

Table 5.66: *Training Factor Analysis*

	Factor 1	Factor 2	Factor 3
Company A baseline	**S19, S20, S24, S39**	S20, **S33,** S40, S60, **S61**	S39, S40, **S60, S87**
Company A	**S19,** S20, S24, **S33,**	S19, **S20,** S60, **S61**	**S24, S60,** S87

final	**S39, S40,** S61, **S87**		
Company C1 baseline	**S19, S20, S24,** S33, S39	**S33,** S40, **S60,** S61, **S87**	S20, S24, **S39, S40, S61**
Company C1 final	**S20,** S24, **S33, S40, S61,** S87	S20, S33, **S39,** S40, **S60**	**S19, S20, S24,** S33
Company C2 baseline	**S19, S20, S24,** S33, **S39, S60, S61**	S19, S20, S24, **S33, S39, S40,** S61, **S87**	N/A
Company C2 final	**S19, S20, S24,** S33, **S39, S40, S60, S61,** S87	**S33, S87**	N/A
Company C3 baseline	S19, **S33, S39, S40, S61, S87**	**S19, S20, S24,** S39	**S24, S40, S60,** S61
Company C3 final	S20, S24, S33, **S40, S60, S61,** S87	S24, **S33, S39,** S61, S87	**S19,** S20, S33, S60

5.5.19 Safety Culture Reliability / Factor Analysis Conclusion

The reliability of the survey appears to show a reasonable result with most surveys achieving an alpha coefficient value greater than 0.7 for each section of the questionnaire.

In the quality factors analysis the alpha coefficient provided good results for those factors with a greater number of statements but less reliable results for those with a lower number of statements. The inter-item correlation values are considered to be more suitable methods of measurement for such situations, as recommended by Pallant (2007).

Whilst several strong factors have been identified throughout the safety culture survey it is clear that more reliability and factor analysis is necessary to enable further development and accuracy of the survey instrument. Many of the factors measured using the inferential methods did not produce good results and the reasons for this are primarily the sample size and number of statements being assessed.

It is essential that further analysis and development of the survey instrument is carried out using a much greater sample size than those surveys already completed, as recommended by Dewberry (2004), in order to provide sufficient data for factor analysis to provide reliable results and to build confidence in the reliability of the survey instrument.

6.0 COLLABORATOR RESPONSE ASSESSMENT

6.1 Company "A" Analysis: Assessment Tool Output

6.1.1 All Personnel

The assessment tool output from the baseline and final safety culture surveys for Company A is detailed below. The quality factors details can be found in Appendix D.

Table 6.1: *Company "A" Assessment Tool Output*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.84		4.28	
Maximum safety culture	7.58		6.79	
No of returned surveys	19		12	
Quality factors: mean value	76.18		60.67	
Response total mean value	57.24		53.3	
Maximum Response Total	75.43		70.12	
	Management		Supervisory	
Maximum quality factors total	149		127.5	
	Management		Supervisory	
Lowest scoring quality value	Disagrees		Indifferent responses	
Lowest scoring section: mode	Incident management		Influencing factors	
Highest scoring section: mode	The organisation		Competence management	
Lowest scoring section: mean	Incident management		Influencing factors	
Highest scoring section: mean	The organisation		My manager	
	Value	Rank	Value	Rank
Safety culture mean	6.73	2	6.30	3
Organisational measures mean	6.04	8	5.54	8
Incident management mean	5.68	9	5.73	6
Competence management mean	6.12	7	6.32	2
Influencing factors mean	6.12	6	5.20	9
My role mean	6.64	4	5.95	5
My manager mean	6.70	3	6.33	1
Communications mean	6.31	5	5.70	7
The organisation mean	6.90	1	6.23	4

The overall safety culture rating has reduced from 4.84 to 4.28 between the baseline survey and the final survey; a reduction of 11.5%. The maximum safety culture value returned from an individual response has reduced from 7.58 to 6.79 (10.4%).

The baseline survey received nineteen responses while the final survey received only twelve. The same number of personnel were employed within the department that took part at the time of both surveys (twenty). This shows that the final survey did not receive the same support as the baseline survey. The number of management responses between surveys did not change (three). The potential causes for this reduced number of responses have been discussed with the company and these were:

1. Time / production pressures
2. Inadequate motivation
3. Complacent attitude of production personnel

At the time of the final survey the whole company was under considerable time and resource pressures because of the need to fulfil their existing orders while still preparing for an increase in production due to new orders. The increased workload was being prepared for with several manufacturing process development projects taking up people's time. This was in contrast to the recent downturn which required a shorter working week being enforced for a period of approximately 6 months.

It was clear that personnel (management and non-management) were under pressure to keep up with production requirements and while the health and safety manager attempted to encourage the production staff to complete the surveys, the workplace priorities at the time simply meant that it was not possible to enforce this. Also, it has to be noted that the company does not have a history of any significant health and safety issues and improving the health and safety performance of a workplace that already has a good safety record (by their own standards and also those of the HSE) is perhaps a lower priority given the production pressures present at the time. It would appear that at the time of the second survey a greater focus was being placed on production rather than safety and that this approach may increase the level of risk present.

The baseline survey lowest-scoring quality factor was “Disagrees”. This would suggest an unwillingness of respondents to select the “disagree” options for negative statements even when this is actually a positive response. In the final survey the lowest-scoring quality factor was “Indifferent Responses”. Two surveys were identified that had an unacceptable number of indifferent responses.

In the baseline survey the section with the greatest number of lowest scores (the mode) was “Incident Management” and the highest scoring modal value was “The Organisation”. Having examined the company’s health and safety performance it was no surprise that “The Organisation” section scored highly. The statements associated with the “Incident Management” section contained three statements in which disagreement is a positive response (S26, S29 & S30). It was considered that there might be a psychological reluctance of people to select disagreement responses throughout the survey but the analysis carried out for all surveys suggests that this is not the case. The “Organisational Measures” quality factor was sixteenth lowest in the quality factors ranking (out of twenty-three) while “Incident Management” ranked twentieth. The “Organisational Measures” and “Incident Management” survey sections were equally the next lowest scoring sections which may also lend weight to this theory regarding an unwillingness to respond positively to disagreement answers. Another contributing factor may be that as incidents and accidents are infrequent, the shop floor operatives may not be aware of or familiar with the procedures and processes in place to assess and investigate any incidents that occur. Their knowledge of these aspects of the workplace procedures may therefore be compromised leading to non-positive or indifferent responses. The mean values calculated for the baseline survey replicated the modal results, i.e. the lowest score was “Incident Management” (5.68) and the highest score was “The Organisation” (6.9).

In the final survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors”. The section with the greatest number of highest scores was “Competence Management”. The next highest modal values in the final survey were “The Organisation” and “Safety Culture” (each scoring highest with three of the respondents each). The mean values calculated showed that “My Manager” was highest (6.33) while the lowest scoring section was “Influencing Factors” (5.20). The “Competence Management” section mean value (6.32) was only marginally lower than the “My Manager” section. This example serves to highlight why the modal and mean values are determined and reported in the assessment tool. Average values can be misleading and should be considered in combination with other data to provide the context in which the measurements being calculated are made.

With new employees being taken on and new processing and manufacturing equipment systems being designed and constructed, a significant quantity of new and refresher training is being carried out throughout the workforce. This may be a contributing factor to the “Competence Management” section scoring so highly in the final survey. It is interesting to note that the “Training” quality factor ranked only twenty-first out of twenty-three. The response to statement 87 was much worse than it should have been. This statement simply enquires if an induction process is in place. A strict induction process is in place and all employees and contractors require to be inducted before being allowed on the shop floor. The statement should therefore have returned a very high number of favourable responses. In the baseline survey, nine people responded indifferently with five selecting agree and disagree each. The management team were very surprised at this result. This would suggest that there is a potential issue with the induction procedures. Additionally the assessment tool may be giving rise to a pessimistic training quality factor. Further examination and development of the training and competence assessment statements is necessary to identify the cause.

The mean and mode values for each section of the surveys were calculated and ranked as shown in Table 6.1. The purpose of using both values is to ensure that the sections with the lowest scores are given the highest priority in terms of defining what aspects of the workplace the implementation of corrective measures should be focussed. These can be antecedent-type measures or behaviour-based measures (based on personnel learning from or being made aware of the consequences of their actions through training or by direct example).

The intended purpose of the assessment tool must be referred to in order to understand what the output of the tool needs to achieve. It is a measurement aid that enables a company to assess the safety culture in its own workplace and assists in ascertaining those aspects most in need of corrective measures. The values representing safety culture and quality factors have no extrinsic meaning beyond this assessment tool and are used simply to prioritise against other aspects of the safety culture measured in exactly the same way. Those aspects that scored highly or even in the middle of the range of results, whilst still important, do not present the issues of most significant concern and are therefore relatively unimportant in the context of the purpose of the assessment tool. The tool is predominantly intended for use in small to medium sized enterprises (SMEs) and as such is intended only to address those most critical aspects of the workplace one at a time. This method of analysis and rectification is easier to manage than addressing all issues at once. In a large multi-national company where there may be many people and departments available to implement such schemes it may be possible to tackle an array of issues at the same time but this would be very difficult in most SMEs because of the lack of people and resources. Such an implementation may also lead to an increased risk if too many aspects of the workplace are changed at the same time. Unless absolutely necessary, as a result of imminent danger, it is considered better to make many small manageable changes over time than to implement major changes all at once as this gives people time to adapt to new methods and therefore less likely to make mistakes. In the case of the prevention of violations being carried out a major change through strict antecedent measures would be expected. Unfortunately, the consequences of such measures are not good for the violator but they provide an excellent behaviour-based consequence learning opportunity for others.

6.1.2 Management Personnel

The modified management-only response for Company A is detailed in Table 6.2 below. For Company A only three personnel were classified as management.

Table 6.2: *Company "A" Assessment Tool Output: Management Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	6.21		5.55	
Maximum safety culture rating	7.58		6.79	
No of returned surveys	3		3	
Quality factors: mean value	117		94	
Response total mean value	66.08		63.05	
Maximum Response Total	75.43		70.12	
	Management		Supervisory	
Maximum quality factors total	149		127.5	
	Management		Supervisory	
Lowest scoring quality value	Incident management		Disagrees	
Lowest scoring section: mode	Incident management		N/A	
Highest scoring section: mode	N/A		Competence management	
Lowest scoring section: mean	Organisational measures		Incident management	
Highest scoring section: mean	The organisation		My manager & Safety culture	
	Value	Rank	Value	Rank
Safety culture mean	7.92	2	7.58	1
Organisational measures mean	6.75	9	6.42	8
Incident management mean	6.81	8	6.14	9
Competence management mean	7.33	5	7.25	4
Influencing factors mean	7.65	4	6.97	5
My role mean	7.69	3	6.86	6
My manager mean	7.02	6	7.58	1
Communications mean	6.83	7	6.75	7
The organisation mean	8.08	1	7.50	3

The overall safety culture rating has reduced from 6.21 to 5.55 between the baseline survey and the final survey; a reduction of 10.6%. Whilst the general result is worth noting it would be unwise to make any firm conclusions regarding these values as only three personnel are in this category.

The maximum safety culture value returned from an individual response reduced from 7.58 to 6.79 (10.4%).

The baseline survey lowest-scoring quality factor was “Incident Management”. This supports the analysis of the survey sections. In the final survey the lowest-scoring quality factor was the “Disagree” statements with “Indifferent Responses” ranked just behind it.

In the baseline survey the section with the greatest number of highest scores (the mode) could not be determined as all three respondents scored three different sections highest (“Safety Culture”, Competence Management” and “The Organisation”). The section with the greatest number of lowest scores was “Incident Management”. The mean values calculated showed that the “The Organisation” section was highest (8.08) while the lowest scoring section was “Organisational Measures” (6.75).

The results from the management personnel show that the “Incident Management” section scored lowest. If the management score is low for this factor it is likely that the shop floor workers would score it even lower. It would be expected that the management would know more about those procedures associated with incident management, and their implementation, than the shop floor workers. As stated previously, the low accident rate already achieved and henceforth the likely unfamiliarity with the incident management procedures is expected to have had an impact on this value.

In the final survey the section with the greatest number of lowest scores (the mode) could not be determined as all three respondents scored three different sections lowest (“Incident Management, “Competence Management” and “Communications”). The highest-scoring section was “Competence Management”. The mean values calculated showed that “Safety Culture” and “My Manager” scored highest equally (7.58) while “Incident Management” scored lowest (6.14).

6.1.3 Non-Management Personnel

The non-management response for Company A is detailed in Table 6.3 below. For Company A, sixteen personnel were classified as non-management in the baseline survey while in the final survey six personnel were in this category.

Table 6.3: *Company "A" Assessment Tool Output: Non-Management Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.58		3.83	
Maximum safety culture rating	6.83		4.52	
No of returned surveys	16		6	
Quality factors: mean value	68.53		49.58	
Response total mean value	55.59		49.58	
Maximum Response Total	71.86		56.4	
	Technician		Technician	
Maximum quality factors total	127		63.5	
	Technician		Technician	
Lowest scoring quality value	Disagrees		Indifferent responses	
Lowest scoring section: mode	Influencing factors & Organisational measures		Influencing factors	
Highest scoring section: mode	The organisation		The organisation	
Lowest scoring section: mean	Incident management		Influencing factors	
Highest scoring section: mean	The organisation		The organisation	
	Value	Rank	Value	Rank
Safety culture mean	6.51	3	5.89	3
Organisational measures mean	5.90	6	5.29	8
Incident management mean	5.47	9	5.47	7
Competence management mean	5.89	7	5.64	4
Influencing factors mean	5.84	8	4.22	9
My role mean	6.45	4	5.56	5
My manager mean	6.64	2	6.00	2
Communications mean	6.21	5	5.48	6
The organisation mean	6.68	1	6.04	1

The overall safety culture rating has reduced from 4.58 to 3.83 between the baseline survey and the final survey; a reduction of 16.3%.

The maximum safety culture value returned from an individual response reduced from 6.83 to 4.52 (33.8%).

The baseline survey lowest-scoring quality factor was "Disagrees". In the final survey the lowest-scoring quality factor was "Indifferent Responses". The "Disagrees" factor ranked seventeenth out of twenty-three.

In the baseline survey there were two sections that scored an equal number of lowest scores: "Influencing Factors" and "Organisational Measures". The highest scoring modal value was "The Organisation". The mean values calculated showed that the "The Organisation" section was highest (6.68) while the lowest scoring section was "Incident Management" (5.47).

The results from the non-management personnel show that the lowest scoring section was "Incident Management". Additionally the "Influencing Factors" section is the modal value in the baseline (along with "Organisational Measures") and final surveys. The "Influencing Factors" section may be an indicator of the feeling of the workforce as a result of the changes to the workplace caused by the recession and recent upturn.

In the final survey the section with the greatest number of lowest scores (the mode) was "Influencing Factors". The highest-scoring section modal value was "The Organisation". The next highest modal value in the final survey was "Safety Culture". The mean values calculated showed that "The Organisation" scored highest (6.04) while "Influencing Factors" scored lowest (4.22).

6.1.4 Poor Quality Responses Removed: All Personnel

To determine if those responses judged to be of poor quality could have a detrimental effect on the overall assessment of safety culture, the results were assessed by removing the data from the assessment tool from surveys that had a high number of indifferent responses or a high number of consecutive indifferent responses.

The results of the baseline and final surveys with poor quality responses removed are detailed in Table 6.4 below. For Company A, two such responses were recorded for the baseline survey and one in the final survey.

The overall safety culture rating reduced from 5.04 to 4.35 between the baseline survey and the final survey; a reduction of 13.6%.

Table 6.4: *Company "A" Assessment Tool Output: Poor Surveys Removed All Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	5.04		4.35	
Maximum safety culture rating	7.58		6.79	
No of returned surveys	17		11	
Quality factors: mean value	81.82		62.68	
Response total mean value	58.67		53.84	
Maximum Response Total	75.43		70.12	
	Management		Supervisory	
Maximum quality factors total	127		127.5	
	Management		Supervisory	
Lowest scoring quality value	Disagrees		Indifferent responses	
Lowest scoring section: mode	Incident management		Influencing factors	
Highest scoring section: mode	The organisation		Competence management	
Lowest scoring section: mean	Incident management		Influencing factors	
Highest scoring section: mean	The organisation		My manager	
	Value	Rank	Value	Rank
Safety culture mean	6.95	2	6.28	4
Organisational measures mean	6.10	8	5.57	8
Incident management mean	5.78	9	5.73	7
Competence management mean	6.28	6	6.44	2
Influencing factors mean	6.24	7	5.21	9
My role mean	6.84	4	6.04	5
My manager mean	6.89	3	6.45	1
Communications mean	6.46	5	5.76	6
The organisation mean	7.12	1	6.34	3

The maximum safety culture value returned from an individual response reduced from 7.58 to 6.79 (10.4%).

The baseline survey lowest-scoring quality factor was “Disagrees”. In the final survey the lowest-scoring quality factor was “Indifferent Responses”. The “Disagrees” ranked twenty-second out of twenty-three in the final survey.

In the baseline survey the section with the highest number of lowest scores (the mode) was “Incident Management”. The highest scoring modal value was “The Organisation”. The mean values calculated showed that the “The Organisation” section was highest (7.12) while the lowest scoring section was “Incident Management” (5.78). In comparison to the baseline analysis, the mean values are slightly different but the modal and mean results from the survey sections are unchanged.

In the final survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors”. The highest-scoring section modal value was “Competence Management”. The next highest modal value in the final survey was “The Organisation” followed by “Safety Culture”. The mean values calculated showed that “My Manager” scored highest (6.45) while “Influencing Factors” scored lowest (5.21).

6.1.5 Poor Quality Responses Removed: Non-Management Personnel

The results of the baseline and final surveys for non-management personnel with poor quality responses removed are detailed in Table 6.5 below. There were two such responses recorded for the baseline survey and only one in the final survey.

The overall safety culture rating has reduced from 4.79 to 3.91 between the baseline survey and the final survey; a reduction of 18.3%.

The maximum safety culture value returned from an individual response reduced from 6.83 to 4.52 (33.8%).

The baseline survey lowest-scoring quality factor was “Disagrees”. In the final survey the lowest-scoring quality factor was “Indifferent Responses”. The “Disagrees” ranked twenty-second out of twenty-three in the final survey.

Table 6.5: *Company "A" Assessment Tool Output: Poor Surveys Removed*

Non-Management Personnel Only

<table>
<tr><th>Measured Variable</th><th colspan="2">Baseline Survey</th><th colspan="2">Final Survey</th></tr>
<tr><td>Overall safety culture rating</td><td colspan="2">4.79</td><td colspan="2">3.91</td></tr>
<tr><td>Maximum safety culture rating</td><td colspan="2">6.83</td><td colspan="2">4.52</td></tr>
<tr><td>No of returned surveys</td><td colspan="2">14</td><td colspan="2">5</td></tr>
<tr><td>Quality factors: mean value</td><td colspan="2">74.29</td><td colspan="2">51.8</td></tr>
<tr><td>Response total mean value</td><td colspan="2">50.08</td><td colspan="2">50.03</td></tr>
<tr><td rowspan="2">Maximum Response Total</td><td colspan="2">71.86</td><td colspan="2">56.40</td></tr>
<tr><td colspan="2">Technician</td><td colspan="2">Technician</td></tr>
<tr><td rowspan="2">Maximum quality factors total</td><td colspan="2">127</td><td colspan="2">63.5</td></tr>
<tr><td colspan="2">Technician</td><td colspan="2">Technician</td></tr>
<tr><td>Lowest scoring quality value</td><td colspan="2">Disagrees</td><td colspan="2">Indifferent responses</td></tr>
<tr><td>Lowest scoring section: mode</td><td colspan="2">Influencing factors & Organisational measures</td><td colspan="2">Influencing factors</td></tr>
<tr><td>Highest scoring section: mode</td><td colspan="2">The organisation</td><td colspan="2">The organisation</td></tr>
<tr><td>Lowest scoring section: mean</td><td colspan="2">Incident management</td><td colspan="2">Influencing factors</td></tr>
<tr><td>Highest scoring section: mean</td><td colspan="2">The organisation</td><td colspan="2">The organisation</td></tr>
<tr><td rowspan="2">Safety culture mean</td><td>Value</td><td>Rank</td><td>Value</td><td>Rank</td></tr>
<tr><td>6.74</td><td>3</td><td>5.77</td><td>3</td></tr>
<tr><td>Organisational measures mean</td><td>5.96</td><td>7</td><td>5.30</td><td>8</td></tr>
<tr><td>Incident management mean</td><td>5.57</td><td>9</td><td>5.43</td><td>7</td></tr>
<tr><td>Competence management mean</td><td>6.06</td><td>6</td><td>5.77</td><td>3</td></tr>
<tr><td>Influencing factors mean</td><td>5.94</td><td>8</td><td>4.06</td><td>9</td></tr>
<tr><td>My role mean</td><td>6.65</td><td>4</td><td>5.67</td><td>5</td></tr>
<tr><td>My manager mean</td><td>6.86</td><td>2</td><td>6.20</td><td>2</td></tr>
<tr><td>Communications mean</td><td>6.38</td><td>5</td><td>5.57</td><td>6</td></tr>
<tr><td>The organisation mean</td><td>6.92</td><td>1</td><td>6.25</td><td>1</td></tr>
</table>

In the baseline survey the sections with the highest number of lowest scores (the mode) were "Influencing Factors" and "Organisational Measures". The highest scoring modal value was "The Organisation". The mean values calculated showed that the "The Organisation" section was highest (6.92) while the lowest scoring section was "Incident Management" (5.57). These results are essentially the same as those achieved in the uncorrected non-management baseline survey. In comparison to the all-personnel analysis, the mean values are slightly different but the modal and mean results from the survey sections are unchanged. This result assists in showing that the assessment tool is capable of providing consistent data even in the presence of potentially poorly filled in responses.

In the final survey the section with the greatest number of lowest scores (the mode) was "Influencing Factors". The highest-scoring section modal value was "The Organisation". The next highest modal values in the final survey were "The Organisation" and "Competence Management" which scored equally. The mean values calculated showed that "The Organisation" scored highest (6.25) while "Influencing Factors" scored lowest (4.06).

The values calculated are expected to be relatively sensitive as a result of the low number of responses in these categories. Whilst this is not ideal it is a factor that is inescapable with small businesses with a low number of employees.

6.1.6 Company "A" Analysis Summary

It can be seen from the modal and mean assessment calculations that "Influencing Factors", "Incident Management" and "Organisational Measures" generally achieved a low ranking while "The Organisation", "Competence Management", "My Manager" and "Safety Culture" achieved a high ranking.

It would therefore be prudent for Company A to concentrate its efforts on those three aspects that ranked low in the analysis. It is difficult from the outside to determine what measures could be implemented in order to improve the "Influencing Factors" responses other than ensuring that the company's good news and continuous progress towards building a full order book and fulfilling orders on time and in budget is continuously communicated to the personnel. This is unlikely to lead to a directly significant change in safety culture but is one of the underlying factors concerning operative attitudes to the workplace. A positive attitude should be encouraged.

It is the author's view that the low ranking of the "Incident Management" section is not as important as the other low ranking sections. The company already has an excellent safety record. Only three personnel from the team surveyed were classified as "management". Those personnel would not actually carry out accident investigations and incident management on their own. All such investigative activities are handled by the senior health and safety management team with assistance from the shop floor supervisory personnel. It is not surprising therefore that this section ranked relatively low.

The "Organisational Measures" section was ranked lowest or near to lowest in most analyses carried out. The statements in this section relate mainly to work procedures, permits to work, worker attitudes to following procedures, availability of written procedures and guidance and involvement of the shop floor operatives in any proposed modifications to plant or processes being considered. This may be the most effective section of the safety culture to address in the first instance. The aspects of the safety culture addressed in this section are those that may present the greatest risk to workers. The corrective measures that could be implemented to rectify this situation would be antecedent measures in the first instance such as brief training sessions on the procedures in place for routine activities, including permits to work, job planning, etc. Additionally the processes involved in determining what to do when an unplanned occurrence takes place can also be reinforced. Periodic communications briefs can be implemented specifically to ensure that workers are aware of all information that is relevant to their ability to work safely within their allotted roles within the workplace. This also provides an opportunity for face-to-face discussions with line management and senior management, thereby building trust and confidence in the workplace situation, i.e. teambuilding. Addressing such issues is also likely to have a positive effect on the outcome of the statements in the "Influencing Factors" section. Only detailed analysis of the workplace will highlight the possible measures that can be put in place but the analysis tool has provided a good estimate of where the company should begin the process.

The HSE statistics for the last two years is detailed in Table 6.6 below. It can be seen that for a company with approximately 325 people in total through all departments that the figures represent a low accident rate but not so low that the company can be complacent.

Table 6.6: *Company "A" Accident Statistics*

Accident Type	2009	2010
Near miss (gas alarms, minor substance release, etc.)	N/A	N/A
Minor accident (elastoplasts, etc.)	31	42
In-house recordable accident (more significant effects than minor, production or health and safety endangered)	7	8
HSE recordable accidents (in accordance with RIDDOR)	0	0
Lost time injury	0	0

Near misses are not specifically recorded as such in Company A. They are classified as minor accidents, even though no losses are actually encountered.

The company operates a continuous improvement system within the production plant. This system not only addresses faults and unplanned incidents that occur but it attempts to implement corrective measures to prevent recurrence in the future. Not only are faults fixed but they are fixed better. This increases reliability and productivity and is likely to have a knock-on effect of increasing the level of safety in the plant as a result of fewer instances of unplanned and potentially poorly planned maintenance activities being carried out. The company implements this system through the guidance provided in a book by Deming (1997). The company records the identification of such proposals for improved operability and productivity on what they call their Kaizen forms. Kaizen comes from the Japanese language and means "improvement". O'Connor (2002) describes the method of continuous improvement being "taken up enthusiastically in Japan, where it is called Kaizen".

6.2 Company “C1” Analysis: Assessment Tool Output

6.2.1 All Personnel

The output from the safety culture assessment tool for Company C1 is detailed in Table 6.7 below.

Table 6.7: *Company “C1” Assessment Tool Output*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	5.10		5.22	
Maximum safety culture	8.60		8.20	
No of returned surveys	15		13	
Quality factors: mean value	85.53		86.69	
Response total mean value	58.30		60.07	
Maximum Response Total	82.59		79.34	
	Supervisory		Management	
Maximum quality factors total	176.5		167	
	Supervisory		Management	
Lowest scoring quality value	Disagrees		Motivation	
Lowest scoring section: mode	Influencing factors		Influencing factors	
Highest scoring section: mode	Safety culture		Safety culture	
Lowest scoring section: mean	Influencing factors		Influencing factors	
Highest scoring section: mean	Competence management		The organisation	
	Value	Rank	Value	Rank
Safety culture mean	7.01	2	7.10	3
Organisational measures mean	6.20	8	6.30	7
Incident management mean	6.24	6	6.66	5
Competence management mean	7.05	1	7.23	2
Influencing factors mean	5.75	9	6.11	9
My role mean	6.47	4	6.14	8
My manager mean	6.23	7	6.38	6
Communications mean	6.40	5	6.70	4
The organisation mean	6.95	3	7.44	1

The overall safety culture rating has increased from 5.1 to 5.22 between the baseline survey and the final survey; an increase of 2.35%. In contrast, the maximum safety culture value returned from an individual response has reduced from 8.6 to 8.2 (1.2%).

The baseline survey received fifteen responses while the final survey received only thirteen. When the baseline survey was taken approximately 25 people were employed within the department. When the final survey was taken approximately 16 people were employed within the department. A much higher return ratio was therefore achieved for the final survey. The number of management responses between surveys did not change (five). The difference between the number of people employed within the department was attributed to the installation of new processing plant / machinery. The new plant was substantially automated thereby enabling personnel to monitor more than one machine at a time. The output from the department is now double what it was capable of before with a little over half the number of people.

The baseline survey lowest-scoring quality factor was “Disagrees”. As discussed for Company A this would suggest an unwillingness of respondents to select the “disagree” options for negative statements even when this is actually a positive response. In the final survey the lowest-scoring quality factor was “Motivation” with “Indifferent Responses” following closely behind. Two surveys were identified that had more than 50 indifferent responses but the maximum number of consecutive indifferent responses was relatively low (nine).

In the baseline survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors” and the highest scoring modal value was “Safety Culture”. The mean values calculated showed that the “Competence Management” section was highest (7.05) while the lowest scoring section was “Influencing Factors” (5.75).

In the final survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors”. The highest-scoring section modal value was also “Safety Culture” as found in the baseline survey. The next highest modal values in the final survey were “Communications” and “Organisational

Measures" which scored equally (two respondents each). The mean values calculated showed that "The Organisation" scored highest (7.44) while "Influencing Factors" scored lowest (6.11).

6.2.2 Management Personnel

The modified management-only response for Company C1 is detailed in Table 6.8. Five personnel were classified as management in the baseline and final surveys.

The overall safety culture rating has reduced from 6.26 to 5.60 between the baseline survey and the final survey; a reduction of 10.5%.

The maximum safety culture value returned from an individual response reduced from 8.6 to 8.2 (4.6%).

The baseline survey lowest-scoring quality factor was "Disagrees". In the final survey the lowest-scoring quality factor was the "Strongly disagree/Strongly agree Ratio" with "Disagrees" ranked just behind it.

In the baseline survey the section with the greatest number of highest scores (the mode) could not be determined as all five respondents scored different sections lowest. The lowest scoring section was "Organisational Measures" The mean values calculated showed that the "My Role" section was highest (8.09) while the lowest scoring section was "Organisational Measures" (6.27).

In the final survey the section with the greatest number of lowest scores (the mode) was "Influencing Factors". The highest-scoring sections were "Safety Culture" and "Competence Management". The mean values calculated showed that "Safety Culture" scored highest (7.75) while "Organisational Measures" scored lowest (6.35).

The results from the management personnel show a potential issue with "Organisational Measures" as it was ranked lowest in three of the four assessment factors.

Table 6.8: *Company "C1" Assessment Tool Output: Management Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	6.26		5.60	
Maximum safety culture rating	8.60		8.20	
No of returned surveys	5		5	
Quality factors: mean value	114.8		95.7	
Response total mean value	67.84		63.38	
Maximum Response Total	82.59		79.34	
	Supervisory		Management	
Maximum quality factors total	176.5		167	
	Supervisory		Management	
Lowest scoring quality value	Disagrees		SD/SA Ratio	
Lowest scoring section: mode	Organisational measures		Influencing Factors	
Highest scoring section: mode	N/A		Safety Culture	
Lowest scoring section: mean	Organisational measures		Organisational measures	
Highest scoring section: mean	The organisation		Safety Culture	
	Value	Rank	Value	Rank
Safety culture mean	7.80	4	7.75	1
Organisational measures mean	6.27	9	6.35	9
Incident management mean	6.79	8	6.88	6
Competence management mean	7.92	3	7.60	2
Influencing factors mean	7.41	7	6.64	8
My role mean	8.09	1	6.92	5
My manager mean	7.77	6	6.95	4
Communications mean	7.80	4	6.75	7
The organisation mean	7.99	2	7.54	3

6.2.3 Non-Management Personnel

The non-management response for Company C1 is detailed in Table 6.9 below. Eight personnel were classified as non-management in the baseline survey while in the final survey seven personnel were in this category.

Table 6.9: *Company "C1" Assessment Tool Output: Non-Management Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.58		4.97	
Maximum safety culture rating	6.73		7.34	
No of returned surveys	8		7	
Quality factors: mean value	73.88		80.07	
Response total mean value	53.57		58.12	
Maximum Response Total	69.32		76.75	
	Technician		Technician	
Maximum quality factors total	126.5		135.5	
	Technician		Technician	
Lowest scoring quality value	Training		Motivation	
Lowest scoring section: mode	Influencing factors		My role	
Highest scoring section: mode	Safety culture		The organisation	
Lowest scoring section: mean	Influencing factors		My role	
Highest scoring section: mean	Competence management		The organisation	
	Value	Rank	Value	Rank
Safety culture mean	6.56	2	6.73	4
Organisational measures mean	6.20	4	6.23	6
Incident management mean	5.97	5	6.59	5
Competence management mean	6.67	1	6.89	3
Influencing factors mean	4.91	9	5.69	8
My role mean	5.71	7	5.52	9
My manager mean	5.38	8	6.11	7
Communications mean	5.74	6	6.91	2
The organisation mean	6.43	3	7.45	1

The overall safety culture rating has increased from 4.58 to 4.97 between the baseline survey and the final survey; an increase of 8.5%.

The maximum safety culture value returned from an individual response increased from 6.73 to 7.34 (9%).

The baseline survey lowest-scoring quality factor was “Training”. In the final survey the lowest-scoring quality factor was “Motivation”. The “Disagrees” ranked twentieth in the baseline survey and twenty-second in the final survey.

In the baseline survey the section with the greatest number of lowest scores was “Influencing Factors” The highest scoring modal value was “Safety Culture”. The mean values calculated showed that the “Competence Management” section was highest (6.67) while the lowest scoring section was “Influencing Factors” (4.91).

In the final survey the section with the greatest number of lowest scores (the mode) was “My Role”. The highest-scoring sections was “The Organisation”. The mean values calculated showed that “The Organisation” scored highest (7.45) while “My Role” scored lowest (5.52).

The results from the non-management personnel show that the “Influencing Factors” section scored lowest again which would suggest that the shop floor operatives feel more at risk than their management counterparts. This has occurred between surveys, i.e. after major changes to the workplace were implemented.

6.2.4 Poor Quality Responses Removed: All Personnel

The results of the baseline and final surveys with poor quality responses removed are detailed in Table 6.10.

It was noted that the baseline survey contained no such poor quality responses and there was only one such poor quality response in the final survey. Fifteen personnel were in the baseline survey while twelve were in the final survey.

The overall safety culture rating has increased from 5.1 to 5.4 between the baseline survey and the final survey; an increase of 5.8%.

The maximum safety culture value returned from an individual response reduced from 8.6 to 8.2 (4.6%).

The baseline survey lowest-scoring quality factor was “Disagrees”. In the final survey the lowest-scoring quality factor was “Motivation”. The “Disagrees” ranked twenty-second out of twenty-three.

Table 6.10: *Company “C1” Assessment Tool Output: Poor Surveys Removed All Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	5.10		5.40	
Maximum safety culture rating	8.60		8.20	
No of returned surveys	15		12	
Quality factors: mean value	85.53		91.42	
Response total mean value	58.30		61.38	
Maximum Response Total	82.59		79.34	
	Supervisory		Management	
Maximum quality factors total	176.5		167	
	Supervisory		Management	
Lowest scoring quality value	Disagrees		Motivation	
Lowest scoring section: mode	Influencing factors		Influencing factors	
Highest scoring section: mode	Safety culture		Competence management	
Lowest scoring section: mean	Influencing factors		Influencing factors	
Highest scoring section: mean	Competence management		The organisation	
	Value	Rank	Value	Rank
Safety culture mean	7.01	2	7.22	3
Organisational measures mean	6.20	8	6.40	7
Incident management mean	6.24	6	6.80	5
Competence management mean	7.05	1	7.40	2
Influencing factors mean	5.75	9	6.26	9
My role mean	6.47	4	6.27	8
My manager mean	6.23	7	6.56	6
Communications mean	6.40	5	6.82	4
The organisation mean	6.95	3	7.65	1

In the baseline survey the section with the highest number of lowest scores (the mode) was “Influencing Factors”. The highest scoring modal value was “Safety Culture”. The mean values calculated showed that the “Competence Management” section was highest (7.05) while the lowest scoring section was “Influencing Factors” (5.75). Other than the highest modal score in the final survey, these results are essentially the same as those achieved in the baseline survey without the poor quality data being removed. In the baseline survey the highest-scoring modal survey section was “Safety Culture” while with the poor quality responses removed the highest-scoring section changed to “Competence Management”.

In the final survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors”. The highest-scoring section modal value was “Competence Management”. The next highest modal values in the final survey were “The Organisation”, “Safety Culture” and “Incident Management” all with two respondents each. The mean values calculated showed that “The Organisation” scored highest (7.65) while “Influencing Factors” scored lowest (6.26).

6.2.5 Poor Quality Responses Removed: Non-Management Personnel

The results of the baseline and final surveys for non-management personnel with poor quality responses removed are detailed in Table 6.11. There were eight such responses recorded for the baseline survey and six in the final survey. These also included those surveys that did not have the job role field filled in (two in each survey) as it could not be determined whether the responses were from management personnel or otherwise.

The overall safety culture rating has increased from 4.58 to 5.28 between the baseline survey and the final survey; an increase of 15.2%.

The maximum safety culture value returned from an individual response increased from 6.73 to 7.34 (9%).

The baseline survey lowest-scoring quality factor was “Training”. In the final survey the lowest-scoring quality factor was “Motivation”. The “Disagrees” ranked twenty-second out of twenty-three.

Table 6.11: *Company "C1" Assessment Tool Output: Poor Surveys Removed Non-Management Personnel Only*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.58		5.28	
Maximum safety culture rating	6.73		7.34	
No of returned surveys	8		6	
Quality factors: mean value	73.88		88.42	
Response total mean value	53.57		60.40	
Maximum Response Total	69.32		76.75	
	Technician		Technician	
Maximum quality factors total	126.5		135.5	
	Technician		Technician	
Lowest scoring quality value	Training		Motivation	
Lowest scoring section: mode	Influencing factors		My role	
Highest scoring section: mode	Safety Culture		The organisation	
Lowest scoring section: mean	Influencing factors		My role	
Highest scoring section: mean	Competence management		The organisation	
	Value	Rank	Value	Rank
Safety culture mean	6.56	2	6.89	4
Organisational measures mean	6.20	4	6.43	6
Incident management mean	5.97	5	6.85	5
Competence management mean	6.67	1	7.17	3
Influencing factors mean	4.91	9	5.92	8
My role mean	5.71	7	5.67	9
My manager mean	5.38	8	6.42	7
Communications mean	5.74	6	7.18	2
The organisation mean	6.43	3	7.86	1

In the baseline survey the section with the highest number of lowest scores (the mode) was "Influencing Factors". The highest scoring modal value was "Safety Culture". The mean values calculated showed that the "Competence Management" section was highest (6.67) while the lowest scoring section was "Influencing Factors" (4.91). These results are essentially the same as those achieved in the baseline survey. In comparison to the baseline non-management analysis, the mean values are slightly different but the modal and mean results from the survey sections are unchanged.

In the final survey the section with the greatest number of lowest scores (the mode) was "My Role". The highest-scoring section modal value was "The Organisation". The mean values calculated showed that "The Organisation" scored highest (7.86) while "My Role" scored lowest (5.67). It can be seen that the mean and modal values are the same.

6.2.6 Company "C1" Analysis Summary

It can be seen from the modal and mean assessment calculations that "Influencing Factors", "My Role" and "Organisational Measures" generally achieved a low ranking while "The Organisation", "Competence Management" and "Safety Culture" achieved a high ranking.

It would therefore be prudent for Company C1 to concentrate its efforts on those three aspects that ranked low in the analysis. As described for Company A, it is difficult for an outsider to determine what measures could be implemented in order to improve the "Influencing Factors" responses. The company has gone through a phase of re-organisation over the past 18 months and, by their own admission, they have allowed certain underperforming personnel to leave the company. They believe that this has assisted them in the reorganisation and has provided a stronger foundation on which to base all of their future business activities by ensuring that the people that remain have the attitude that the company desires for its business. Production targets have already been surpassed and new investment is currently on-going. A gentle reinforcement of the good news would be beneficial in terms of ensuring the workforce is aware of its achievements and its goals.

The "Organisational Measures" section was ranked near to lowest in most analyses carried out. As described for Company A, this may be the most effective section of the safety culture to address in the first instance. The aspects of the safety culture addressed in this section are those that may present the greatest risk to workers, especially considering the hazards that are actually present within this workplace.

Table 6.12: *Company "C" Accident Statistics*

Accident Type	2009	2010
Near miss (gas alarms, minor substance release, etc.)	27	36
Minor accident (elastoplasts, etc.)	19	9
In-house recordable accident (more significant effects than minor, production or health and safety endangered)	7	5
HSE recordable accidents (in accordance with RIDDOR)	0	0
Lost time injury	0	0

The company operates a rigorous safety regime which involves all personnel from managing director down to support staff. The accident record for the last two years is noted in Table 6.12 above.

It can be seen that for a company with approximately 300 personnel on one site (made up of many small departments) these accident statistics are representative of a very good safety record and potentially, a very good safety culture. The company acknowledges that they are not perfect and they are not complacent with this accident rate, hence their willingness to participate in this research study. Given the hazards present on site (highly explosive and also pyrophoric gases) and the conditions in which those materials are used (5bar & 1700°C within the reactors), the low accident rate is indicative of the high regard the team give to safety aspects within the plant.

Much of the work carried out in the C1 department is procedural and does not ordinarily require a great deal of complex decision making. When an unplanned event occurs the personnel are trained for these eventualities in terms of how to safely recover from the situation. This may be by automatic plant shutdown systems or by manual intervention.

As with Company A, the organisational measures that could be implemented to improve the scoring of this section would be antecedent measures in the first instance with a view to carrying out periodic communications briefs to ensure that workers are aware of all information that is relevant to their workplaces, thereby building trust and confidence in the workplace situation, i.e. teambuilding while doing so. As stated previously, addressing such issues is also likely to have a positive effect on the outcome of the statements in the "Influencing Factors" section.

The "Training", "Motivation", "Communications" and "Disagree" quality factors were frequently ranked very low. These would suggest that people are in need of some formal training in order to satisfy them that they have adequate skills and knowledge with which to carry out their present duties. This may be a false positive if the personnel are already adequately trained but as long this quality factor only achieves a low ranking it should not be dismissed from any discussion on how to improve the situation.

As discussed previously, the "Disagree" quality factor is ranked very low on most surveys returned. This was anticipated hence the insertion of such a quality factor and is discussed further in section 7.0 and section 9.0 of this thesis.

The "Training" quality factor is also suspected of providing a false low value. Statements 20 and 24 are noted to have provided a consistently poor response and these two statements do not relate directly to the majority of operatives. Further analysis of this reveals that if those two statements were removed from the training quality factor the ranking would rise from 21st to 17th. Whilst this lends weight to show that those two statements are giving rise to a falsely low value, the overall quality factor rating is still relatively low and consideration should be given to rectification through more training in the workplace.

The "Motivation" quality factor may be scored low if there is an overbearing management style in place or if personnel are free to take shortcuts and not adhere strictly to written instructions and procedures. This factor is not so much about how good people feel about the workplace but is more about what motivates people to do the things they do (especially if this means violating safety rules). Communication of what is acceptable behaviour is critically important if this section is to score highly. Not only that, communication of such information is not simply to threaten the workforce with punishment if they break the rules but it should be done to ensure that the workforce understand that the antecedent measures in place are there for their own safety and that of the plant, i.e. to avoid the potentially irreversible consequences of the incidents that may occur if rules are not followed.

6.3 Company "C2" Analysis: Assessment Tool Output

6.3.1 All Personnel

The output from the safety culture assessment tool for Company C2 is detailed in Table 6.13.

The overall safety culture rating has increased from 4.42 to 5.00 between the baseline survey and the final survey; an increase of 13.1%. The maximum safety culture value returned from an individual response has increased from 7.83 to 8.30 (6%).

The baseline survey received forty six responses while the final survey received only twenty-three. When the baseline survey was taken approximately 50 people were employed within the department. When the final survey was taken approximately 30 people were employed within the department. A slightly higher return ratio was therefore achieved for the baseline survey. The number of management responses in the baseline survey was ten while in the final survey this was only three. This department has also been substantially reorganised over the past eighteen months and as a result of new investment in machines and process plant equipment another four personnel have recently been recruited to work in this area.

The baseline survey lowest-scoring quality factor was "Training" closely followed by "Disagrees" In the final survey the lowest-scoring quality factor was "Disagrees" and "Communications".

Six surveys were identified that had more than 50 indifferent responses but the maximum number of consecutive indifferent responses was relatively low (eleven). All returned surveys were therefore considered to be acceptable for the purposes of further analysis.

In the baseline survey the section with the greatest number of lowest scores (the mode) was "Influencing Factors" and the highest scoring modal value was "Safety Culture". The mean values calculated showed that the "Safety

Culture" section was highest (6.65) while the lowest scoring section was "Influencing Factors" (5.09).

Table 6.13 *Company "C2" Assessment Tool Output*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.42		5.00	
Maximum safety culture	7.83		8.30	
No of returned surveys	46		23	
Quality factors: mean value	69.22		85.24	
Response total mean value	52.39		56.73	
Maximum Response Total	78.48		78.25	
	Technician		Technician	
Maximum quality factors total	152.5		174	
	Technician		Technician	
Lowest scoring quality value	Training		Disagrees & Communications	
Lowest scoring section: mode	Influencing factors		Influencing factors	
Highest scoring section: mode	Safety culture		Safety culture	
Lowest scoring section: mean	Influencing factors		Communications	
Highest scoring section: mean	Safety culture		Safety culture	
	Value	Rank	Value	Rank
Safety culture mean	6.65	1	6.99	1
Organisational measures mean	5.84	5	6.23	5
Incident management mean	5.85	4	6.41	4
Competence management mean	6.08	3	6.67	2
Influencing factors mean	5.09	9	5.92	8
My role mean	5.76	6	6.18	7
My manager mean	5.68	7	6.18	6
Communications mean	5.34	8	5.57	9
The organisation mean	6.10	2	6.59	3

In the final survey the section with the greatest number of lowest scores (the mode) was "Influencing Factors". The highest-scoring section modal value was also “Safety Culture” as found in the baseline survey. The next highest modal value in the final survey was “Competence Management”. The mean values calculated showed that “Safety Culture” scored highest (6.99) while “Communications” scored lowest (5.57).

6.3.2 Management Personnel

The modified management-only response for Company C2 is detailed in Table 6.14. Ten personnel were classified as management in the baseline survey and in the final survey three personnel were classified as management. As stated previously, the low number of personnel in the final group may make this analysis highly sensitive to certain factors calculated. Whilst this may invalidate the data in a broad sense, it is the same data from the same team in any one workplace and the most important measure is the difference between baseline and final surveys.

The overall safety culture rating increased from 5.03 to 5.26 between the baseline survey and the final survey; an increase of 4.5%.

The maximum safety culture value returned from an individual response reduced from 7.02 to 6.37 (9.2%).

The baseline survey lowest-scoring quality factor was “Training”. In the final survey the lowest-scoring quality factor was also “Training”.

In the baseline survey the section with the greatest number of highest scores (the mode) was “Safety Culture”. The sections with the greatest number of low scores were “Influencing Factors and “My Role” (each with two respondents scoring these lowest). The mean values calculated showed that the “Safety Culture” section was highest (7.37) while the lowest scoring section was “Communications” (5.95).

In the final survey no conclusion can be drawn from the lowest-scoring modal values as each respondent scored a different section lowest. The three sections that were scored lowest were “Safety Culture”, “Influencing Factors” and “Communications”. Similarly in the final survey three different sections were scored highest, namely “Safety Culture”, “Competence Management” and “Communications”. It is interesting to note in this case that all three surveys were returned from supervisory staff yet a significant difference appears to be present in terms of the "Safety Culture" section being scored lowest and highest within such a small group of similar personnel.

Table 6.14: *Company "C2" Assessment Tool Output: Management Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	5.03		5.26	
Maximum safety culture rating	7.02		6.37	
No of returned surveys	10		3	
Quality factors: mean value	83.9		89.0	
Response total mean value	57.74		59.87	
Maximum Response Total	72.15		64.69	
	Supervisory		Supervisory	
Maximum quality factors total	135		122	
	Supervisory		Supervisory	
Lowest scoring quality value	Training		Training	
Lowest scoring section: mode	Influencing Factors & My Role		N/A	
Highest scoring section: mode	Safety Culture		N/A	
Lowest scoring section: mean	Communications		Influencing Factors	
Highest scoring section: mean	Safety Culture		The organisation	
	Value	Rank	Value	Rank
Safety culture mean	7.37	1	6.58	5
Organisational measures mean	6.29	5	6.42	7
Incident management mean	6.07	7	6.39	8
Competence management mean	6.27	6	6.92	3
Influencing factors mean	5.98	8	6.36	9
My role mean	6.40	4	6.92	2
My manager mean	6.74	2	6.75	4
Communications mean	5.95	9	6.58	5
The organisation mean	6.68	3	6.94	1

The mean values calculated showed that the “The Organisation” section was scored highest (6.94) while the lowest scoring section was “Influencing Factors” (6.36).

The results from the management personnel show that “Influencing Factors” and “Communications” were ranked lowest in three of the four assessment factors.

In the final survey the sample size was not conducive to forming any firm conclusions as all three respondents scored the survey sections differently (but with some commonality).

6.3.3 Non-Management Personnel

The non-management response for Company C2 is detailed in Table 6.15. Twenty-nine personnel were classified as non-management in the baseline survey while in the final survey twenty personnel were in this category.

The overall safety culture rating has increased from 4.25 to 4.97 between the baseline survey and the final survey; an increase of 16.9%.

The maximum safety culture value returned from an individual response increased from 7.83 to 8.3 (6%).

The baseline survey lowest-scoring quality factor was “Motivation”. In the final survey the lowest-scoring quality factor was “Disagrees”. The “Disagrees” ranked twenty-second out of twenty-three in the baseline survey.

In the baseline survey the lowest modal score was “Influencing Factors” (eleven respondents) with “Communications” following closely behind (with seven respondents); equal with “My Manager”. The highest scoring modal value was “Safety Culture”. The mean values calculated showed that the “Safety Culture” section was highest (6.52) while the lowest scoring section was “Influencing Factors” (4.85).

In the final survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors”. The highest-scoring section modal value was “Safety Culture”. The mean values calculated showed that “Safety Culture” scored highest (7.06) while “Communications” scored lowest (5.42).

The results from the non-management personnel also appear to show a potential issue with the “Influencing Factors” section.

Table 6.15: *Company "C2" Assessment Tool Output: Non-Management Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.25		4.97	
Maximum safety culture rating	7.83		8.3	
No of returned surveys	29		20	
Quality factors: mean value	65.47		84.68	
Response total mean value	50.94		56.26	
Maximum Response Total	78.48		78.25	
	Technician		Technician	
Maximum quality factors total	152.5		174	
	Technician		Technician	
Lowest scoring quality value	Motivation		Disagrees	
Lowest scoring section: mode	Influencing factors		Influencing factors	
Highest scoring section: mode	Safety culture		Safety culture	
Lowest scoring section: mean	Influencing factors		Communications	
Highest scoring section: mean	Safety culture		Safety culture	
	Value	Rank	Value	Rank
Safety culture mean	6.52	1	7.06	1
Organisational measures mean	5.77	4	6.20	5
Incident management mean	5.70	5	6.42	4
Competence management mean	6.15	2	6.63	2
Influencing factors mean	4.85	9	5.86	8
My role mean	5.58	6	6.06	7
My manager mean	5.29	7	6.09	6
Communications mean	5.18	8	5.42	9
The organisation mean	5.88	3	6.53	3

6.3.4 Poor Quality Responses Removed: All Personnel

The results of the baseline and final surveys with poor quality responses removed are detailed in Table 6.16.

It was noted that the baseline survey contained no such poor quality responses and there was only one such poor quality response in the final survey. This was detected by the number of consecutive responses over the last two sections (twenty) with the two final statements not even answered.

Table 6.16: *Company "C2" Assessment Tool Output: Poor Surveys Removed All Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.42		5.08	
Maximum safety culture rating	7.83		8.30	
No of returned surveys	46		22	
Quality factors: mean value	69.22		87.52	
Response total mean value	52.39		57.2	
Maximum Response Total	78.48		78.25	
	Technician		Technician	
Maximum quality factors total	152.5		174	
	Technician		Technician	
Lowest scoring quality value	Training		Communications	
Lowest scoring section: mode	Influencing factors		Influencing factors	
Highest scoring section: mode	Safety culture		Safety culture	
Lowest scoring section: mean	Influencing factors		Communications	
Highest scoring section: mean	Safety culture		Safety culture	
	Value	Rank	Value	Rank
Safety culture mean	6.65	1	7.04	1
Organisational measures mean	5.84	5	6.26	5
Incident management mean	5.85	4	6.51	4
Competence management mean	6.08	3	6.71	2
Influencing factors mean	5.09	9	5.97	8
My role mean	5.76	6	6.26	6
My manager mean	5.68	7	6.21	7
Communications mean	5.34	8	5.60	9
The organisation mean	6.10	2	6.66	3

The overall safety culture rating has increased from 4.42 to 5.08 between the baseline survey and the final survey; an increase of 14.9%.

The maximum safety culture value returned from an individual response increased from 7.83 to 8.3 (6%).

The baseline survey lowest-scoring quality factor was "Training". In the final survey the lowest-scoring quality factor was "Communications". The "Disagrees" ranked twenty-second out of twenty-three in the baseline and final surveys.

In the baseline survey the section with the highest number of lowest scores (the mode) was "Influencing Factors". The highest scoring modal value was "Safety Culture". The mean values calculated showed that the "Safety Culture" section was highest (6.65) while the lowest scoring section was "Influencing Factors" (5.09). These results are essentially the same as those achieved in the baseline survey without the poor quality data being removed.

In the final survey the section with the greatest number of lowest scores (the mode) was "Influencing Factors". Eight respondents scored this section lowest. The next lowest modal score was "Communications" (with seven respondents scoring this lowest). The highest-scoring section modal value was "Safety Culture" with seven respondents scoring this highest. The next highest modal values in the final survey were "Competence Management" with five respondents scoring this highest. The mean values calculated showed that "Safety Culture" scored highest (7.04) while "Communications" scored lowest (5.6).

6.3.5 Poor Quality Responses Removed: Non-Management Personnel

The results of the baseline and final surveys for non-management personnel with poor quality responses removed are detailed in Table 6.17 below.

There were twenty-nine such responses recorded for the baseline survey and nineteen in the final survey. These also included those surveys that did not have the job role field filled in; seven in the baseline survey and none in the final survey.

The overall safety culture rating has increased from 4.25 to 5.05 between the baseline survey and the final survey; an increase of 18.8%.

Table 6.17: *Company "C2" Assessment Tool Output: Poor Surveys Removed Non-Management Personnel Only*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.25		5.05	
Maximum safety culture rating	7.83		8.30	
No of returned surveys	29		19	
Quality factors: mean value	65.47		87.29	
Response total mean value	50.94		56.78	
Maximum Response Total	78.48		78.25	
	Technician		Technician	
Maximum quality factors total	152.5		174	
	Technician		Technician	
Lowest scoring quality value	Motivation		Disagrees	
Lowest scoring section: mode	Influencing factors		Influencing factors	
Highest scoring section: mode	Safety Culture		Safety Culture	
Lowest scoring section: mean	Influencing factors		Communications	
Highest scoring section: mean	Safety Culture		Safety Culture	
	Value	Rank	Value	Rank
Safety culture mean	6.52	1	7.11	1
Organisational measures mean	5.77	4	6.23	5
Incident management mean	5.70	5	6.53	4
Competence management mean	6.15	2	6.67	2
Influencing factors mean	4.85	9	5.91	8
My role mean	5.58	6	6.15	6
My manager mean	5.29	7	6.12	7
Communications mean	5.18	8	5.44	9
The organisation mean	5.88	3	6.61	3

The maximum safety culture value returned from an individual response increased from 7.83 to 8.30 (6%).

The baseline survey lowest-scoring quality factor was "Motivation". In the final survey the lowest-scoring quality factor was "Disagrees". The

“Disagrees” ranked twenty-second out of twenty-three in the baseline survey.

In the baseline survey the section with the highest number of lowest scores (the mode) was “Influencing Factors”. The highest scoring modal value was “Safety Culture”. The mean values calculated showed that the “Safety Culture” section was highest (6.52) while the lowest scoring section was “Influencing Factors” (4.85). These results are essentially the same as those achieved in the baseline survey. In comparison to the baseline non-management analysis, the mean values are slightly different but the modal and mean results from the survey sections are unchanged.

In the final survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors”. The highest-scoring section modal value was “Safety Culture”. The mean values calculated showed that “Safety Culture” scored highest (7.11) while “Communications” scored lowest (5.44).

6.3.6 Company “C2” Analysis Summary

It can be seen from the modal and mean assessment calculations that “Influencing Factors”, “Communications” and “My Manager” sections generally achieved a low ranking while “The Organisation”, “Competence Management” and “Safety Culture” achieved a high ranking. The “Safety Culture” section was ranked highest in every assessment (mode and mean). This is in contrast to company C1 (part of the same organisation) in which “Influencing Factors”, “My Role” and “Organisational Measures” scored lowest. This analysis shows that even within the same organisation, the assessment tool is able to identify departmental differences in safety culture and to assist in defining those aspects most in need of attention.

It would be prudent for Company C2 to concentrate its efforts on those three aspects that ranked lowest in the analysis. However, as the “Influencing Factors” section scored lowest overall between Company C1 and Company C2 perhaps a unified approach from the whole company to address these issues would be best in order to apply any corrective measures to all departments.

The “Communications” section was ranked near to lowest in most analyses carried out. In combination with the “My Manager” section, which also scored relatively low in Company C2, this highlighted a particular issue with the management personnel or the management structure within the department. In recognition of this and as part of the restructuring that has occurred in this department, the department managers are now located within the production area instead of being based in a remote office elsewhere on the site. This has made the management more approachable and the company state that this has already had a positive effect on the workplace (but unfortunately too late to be measurable in the final safety culture survey).

As with Company C1, much of the work carried out in the C2 department is procedural, using an array of highly complex and potentially dangerous machinery. The work carried out does not ordinarily require a great deal of complex decision making from the shop floor operatives.

The "Training", "Motivation", "Communications" and "Disagree" quality factors were again ranked very low as found with Company C1. The quality factors therefore serve to show that there are common issues within the site that can be addressed as a whole and applied throughout.

6.4 Company "C3" Analysis: Assessment Tool Output

6.4.1 All Personnel

The output from the safety culture assessment tool for Company C3 is detailed in Table 6.18.

The overall safety culture rating has increased from 4.29 to 4.38 between the baseline survey and the final survey; an increase of 2%. The maximum safety culture value returned from an individual response has increased from 5.94 to 6.59 (10.9%).

The baseline survey included seven responses while the final survey included twelve. When the baseline survey was taken approximately twenty-six people were employed within the department. When the final survey was taken approximately twenty-two people were employed within the department. A much higher return ratio was therefore achieved for the final survey. The number of management responses in the baseline survey was one while in the final survey there were three.

This department provides technical support services to all other departments within the site. It has also been re-organised over the past eighteen months and has lost a few personnel but also changed several more through internal transfers.

Table 6.18: *Company "C3" Assessment Tool Output*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.29		4.38	
Maximum safety culture	5.94		6.59	
No of returned surveys	7		12	
Quality factors: mean value	64.86		67.21	
Response total mean value	51.84		52.60	
Maximum Response Total	63.83		69.38	
	Technician		N/A	
Maximum quality factors total	105.5		120.5	
	Technician		N/A	
Lowest scoring quality value	Motivation & Organisational measures		Motivation	
Lowest scoring section: mode	Organisational measures		Influencing factors	
Highest scoring section: mode	Safety culture		Safety culture	
Lowest scoring section: mean	Influencing factors		Influencing factors	
Highest scoring section: mean	The organisation		Safety culture	
	Value	Rank	Value	Rank
Safety culture mean	6.24	2	6.51	1
Organisational measures mean	5.21	8	5.92	4
Incident management mean	5.79	5	5.73	7
Competence management mean	5.69	6	5.91	5
Influencing factors mean	5.06	9	4.80	9
My role mean	6.13	3	6.18	2
My manager mean	5.84	4	5.83	6
Communications mean	5.55	7	5.64	8
The organisation mean	6.35	1	6.08	3

The baseline survey lowest-scoring quality factors were “Organisational Measures” and “Motivation” which scored equally. “Disagrees” was ranked twentieth out of twenty-three. In the final survey the lowest-scoring quality factor was “Motivation” with “Disagrees” ranked twenty-second.

Two questionnaires were identified in the baseline survey that had more than 50 indifferent responses but the maximum number of consecutive indifferent responses was relatively low (eight). In the final survey two questionnaires were also identified but the maximum number of consecutive responses was still relatively low (fourteen). All returned surveys were therefore considered to be acceptable for the purposes of further analysis.

In the baseline survey the section with the greatest number of lowest scores (the mode) was “Organisational Measures” and the highest scoring modal value was “Safety Culture”. The mean values calculated showed that the “The Organisation” section was highest (6.35) while the lowest scoring section was “Influencing Factors” (5.06).

In the final survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors”. The highest-scoring section modal value was also “Safety Culture” as found in the baseline survey. The mean values calculated showed that “Safety Culture” scored highest (6.51) while “Influencing Factors” scored lowest (4.80).

6.4.2 Management Personnel

The modified management-only response for Company C3 is detailed in Table 6.19. Only one person was classified as management in the baseline survey and in the final survey three personnel were classified as management. It can be argued that such small numbers will not provide reliable data but the trend between surveys is also important, irrespective of the number of people in the survey.

The overall safety culture rating decreased from 4.23 to 3.97 between the baseline survey and the final survey; a decrease of 6.1%.

The maximum safety culture value returned from an individual response increased from 4.29 to 4.88 (13.7%).

Table 6.19: *Company "C3" Assessment Tool Output: Management Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.23		3.97	
Maximum safety culture rating	4.29		4.88	
No of returned surveys	1		3	
Quality factors: mean value	64.0		56.67	
Response total mean value	51.07		49.26	
Maximum Response Total	51.07		57.50	
	Supervisory		Supervisory	
Maximum quality factors total	64.0		74	
	Supervisory		Supervisory	
Lowest scoring quality value	N/A		Safety culture, Management pressure & Resources	
Lowest scoring section: mode	N/A		Influencing Factors	
Highest scoring section: mode	N/A		Safety Culture	
Lowest scoring section: mean	Influencing Factors		Influencing Factors	
Highest scoring section: mean	Competence management		The organisation	
	Value	Rank	Value	Rank
Safety culture mean	5.60	5	5.78	2
Organisational measures mean	5.25	7	5.62	4
Incident management mean	6.46	2	5.49	7
Competence management mean	6.50	1	5.62	4
Influencing factors mean	4.77	9	4.41	9
My role mean	6.15	3	5.92	1
My manager mean	5.00	8	5.13	8
Communications mean	5.50	6	5.58	6
The organisation mean	5.83	4	5.71	3

The baseline survey lowest-scoring quality factor could not be determined as there was only one response in this analysis causing many factors to be scored equally. In the final survey the lowest-scoring quality factors were "Safety Culture", "Management Pressure" and "Resources".

In the baseline survey the section with the highest score was "Competence Management" (6.5). As there was only one response no mode or mean rankings were possible. The section with the lowest score was "Influencing Factors" (4.77).

In the final survey no conclusion can be drawn from the highest-scoring modal values as each respondent scored a different section lowest. The three sections that were scored highest were "Safety Culture", "My Role" and "The Organisation". The section with the greatest number of lowest scores was "Influencing Factors" (all three respondents scored this the lowest). The mean values calculated showed that the "My Role" section was scored highest (5.92) while the lowest scoring section was "Influencing Factors" (4.41).

The results from the management personnel again show a potential issue with "Influencing Factors" as it was ranked lowest in all four assessment factors.

As stated previously the sample size was not conducive to forming any firm conclusions in this analysis although some commonality in the responses is clearly present.

6.4.3 Non-Management Personnel

The non-management response for Company C3 is detailed in Table 6.20. Five personnel were classified as non-management in the baseline survey while in the final survey six personnel were in this category.

The overall safety culture rating has reduced slightly from 4.27 to 4.25 between the baseline survey and the final survey; a reduction of 0.4%.

The maximum safety culture value returned from an individual response reduced from 5.94 to 5.69 (4.2%).

The baseline survey lowest-scoring quality factors were "Motivation" and "Organisational Measures". In the final survey the lowest-scoring quality factor was "Motivation". The "Disagrees" ranked eighteenth out of twenty-three in the baseline survey an twentieth in the final survey.

Table 6.20: *Company "C3" Assessment Tool Output: Non-Management Personnel*

Measured Variable	Baseline Survey		Final Survey	
Overall safety culture rating	4.27		4.25	
Maximum safety culture rating	5.94		5.69	
No of returned surveys	5		6	
Quality factors: mean value	65.5		63.58	
Response total mean value	51.22		51.62	
Maximum Response Total	63.83		62.88	
	Technician		Technician	
Maximum quality factors total	105.5		96.5	
	Technician		Technician	
Lowest scoring quality value	Organisational measures & Motivation		Motivation	
Lowest scoring section: mode	Organisational measures		Influencing factors	
Highest scoring section: mode	Safety culture & Competence Management		Safety culture	
Lowest scoring section: mean	Influencing factors		Influencing factors	
Highest scoring section: mean	Safety culture		Safety culture	
	Value	Rank	Value	Rank
Safety culture mean	6.21	2	6.50	1
Organisational measures mean	4.95	8	6.14	2
Incident management mean	5.68	5	5.53	7
Competence management mean	5.61	6	5.69	5
Influencing factors mean	4.95	9	4.68	9
My role mean	6.19	3	5.91	4
My manager mean	5.92	4	6.02	3
Communications mean	5.32	7	5.46	8
The organisation mean	6.39	1	5.69	6

In the baseline survey the section that scored the greatest number of lowest scores was "Organisational Measures" (two respondents) with "Communications", "Competence Management" and "Influencing Factors" all scoring lowest once each. The highest scoring modal values were “Safety Culture” and “Competence Management” equally with two respondents each. The mean values calculated showed that the “The Organisation” section was highest (6.39) while the lowest scoring section was “Influencing Factors” (4.95).

In the final survey the section with the greatest number of lowest scores (the mode) was “Influencing Factors”. The highest-scoring section modal value was “Safety Culture”. The mean values calculated showed that “Safety Culture” scored highest (6.5) while “Influencing Factors” scored lowest (4.68).

The results from the non-management personnel also appear to show a potential issue with the “Influencing Factors” and the “Organisational Measures” sections.

6.4.4 Poor Quality Responses Removed: All Personnel

It was noted that the baseline survey and the final survey contained no such poor quality responses. The results for this are therefore identical to that described for the baseline and final responses (section 6.4.1).

6.4.5 Poor Quality Responses Removed: Non-Management Personnel

As stated above there were no poor quality responses from this survey. The results for this are therefore identical to that described for the baseline non-management and final non-management responses (section 6.4.3).

6.4.6 Company “C3” Analysis Summary

It can be seen from the modal and mean assessment calculations that “Influencing Factors” and “Organisational Measures” sections generally achieved a low ranking while “The Organisation”, “Competence Management” and “Safety Culture” achieved a high ranking. This was a very similar result to Company C2.

Much of the work carried out in the C3 department requires permits to work as the personnel frequently enter operational process areas to carry out routine and non-routine activities; often requiring process and plant isolations to be in place prior to commencing work. Communications and planning are therefore particularly important requirements for this department. The

“Communications” section of the survey was scored lowest by a few personnel but never so often that it became the modal survey section.

The work carried out often requires the personnel to act upon their own experience, training and competence in the fulfilment of their tasks. Some of the written comments on the returned surveys referred to the need for senior management to be more realistic in terms of how tasks requiring permits to work are planned and executed, especially during plant outages. This is reflected in the scoring achieved for “Organisational measures”.

The “Training”, “Motivation”, “Organisational Measures”, and “Disagree” quality factors were ranked very low. The quality factors measured for Company C3 therefore also confirm that common dominant factors have been detected by the assessment tool.

6.5 General Analysis

6.5.1 Management Scoring versus Non-Management Scoring

In the tables below it can be seen that in Company A and in the manufacturing departments C1 & C2 the management personnel consistently provide higher scores than the non-management personnel. In the service department (C3) the opposite is true but the difference is much smaller.

Table 6.21: *Company “A” Management / Non-Management Comparison*

Baseline	Non-Management	Management
Overall Safety Culture Rating	4.58	6.21
Quality Factors Mean	68.53	117
Response Total Mean	55.59	66.08
Final		
Overall Safety Culture Rating	3.83	5.55
Quality Factors Mean	49.58	94
Response Total Mean	49.58	63.05

It is worthy to note that the management personnel’s perception of safety culture is considerably higher than the non-management personnel in most cases. The “Management” classification for the purposes of this analysis is defined as those responses received from supervisory, professional and management personnel (as denoted by the base data fields filled in on the front page of each survey). Non-management responses are therefore the responses remaining from technician and support personnel. In all of the safety culture surveys carried out only a small proportion of responses were from management personnel. Such a small sample size makes it difficult to form any firm conclusions and any such conclusions must be treated with caution.

There may be many reasons for the perceived difference in safety culture between management and non-management personnel. It is the author's experience that those personnel classified as management in this analysis are more aware of the health and safety policies and procedures in place as it is they who are responsible for creating and implementing them. In the companies that took part in this research project the non-management personnel predominantly receive health and safety information and guidance through the line management and formal training processes in place (antecedents). This method of disseminating information may give rise to some dilution and shop floor operatives may therefore be less aware of the formal arrangements in place.

Table 6.22: *Company "C1" Management / Non-Management Comparison*

Baseline	Non-Management	Management
Overall Safety Culture Rating	4.58	6.26
Quality Factors Mean	73.88	114.8
Response Total Mean	53.57	67.84
Final		
Overall Safety Culture Rating	4.97	5.60
Quality Factors Mean	80.07	95.7
Response Total Mean	58.12	63.38

Table 6.23: *Company "C2" Management / Non-Management Comparison*

Baseline	Non-Management	Management
Overall Safety Culture Rating	4.25	5.03
Quality Factors Mean	65.47	83.9
Response Total Mean	50.94	57.74
Final		
Overall Safety Culture Rating	4.97	5.26
Quality Factors Mean	84.68	89.0
Response Total Mean	56.26	59.87

Table 6.24: *Company "C3" Management / Non-Management Comparison*

Baseline		
	Non-Management	Management
Overall Safety Culture Rating	4.27	4.23
Quality Factors Mean	65.5	64.0
Response Total Mean	51.22	51.07
Final		
Overall Safety Culture Rating	4.25	3.97
Quality Factors Mean	63.58	56.67
Response Total Mean	51.62	49.26

The only way that higher scores can be achieved in the assessment tool is for personnel to answer the statements with a greater number of "strongly agree" or "strongly disagree" responses.

It can be seen from the results of the C3 department that this situation is reversed and there appear to be good reasons for this. It was noted during the consultations with the company and in the returned surveys that the C3 department had a particularly strong willed and outspoken team. Many of the personnel in this department are time-served craftsmen / technicians with many years of high tech engineering experience in the hazardous industries. The management style within the department also encourages people to communicate any issues as a means of rectifying them for the benefit of all. A blame culture is almost certainly not present. The personnel were keen to participate in the research as a means of assisting in risk reduction and they showed this in their enthusiastic participation.

6.5.2 Indifferent Responses

Several surveys were noted to have an unacceptable number of indifferent responses or an unacceptable number of consecutive indifferent responses (as defined in section 5.2.19). Analysis of the overall survey results was also carried out with these survey responses removed to assess the difference that they may have made to the original (complete) results. It was found that an unacceptable number of indifferent responses did little to affect the overall assessment tool output in terms of calculating the modal and mean values of the survey sections. There were no surveys returned that had an unacceptably high number of "strongly agree" or "strongly disagree" responses. It is clear that such a response would adversely affect the outcome of the analysis. The surveys received assisted in showing that human nature favours the neutral option when in doubt or when displaying an indifferent attitude.

6.5.3 Baseline versus Final Mean Values

There is no strong evidence from the results in the tables above that shows a trend for the final survey analysis scoring lower or higher than the baseline analysis. The results from the analysis tool are dependent only on the activities, attitudes and influencing factors prevalent at the time that the surveys were filled in. There does not appear to be any specific time related factors other than the effect that changes to the workplace can have over a given time period.

6.5.4 Disagrees Quality Factor

The "Disagree" quality factor consistently ranked very low or lowest for all the analyses carried out. This appeared to show that people were unwilling to select the "disagree" answers even when the statement may have been worded negatively to prompt such a response. The results obtained may also point to the fact that people simply selected what they felt were true and honest representations of their feelings at that time.

Further analysis was carried out by cross-linking some specific statements to clarify this situation.

The answers to statements 26 and 30 were compared. These statements are specifically about the people who cause accidents. Statement 26 asserts "The people who cause incidents are not held sufficiently accountable for their actions." while S30 asserts "A trend is present which shows that incidents are repeatedly caused by the same people." In a good safety culture both statements should return "disagree" responses. The results are shown in Table 6.25. In Company A the mean value for S26 rose from 0.45 to 0.48 between baseline and final surveys. In company C1 it rose from 0.48 to 0.56. In Company C2 it fell from 0.48 to 0.43 and in Company C3 it rose from 0.50 to 0.58. There is no significant difference between the baseline and final surveys for S26. In Company A S30 response did not change by a significant margin. In Company C1 a similar result occurred. In Company C2 the response fell from 0.61 to 0.57 and in Company C3 it rose from 0.57 to 0.67. The responses show a slight improvement between baseline and final surveys but very few people actually responded with expected results. The results could be classified as random and therefore not showing that people are particularly averse to selecting the disagree response.

Statements 37, 40 and 42 were also compared. Statement 37 should promote a "disagree" response while the other two should promote "agree" responses. Statement 37 is about the respondent being unsure what to do sometimes to maintain health and safety. Statement 40 should confirm that adequate training has been provided to maintain health and safety while statement 42 asserts that the respondent is clear about their role in health and safety. There was much more agreement between people on these statements and many more responded with the expected results. It could be stated that these statements are more straightforward than S26 and S30 and thereby promote fewer indifferent responses and more favourable responses.

Statements 59 and 65 were compared. Statement 59 seeks the respondent's view on the working practices of their colleagues in terms of how safely they actually work in practice. It is worded negatively and should promote a "disagree" response. Statement 65 is a very similar statement but is worded in a positive and different manner. This statement asks about the capability of their colleagues to asses risk and act accordingly rather than what they actually do in practice. This statement should promote a positive response.

Table 6.25: *Additional Disagree Statements Analysis*

	S26 / S30	S37 / S40 / S42	S59 / S65
Company A Baseline	2/19 M:1 NM:1	4/19 M:1 NM:3	5/19 M:2 NM:3
Company A Final	1/12 M:0 NM:0 N/A:1	4/12 M:1 NM:1 N/A:1	1/12 M:0 NM:0 N/A:1
Company C1 Baseline	1/15 M:0 NM:1	10/15 M:4 NM:6	3/15 M:2 NM:1
Company C1 Final	2/13 M:1 NM:1	7/13 M:3 NM:3 N/A:1	2/13 M:1 NM:1
Company C2 Baseline	4/46 M:1 NM:2 N/A:1	18/46 M:4 NM:12 N/A:2	6/46 M:0 NM:4 N/A:2
Company C2 Final	3/23 M:1 NM:2	7/23 M:2 NM:5	6/23 M:1 NM:5
Company C3 Baseline	0/7 M:0 NM:0	0/7 M:0 NM:0	1/7 M:1 NM:0
Company C3 Final	2/12 M:1 NM:0 N/A:1	4/12 M:1 NM:2 N/A:1	6/12 M:2 NM:2 N/A:2

M: Management NM: Non-Management N/A: Not available

(The numbers in the table above are the number of people who responded to the statements as described in section 6.5.4.)

It is clear from the results listed and in the detailed analysis of the statement responses that people appear to have a good respect for their colleagues in terms of their competency (S65) but less so for their ability to put those skills into practice (S59). Such issues are exactly what behaviour-based safety systems of control can rectify. Intervention can reduce risk in such situations when people know that they are doing something wrong but are taking a chance on using a shortcut.

The analysis shows that people do not appear to be averse to selecting "disagree" responses any more than they would the "agree" responses.

In the charts below the blue bars represent the baseline survey while red bars represent the final survey.

Figure 6.1: *Company A Colleague Competence Assessment*

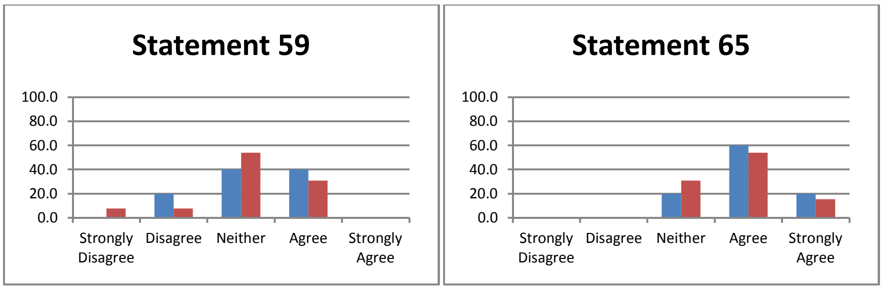

Figure 6.2: *Company C1 Colleague Competence Assessment*

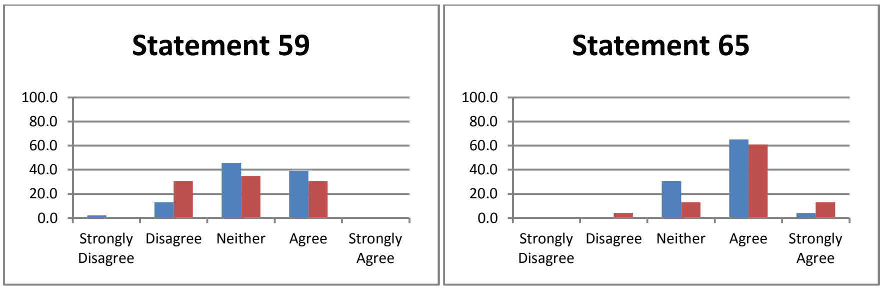

Figure 6.3: *Company C2 Colleague Competence Assessment*

Figure 6.4: *Company C3 Colleague Competence Assessment*

6.5.5 Test Statements (S35, S38 & S87)

Survey quality is estimated from the responses to these statements. These statements should have prompted a 100% favourable response but this did not occur for any of the surveys carried out. In Company A only S38 prompted negative responses in the baseline survey while S35 did so in the final survey. In Company C1 all three statements prompted negative responses while in the final survey only S35 did so. In Company C2 negative responses were received for all three statements in the baseline survey but only in S35 for the final survey. C2 was the largest survey (with 46 surveys returned). In Company C3 negative responses were recorded for S35 & S38 in the baseline and final surveys. This was somewhat disappointing as it showed that the respondents either did not take the survey seriously by not reading the statements and potential responses with enough care or simply that they did not understand the statement. The answers to the statements entered for this purpose should have been so simple (to the respondent) that it is difficult to comprehend how better results were not achieved.

7.0 CRITICAL ASSESSMENT OF THE RESEARCH

7.1 Research Project Objectives

7.1.1 Intended Beneficiaries

This research project was aimed at creating a system of human factors assessment that could be used by SME in-house personnel that do not possess the underpinning knowledge and understanding the subject would normally require. The system was not intended to replace the role of the professional industrial psychologists that are able to implement such methods in more depth and with far greater understanding and analysis of the situation. Such implementation may well be capable of identifying all the major and minor issues present but this could be a long and expensive process. The intention of this research project was to implement a more basic method of identifying the most significant issues thereby enabling the company to act upon them and prevent an accident that may have otherwise occurred.

Eighteen companies were contacted to take part in the research; including SMEs and multi-nationals; but only two actually took part and they were multi-nationals. It is disappointing that no SMEs took part as it means that the use of the safety culture assessment tool by in-house personnel could not be verified directly. The tool has been created and made ready for such an implementation but this needs to be tested and developed by the companies for which it was intended in order to prove its worth and usability.

7.1.2 Collaborator Commitment

The companies approached to take part in this research project were mostly enthusiastic to take part when they first heard about its aims and what it could achieve for them. When the companies realised that it would require some resource and commitment from them they were somewhat cooler to the idea of taking part. The method used to recruit potential collaborators was to contact previous and present clients of the author as good working relationships were already in place. It became apparent that many of the businesses seemed to believe that HF was some form of magic bullet that could be brought in to fix a multitude of problems with little or no cost or resource requirements. The realisation that this was not the case appears to be the point at which most of them decided to withdraw from collaboration.

None of the companies stated as such but there is a possibility that their decision not to take part may have been guided by a concern about the data from the surveys getting into the public domain and potentially being used against them commercially or even in litigation in the event of an accident.

7.1.3 Collaborator Activities: Post Survey

Once the safety culture survey has been analysed the company is then able to implement suitable and adequate control and mitigation measures to rectify any issues highlighted such as rewriting procedures, purchasing new equipment, re-training, etc. The full implementation of a behaviour-based safety system using antecedents, behaviours and consequences (ABC), as described previously, may also be implemented. This stage of the risk reduction process appears to be the stumbling block for the businesses approached as they seemed to be able to detect what may be required in the future before they had even started the process. It is feasible that the businesses may already be acutely aware of their present situation in terms of existing hazards and issues and that identifying such things in written form may not be a prudent thing to do if they do not want those issues brought out into the open. This is a somewhat negative and cynical hypothesis but it cannot be ignored or assumed to be absent from the minds of personnel in those companies without them proving otherwise. Only further collaboration and testing of the assessment tool in real SME situations will prove whether this is the case or not.

If a business is to implement an HF assessment system it must be prepared to provide sufficient resources to address any issues highlighted in order to keep up the risk reduction momentum and to actively promote potentially new methods of working. Until companies attempt to implement such measures it is likely that the best they will achieve will plateau based on the antecedent measures currently in place.

7.2 Safety Culture Survey

7.2.1 Unnecessary Sections

In some companies the safety culture survey may be too extensive for their requirements. An example of this is the incident management section. The companies that took part have very good safety records with very few incidents per year. In some cases the statements in this section may therefore be considered irrelevant to the shop floor workforce and possibly also the middle management. A low accident rate means that familiarity with incident management situations may not be sufficient to answer the statements with a high degree of certainty. This is likely to give rise to a high number of indifferent responses but it has been shown that the assessment tool is insensitive to such responses and the outcome is not adversely affected.

7.2.2 Balance of Negative / Positive Statements

In this survey there were eighty-four positively-worded statements and fourteen negatively worded statements. The format and polarity of the statements within the survey remained relatively unchanged from the original surveys from which they were derived. In hindsight the survey would have been better if there had been a similar number of positive and negative statements. This would have placed less emphasis on the need to consider whether people were minded to select "disagree" responses. The quality factor that assesses the ratio between "strongly disagree" and "strongly agree" responses has served to show that this initial concern was not apparent in the actual results. There was also no discernible difference between different groups of people in their willingness to answer strongly at either end of the scale.

The quality factors that are used within the analysis would also benefit from a more balanced series of statements to ensure that the ratio between positive and negative statements was as close to 1:1 as possible. The same is also true for each of the nine different sections within the survey.

It was also noted that there are sections within the survey that have a high number of consecutive positive or negative statements. The survey would benefit from a more balanced layout that spreads positive and negative statements more evenly throughout the survey.

7.2.3 Survey Quantity

The number of surveys returned for analysis was low in some cases. This is not considered to be of major concern as the assessment tool was designed for use with SMEs which may only have a few people. The largest survey had forty six respondents while the smallest one had only seven respondents. It was shown in the assessment tool output that surveys of this size can be carried out and that reasonable and repetitive results can be obtained.

7.2.4 Quality Factors

The quality factors were created based on the themes addressed by the statements in the safety culture survey. Some factors were ranked consistently high while others were ranked consistently low. Completely different factors can be created based on the specific requirements of the company carrying out the survey.

There is no limit to the number of factors that could be introduced to the assessment tool but these would require a degree of coding into the calculations. With more development of the assessment tool it is feasible that this could be carried out by the company directly. The assessment tool is currently implemented using a spreadsheet but the same functionality could be developed into a fully functional standalone application with all such configurability embedded within the application.

7.2.5 Safety Culture Survey Base Data

A small number of returned surveys did not have the base data filled in. This was in the form of tick boxes just below the safety culture survey instructions / guidance on the front page. The design of the survey front page may be such that these statements may have simply been missed by some respondents rather than ignored. Improvements to the survey layout are necessary to ensure that such issues are designed out of the forms.

7.2.6 Safety Culture Survey Reliability

As described in section 5, the reliability of the safety culture survey could not be proven using the data available from this study. To provide acceptable and reliable factor analysis and Cronbach's alpha coefficient analysis it is necessary to conduct surveys with a much greater number of respondents. Dewberry (2004) states that around 300 responses is required to provide enough data for reliable factoring and analysis. This presents an integrity issue in the short term for this safety culture survey as it needs to be properly validated before it can be used with a high degree of confidence that it is actually performing the task for which it was intended. This situation can be improved by engaging more businesses to take part in the research. Clearly engaging businesses with a much greater number of employees would be beneficial in order to assist in proving the integrity of the safety culture survey tool and to assist in developing the sections and statements therein in order to assist with its implementation within SMEs.

The factor analysis carried out shows that there are potentially more factors present than desired (and expected) and that the factor analysis results were not repeatable between surveys even within the same company. This would suggest that there may be too many statements in each section and that perhaps more sections need to be identified with a tighter scope of the aspect being measured. Reduction of the number of items to less than ten in any section may result in a better factor analysis but may also result in poorer Cronbach's alpha coefficient analysis (Pallant, 2007).

7.3 General Comment on Research

This research project has encountered several challenges as listed below.

- Collaborator recruitment and subsequent withdrawal
- Part-time study programme
- Reluctance to seek early help and assistance from supervisors

The recruitment of participating companies has been a long running problem with this research programme. Many have been recruited only for them to drop out later, wasting much time and resource.

This lack of involvement from the group that represented the main benefactors of the research project has precluded the original aims of the project from being fully realised as the quantity and type of data collected may not be directly applicable to that type of company. This is not believed to be the case but remains a possibility.

The part-time study programme is an excellent method of continuing academic achievement but it presents a very difficult time management situation in terms of balancing commitments to work, home and research. This has given rise to a longer than expected research programme.

The issues encountered with recruitment of suitable collaborators could have been handled differently and the effects of these issues on the overall research programme could have been minimised if they had been discussed with academic and industrial supervisors earlier. The collaborator issues may have had less impact if alternative options had been discussed and implemented through discussion of ideas with supervisors.

7.4 HF Implementation Process (Think, Plan, Consult, Do, Review)

The five-stage process of human factors implementation as proposed in section 2 and subsequently trialled has been found to be suitable for the companies that participated. No significant issues have been identified that would prevent the method being applied within SMEs or multi-nationals.

The “think” and “plan” stages were fundamentally completed prior to discussing (consulting) implementation with potential participants. Once the companies agreed to participate the “plan” and “consult” stages were completed and the employee survey questionnaires were issued. The consultation phase included discussion of how and when the surveys would be distributed to employees and how and when the results would be available and presented back to the business. This phase also included a review of the survey questionnaires and to modify as necessary prior to issuing to the workforce. The scope of application within the business was also discussed and agreed at the “consult” stage of the implementation process. The “do” phase of the implementation process is comprised of two distinct stages: firstly to carry out the baseline survey and secondly to review the survey results and implement appropriate improvement measures. The “do” stage prompted more consultation between the author and participating companies but, more importantly, prompted consultation within the participating companies in identifying potential improvement measures to build a better safety culture and reduce risk.

After a period of time the review stage commenced with a second employee safety culture survey. The results of the second survey were analysed and compared to the baseline survey to determine if the safety culture had changed (as measured by the survey analysis tool) as a result of the measures implemented by the companies.

The review phase serves two purposes: firstly, for the participating companies to determine where improvements may be implemented thereby promoting a better safety culture and reducing risk and secondly, to enable the HF assessment system to be reviewed and modified as necessary to develop and improve the system for future implementations.

8.0 CONCLUSIONS

8.1 Background

The type of human factors assessment proposed by this research project is one that creates a snapshot of the perceived safety culture of a business at a single point in time. The data from this snapshot is then used to prioritise the issues raised as a means of applying corrective measures for the reduction of risk. The system therefore attempts to measure the present safety culture status with a view to affecting how that status may be changed for the better in the future as a result of the rectification of any identified problems.

In the introduction and background to this research project, several high-profile example accidents are discussed as examples of what can go wrong when the human element of accident causation is inadequately addressed. Every day in industry the same errors and failings also play themselves out in small businesses in the form of accidents that are not high profile but which cause the same injuries and suffering to people just as in the high profile cases noted. The examples are all large companies with a wide array of professionally qualified people with which to implement safety systems and controls but even in such situations, accidents still occur. In a small business the level of resourcing available is often significantly less than in large businesses and those businesses need all the help they can get if they are to continually reduce accident rates.

Not all human errors are immediately detectable. Covert latent errors within systems may only manifest themselves after many years of operation and even then, perhaps only after a series of events or factors combine to cause the accident. This is one of the issues of accounting for human error: after many years of operation or after doing the same thing countless times, humans become complacent and use their previous knowledge and experience of a situation to estimate what will happen in the present situation. There is an element of behaviour in every human that wants to believe that "it won't happen to them"; but it often does. If any factors in the present situation are different to those previously encountered and not sufficiently accounted for then the judgement and decision-making process may be flawed, leading to an accident.

Human errors can occur at any time in the lifecycle of plant or equipment and, as noted above, latent errors may lie dormant for many years before their effects are realised. Only constant review and monitoring can lead to their discovery before the accident occurs and effective management systems therefore need to be in place to maximise the probability of detecting such errors. In the context of human factors, effective management means a good safety culture is present and a good safety culture is one that is comprised of the elements listed below.

- The activities carried out have been correctly assessed and designed;
- the activities are adequately controlled and monitored and sufficient resources are in place to ensure they can be carried out safely;
- people are adequately trained and competent for the tasks they perform and in how to cope with non-routine events that may occur;
- all near misses and accidents are recorded and treated as a source for learning and future prevention;
- personnel interact with each other at all levels and can have open safety discussions without fear of retribution;
- personnel continually seek to improve the safety and operability of the workplace and they are encouraged to do so by management;
- operating procedures reflect working practice and procedures are routinely obeyed and regularly audited;
- a good balance between production and safety exists and that the two are not treated as separate entities: more that they go hand in hand as part of the way the business is run and operated;
- a mutual respect exists between management and shop floor and the overall aims and objectives of the business are understood by all.

This is not a finite list but represents the main factors likely to be present in most workplaces that could give rise to unsafe behaviours and accident causation.

8.2 Literature Review

A literature review was carried out to determine what human factors assessment and implementation systems were currently in use. Many texts provide information and guidance on human factors, safety culture and behavioural safety. None of the literature reviewed actually offered a system of analysis that a layman employed within a small business could use. The assessment tool created as part of this research project serves to fill this gap. A tool is available from the Health and Safety Laboratory that also performs a similar function but is more complex in its application, use and analysis.

The assessment tool created as part of this research project serves to assist in the application of HF methods of risk reduction and can be considered as a more simplistic version of what industrial psychologists would assess and implement through a full scale implementation. The tool enables the assessment to be carried out with much lower costs and complexity thereby enabling the assessment to be carried out by in-house personnel.

8.3 Safety Culture Survey Design

The design of the safety culture survey is spread over nine different topics and presents employees with a series of statements about their workplace. The overall design of the survey in terms of topics and statements presented no major issues in the execution of the surveys but it was noted (as described in the future work section) that there were elements of the survey that could be developed to provide a more balanced set of statements and quality factors analysis and to ensure that the base data is properly filled in.

8.4 Assessment Tool

The assessment tool was created using a spreadsheet for data entry and analysis. This may not be the most efficient method of implementing such a system but the benefits of this are that it makes it easy for small businesses to use without the need for purchasing any more specialist software packages. Minimal training would be required (if at all) in order to use the tool as all functionality is implemented simply in accordance with using the spreadsheet software. Also, the spreadsheet format allows company-specific modifications to be implemented quickly and easily. Its simplicity means that it is ultimately configurable by the end user: a key requirement. The simplistic data entry and output from the tool masks the many calculations and statement response comparisons being carried out within the tool. The intelligence within the assessment tool lies with the statement cross-linking that is contained within the spreadsheet formulas and these are easily modified to suit each company should this be required. The output of the assessment tool enables companies to prioritise what aspects of the workplace should be addressed.

8.5 Data Analysis

The various graphs and values currently available from the assessment tool are shown in Appendix D. The output shown is for Company A only and serves to present an example of what is currently incorporated into the tool rather than being provided for detailed analysis of the company's responses and safety culture rating. The output serves to show that meaningful results can be obtained from the assessment tool and that the analysis system incorporated is capable of separating out the most critical human factors aspects of the business for remediation to be implemented.

The main output from the tool is the calculation of safety culture values and the baseline and final surveys statement comparison bar graphs. The bar graphs display mean values of all the statements. The values shown on the graphs represent the assigned secondary values. Using the secondary value takes account of the negative statements incorporated within the survey and means that a 1 is favourable and a 0 is unfavourable irrespective of whether the statement is positive or negative.

The graphs currently available within the tool are the baseline and final surveys but other graphs representing the different demographics in place would be easily implemented.

The analysis tool output is dependent on the base data being used to be reliable. The internal reliability and consistency of the safety culture survey tool has been subjected to reliability analysis (Cronbach's alpha coefficient) to ensure that the base data is valid. The internal reliability for each section of the safety culture survey tool has been shown to be acceptable with alpha coefficient values generally greater than 0.7. Factor analysis was also carried out and it was noted that this did not provide a good result in terms of matching factors with questionnaire sections. Further development of the statements within the survey tool is necessary in order to make the desired and actual results converge.

8.6 General Conclusions

The overriding finding of this research study is that small to medium sized enterprises do not appear to want to change; as evidenced by the number of businesses that took part. Two out of eighteen companies does not show a committed approach to the implementation of new methods of risk reduction. Whilst those companies may not have been satisfied with their current antecedent arrangements and safety performance they showed minimal interest in working for a better safety culture. They all stated they would like to see this in their workplaces but none of them were willing to commit to it.

The two companies that took part already had good safety cultures in place with good safety records. The health and safety managers in those companies were not complacent and they were both genuinely concerned for the safety and welfare of their employees. This situation highlights the main cause of the non-participation of the small businesses: people are all different and they have different levels of care and empathy for others. The level of responsibility and accountability felt and displayed by the managers of the companies that took part was far greater than that shown by the people in those businesses that did not participate.

It is therefore postulated that the level of success achieved with any health and safety management system or human factors assessment system is not dependent entirely on the rules and procedures in place within a company, but is more dependent on the professionalism, competence and duty of care of those people responsible for the creation, implementation and enforcement of such systems, policies and procedures.

The work carried out as part of this research project shows that it is feasible for small to medium sized enterprises to carry out an in-house assessment of the safety culture within their own workplaces. The benefits of doing so are continuous safety performance improvements which will ultimately bring with it cost reductions in terms of less absenteeism, more efficient processes, less accidents, less production down time and hence lower operating costs with greater profits.

The theory stands up well to scrutiny and there is evidence in the referenced texts to show that antecedents, behaviours and consequences (ABC) and behaviour-based safety systems (BBS) of risk reduction are effective when implemented correctly and with the commitment required. This commitment is one of the weak points of the system as it may require a fundamental change in the way people think about their safety in the workplace.

It is clear that competent people create good safety cultures and that the antecedent and behavioural measures in place are only effective if they are actually used and enforced. Human factors assessment of the workplace enables all such measures to be reviewed and highlights any underlying problems that may be present. What happens beyond this assessment is dependent entirely on the people involved.

9.0 FURTHER WORK

There are several options for taking this research programme further.

1. Recruitment of many more SMEs to test the assessment tool in real workplace situations.
2. Development and verification of the assessment tool quality factors through more collaboration partners.
3. Consider alternative methods for recruiting SMEs into the research programme such as driving participation from the bottom up through initiation with union and shop floor operatives rather than from the senior management downwards.
4. Development of the assessment tool to include configurable options for company size and complexity, selection of part surveys, selection and configuration of new quality factors.
5. Development of the assessment tool to include guidance on the potential measures that can be implemented based on the assessment findings.
6. Development of the assessment tool to include weighting factors to assist companies to concentrate on the issues most important to them.
7. Development of the tool to enable sorting of returned surveys to be carried out. This will enable similar groups of personnel to be analysed separately.
8. Development of the assessment tool to automatically reject or ignore those surveys that are judged to be of poor quality.
9. Development of the tool to be a standalone fully-functional application perhaps with a web-based survey and results analysis interface.
10. Develop guidance and instructions for SMEs to enable them to implement the assessment tool in-house with little or no assessment tool designer input. Develop guidance for safety culture re-assessment recommended frequencies to detect any improvements and also (more importantly) to detect any new issues caused by the introduction of new control measures.
11. Seek more involvement with future respondents to determine their views on the safety culture survey design and also to determine whether they believe that the survey is comprehensive (hence the few

written comments received) or if there is anything missing that they would preferred to have seen included.

9.1 Recruitment of More Participating Companies

The recruitment of more companies is essential if the usefulness and repeatability of the assessment tool is to be proven.

The companies contacted as part of this research programme predominantly had high risk situations within the workplace. Any proposed changes to operating procedures or work methods in such situations may be considered to present an unnecessarily high risk unless rigorous pre-assessment work is carried out.

An option for progressing this research may therefore lie with those companies that have a lower level of inherent risk present but still present enough risk such that the HF methods would be able to implement a discernible and worthwhile risk reduction.

A weakness of this research project was the lack of many more suitable participating companies. As noted within this thesis one of the most challenging aspects of the research project was to recruit companies to take part.

9.2 Assessment Tool Quality Factors

There are currently twenty three quality factors within the assessment tool. They can be developed to increase accuracy and variance. Some of the factors continuously scored low or high and these need to be examined in more detail to determine any particular sensitivities that may be present as a result of the statements chosen for their assessment.

New quality factors can be developed and implemented to suit the companies' particular requirements.

9.3 Alternative Recruitment Methods

Using unions and shop floor workers to get companies interested in the HF assessment system of risk reduction may be a valid option in some cases. The difficulty in attempting such methods is that of identifying the correct personnel to initiate such collaboration. Given the likely support the unions would attract in any such scheme this may well be a strong possibility for future development of the system.

9.4 Assessment Tool Development

The tool can be developed to make it ultimately configurable by the end user to enable it to be modified according to the size, complexity and hazards present within the business. Partial implementation can also be configured for the creation of company-specific safety culture surveys with fewer sections and statements if this is what is required. Any such modification would also necessitate the safety culture survey tool reliability to be reassessed.

Based on the assessment tool output of any issues identified the tool can be developed to provide guidance to the user as to how these issues may be addressed. This would be based on statistical analysis of the safety culture survey and the categorisation of the personnel filling in the surveys, in terms of job role, department and employment status. The guidance given would be based on industry best practice for each particular type of industrial situation such as chemical plants, manufacturing plants, etc.

The tool can be developed to include weighting factors for any aspects that a company would like to pay particular attention to either permanently or for a temporary period to focus on any one particular topic that they are trying to rectify. The weighting assessment system must be formed such that it does not degrade or mask other significant issues.

The assessment tool (as currently designed) requires to be manually modified to collate information from any particular group of similar personnel or workplace situation. An enhanced tool would enable all such collation of results to be executed much more efficiently.

When poor quality surveys are detected by the assessment tool the data associated with those surveys needs to be manually discarded from the analysis. Development of the tool to automatically reject such poor quality surveys (whilst still retaining the data in the background for future reference and analysis) would be a welcome and highly usable function.

It is considered feasible that the tool can be implemented as a standalone application, preferably web-based, whereby all surveys and analysis can be accessed by a multitude of personnel at any time for the purposes of providing reports and guidance. Whilst this may be an expensive implementation there is evidence to suggest that such software has commercial merit. The experience gained from this research project suggests that there are not enough SMEs interested enough to warrant such a development at the present time.

As a means of enabling companies to use the assessment tool as designed an instruction manual and guidance document would be essential in order to explain how to use the tool and to explain what it is and what it is not capable of doing.

9.5 More Respondent Involvement

In this research project the intended method of implementation was for companies to introduce their employees to the safety culture survey and to request them to fill in the surveys as necessary. Some companies wanted more of a hands-on implementation with complete involvement of the author overseeing all surveys returned. It is the view of the author that the best solution lies somewhere between the two options described.

It is impossible for any person to single-handedly oversee every survey filled in. Such tight control and observation of surveys being completed may also curtail the willingness of the respondent to answer the statements honestly. It would severely affect the perception of a truly anonymous survey being possible and again may result in the survey being filled in differently than if real anonymity was seen to be in place.

The main issue found with stepping back from overseeing the completion of surveys is that they tend not to be carried out at all or are very slow to be carried out.

A satisfactory alternative is considered to be several people filling in surveys at the same time (preferably by computer) to protect anonymity and with a co-ordinator on standby should any support be required. These sessions would be by pre-arranged appointment thereby ensuring that a formal programme of safety culture surveys is adhered to. These sessions would allow the co-ordinator to engage the respondents in conversation to determine any particular issues they may have encountered with the survey or its intended outcome.

9.6 Safety Culture Survey Development

The reliability analysis and factor analysis carried out showed that there may be potential issues with safety culture survey tool.

The sample size in each of the surveys completed was lower than would be ideal for the accurate estimation of reliability and factor analysis. The alpha coefficient results, though useful, must therefore be treated with caution until the reliability of the survey tool can be proven through repeating the assessment with a number of surveys containing a sample size suitable for validation.

Reliability was assessed using SPSS to calculate the Cronbach's alpha coefficient for each questionnaire section within each survey carried out. The reliability values achieved were generally acceptable with most values being greater than 0.7. Several statements within the survey were identified as having an adverse effect on the reliability coefficient. These statements can be modified to remove any ambiguities or simply deleted if the information obtained is not considered to be providing significant value to the overall survey (whether unreliable or unnecessary).

Factor analysis showed that there was not a clear identification of one aspect to each section of the survey. The distribution of statements throughout the factors identified suggests that a number of separate (but indistinct) factors are present within each section. The safety culture survey tool was formed by the agglomeration of statements from several similar surveys and also those statements specifically entered by the author. The original surveys from which the statements in this survey were formed were stated to have been validated by their original developers (OTR 1999/063, HSE (2001)). The formation of a new survey tool with statements from a number of different surveys may be the cause of poor factor analysis results.

As described above, the sample size for achieving a reliable factor analysis is approximately 300 (Dewberry (2004). Such a large number is only likely to be achieved with the assistance and participation of large businesses. This research project was primarily for the benefit of SMEs but it would appear that a reliable survey tool can only be designed and implemented with the assistance of large businesses. The implementation of the survey and assessment tools in SMEs following development within large business may also have inherent issues as a result of the different attitudes and methods of working between the two business types. Development of a reliable survey tool within large business may make it unsuitable for use within SMEs without some modification.

The statements within the tool were assumed to be of equal value throughout. It is feasible that each statement within the survey does not have the same value or relevance and that weighting may therefore be necessary in order to accurately measure the real situation. Further assessment with larger sample sizes and development of the survey and analysis tools will be necessary to identify, develop and implement any such weighting necessary so as to achieve reliable and accurate results.

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A. APPENDIX: COLLABORATOR PRESENTATION

Care
Culture
Competence

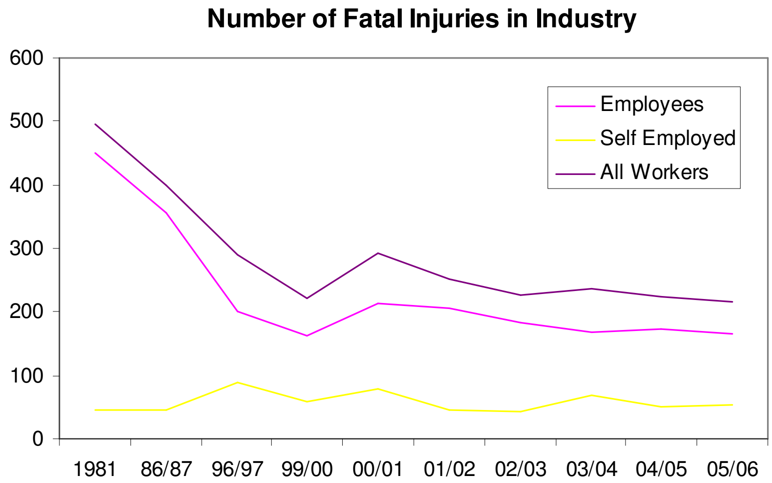
Removing the Human Factor from Industry and Transportation

William Rose
4 Square Engineering Consultancy Limited
In association with Napier University

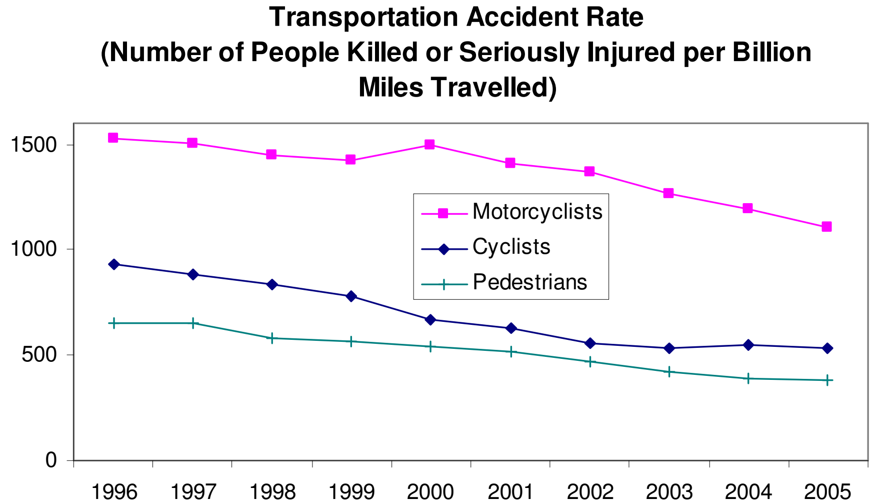
Human Factors

- Human Factors
  - The study of why people do what they do
  - Assessment of human capability
- Human Factors Engineering
  - A means of ensuring that people do what they should
  - Guaranteed operation within human capability

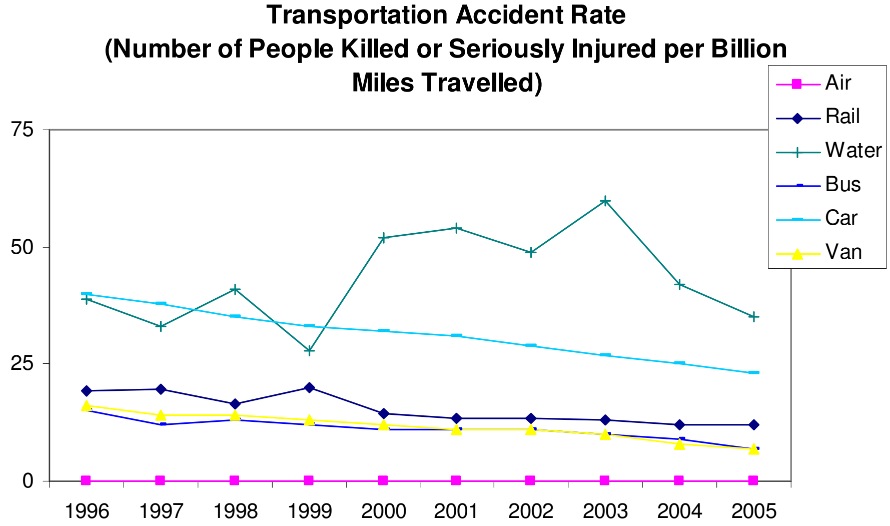
Why we need to care



Why we need to care



Why we need to care



What can human factors achieve?

- Improved safety performance
  - Reduced number of accidents, scale of effects
- More robust safety management systems
  - Specification, design, planning, operation, maintenance
- Improved training, competence, motivation
- Reduced operating costs
- Better use of existing resources

Research Project Objectives

- Confirm non-specialist engineers / managers can implement HFE with positive results
- Create a HFE risk reduction system for application within industry / transportation
- Achieve high percentage of the HFE-related benefits without the associated costs of external consultants, e.g. 80% of the benefits / 20% of the costs

Major Industrial Accidents

- Flixborough
- Seveso
- Grangemouth
- Texas City
- Buncefield
- Arianne 5
- Challenger +

Review of Common Factors

- Human error
  - Incorrect assumptions
  - Failure to determine / perceive risk
  - Failure to apply appropriate risk controls
- Management
  - Inadequate procedures / systems
  - Inadequate personnel competence
  - Inadequate safety management system

What can be done?

- Enforced regulation – Unwilling Compliance
  - Reasons for compliance not always obvious
  - Costly to implement but essential (HSE/HSC)
  - Requires significant co-operation between government agencies and industry (lack of inspectors / very slow process)
- Self regulation – Willing Compliance
  - Because you want to - reasons for compliance are obvious
  - Common standards and benefits
  - Convergence of best practice, improved efficiency / performance
  - Shared learning / more robust passage of shared knowledge
- What culture does *your* organisation operate?
  - Does everyone think the same?

Where does HF begin?

- Assessment of safety-critical decision making processes.
  - What factors do people use during decision making?
  - On what basis are these factors founded?
    - Training, experience, procedures, supervision?
- Assessment of training, experience, competence.
- Assessment of safety culture, human behaviours / attitudes.
- Optimised procedures and processes
  - Remove human-specific safety decision making by design
- Optimised review processes (safety-critical decision making)
- Impartial and open auditing and monitoring systems

Partner Collaboration Activity

- Assess current position (survey)
- Identify target areas for addressing potential issues
- Apply systems of control and safety management
- Monitor / review (8-12 months)
- Reap the benefits
- Measure results (re-survey)

Partner Benefits

- Strategic review and control of safety-critical decision processes
- Improved safety performance
- Improved productivity
- Lower operating costs
- Excellent marketing opportunity

B. APPENDIX – SAFETY CULTURE SURVEY QUESTIONNAIRE

The content of this appendix is a description of each statement within the survey and the intent of those statements. The potential significance of the responses to those statements is described.

B.1 Safety Culture Statements

This series of statements serves to assess people's perception of their own workplace and their own position within that workplace. All of the answers to the "Safety Culture" section are subjective and entirely dependent on a respondent's own experience of the workplace, its systems (physical and organisational), its hazards and its risk to them as they carry out their allotted tasks.

Statement 1 asserts "The standard of safety is very high at my workplace." This statement asks about the level of safety being "very high", i.e. it would need to be impeccably high for all respondents to answer strongly agree. This would be a highly unlikely outcome. If the statement had simply been to ask if the standard was high then it would be expected that a higher proportion of respondents would answer "strongly agree". An overall positive result is clearly the desired outcome for this statement.

Statement 2 asserts "It is important to me that there is a continuing emphasis on safety." This statement serves to discover if the respondent understands that safety can never be taken for granted and that people must focus on safety-related issues at all times and must build on previous experience and knowledge in order to improve in the future.

Statement 3 asserts "When I see safety rules being broken I point it out immediately." This statement not only seeks to find out if the correct action is taken by the respondent but also to determine if that action is taken "immediately" to prevent a potential accident or if it is taken to prevent accidents occurring in the future. This is also a measure of the safety culture of the business as it shows whether people feel empowered to intervene immediately and stop other people carrying out unsafe acts that may cause harm to themselves and others. Statement 9 (S9) also asks about this subject but from the respondent's viewpoint of the actions of their colleagues in a similar situation and by implementing a company policy to do so.

Statement 4 asserts "This workplace operates a no-blame safety culture." Most people working within industry will be familiar with the term "blame culture" and what it means in practice. The companies with the best safety cultures strive to ensure that the way they operate promotes learning from mistakes and near misses without attribution of blame but not all companies have reached this goal. A blame culture within any organisation is not conducive to building good relationships founded on trust. Such a culture would indirectly encourage people to withhold information and not report accidents and near misses if they could be covered up quietly. It also serves to prevent an on-going culture of learning from previous mistakes and errors. A company must therefore do everything in its power to avoid a blame culture or a perception of a blame culture being present. In contrast to setting this statement in such a forthright manner, two similar statements are contained in the Incident Management section (S22 and S23). These two statements serve to discover if a respondent truly believes if a real "blame culture" is in place as a result of their own experience or through colleague views and discussions by asking about the incident investigation process in place within the business in a less direct manner. Positive responses to S22 and S23 would show that a blame culture is not in place. Disagreement with S4 and with these two statements would obviously mean that the respondent has not read the statements with enough care and that they believe that a blame culture is present through their own experience within the workplace. It is clear that in some cases, especially with violations of procedures and safety rules, blame may be attributed to one or more people as a direct result of their actions. In such cases it must be proven without doubt that there are no underlying causes or conditions prior to personnel being punished in accordance with company procedures and potentially through the judicial system if corporate criminal negligence has taken place. The "blame culture" attitude would not apply in such cases as blame could be rightfully attributed to someone. The "blame culture" tag is applied to those businesses that don't have adequate systems of safety management in place such as personnel training, procedures, safe work equipment and machinery, PPE, etc. and which then subsequently attempt to blame their employees for the errors and mistakes that occur when the root causes are founded in the organisational aspects of the business and not on the shop floor.

Statement 5 asserts "People are willing to report accidents and near misses." This statement is trying to find out if the respondent believes that employees are willing to own up to mistakes and errors that have caused incidents with the potential to cause harm. The answer to this statement not only gives us a view of their perception of how they see others around them but it also provides us with a view (indirectly if a blame culture exists) of whether people are afraid of reporting incidents for fear of the consequences. If there is truly a no-blame culture present and all incidents are looked upon as a means of learning then this statement should have a high percentage of positive responses. This is one of a series of statements throughout the survey that attempt to ascertain the level of employee empowerment in place.

Statement 6 asserts "Mistakes are corrected without punishment and treated as a learning opportunity for all." This is another double edged statement where we are trying to find out if there is a formal process in place with which to officially reprimand people who make mistakes and also to determine whether that process is carried out with care and in a manner that treats the incident as an opportunity for learning or improvement or if the process is in place for the purposes of making people afraid to make similar mistakes in future and to potentially give cause for some future official warning or dismissal process. It would be expected in any industrial situation that a formal procedure would be in place to reprimand people who make mistakes and cause incidents with the potential to harm themselves and others but it is how this procedure is enforced that determines the actual safety culture in place within the company. Clearly a high percentage of agreement with this statement is desirable but some people may focus on the negative side of the statement concerning punishment while others may focus on the more positive opportunity for learning from errors. The perception of the personnel is what is important and if the emphasis is on the negative side then there is clearly room for improvement and this would suggest that the company's policy is directed more towards a heavy-handed approach rather than the learning approach.

Statement 7 asserts “I can trust the people who I work with to work safely.” This statement requires the respondent to give their view on the practices and perceived competence of their colleagues. Such a statement obviously requires some form of reference and the reference or standard to which this statement refers is their own safety awareness, safety behaviour and competence. In a team with a good safety culture operating in an industry or an environment that contains significant hazards with high risk and which has been established for some considerable time this statement should have a high positive response. In such environments it is essential that people can trust their colleagues to do the work safely every time as a small incident can easily escalate out of control, potentially affecting many others. A negative response to this statement would highlight potentially serious issues with the workplace and could point to other factors that may be present such as personality clashes between colleagues and managers or perhaps a lack of training, equipment or resources with which to carry out work safely. This statement is one of several throughout the survey that attempt to ascertain the level of colleague trust that is present.

Statement 8 asserts “People in this workplace refuse to do work if they feel the task is unsafe.” This statement serves to discover if the respondent believes that people are empowered to stop working on the grounds of safety or whether there is an underlying emphasis on production at all costs. If a company has a good policy in place for this then the answer should provide a high number of positive responses. It is true that some companies have very good policies but if they are not positively enforced in the workplace by the actions of supervisors and managers then they are worthless. Positive enforcement of such policies is an essential part of a good safety culture. This statement can also be linked to S7. A high positive response to S8 should also be reflected in S7.

Statement 9 asserts “Company policy supports the right of any person to intervene in the interests of safety.” This statement seeks to find out the respondents perception of whether employees are empowered to stop unsafe acts irrespective of who is responsible through a formal policy implemented by the employer. As discussed in S3 this statement is more about what the respondent thinks about their colleagues’ actions in the presence of a formal policy allowing them to do this. Based on personal experience, a high positive response would be expected from this statement as most companies with high risk elements to their core business have such policies in place. Even without a formal policy in place employees should always feel empowered to intervene in the interests of safety. This statement is therefore important in terms of estimating the overall safety culture in place. It also adds to the assessment of whether people feel empowered in their own roles to look after the safety of others around them.

Statement 10 asserts “Recognition is given for proactive intervention.” This statement serves to discover if the safety culture of the business is such that positive encouragement is given to employees who have a proactive approach to safety and also to show whether a business is implementing such policies effectively by giving recognition to those personnel implementing them through good communications and teamwork. This is one of a series of statements that attempt to ascertain the employee’s perception of their value within the business. It is noted that such a policy can be counter-productive to the intended outcome. Personnel invoking the intervention policy can use it to bring about a stoppage for the most trivial of reasons and this can build resentment between management and shop floor. In such a situation the desired outcome of the management and the person invoking a stoppage is clearly different and while this situation continues the safety culture of the business is compromised. The frequency of such situations must be minimised and controlled in order to limit the potential damage caused.

B.2 Organisational Measures Statements

This series of statements serves to assess the respondent’s perception of the fundamental safety-related organisational measures that are in place. All of the answers to the “Organisational Measures” section are also subjective. There are no statements in this section that can be regarded as providing a certain expected response.

Statement 11 asserts “Written safety rules and procedures are easily understood and implemented.” This statement serves to determine whether the respondent has seen written rules and procedures and if so, whether they were easily understood and easily implemented. The statement serves to estimate whether the respondent believes that their competence is suitable for the tasks for which they are responsible. A high positive response would show that there are procedures in place. Along with other answers in the survey this statement also serves to determine whether personnel have been adequately trained in order to understand and implement them in the workplace. A high negative response could mean that written procedures are in place but that they are not easy to understand or that they are not written with due cognisance of the actual task to be carried out and are therefore difficult to implement in practice. Whilst a positive response is good, a negative response does not define the problem explicitly but highlights a potential choice of two issues that need to be addressed.

Statement 12 asserts “Permit forms and procedures are clear, unambiguous and easy to use.” This statement refers specifically to the clarity of permit to work forms and procedures. The statement tests the respondent’s knowledge of the permit to work system and attempts to discover whether a permit to work system is actually in place and to what extent training has been provided for its implementation in the workplace. This is another statement where a high positive response is desirable. A high negative response would signify that there are clear problems with the permit to work system. A predominantly indifferent response would signify that a permit to work system is either not in place, is not implemented as part of normal activities or simply that the respondent did not understand the statement.

Statement 13 asserts “The PTW system is a way of covering people's backs.” This statement serves to determine what the respondent thinks of the permit to work system in terms of its usefulness in maintaining a safe place of work. If the permit to work system was seen as a burden that didn’t add much in terms of ensuring safety then it would most likely receive a high positive response. If the permit to work system is being used to its full potential and for the correct reasons then a high negative response is desirable.

Statement 14 asserts “Some health and safety procedures/instructions/rules do not need to be followed to get the job done safely.” This statement is an attempt to discover if the respondent knows of the rules and procedures associated with their tasks and to determine if they regularly take shortcuts in the tasks they carry out rather than following the procedures. It also provides us with an indication of whether the procedures are considered to be over-cautious (from the respondent's viewpoint) and whether the respondent's perception of their own competence is greater than that for which the procedures were written in the first place, i.e. we are attempting to discover if people are making foolhardy decisions because they think they know better. In a team with personnel of vast experience with an excellent safety record but with poorly written procedures it may be expected that this statement would provide a high positive response (if they are answering truthfully). The same team with well written procedures could give rise to a high number of negative responses. In this scenario the procedures would have been adapted and reviewed for the tasks carried out and would therefore be a realistic representation of what actually occurs on the shop floor. An experienced team that follows comprehensive, well-written procedures is a team that will have a good safety record and will be pleased to defend what they do by disagreeing with this statement, i.e. shortcutting safety procedures without approval and a good safety case to do so is simply not acceptable.

Statement 15 asserts "Procedures reflect working practice." This is a statement that serves to discover if procedures are present and if so, are they actually correct in terms of how activities are carried out. This is similar to S14 but is asked much more directly. This statement should result in a high positive response for a company with a good safety culture.

Statement 16 asserts "Information relative to work activities is easily accessible to allow comprehensive work planning." This statement will let us know if employees have access to all the relevant information necessary with which to ensure that the level of safety in the workplace can be maximised for the hazards present for any planned activities. A high negative response would be undesirable and would perhaps point towards a team that was open to making mistakes or errors as a result of poor communications and planning (latent organisational errors). In a team with a good safety culture such issues are likely to be detected prior to any incident occurring but in a team that is less organised and less experienced such failures could easily lead to more significant events.

Statement 17 asserts "Systems are in place to assess the potential impact of plant modifications or changes to operating procedures." This statement seeks to determine if the respondent is aware of the presence of plant modification procedures and what kind of modifications that those procedures actually refer to. Their awareness of the procedures also suggests that a good communications system is present by which employees are kept informed of any potential modifications and developments to the process, plant and procedures with which they work. A significant number of industrial accidents and near misses that have occurred in the past have occurred as a result of modifications having been carried out to plant or processes without due regard having been paid to the effects of those modifications. This is a critically important human factor element of any industrial process with high risk activities. A high positive response is desirable.

Statement 18 asserts "Staff are encouraged to comment on proposed changes before they are implemented?" This statement serves to determine if the company actively involves the affected people in the design of any proposed modifications to plant or processes. It is also used to determine management attitudes to the modification procedures in terms of whether such procedures are actually in place and to what degree the management actually consult and implement these with the affected personnel. The statement is worded in a positive manner by querying respondents on how they are encouraged to comment on proposals. If they feel they are not positively encouraged to comment on proposals then this statement should result in a high negative response. A high positive response would suggest that a good safety culture is present with good communications in a downward and upward direction.

Statement 19 asserts "Personnel training is updated prior to changes being implemented." Clearly this statement should always result in a high positive response for companies with a good safety culture, where personnel are trained in all aspects of any modifications prior to implementation. The statement serves to show whether the management of the company take their management of change responsibilities seriously.

Statement 20 asserts "All personnel are trained in change management procedures." This statement could be considered to be potentially misleading to the respondent. It is clear that all personnel within a business do not require to be trained in change management procedures. Only those responsible for designing and implementing the changes need be trained for the task and as this will be a relatively small proportion of the workforce it is expected that this statement will result in a high negative response. People may view selecting the disagree response as an undesirable response and they may lean more towards the indifferent or agree response as a result. A high positive response would indicate that people have either not read the statement thoroughly enough or that they have misunderstood the meaning of the statement.

B.3 Incident Management Statements

This series of statements was directed at the respondent's knowledge of the incident management processes within the business. All of the answers to the "Incident Management" section are subjective. There are no statements in this section that can be regarded as providing a certain expected response.

Statement 21 asserts "The causes of incidents and near misses are investigated." This is a simple statement that should result in a high positive response in all but the worst industrial situations. Companies that do not investigate incidents miss out on a significant source of learning with which to improve safety. A company that does not investigate incidents is also likely to score poorly in many other aspects of the safety culture survey.

Statement 22 asserts "Incident investigation is an open process which prevents incidents recurring through good communications." This statement serves to find out what the respondent thinks about how the management carry out investigations and whether they believe that the mode of investigation and subsequent communications to the workforce will assist in preventing such occurrences in the future. This statement is also related to S4 regarding the presence of a blame culture. This statement asks specific detail of the investigation process rather than simply suggesting a blame culture may be present. A high positive response is the desired outcome for this statement. A high negative response along with a negative response in statement 4 would not be a good situation. This would point towards a company that focuses on blaming people for causing accidents rather than coaching them to prevent such accidents occurring.

Statement 23 asserts "Incident investigations are carried out to discover root cause and not specifically to find out who is to blame." This statement is worded in a more forthright manner and directly links the answers of S4 and S22 to reinforce the true feelings of respondents.

Statement 24 asserts "Personnel are formally trained in incident investigation techniques." This statement serves to find out if the respondent is aware of any formal training received by investigators. If they are not aware of any such training it is feasible that they may still answer positively as a result of their own perception of how management actually carry out investigations. In any case a high negative response is an undesirable outcome.

Statement 25 asserts "Recommendations produced from incident investigations are always implemented and enforced." This statement serves to confirm that the investigation process in place is robust, that it is operated by competent management personnel and that there is a real opportunity for learning to occur by means of the communication processes in place. There is an emphasis on the word "always" which may sway people away from selecting the strongly agree response but the overall response should be a high proportion of positives. This would reinforce earlier statements concerning blame culture.

Statement 26 asserts "The people who cause incidents are not held sufficiently accountable for their actions." This is a statement that attempts to discover primarily if the respondent believes that people who cause accidents are properly dealt with. Additionally, the statement seeks to gauge whether the respondent believes that perhaps a stronger disciplinary procedure should be in place. The statement is worded such that the respondent is again comparing the performance of others to that of themself. A high number of positive responses would tend to suggest that they believe that their less-safe colleagues are reducing the overall performance of the team. Such feelings are unlikely to be dispelled until they have been suitably addressed by management in terms of ensuring that all accidents are used as learning opportunities for all. As discussed previously, the main cause of accidents is human error, either caused by systematic failure of training, monitoring, work planning, etc. or violations, caused by a wanton attitude of not caring about the consequences. It is the author's own experience that violators are not tolerated by anyone in the high risk industries: the outcome of incidents is known and understood by all to be too costly in terms of human life and plant operations. People who make errors as a result of inadequate training, experience, etc. are generally regretful for their errors and invariably express remorse even though the root cause may have been organisational. They invariably want to improve their performance to prevent future occurrences and can be trained to do so. They have the right attitude and can improve. Violators, by virtue of their actions, do not have this care and mutual respect for their colleagues and do not care of the consequences to others.

The statement also uses the strong word "enforced". It implies that the recommendations from the incident investigation would be implemented by some heavy-handed solution. As a result of the strong wording it would be expected that people may not select the strongly agree response, even in organisations with such a system in place. The overall outcome should still be a high positive result in the companies with a good safety culture.

Statement 27 asserts "Adequate resources are provided for incident investigations." This statement seeks to determine if the respondent believes that there are enough suitably trained management personnel in place with which to properly investigate incidents. It is a common belief among industrial shop floor workers that there are "too many managers and not enough workers". Such widely held beliefs would therefore be expected to result in a high positive response. Anything other than this type of response would suggest that there may be a problem. A high negative response would be a worrying situation as it would indicate that there was a sufficient number of accidents occurring such that there would be a perceived need for more resources. The expected outcome of this statement is an indifferent response. It could be argued that shop floor workers may not be aware of the resources in place for such investigations.

Statement 28 asserts "A formal communications process is in place to ensure all relevant personnel are aware of the learning points." This statement assists in confirming that such a communications process is in place, along with the answers provided to S70, S75, S77, S79, S81, S83 and S86. A high positive response is desirable and would show that the management operate a good system of investigation and communication of safety issues. A high negative response would indicate that the system of investigation and reporting was inadequate.

Statement 29 asserts “Management are slow to act on improvements unless incidents have occurred.” This statement serves to find out if the management are perceived to have a pro-active or reactive attitude towards safety improvements. Clearly, a high negative response is desirable. Such a response can only occur if there are other systems in place that can be used to prevent accidents occurring such as employee suggestion schemes.

Statement 30 asserts “A trend is present which shows that incidents are repeatedly caused by the same people.” This is a statement that serves to determine the respondent’s own perception of whether they believe that a small number of people are responsible for the majority of the accidents that occur. Additionally it asks if a trend is present to record this. It follows that if a high positive response is received then this would indicate that the management are attempting to monitor the situation. The presence of such monitoring would also suggest that the mentoring, personnel education and training systems for those people causing accidents is not achieving the necessary results, i.e. an inadequate management system is potentially present and this would not be a good indicator for a good safety culture. Management competence should be under question along with the management selection process.

Statement 31 asserts “Most incidents occur during routine activities.” This statement seeks to determine whether the respondent believes that accidents are caused during routine or non-routine activities. A high positive response would indicate that the business may not be putting enough resources into the control and monitoring of routine activities. A high negative response would indicate that the control of non-routine activities is not adequate and that additional measures or monitoring of permit to work and work planning processes should be implemented. There is no clear desirable outcome of this statement.

Statement 32 asserts "When incidents occur a clear incident handling process is in place and people are trained in its operation." This statement reinforces the answers already given in S21 and S23. A high positive response is desirable and would show that there is a transparent process in place which the employees believe is properly implemented. This would also imply that the investigating team are sufficiently trained and competent to do so.

B.4 Competence Management Statements

This series of statements serves to determine what measures the company has in place to ensure that its employees are adequately trained and competent for the tasks being carried out. Most of the answers to the "Competence Management" section are subjective. There are two statements (S35 and S38) in this section that can be regarded as providing a certain expected response as a result of the measures confirmed to be in place within the companies that took part.

Statement 33 asserts "I have received risk assessment and observation skills training." Companies with a good safety culture are likely to have provided such training as it can give workers an added dimension to their perception and recognition of hazards. This statement also serves to discover if the management have realised the value of such basic training and will indicate if a good safety culture is present at the senior management level of the business.

Statement 34 asserts "I only work within my capabilities and competencies." This statement seeks to determine if respondents have a clear view of their own competence level in terms of the activities carried out. This statement also serves to indicate if employees are ever asked to (or be expected to) carry out activities for which they may not have been adequately trained or for which they feel that they are not sufficiently competent. A high positive response is desirable but this may disguise potential issues that may be present. If we were to ask a number of drivers if they thought they were a good driver the vast majority of them would answer positively. In an article (The Independent) by the then Institute of Advanced Motorists (IAM) Chief Examiner (Chris Bullock) it was stated that 86% of 17-24 year olds believed themselves to be good drivers. The latest report on UK road casualties shows that this age group is responsible for 25% of all fatal road collisions in the UK: a disproportionate ratio (Department for Transport, 2010). It is clear from this that young drivers overrate their own safety awareness and skill levels to a high degree. Older drivers have far fewer accidents than young drivers and can therefore generally be classed as safer drivers. The same is not true for the workplace. The most recently published statistics show that the age group with the greatest number of accidents is the 25-54 year olds and that with the fewest is the group below age 25 (Health and Safety Executive, 2011). This outcome is the similar for self-reported injuries and RIDDOR injuries. Safety awareness and safety procedures must be reinforced periodically to ensure that the skill levels and competence of employees is monitored and maintained to the required standard in order to ensure that an adequate degree of safety is maintained. In this context, “adequate” means no accidents.

Statement 35 asserts “I have an up to date job description clearly stating my role, responsibilities and required competencies.” This is one of the test statements within the survey. The companies that took part in the research have good systems in place and are able to provide evidence of such documentation and show that it is reviewed periodically. If the employee answers negatively then it shows that either they have not answered truthfully or that they genuinely believe that such records do not exist. Additionally, it may mean that they have lost interest in the survey and are not answering thoughtfully or that they are attempting to make their company’s attitude to safety look worse than it actually is. A high positive response is desirable and anything less than this would suggest that the company has not placed enough emphasis on the competence management system to the employees (whether the responses are correct or not).

Statement 36 asserts “A competency mapping system is in place with which my competence is periodically measured and recorded.” This statement is clearly linked with the response expected from S35 but is asking directly about competence management only. Companies with the best safety culture will have such analysis in place and will be pro-actively looking for assurance that their employees have sufficient knowledge, experience and training with which to carry out their jobs safely and efficiently. A high positive response would confirm that such a system is in place and that the management values its use by regularly reviewing the status of all employees involved in potentially high risk activities. A negative response would be undesirable but may not specifically mean that the people are any less safe than those in companies with competence assessment systems. The competence assessment system merely confirms that adequate competence is in place. Provided all employees are competent the system would only be used to reinforce and maintain existing competence.

Statement 37 asserts “Sometimes I am uncertain what to do to ensure health and safety is maintained in the work for which I am responsible.” This statement is directed at finding out if respondents ever feel that they are potentially at risk in some situations where they may not have the relevant competence with which to make safety-related decisions. A high positive response to this statement would raise serious doubts about personnel selection and the training and competence assessment systems in place within the business. A high proportion of negative responses is desirable.

Statement 38 asserts “Compliance with safety rules is a core company value.” This is also one of the fundamental test statements. All companies the author has worked with that have high risk activities stress this requirement to all people who enter their factories in the company health and safety induction. It is the fundamental principle on which all other activities are based. A negative response to this statement would indicate that, even though the company standards require a high degree of professionalism, certain people within the business may be willing to overlook these and take shortcuts where it suits them, potentially putting themselves and their colleagues at risk. A negative response would also show that the company induction and core health and safety policy requirements are not being adequately managed or conveyed to employees.

Statement 39 asserts “I have been consulted to establish my training needs.” Most companies now carry out employee assessments or appraisals on a periodic basis in which performance and training requirements can be discussed. This is seen as good practice as it gives management and employees the opportunity to formally discuss any issues of concern, including training. All such communications are indicative of attempts to build a good safety culture.

Statement 40 asserts “My training covered all the health and safety risks associated with the work for which I am responsible.” This is also a fundamentally important statement to assess whether the employee thinks the training is thorough enough for the activities being carried out. Any negative responses to this statement would highlight potentially serious issues with the quality of the training received and also perhaps its method or pace of delivery. Negative responses would also highlight potential issues of communication between management and employees as such situations should not be present for any significant period of time.

Statement 41 asserts “The competence requirements of my role are periodically reviewed.” This statement reinforces the answer to S35, S36 and S39. The responses to all these statements should be broadly similar. Any variance would indicate a less than careful approach to the survey or a misunderstanding of the statement. As described above this statement should give a high proportion of positive responses.

Statement 42 asserts “I am clear about what my responsibilities are for health and safety.” This statement serves to reinforce the answers to S34, S37 and S40 but in a much more direct manner. Clearly this statement should result in a high proportion of positive responses. A number of negative responses to this statement would be highly undesirable and would be indicative of the fundamental health and safety information provided to people as being inadequate, incorrect or out of date.

B.5 Influencing Factors Statements

This series of statements serves to determine what state of mind the respondent was in when the survey was filled in and also what issues may be present in the respondent’s own situation. There are no statements in this section that can be regarded as providing a certain expected response.

Statement 43 asserts “I am confident about my future with the company.” A high positive response is desirable as the respondents will have been in a frame of mind that their jobs were safe from the effects of recession and order book uncertainties. A negative response may indicate that the respondents’ answers may not be a true reflection of the actual situation within the business or perhaps that the person is doubtful about their own competence and capabilities compared to that of their colleagues and how they perceive their own security within the business as a result.

Statement 44 asserts “Motivation among the workforce is high.” The statement serves to determine the respondents’ perception of the morale of their work colleagues. Clearly this is also an indicator of their own morale. A high proportion of positive responses is desirable.

Statement 45 asserts “There is never any pressure to put production before safety. This statement serves to determine the answer to two matters: firstly it tries to get behind any kind of protective feelings that the respondent may have towards the management style by telling us if the management have a culture of pressurising employees to break rules and procedures and secondly it tells us if there is a culture of favouring production over safety. A high proportion of positive responses is desirable.

Statement 46 asserts “There are always enough people to get the job done safely.” This statement serves to determine if the respondent has personal experience of being under pressure due to the lack of resources. It is fair to say that people will always tend to state that there are never enough resources and this is considered to be an expected response without coming to any specific strong conclusions. A high number of negative responses may suggest that a resource problem is present within the workplace but the response to this statement would not be treated as a strong indicator as a result of the tendency for respondents to answer negatively irrespective of the real situation. Such a shortfall in resources would most likely be recognised through the supervisory system rather than through a safety culture survey. A high proportion of positive responses would be the desired response to this statement.

Statement 47 asserts “The company would stop us working due to safety concerns, even if it meant losing money.” This statement serves to determine how deep the culture of safety is within the management style of the business. The response to this statement serves to reinforce the answer given to S45 but it is asked in a different manner with the emphasis on the financial penalty of the business for doing so rather than simply the management style.

Statement 48 asserts “Systems and checks are in place to ensure that safety is adequately prioritised by operational staff.” This statement serves to determine whether an on-going system of monitoring is in place with which the respondent is able to have an input to or receive information from regarding the safety status of their own workplace situation. A high positive response is desirable which would show that such monitoring systems are in place and that the management style is one which constantly reviews the situation and feeds back information to the workforce in order to prevent careless and lazy practices from setting in.

Statement 49 asserts “My supervisor is aware of the risks and pressures I work under.” This statement tells us two things again: firstly it confirms the obvious response that the supervisor is able to understand the pressures of the role that the respondent fulfils and secondly: it tells us that there is an effective communication process between employee and supervisor. A high proportion of positive responses is desirable.

Statement 50 asserts “I can get the job done quicker by ignoring some safety rules.” This statement serves to determine several things. Firstly, it provides an indication of the respondent’s attitude towards safety rules and procedures. Secondly it tells us if the respondent is likely to have broken safety rules in the past and if they have the attitude to continue to do so. Thirdly it tells us that the management system is ineffective as it allows for such violations to occur. Admittedly, a high positive response may simply mean that the respondent is stating that they could do things quicker but it is not a clear indication that they have actually done so or ever would. The most that could be read into a positive response is that the respondent has the attitude that they think they know better than the rules and procedures in place to keep themselves safe. It is this attitude that must be changed to improve the safety culture of the workplace. Even in an anonymous survey it is debatable whether people would respond truthfully to this statement. The ABC method of observing behaviours and providing immediate feedback is more likely to identify such issues in practice.

Statement 51 asserts “Sometimes it is necessary to ignore safety rules to maintain production.” This statement directly asks the respondent if they are aware of safety rules being broken for the purposes of maintaining production. The response to this statement reinforces the answers to S45, S47 and S50. A high negative response is desirable for this statement. Anything other than this would indicate a serious failure of management to set and maintain appropriate safety behaviour.

Statement 52 asserts “My workplace is designed such that ergonomics / human capability issues are routinely assessed and rectified.” This statement serves to determine if the respondent is content with the loads and position of the work carried out is within their capability. A high proportion of positive responses would indicate that management have considered the physical effects of the work carried out.

Statement 53 asserts” I sometimes take shortcuts which involve little or no risk.” This statement determines whether the respondent has taken shortcuts, which may be a clear breach of safety rules, and it also gives us an indication of the respondent’s perception of their own competence level in terms of hazard recognition and workplace risk assessment. A high proportion of positive responses may indicate a highly skilled and competent autonomous workforce that is able to take effective safety-related decisions at all times though this must be seen as an exception as such a situation is highly unlikely in practice. This would be a good situation to be in but is unlikely to be effective 100% of the time and the gap must be filled with antecedents such as safety rules and procedures to provide the baseline level of safety on which no leeway can be given. If such a situation were to exist it would suggest that the existing rules and procedures were inadequate. A high proportion of negative responses may indicate that the management style may be too overbearing and may not allow competent people the freedom with which to do things more efficiently but still with an adequate level of safety or simply that the procedures are adequate and that there is no need to take shortcuts.

B.6 My Role Statements

This series of statements serves to determine the level of engagement and empowerment felt by respondents, especially in safety management issues.

There are no statements in this section that can be regarded as providing a certain expected response.

Statement 54 asserts “I can influence health and safety performance in the workplace.” This statement serves to determine if the respondent is empowered and capable of promoting and improving safety in the workplace. It also tells us if the safety management system is capable of using the information provided by employees and is able to respond by changing things for the better. A high proportion of negative responses would indicate that people may be feeling devalued by the management style in force.

Statement 55 asserts “My input is valued when health and safety procedures, instructions and rules are developed or reviewed.” This statement not only tells us if the respondent’s views are sought when safety procedures are being drawn up or modified but the use of the word “valued” also emphasises that their views are important. A high proportion of positive responses would indicate that a good style of management is in place which is essential for developing a good safety culture.

Statement 56 asserts “I am involved in informing management of important safety issues.” This statement reinforces the answers to S54 and S55. It tells us if the respondent is aware of the need to inform management of potential issues and also confirms that they are not afraid to highlight such issues. An open communications process is essential for this to work effectively. A high proportion of positive responses would show that employees’ views on safety management are valued.

Statement 57 asserts “Management formally recognise exceptional safety performance.” The emphasis of this statement is on the words “formally” and ”exceptional”. A high proportion of positive responses is desirable but the most likely situation in reality is an informal recognition of good safety management.

Statement 58 asserts “I stop work for guidance when safety rules conflict with the task being carried out.” This statement serves to reinforce the answers given to S34, S37, S40 and S42. A high proportion of positive responses would indicate that people place safety management very high on their list of priorities and are willing to delay or stop production for clarification when necessary. This clearly shows the presence of a good safety culture positively reinforced by management. It also serves to show that a good communications process is present between shop floor and management.

Statement 59 asserts “I believe that members of my team could work more safely.” This statement serves to find out what the respondent thinks of the behavioural safety of their colleagues. A high proportion of positive responses would indicate that there is something wrong with the safety management system. If most people answered positively then it would again suggest the people involved think that they are safer than others and, as discussed previously, they cannot all be correct. A high number of positive responses would suggest that the business has some way to go to build a good safety culture.

Statement 60 asserts “The company provides a means of mentoring poor performers.” This statement serves to determine if the respondent is aware of a mentoring system for those personnel who have made mistakes or caused accidents. In a good safety culture people who have made mistakes and caused accidents should not be allowed to continue without corrective action being taken but part of that action must include rehabilitation and training in order to build knowledge, experience and competence and to reinforce company safety values and expectations. The self-esteem of a person who has caused an accident must not be reduced but their performance must be improved through positive reinforcement. A high proportion of positive responses is therefore desirable. A high proportion of negative responses would suggest that a blame culture may be present.

Statement 61 asserts “I have been trained in safety leadership and safety behavioural skills expectations.” This statement serves to discover if the company has a safety leadership programme in place and whether that programme extends to all employees or just to management and supervisors. It would be normal to have such a programme in place for managers and supervisors but this would not necessarily extend to shop floor workers directly. The response profile is expected to follow the supervisor / shop floor worker ratio but anything more positive than this would indicate a good safety culture being in place.

Statement 62 asserts “I feel empowered to stop unsafe acts or safety breaches by others.” This statement serves to determine the level of empowerment in place for each respondent. A high proportion of positive responses would indicate a good safety culture where people can intervene in any situation where they see a potential for harm to occur. Such empowerment can only come from repeated and on-going positive reinforcement from the management which indicates that a good safety culture is present throughout the business.

Statement 63 asserts “I can report incidents without fear of repercussions to me or my colleagues.” This statement serves to determine the actual attitude of the management through perception of the respondents in terms of determining whether a blame culture is present or whether the culture is centred on accident prevention and development of efficient and workable safety systems. A high proportion of positive responses would indicate that a good safety culture has been developed over a significant period of time through a trusting relationship between management and shop floor. A high proportion of negative responses would suggest that people are fearful of reporting accidents and near misses indicating the presence of a blame culture.

Statement 64 asserts “I often rely on my own experience in making safety-related decisions.” This statement serves to determine several things. Firstly it will indicate if the respondents’ need to make safety-related decisions in their work activities and secondly it provides an indication of the respondents’ view of their own competence being adequate to make such decisions. A high proportion of positive responses could also indicate whether the company is satisfied that its employees have reached a level of competence with which they are empowered to make such decisions.

Statement 65 asserts “My colleagues are able to determine risk and make appropriate decisions to maintain safety.” This statement serves to determine what the respondent thinks of the competence of their colleagues in terms of safety-related decision making. It gives an indication of the level of trust in terms of working safely that is present between colleagues. S64 asks the same question of the respondents' level of competence whereas S65 asks the question of the respondents' perception of their colleagues' level of competence. A high proportion of positive responses would indicate the presence of good team work built on trust, mutual respect and a high level of competence, i.e. an element of a good safety culture.

Statement 66 asserts "I operate in a working environment where safety-critical decision making processes are present." This statement serves to determine if there is a perception of high risk within the workplace from the respondents. For the companies that took part within the research the expected response would be a high proportion of positives. Some personnel may not be directly involved with the high risk tasks and may return an indifferent response but most would be expected to agree with the statement.

B.7 My Manager Statements

This series of statements serves to determine respondents' views on the performance and attitude of their line managers. There is one statement in this section that can be regarded as providing a certain expected response.

Statement 67 asserts "My line manager has clearly defined my safety roles and responsibilities." This statement should have a 100% positive response as all companies involved in the research have induction systems in place in which the basic and most important safety rules, responsibilities and expectations are made clear. Anything other than a completely positive response would indicate that the respondents were either not answering the survey truthfully or that they believed that they had not been clearly advised. Whether correct or not, the perceived situation is what is most important as it is the employee's perception that determines what their thoughts are on the subject. On-going reinforcement of such measures must be in place in order to ensure that personnel are aware of their roles and responsibilities.

Statement 68 asserts "My line manager regularly spends time in operational areas." A good safety culture is built on good team work and communications between management and shop floor. An on-going presence of management on the shop floor for the right reasons is a good way of building trust and communication channels, especially if positive reinforcement is given at the same time. Such a presence indicates that the management have a genuine concern for what happens on the shop floor. A high positive response is desirable for this statement.

Statement 69 asserts "My line manager ensures that safety tours are regularly carried out." This statement serves to determine if a system of workplace safety tours / inspections is in place and whether they are carried out regularly. The statement also implies that the line manager is responsible for ensuring that such tours are carried out but the most important factor is they are in place and not necessarily who organises them. A high proportion of positive responses is desirable. A high proportion of negative responses would suggest that, although a workplace may have many safety controls and procedures, without regular auditing and interaction between management and shop floor they will not achieve the desired outcome.

Statement 70 asserts "My line manager is good at communicating safety information to my team." Clearly a high positive response is the desirable outcome and this would indicate that respondents are satisfied that line managers are looking after the safety aspects of the team to an acceptable level. A high negative response must be investigated and corrected if this situation is to be prevented from getting worse.

Statement 71 asserts "My line manager influences my safety behaviour by example and by providing support for issues raised." This statement is only true for a company with a good safety culture and where good behaviours are set by management and positively reinforced by their actions. A high negative response would indicate that what the management say and do are two different things and that such a situation must be addressed to build a better safety culture.

Statement 72 asserts "My line manager is genuinely concerned about the health and safety of people at this workplace." This statement serves to determine the respondents' perception of their manager's empathy with their own workplace situation. A high proportion of positive responses can only be achieved if the line manager is a good communicator and is constantly in contact with the workforce. Their handling of worker concerns will undoubtedly affect how this statement is answered.

Statement 73 asserts "The safety manager only appears when there is a problem." This is an all too familiar statement to be heard in many industrial situations. A company with a good safety culture will have a safety manager who is known to the workforce and who is approachable. A high proportion of negative responses would indicate that the safety manager is a good communicator and has built a culture in which people are not afraid to raise their concerns regarding safety issues. A high proportion of positive responses would indicate that the safety manager is not devoting sufficient time to core functions. Building a better safety culture will not be possible until this attitude is corrected.

Statement 74 asserts "My line manager devotes sufficient effort to health and safety." This statement serves to determine what the respondents' perception of their line manager's attitude to safety is. A high proportion of positive responses would indicate that the respondent is satisfied with the safety performance of the manager.

Statement 75 asserts "There are sufficient opportunities to communicate with senior managers about safety." This statement serves to determine if the respondent feels that they can discuss safety issues with managers often enough. A high proportion of positive responses would indicate that senior managers take safety seriously enough to make themselves available for such discussions.

Statement 76 asserts "My line manager sometimes turns a blind eye when the rules are bent." This situation can never be acceptable in any company. A positive response to this statement shows that the manager has distanced themself from their responsibilities and is no longer managing the situation competently. Unfortunately, it will be the shop floor worker who will inevitably suffer the physical consequences. With such poor management it is also likely that the shop floor worker will be "blamed" for the accident when it occurs. It is feasible that the line manager may trust the worker sufficiently to carry out tasks by knowingly breaking the rules but positive reinforcement of such rule breaking will lead to propagation of such behaviour if it were to go unchecked and may ultimately result in an accident. Only a high proportion of negative responses would be an acceptable outcome for this statement.

B.8 Communications Statements

This series of statements serves to determine the state of communications within the business. All of the answers to the "Communications" section are entirely dependent on a respondent's own experience of the workplace, its systems (physical and organisational), its hazards and its risk to them as they carry out their allotted tasks.

Statement 77 asserts "Shift handover communications are formal, structured and specifically cover safety aspects." This statement serves to determine whether such formal communications systems are in place and whether they are used at shift changeovers for the purposes of ensuring all safety aspects are adequately addressed between different teams of personnel. A high proportion of negative responses would indicate that personnel are not communicating clearly with each other which may lead to misunderstandings and the creation of a situation which may contribute to an accident occurring.

Statement 78 asserts "The consequences of poor communications are understood." This statement serves to determine whether the respondent understands the potential effects of poor communications directly and through escalation mechanisms. Poor communications between shifts and operations / maintenance teams was a significant contributing factor in the Piper Alpha disaster in the North Sea and many other documented accidents. All safety-related information must be handed off correctly if people are to be kept safe. This statement reinforces the answer to S77. Any mismatch between the two responses would indicate the presence of a potential problem but with an unwillingness to do anything to rectify the issue. This would clearly be a poor safety culture.

Statement 79 asserts "Formal safety communication systems are regularly reviewed." This statement is not expected to return a high positive response as such reviews and audits may not actually involve all personnel. A high proportion of positive responses may not actually be directly indicative of a good safety culture. A high proportion of negative responses however would mean that there is a problem that requires to be addressed.

Statement 80 asserts "My input to safety is encouraged through several different means of communication." This statement is seeking to determine the answers to two aspects. Firstly; is the input from employees encouraged and secondly are there actually different methods of communication in place such as suggestion schemes (anonymity included), verbal, safety committees, unions, etc? A good safety culture will provide multiple means of communication. As with the previous statement a high proportion of positive responses would indicate a good safety culture but anything other than this would indicate that the views of the employees were not adequately valued by the management. The statement also serves to determine whether the respondent is willing to put forward their views by intervening in potentially unsafe behaviours.

Statement 81 asserts “Timely and effective feedback is provided on positive and negative issues raised.” This statement serves to reinforce the answers given to S10, S28, S55, S70, and S75. A good safety culture will always have effective communications and will provide feedback to personnel in order to ensure that learning points are used for the improvement of safety. Feeding back decisions made on all such issues builds upon the trust present between managers and shop floor and ensures that continued dialogue occurs.

Statement 82 asserts “A schedule is provided for regular site visits by line and senior management to communicate with employees.” This statement serves to determine if the respondents are aware of a formal schedule for workplace site visits by management. This is most often achieved by the implementation of periodic safety tours or similar. A high proportion of negative responses indicates an infrequent presence of management on the shop floor and would suggest that there are insufficient opportunities for safety discussions with management.

Statement 83 asserts “There is good communication here about safety issues which affect me.” This statement serves to determine what the respondents’ perception of the quality of communication is within the workplace. Only a high proportion of positive responses would be expected for a workplace with a good safety culture.

Statement 84 asserts “There is poor communications between operator and contractor staff.” Safety discussions with contractors are just as important as those with employees; possibly more so as a result of them having less knowledge and experience of the site. This statement serves to confirm that the communication systems in place are utilised for all personnel at risk and not just employees.

Statement 85 asserts “The identification and communication of solutions to problems is encouraged.” This statement serves to determine the perception of the respondents’ worth to the business and reinforces the answers to S18, S54 and S80. A company with a good safety culture will always encourage employees to share their ideas for improvements to safety within the plant.

Statement 86 asserts “Safety communications are provided in clear and concise language avoiding jargon and abbreviations.” This is an essential requirement for high risk workplaces if accidents are to be avoided. Any misunderstandings of the intention of procedures and safety rules could have serious consequences. Only a high proportion of positive responses is desirable for this statement.

B.9 The Organisation Statements

This series of statements serves to determine the respondents’ views of how the company approaches safety control and management. There is one statement (S87) in this section that can be regarded as providing a certain expected response.

Statement 87 asserts “An induction process is in place which provides clear expectations for all employees and contractors.” Of all the companies that the author has visited not one hasn’t had some form of safety induction for employees and visitors. This is also true for the companies that took part in the research survey. This statement should therefore return only a positive response. Any negative responses in this statement would suggest that the respondent has not filled in the survey truthfully or read the statements with enough care to place a high level of reliance on the responses to the other statements in the survey.

Statement 88 asserts “A policy promoting personnel intervention in the interest of safety is in place and supported at all levels.” Most companies have such policies in place. A good safety culture would result in a high proportion of positive responses. The response to this statement reinforces the responses to S62 and S63.

Statement 89 asserts “Clear and simple safety rules and principles are communicated to all employees and contractors.” The response to this statement also reinforces those from S83, S84 and S87. Only a high proportion of positive responses would be expected for a company with a good safety culture.

Statement 90 asserts “The same rules apply to all personnel and at all levels.” This statement serves to determine if there is any hint of a “them and us” culture within the business. Negative responses to this statement should not be present in a company with a good safety culture.

Statement 91 asserts “The company cares about the health and safety of the people who work here.” This statement serves to determine directly whether the respondents believe that the company genuinely cares about its people. Negative responses would indicate that perhaps the company cared more about the accident figures than the well-being of its employees.

Statement 92 asserts “Management acts decisively when a safety concern is raised.” This statement determines the respondents’ perception of how well management respond to safety concerns that are identified. Only a high proportion of positive responses would be expected in a company with a good safety culture.

Statement 93 asserts “The company encourages suggestions on how to improve health and safety.” This statement tells us if there is a good safety culture in place where the management are seen to listen effectively to the views of the employees. The statement reinforces the answers given to S18, S80 and S85.

Statement 94 asserts “Personnel are actively encouraged to participate in initiatives which can improve safety.” This statement serves to discover if respondents know of the existence of any such initiatives and whether they are actually involved. Participation can build trust and contribute to better teamwork. A high proportion of positive responses is desired.

Statement 95 asserts “This is a safer place to work than previous employers.” This statement serves to provide a baseline estimation of the respondents’ perception of risk with reference to other workplaces. A high proportion of positive responses would be desirable. A positive response would indicate that the other statements relating to their perception of safety may tend to be scored highly while a negative response may indicate that they are less content with their present situation than in previous workplaces and may have scored other safety-related statements lower.

Statement 96 asserts “Sufficient resources are available for health and safety here.” This determines the respondents’ perception of the general importance that management place on safety. This statement also reinforces the answers to S27 and S46.

Statement 97 asserts “Some safety rules / procedures are impractical.” This statement serves to determine the respondents’ view of the quality of the existing rules and procedures and whether they believe that they are capable of working safely without them, i.e. potentially by taking shortcuts. The statement serves to indicate whether they are likely to take shortcuts and reinforces the answers given to S14, S15, S46, S50, S51, S53, S76,

Statement 98 asserts “Management sometimes turn a blind eye to health and safety procedures/instructions/rules being broken.” This final statement serves to determine the respondents’ perception of whether management knowingly allow safety rules and procedures to be broken, i.e. positive reinforcement of a poor safety culture. A high proportion of negative responses is desirable for this statement.

C. APPENDIX – SAFETY CULTURE SURVEY QUESTIONNAIRE

4 Square Engineering Consultancy Limited

NAPIER UNIVERSITY EDINBURGH

Investigation into the Causation of Accidents in Industry and Transportation and the Implementation of Human Factors Engineering as a Preventative Measure

Human Factors Engineering – Partner Survey

Your employer has agreed for you to take part in this survey as part of their ongoing strategy towards improving safety and performance. Your responses are important and will be used to identify where potential improvements can be implemented in your workplace.

This survey forms part of a research study being carried out in association with 4 Square Engineering Consultancy Limited and Napier University.

It is important that you answer the questions carefully and frankly based on your own perception. The survey should take around 15 to 20 minutes to complete.

Confidentiality

This survey and its results will be treated as strictly confidential between 4 Square Engineering Consultancy Limited, Napier University and your organisation. The identities of individuals are not requested and details of companies taking part won't be released through the survey or any associated documentation produced unless with prior written agreement.

Your Role in the Organisation

To assist with analysis of the survey data please tick the appropriate boxes below which best describe your function within the organisation.

"Job Function" has been broadly defined from managerial functions to shop floor workers in terms of how safety policies would be implemented within your workplace.

Status	Employee	Contractor			
Department	Production	Maintenance	Support Services		
Job Function	Managerial (Safety policy creation)	Professional (Engineering) (Enable policy compliance)	Supervisory (Policy implementation)	Technician / Operator (Policy compliance)	Support Role (Policy compliance)

Company A

Please mark your response to the questions (X or √) in the boxes opposite. If you would like to change your first response simply score out the original and remark as necessary.	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
Safety Culture					
1. The standard of safety is very high at my workplace.					
2. It is important to me that there is a continuing emphasis on safety.					
3. When I see safety rules being broken I point it out immediately.					
4. This workplace operates a no-blame safety culture.					
5. People are willing to report accidents and near misses.					
6. Mistakes are corrected without punishment and treated as a learning opportunity for all.					
7. I can trust most people who I work with to work safely.					
8. People in this workplace refuse to do work if they feel the task is unsafe.					
9. Company policy supports the right of any person to intervene in the interests of safety.					
10. Recognition is given for proactive intervention.					
Organisational Measures	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
11. Written safety rules and procedures are easily understood and implemented.					
12. Permit forms and procedures are clear, unambiguous and easy to use.					
13. The PTW system is a way of covering people's backs.					
14. Some health and safety procedures/instructions/rules do not need to be followed to get the job done safely.					
15. Procedures reflect working practice.					
16. Information relative to work activities is easily accessible to allow comprehensive work planning.					
17. Systems are in place to assess the potential impact of plant modifications or changes to operating procedures.					
18. Staff are encouraged to comment on proposed changes before they are implemented?					
19. Personnel training is updated prior to changes being implemented.					
20. All personnel are trained in change management procedures.					
Incident Management	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
21. The causes of incidents and near misses are investigated.					
22. Incident investigation is an open process which prevents incidents recurring through good communications.					

Company A

Please mark your response to the questions (X or √) in the boxes opposite. If you would like to change your first response simply score out the original and remark as necessary.	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
23. Incident investigations are carried out to discover root cause and not specifically to find out who is to blame.					
24. Personnel are formally trained in incident investigation techniques.					
25. Recommendations produced from incident investigations are always implemented and enforced.					
26. The people who cause incidents are not held sufficiently accountable for their actions.					
27. Adequate resources are provided for incident investigations.					
28. A formal communications process is in place to ensure all relevant personnel are aware of the learning points.					
29. Management are slow to act on improvements unless incidents have occurred.					
30. A trend is present which shows that incidents are repeatedly caused by the same people.					
31. Most incidents occur during routine activities.					
32. When incidents occur a clear incident handling process is in place and people are trained in its operation.					
Competence Management	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
33. I have received risk assessment and observation skills training.					
34. I only work within my capabilities and competencies.					
35. I have an up to date job description clearly stating my role, responsibilities and required competencies.					
36. A competency mapping system is in place with which my competence is periodically measured and recorded.					
37. Sometimes I am uncertain what to do to ensure health and safety is maintained in the work for which I am responsible.					
38. Compliance with safety rules is a core company value.					
39. I have been consulted to establish my training needs.					
40. My training covered all the health and safety risks associated with the work for which I am responsible.					
41. The competence requirements of my role are periodically reviewed.					
42. I am clear about what my responsibilities are for health and safety.					
Influencing Factors	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
43. I am confident about my future with the company.					
44. Motivation among the workforce is high.					
45. There is never any pressure to put production before safety.					

Company A

Please mark your response to the questions (X or √) in the boxes opposite. If you would like to change your first response simply score out the original and remark as necessary.	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
46. There are always enough people to get the job done safely.					
47. The company would stop us working due to safety concerns, even if it meant losing money.					
48. Systems and checks are in place to ensure that safety is adequately prioritised by operational staff.					
49. My supervisor is aware of the risks and pressures I work under.					
50. I can get the job done quicker by ignoring some safety rules.					
51. Sometimes it is necessary to ignore safety rules to maintain production.					
52. My workplace is designed such that ergonomics / human capability issues are routinely assessed and rectified.					
53. I sometimes take shortcuts which involve little or no risk.					
My Role	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
54. I can influence health and safety performance in the workplace.					
55. My input is valued when health and safety procedures, instructions and rules are developed or reviewed.					
56. I am involved in informing management of important safety issues.					
57. Management formally recognise exceptional safety performance.					
58. I stop work for guidance when safety rules conflict with the task being carried out.					
59. I believe that members of my team could work more safely.					
60. The company provides a means of mentoring poor performers.					
61. I have been trained in safety leadership and safety behavioural skills expectations.					
62. I feel empowered to stop unsafe acts or safety breaches by others.					
63. I can report incidents without fear of repercussions to me or my colleagues.					
64. I often rely on my own experience in making safety-related decisions.					
65. My colleagues are able to determine risk and make appropriate decisions to maintain safety.					
66. I operate in a working environment where safety-critical decision making processes are present.					
My Manager	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
67. My line manager has clearly defined my safety roles and					

Company A

Please mark your response to the questions (X or √) in the boxes opposite. If you would like to change your first response simply score out the original and remark as necessary.	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
responsibilities.					
68. My line manager regularly spends time in operational areas.					
69. My line manager ensures that safety tours are regularly carried out.					
70. My line manager is good at communicating safety information to my team.					
71. My line manager influences my safety behaviour by example and by providing support for issues raised.					
72. My line manager is genuinely concerned about the health and safety of people at this workplace.					
73. The safety manager only appears when there is a problem.					
74. My line manager devotes sufficient effort to health and safety.					
75. There are sufficient opportunities to communicate with senior managers about safety.					
76. My line manager sometimes turns a blind eye when the rules are bent.					
Communications	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
77. Shift handover communications are formal, structured and specifically cover safety aspects.					
78. The consequences of poor communications are understood.					
79. Formal safety communication systems are regularly reviewed.					
80. My input to safety is encouraged through several different means of communication.					
81. Timely and effective feedback is provided on positive and negative issues raised.					
82. A schedule is provided for regular site visits by line and senior management to communicate with employees.					
83. There is good communication here about safety issues which affect me.					
84. There is poor communications between operator and contractor staff.					
85. The identification and communication of solutions to problems is encouraged.					
86. Safety communications are provided in clear and concise language avoiding jargon and abbreviations.					
The Organisation	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
87. An induction process is in place which provides clear expectations for all employees and contractors.					
88. A policy promoting personnel intervention in the interest of					

Company A

Please mark your response to the questions (X or √) in the boxes opposite. If you would like to change your first response simply score out the original and remark as necessary.	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE
safety is in place and supported at all levels.					
89. Clear and simple safety rules and principles are communicated to all employees and contractors.					
90. The same rules apply to all personnel and at all levels.					
91. The company cares about the health and safety of the people who work here.					
92. Management acts decisively when a safety concern is raised.					
93. The company encourages suggestions on how to improve health and safety.					
94. Personnel are actively encouraged to participate in initiatives which can improve safety.					
95. This is a safer place to work than previous employers.					
96. Sufficient resources are available for health and safety here.					
97. Some safety rules / procedures are impractical.					
98. Management sometimes turn a blind eye to health and safety procedures/instructions/rules being broken.					

<u>Additional Comments</u>

If you would like to add any comments regarding, safety culture, operating procedures, job satisfaction, safety training and awareness, organisational methods, etc. please do so below. Please remember that these surveys are anonymous and that all of your comments are valued.

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On behalf of the research study and your company, thank you for spending the time filling in this questionnaire.

Company A

D. APPENDIX – ASSESSMENT TOOL EXAMPLE OUTPUT

Table D.1: *Company A Baseline: Safety Culture Quality Factors*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	4.29	3	Average Empowerment	2.97	13
Average N° Quality	9.16	1	Average Procedural awareness	3.05	11
Average Disagrees	1.26	23	Average Management pressure	3.18	9
Average Blame	2.71	14	Average Valued / worth	3.39	7
Average Colleague Trust	3.13	10	Average Safety promotion	2.34	17
Average Intervention	3.82	4	Average Resources	3.03	12
Average Communications	2.29	19	Average Indifferent	3.45	6
Average Incident Management	1.76	20	Average Motivation	1.37	22
Average Competence	2.32	18	Average Training	1.61	21
Average R&R	2.66	15	Average SD/SA	3.39	7
Average Safety Culture	3.79	5	Average Consecutive Indifferent	8.82	2
Average Organisational measures	2.39	16	Average Quality	3.31	

Table D.2: *Company A Baseline: Modal / Mean Values*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	1	4	6.73	2
Organisational measures	4	3	6.04	8
Incident Management	5	0	5.68	9
Competence Management	2	1	6.12	7
Influencing factors	4	0	6.12	6
My role	1	3	6.64	4
My Manager	1	1	6.70	3
Communications	1	1	6.31	5
The organisation	0	6	6.90	1
Total Check Value				
Mode	Incident management	The organisation		

Table D.3: *Company A Baseline: Safety Culture Values*

Safety Culture	Value
Maximum Quality Value	149.00
Maximum Questions Total Value	75.43
Maximum N° of Consecutive Indifferent Responses	97.00
Mean Total	57.24
Mean Quality	76.18
Maximum Safety Culture	7.58
Safety Culture Value	4.84

Table D.4: *Company A Baseline: Management Safety Culture Quality Factors*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	7.33	4	Average Empowerment	4.67	11
Average N° Quality	10.00	1	Average Procedural awareness	4.33	13
Average Disagrees	3.33	18	Average Management pressure	6.00	6
Average Blame	4.67	11	Average Valued / worth	4.33	13
Average Colleague Trust	5.00	10	Average Safety promotion	2.67	20
Average Intervention	6.00	6	Average Resources	6.00	6
Average Comms	2.67	20	Average Indifferent	6.33	5
Average Incident Management	1.67	23	Average Motivation	3.00	19
Average Competence	4.33	13	Average Training	2.67	20
Average R&R	3.67	16	Average SD/SA	8.67	3
Average Safety Culture	6.00	6	Average Consecutive Indifferent	10.00	1
Average Organisational measures	3.67	16	Average Quality	5.09	

Table D.5: *Company A Baseline: Management Modal / Mean Values*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	0	1	7.92	2
Organisational measures	0	0	6.75	9
Incident Management	2	0	6.81	8
Competence Management	0	1	7.33	5
Influencing factors	0	0	7.65	4
My role	0	0	7.69	3
My Manager	1	0	7.02	6
Communications	0	0	6.83	7
The organisation	0	1	8.08	1
Total Check Value	3	3		
Mode	Incident management	Safety culture		

Table D.6: *Company A Baseline: Management Safety Culture Values*

Safety Culture	Value
Maximum Quality Value	149.00
Maximum Questions Total Value	75.43
Maximum N° of Consecutive Indifferent Responses	3.00
Mean Total	66.08
Mean Quality	117.00
Maximum Safety Culture	7.58
Safety Culture Value	6.21

Table D.7: *Company A Baseline: Non-Management Safety Culture Quality Factors*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	3.72	3	Average Empowerment	2.66	10
Average N° Quality	9.00	1	Average Procedural awareness	2.81	8
Average Disagrees	0.88	23	Average Management pressure	2.66	10
Average Blame	2.34	15	Average Valued / worth	3.22	6
Average Colleague Trust	2.78	9	Average Safety promotion	2.28	16
Average Intervention	3.41	4	Average Resources	2.47	12
Average Comms	2.22	17	Average Indifferent	2.91	7
Average Incident Management	1.78	20	Average Motivation	1.06	22
Average Competence	1.94	19	Average Training	1.41	21
Average R&R	2.47	12	Average SD/SA	2.41	14
Average Safety Culture	3.38	5	Average Consecutive Indifferent	8.59	2
Average Organisational measures	2.16	18	Average Quality	2.98	

Table D.8: *Company A Baseline: Non-Management Modal / Mean Values*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	1	3	6.51	3
Organisational measures	4	3	5.90	6
Incident Management	3	0	5.47	9
Competence Management	2	0	5.89	7
Influencing factors	4	0	5.84	8
My role	1	3	6.45	4
My Manager	0	1	6.64	2
Communications	1	1	6.21	5
The organisation	0	5	6.68	1
Total Check Value	16	16		
Mode	Organisational measures	The organisation		

Table D.9: *Company A Baseline: Non-Management Safety Culture Values*

Safety Culture	Value
Maximum Quality Value	127.00
Maximum Questions Total Value	71.86
Maximum N° of Consecutive Indifferent Responses	97.00
Mean Total	55.59
Mean Quality	68.53
Maximum Safety Culture	6.83
Safety Culture Value	4.58

Table D.10: *Company A Baseline: Safety Culture Quality Factors: Poor Quality Responses Removed*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	4.68	3	Average Empowerment	3.21	13
Average N° Quality	9.29	2	Average Procedural awareness	3.24	12
Average Disagrees	1.29	23	Average Management pressure	3.44	9
Average Blame	2.94	14	Average Valued / worth	3.68	8
Average Colleague Trust	3.38	10	Average Safety promotion	2.50	17
Average Intervention	4.15	4	Average Resources	3.26	11
Average Communications	2.44	19	Average Indifferent	3.79	6
Average Incident Management	1.88	20	Average Motivation	1.41	22
Average Competence	2.47	18	Average Training	1.71	21
Average R&R	2.85	15	Average SD/SA	3.74	7
Average Safety Culture	4.15	4	Average Consecutive Indifferent	9.76	1
Average Organisational measures	2.56	16	Average Quality	3.56	

Table D.11: *Company A Baseline: Modal / Mean Values: Poor Quality Responses Removed*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	0	3	6.95	2
Organisational measures	4	2	6.10	8
Incident Management	5	0	5.78	9
Competence Management	1	1	6.28	6
Influencing factors	4	0	6.24	7
My role	1	3	6.84	4
My Manager	1	1	6.89	3
Communications	1	1	6.46	5
The organisation	0	6	7.12	1
Total Check Value	17	17		
Mode	Incident management	The organisation		

Table D.12: *Company A Baseline: Safety Culture Values: Poor Quality Responses Removed*

Safety Culture	Value
Maximum Quality Value	149.00
Maximum Questions Total Value	75.43
Maximum N° of Consecutive Indifferent Responses	14.00
Mean Total	58.67
Mean Quality	81.82
Maximum Safety Culture	7.58
Safety Culture Value	5.04

Table D.13: *Company A Baseline: Non-Management: Safety Culture Quality Factors: Poor Quality Responses Removed*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	4.11	3	Average Empowerment	2.89	10
Average N° Quality	9.14	2	Average Procedural awareness	3.00	9
Average Disagrees	0.86	23	Average Management pressure	2.89	10
Average Blame	2.57	15	Average Valued / worth	3.54	6
Average Colleague Trust	3.04	8	Average Safety promotion	2.46	16
Average Intervention	3.75	4	Average Resources	2.68	12
Average Communications	2.39	17	Average Indifferent	3.25	7
Average Incident Management	1.93	20	Average Motivation	1.07	22
Average Competence	2.07	19	Average Training	1.50	21
Average R&R	2.68	12	Average SD/SA	2.68	12
Average Safety Culture	3.75	4	Average Consecutive Indifferent	9.71	1
Average Organisational measures	2.32	18	Average Quality	3.23	

Table D.14: *Company A Baseline: Non-Management: Modal / Mean Values: Poor Quality Responses Removed*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	0	2	6.74	3
Organisational measures	4	2	5.96	7
Incident Management	3	0	5.57	9
Competence Management	1	0	6.06	6
Influencing factors	4	0	5.94	8
My role	1	3	6.65	4
My Manager	0	1	6.86	2
Communications	1	1	6.38	5
The organisation	0	5	6.92	1
Total Check Value	14	14		
Mode	Organisational measures	The organisation		

Table D.15: *Company A Baseline: Non-Management: Safety Culture Values: Poor Quality Responses Removed*

Safety Culture	Value
Maximum Quality Value	127.00
Maximum Questions Total Value	71.86
Maximum N° of Consecutive Indifferent Responses	14.00
Mean Total	57.08
Mean Quality	74.29
Maximum Safety Culture	6.83
Safety Culture Value	4.79

Table D.16: *Company A Final: Safety Culture Quality Factors*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	4.88	3	Average Empowerment	2.04	10
Average N° Quality	9.33	1	Average Procedural awareness	2.21	9
Average Disagrees	1.00	22	Average Management pressure	1.75	13
Average Blame	2.96	5	Average Valued / worth	1.38	20
Average Colleague Trust	1.83	12	Average Safety promotion	1.42	18
Average Intervention	2.58	8	Average Resources	1.96	11
Average Communications	1.42	18	Average Indifferent	0.92	23
Average Incident Management	1.58	14	Average Motivation	1.46	17
Average Competence	2.71	7	Average Training	1.33	21
Average R&R	3.04	4	Average SD/SA	2.88	6
Average Safety Culture	1.58	14	Average Consecutive Indifferent	8.88	2
Average Organisational measures	1.54	16	Average Quality	2.64	

Table D.17: *Company A Final: Modal / Mean Values*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	0	3	6.30	3
Organisational measures	0	0	5.54	8
Incident Management	1	0	5.73	6
Competence Management	3	6	6.32	2
Influencing factors	4	0	5.20	9
My role	0	0	5.95	5
My Manager	1	0	6.33	1
Communications	3	0	5.70	7
The organisation	0	3	6.23	4
Total Check Value	12	12		
Mode	Influencing factors	Competence management		

Table D.18: *Company A Final: Safety Culture Values*

Safety Culture	Value
Maximum Quality Value	127.50
Maximum Questions Total Value	70.12
Maximum N° of Consecutive Indifferent Responses	75.00
Mean Total	53.30
Mean Quality	60.67
Maximum Safety Culture	6.79
Safety Culture Value	4.28

Table D.19: *Company A Final: Management: Safety Culture Quality Factors*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	7.33	3	Average Empowerment	4.00	8
Average N° Quality	10.00	1	Average Procedural awareness	3.33	10
Average Disagrees	1.17	23	Average Management pressure	2.67	18
Average Blame	6.00	4	Average Valued / worth	3.00	12
Average Colleague Trust	2.67	18	Average Safety promotion	3.00	12
Average Intervention	5.00	5	Average Resources	4.67	6
Average Communications	3.00	12	Average Indifferent	2.17	22
Average Incident Management	2.67	18	Average Motivation	3.00	12
Average Competence	3.00	12	Average Training	2.67	18
Average R&R	4.67	6	Average SD/SA	3.67	9
Average Safety Culture	3.00	12	Average Consecutive Indifferent	10.00	1
Average Organisational measures	3.33	10	Average Quality	4.09	

Table D.20: *Company A Final: Management: Modal / Mean Values*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	0	1	7.58	1
Organisational measures	0	0	6.42	8
Incident Management	1	0	6.14	9
Competence Management	1	2	7.25	4
Influencing factors	0	0	6.97	5
My role	0	0	6.86	6
My Manager	0	0	7.58	1
Communications	1	0	6.75	7
The organisation	0	0	7.50	3
Total Check Value	3	3		
Mode	Incident management	Competence management		

Table D.21: *Company A Final: Management: Safety Culture Values*

Safety Culture	Value
Maximum Quality Value	127.50
Maximum Questions Total Value	70.12
Maximum N° of Consecutive Indifferent Responses	5.00
Mean Total	63.05
Mean Quality	94.00
Maximum Safety Culture	6.79
Safety Culture Value	5.55

Table D.22: *Company A Final: Non-Management: Safety Culture Quality Factors*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	3.75	3	Average Empowerment	1.42	11
Average N° Quality	9.33	1	Average Procedural awareness	2.17	7
Average Disagrees	0.92	17	Average Management pressure	1.50	10
Average Blame	2.50	5	Average Valued / worth	0.83	19
Average Colleague Trust	1.33	12	Average Safety promotion	1.00	15
Average Intervention	1.92	9	Average Resources	1.08	14
Average Communications	0.92	17	Average Indifferent	0.50	23
Average Incident Management	1.00	15	Average Motivation	0.75	22
Average Competence	2.25	6	Average Training	0.83	19
Average R&R	2.08	8	Average SD/SA	3.67	4
Average Safety Culture	1.25	13	Average Consecutive Indifferent	7.75	2
Average Organisational measures	0.83	19	Average Quality	2.16	

Table D.23: *Company A Final: Non-Management: Modal / Mean Values*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	0	2	5.89	3
Organisational measures	0	0	5.29	8
Incident Management	0	0	5.47	7
Competence Management	2	1	5.64	4
Influencing factors	3	0	4.22	9
My role	0	0	5.56	5
My Manager	0	0	6.00	2
Communications	1	0	5.48	6
The organisation	0	3	6.04	1
Total Check Value	6	6		
Mode	Influencing factors	The organisation		

Table D.24: *Company A Final: Non-Management: Safety Culture Values*

Safety Culture	Value
Maximum Quality Value	63.50
Maximum Questions Total Value	56.40
Maximum N° of Consecutive Indifferent Responses	75.00
Mean Total	49.58
Mean Quality	49.58
Maximum Safety Culture	4.52
Safety Culture Value	3.83

Table D.25: *Company A Final: Safety Culture Quality Factors: Poor Quality Responses Removed*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	5.23	3	Average Empowerment	2.14	9
Average N° Quality	9.27	2	Average Procedural awareness	2.14	9
Average Disagrees	1.00	22	Average Management pressure	1.82	13
Average Blame	2.68	7	Average Valued / worth	1.45	18
Average Colleague Trust	1.91	12	Average Safety promotion	1.45	18
Average Intervention	2.55	8	Average Resources	2.05	11
Average Communications	1.45	18	Average Indifferent	0.95	23
Average Incident Management	1.64	14	Average Motivation	1.50	17
Average Competence	2.86	6	Average Training	1.41	21
Average R&R	3.23	4	Average SD/SA	3.09	5
Average Safety Culture	1.64	14	Average Consecutive Indifferent	9.64	1
Average Organisational measures	1.59	16	Average Quality	2.73	

Table D.26: *Company A Final: Modal / Mean Values: Poor Quality Responses Removed*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	0	2	6.28	4
Organisational measures	0	0	5.57	8
Incident Management	1	0	5.73	7
Competence Management	2	6	6.44	2
Influencing factors	4	0	5.21	9
My role	0	0	6.04	5
My Manager	1	0	6.45	1
Communications	3	0	5.76	6
The organisation	0	3	6.34	3
Total Check Value	11	11		
Mode	Influencing factors	Competence management		

Table D.27: *Company A Final: Safety Culture Values: Poor Quality Responses Removed*

Safety Culture	Value
Maximum Quality Value	127.50
Maximum Questions Total Value	70.12
Maximum N° of Consecutive Indifferent Responses	17.00
Mean Total	53.84
Mean Quality	62.68
Maximum Safety Culture	6.79
Safety Culture Value	4.35

Table D.28: *Company A Final: Non-Management: Safety Culture Quality Factors: Poor Quality Responses Removed*

Quality Factor	Value	Rank	Quality Factor	Value	Rank
Average Test Quality	4.30	3	Average Empowerment	1.50	11
Average N° Quality	9.20	1	Average Procedural awareness	2.00	7
Average Disagrees	0.90	17	Average Management pressure	1.60	10
Average Blame	1.80	8	Average Valued / worth	0.90	17
Average Colleague Trust	1.40	12	Average Safety promotion	1.00	15
Average Intervention	1.70	9	Average Resources	1.10	14
Average Communications	0.90	17	Average Indifferent	0.50	23
Average Incident Management	1.00	15	Average Motivation	0.70	22
Average Competence	2.50	5	Average Training	0.90	17
Average R&R	2.30	6	Average SD/SA	4.30	3
Average Safety Culture	1.30	13	Average Consecutive Indifferent	9.20	1
Average Organisational measures	0.80	21	Average Quality	2.25	

Table D.29: *Company A Final: Non-Management: Modal / Mean Values: Poor Quality Responses Removed*

	LOWEST SCORE	HIGHEST SCORE	MEAN	
			Value	Rank
Safety culture	0	1	5.77	3
Organisational measures	0	0	5.30	8
Incident Management	0	0	5.43	7
Competence Management	1	1	5.77	3
Influencing factors	3	0	4.06	9
My role	0	0	5.67	5
My Manager	0	0	6.20	2
Communications	1	0	5.57	6
The organisation	0	3	6.25	1
Total Check Value	5	5		
Mode	Influencing factors	The organisation		

Table D.30: *Company A Final: Non-Management: Safety Culture Values: Poor Quality Responses Removed*

Safety Culture	Value
Maximum Quality Value	63.50
Maximum Questions Total Value	56.40
Maximum N° of Consecutive Indifferent Responses	17.00
Mean Total	50.03
Mean Quality	51.80
Maximum Safety Culture	4.52
Safety Culture Value	3.91

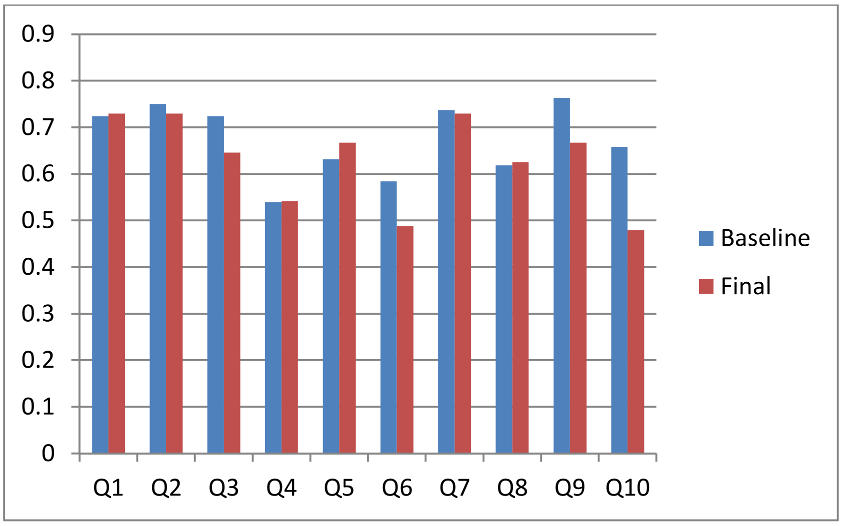

Figure D.1: Company A – Safety Culture Statements

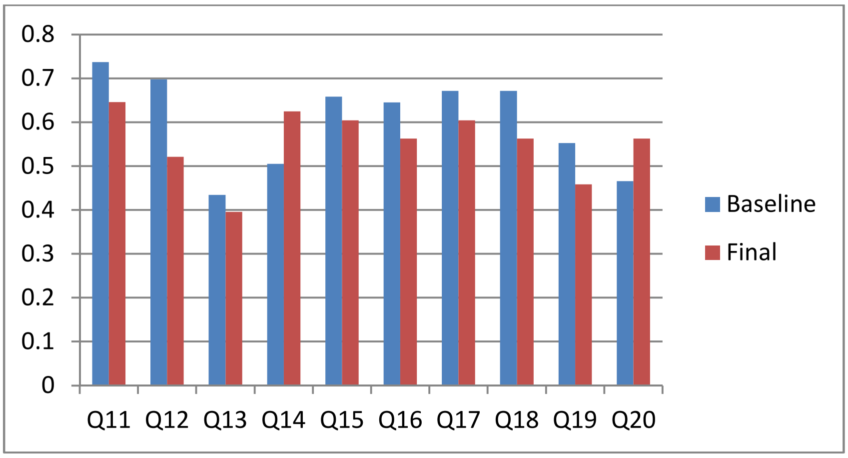

Figure D.2: Company A – Organisational Measures Statements

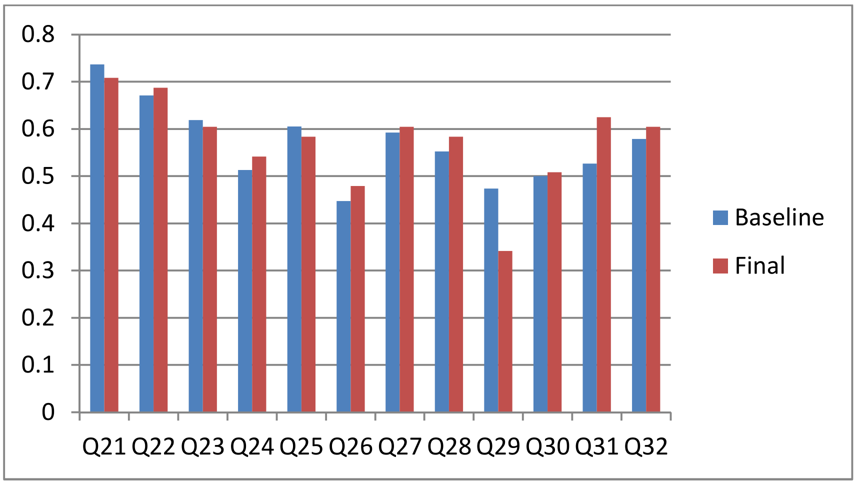

Figure D.3: Company A – Incident Management Statements

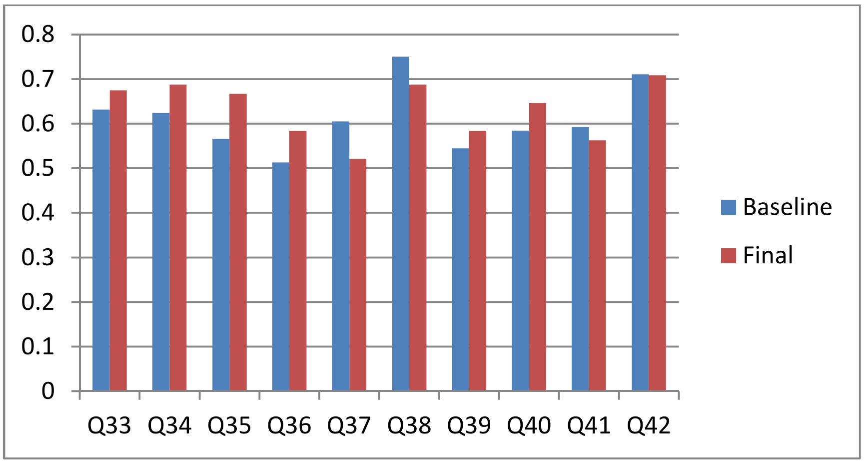

Figure D.4: Company A – Competence Management Statements

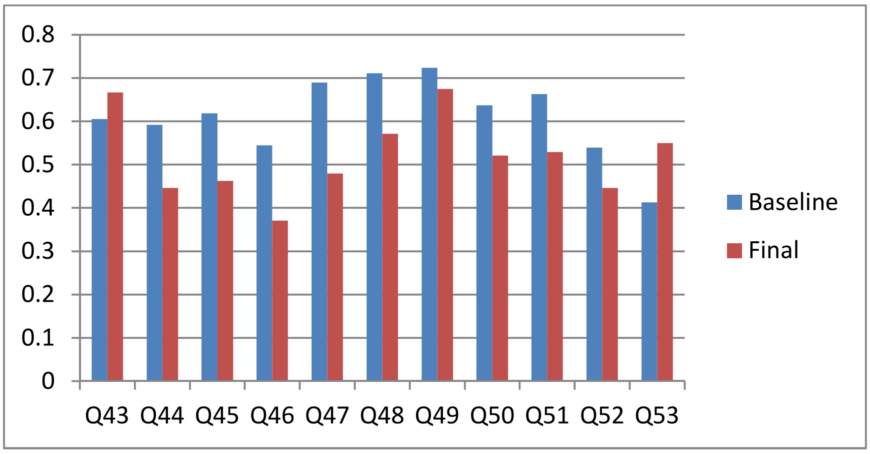

Figure D.5: Company A – Influencing Factors Statements

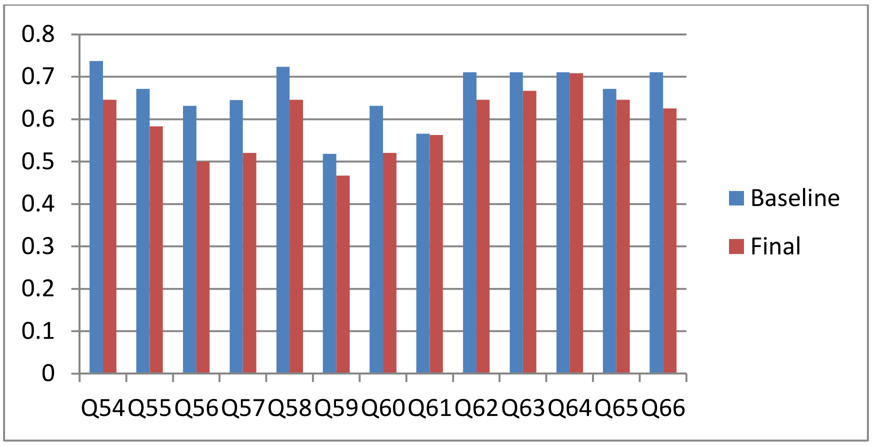

Figure D.6: Company A – My Role Statements

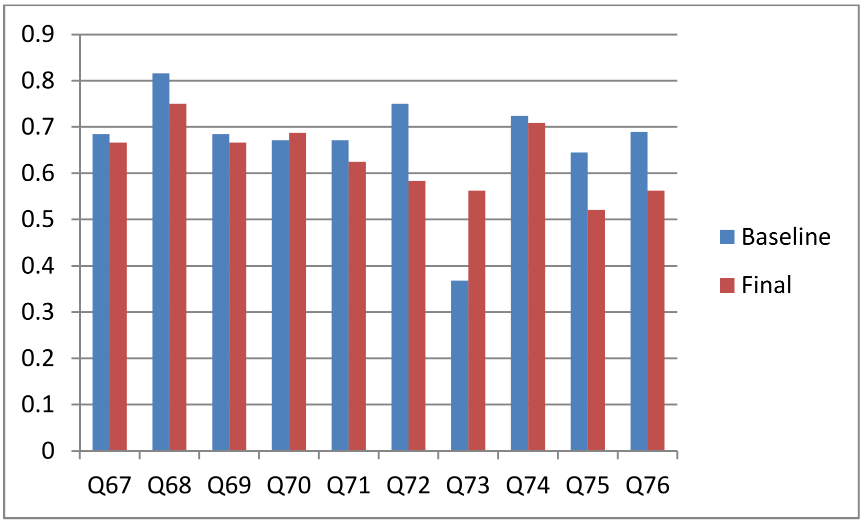

Figure D.7: Company A – My Manager Statements

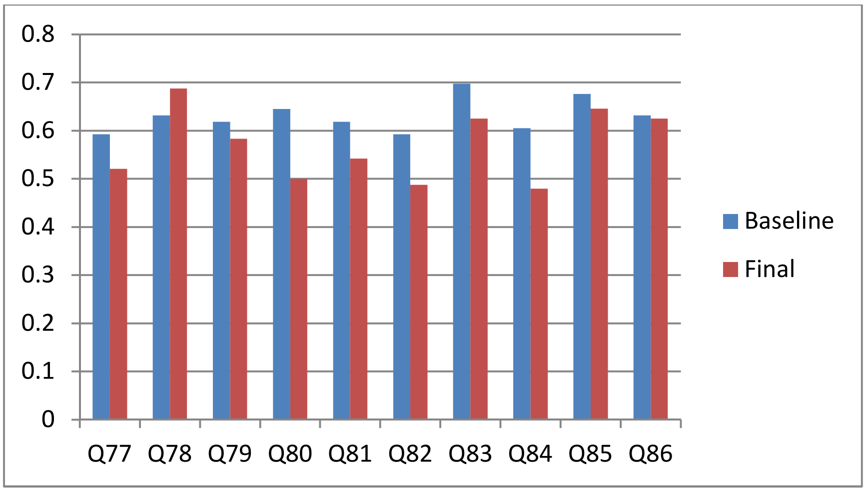

Figure D.8: Company A – Communications Statements

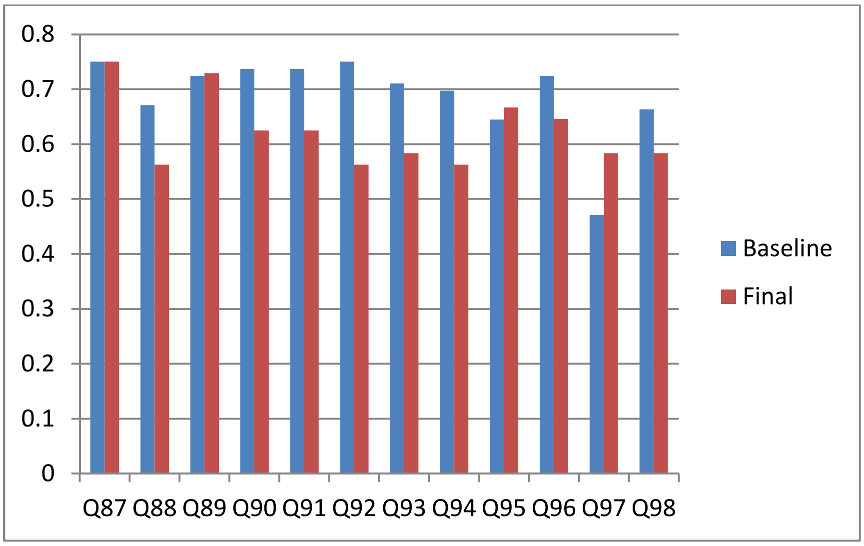

Figure D.9: Company A – The Organisation Statements

E APPENDIX – AUTHOR EXPERIENCE

The author of this thesis comes from an engineering background having completed a 4-year apprenticeship in the oil and gas industry followed by nine years as a technician responsible for the inspection and maintenance of instrument and electrical equipment including safety-critical systems.

This was followed by several professionally graded roles (also within the oil and gas industry) in project engineering, planning and instrument/electrical engineering.

The author completed a bachelor of engineering honours degree in electronic and electrical engineering in 2002 and achieved Chartered Engineer status in 2003.

For the past eight years the author has operated his own engineering consultancy business specialising in health and safety within high-risk businesses, particularly with those businesses with flammable / explosive materials within their storage and processing systems. The vast majority of the clients served are small to medium sized enterprises that do not employ personnel with the level of expertise necessary to ensure compliance with the relevant industrial laws or to satisfy the regulators that appropriate safety measures are in place to minimise risk to a tolerable level. The type of work carried out includes performing HAZOP and SIL analysis, hazardous area classification and the provision of hazardous area risk assessments.

The author's experience in working within the multi-national oil and gas industry provided the baseline knowledge and experience essential for development of a business involved in working with SMEs.

The author has carried out and is actively engaged in carrying out work for clients in a wide range of industry sectors including food and beverage, plastics manufacture, defence research & design, oil & gas, chemical, power generation (nuclear, coal, bio-fuels, gas), water treatment, semi-conductor, pharmaceutical, printing, civil aviation, powder coating and mining.

F APPENDIX – EXAMPLE RELIABILITY ANALYSIS (COMPANY A)

The tables below show an example of the reliability analysis carried out for each survey. Only Company A baseline survey data is included.

F.1 Company A – Safety Culture Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.852	.856	10

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S1	19.8125	19.629	.619	.541	.834
S2	20.0625	20.996	.410	.806	.850
S3	19.8750	17.050	.811	.810	.812
S4	19.0625	20.729	.463	.594	.846
S5	19.5625	20.529	.337	.472	.858
S6	19.2500	19.000	.424	.725	.856
S7	19.8750	20.250	.565	.600	.839
S8	19.4375	17.463	.799	.883	.814
S9	19.9375	18.329	.756	.838	.821
S10	19.4375	19.463	.476	.370	.846

F.2 Company A – Organisational Measures Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.509	.632	10

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S11	23.4375	6.796	.649	.907	.366
S12	23.3125	7.163	.421	.905	.420
S13	22.3750	8.383	.084	.774	.517
S14	22.5625	6.663	.273	.751	.463
S15	23.0625	7.929	.148	.850	.502
S16	23.2500	7.533	.543	.702	.421

S17	23.1875	7.229	.625	.855	.396
S18	23.1875	8.163	.101	.638	.516
S19	22.8125	6.829	.473	.859	.397
S20	22.3125	10.763	-.423	.782	.698

F.3 Company A – Incident Management Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.710	.740	12

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S21	29.2667	13.638	.665	.967	.634
S22	29.0667	13.924	.838	.914	.618
S23	29.0000	16.429	.418	.970	.684
S24	28.4667	16.410	.297	.912	.699
S25	28.9333	14.924	.736	.996	.642
S26	28.3333	19.238	-.119	.847	.742
S27	28.8667	15.552	.774	.949	.651
S28	28.6667	18.238	.014	.925	.739
S29	28.5333	17.124	.272	.857	.701
S30	28.6667	16.952	.170	.987	.721
S31	28.8667	17.552	.053	.946	.747
S32	28.7333	16.352	.448	.989	.680

F.4 Company A – Competence Management Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.890	.897	10

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S33	23.0000	34.875	.520	.734	.886
S34	23.0588	32.684	.757	.807	.870

S35	22.8235	32.654	.715	.850	.872
S36	22.5294	33.390	.766	.858	.871
S37	22.9412	40.684	-.053	.491	.927
S38	23.5294	35.015	.657	.655	.878
S39	22.7059	30.471	.792	.806	.866
S40	23.0000	30.000	.844	.903	.861
S41	22.8235	32.904	.689	.764	.874
S42	23.3529	33.618	.814	.823	.869

F.5 Company A – Influencing Factors Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.917	.914	11

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S43	24.8125	45.629	.632	.797	.912
S44	24.8125	46.696	.667	.935	.910
S45	25.0000	46.533	.691	.833	.909
S46	24.6250	42.383	.813	.914	.902
S47	25.1875	41.629	.834	.921	.901
S48	25.1875	44.429	.869	.967	.901
S49	25.3125	47.296	.751	.914	.908
S50	24.8750	41.583	.911	.985	.896
S51	25.1250	43.317	.737	.942	.907
S52	24.7500	50.067	.413	.655	.920
S53	24.0625	52.596	.135	.708	.932

F.6 Company A – My Role Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.931	.940	13

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S54	28.4211	53.480	.804	.931	.922
S55	28.1579	52.807	.737	.910	.924
S56	28.0000	51.111	.799	.881	.921
S57	28.0526	52.719	.802	.894	.922
S58	28.3684	51.246	.818	.883	.921
S59	27.5263	61.152	.011	.880	.951
S60	28.0000	54.333	.725	.912	.925
S61	27.7368	53.427	.506	.788	.934
S62	28.3158	50.673	.843	.935	.920
S63	28.3158	50.117	.891	.942	.918
S64	28.3158	55.339	.732	.949	.925
S65	28.1579	53.918	.801	.960	.923
S66	28.3158	53.339	.841	.972	.921

F.7 Company A – My Manager Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.818	.858	10

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S67	21.3333	22.235	.692	.808	.790
S68	21.6667	20.588	.791	.808	.774
S69	21.1111	19.163	.805	.889	.765
S70	21.0556	19.938	.841	.953	.766
S71	21.0556	20.291	.701	.942	.779
S72	21.3889	20.016	.797	.976	.770
S73	19.8333	34.971	-.788	.796	.936
S74	21.3333	20.353	.797	.955	.772
S75	21.0556	20.997	.670	.763	.784
S76	21.1667	19.441	.658	.774	.782

F.8 Company A – Communications Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.918	.921	10

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S77	22.0000	29.875	.646	.942	.913
S78	22.2353	27.816	.852	.866	.900
S79	22.2941	31.596	.468	.811	.923
S80	22.3529	29.743	.699	.908	.910
S81	22.3529	30.743	.775	.947	.908
S82	22.0588	28.434	.730	.847	.908
S83	22.5294	29.390	.795	.937	.905
S84	22.1765	29.279	.680	.878	.911
S85	22.5882	29.632	.793	.941	.905
S86	22.2941	31.346	.570	.866	.917

F.9 Company A – The Organisation Section

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.872	.890	12

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S87	24.9474	33.275	.724	.759	.852
S88	24.6316	33.579	.775	.798	.851
S89	24.8421	33.807	.760	.951	.852
S90	24.8947	34.877	.653	.938	.858
S91	24.8947	31.322	.844	.899	.843
S92	24.9474	31.053	.916	.928	.839
S93	24.7895	32.398	.733	.890	.850
S94	24.7368	31.760	.785	.923	.847
S95	24.5263	32.041	.651	.737	.855

S96	24.8421	31.696	.845	.920	.843
S97	23.7895	43.398	-.351	.742	.916
S98	24.5789	39.368	-.027	.746	.904

G APPENDIX – EXAMPLE FACTOR ANALYSIS (COMPANY A)

The tables below show an example of the factor analysis carried out for each survey. Only Company A baseline survey data is included.

G.1 Company A – Factor Analysis – Safety Culture Section

Rotated Component Matrix

	Component		
	1	2	3
S1	.492	.365	.341
S2	.934	-.169	.099
S3	.702	.445	.351
S4	-.004	.792	.159
S5	.017	-.009	.864
S6	.100	.897	-.075
S7	.365	.100	.732
S8	.387	.833	.245
S9	.861	.333	.194
S10	.205	.182	.676

G.2 Company A – Factor Analysis – Organisational Measures Section

Rotated Component Matrix

	Component			
	1	2	3	4
S11	.938	.162	.077	.129
S12	.858	.179	-.192	.211
S13	-.338	-.178	.665	.495
S14	.087	-.083	.919	-.182
S15	.315	.214	-.100	.895
S16	.800	.102	.062	.016
S17	.643	.393	.479	-.334
S18	.194	.718	-.135	-.057
S19	.262	.713	.554	.074
S20	-.082	-.906	.087	-.229

G.3 Company A – Factor Analysis – Incident Management Section

Rotated Component Matrix

	Component			
	1	2	3	4
S21	.882	.132	-.242	.051
S22	.854	.229	.028	.233
S23	.205	.578	-.114	.687
S24	.261	.030	-.053	.892
S25	.886	-.048	.355	-.036
S26	-.006	.216	-.826	-.184
S27	.797	.193	.116	.231
S28	.109	.015	.807	-.325
S29	.080	.883	-.048	.041
S30	.015	.893	-.183	.140
S31	.476	-.360	.536	-.423
S32	.733	-.326	.124	.090

G.4 Company A – Factor Analysis – Competence Management Section

Rotated Component Matrix

	Component	
	1	2
S33	.759	.113
S34	.368	.786
S35	.814	.278
S36	.800	.356
S37	-.582	.654
S38	.234	.808
S39	.539	.676
S40	.815	.439
S41	.781	.296
S42	.442	.782

G.5Company A – Factor Analysis – Influencing Factors Section

Rotated Component Matrix

	Component	
	1	2
S43	.731	-.172
S44	.715	.150
S45	.768	-.086
S46	.861	.037
S47	.885	.052
S48	.858	.431
S49	.744	.508
S50	.920	.139
S51	.782	.150
S52	.388	.743
S53	.327	-.857

G.6 Company A – Factor Analysis – My Role Section

Rotated Component Matrix

	Component	
	1	2
S54	.881	.151
S55	.912	-.057
S56	.767	.310
S57	.693	.444
S58	.681	.542
S59	.525	-.775
S60	.444	.820
S61	.259	.736
S62	.715	.538
S63	.761	.527
S64	.550	.669
S65	.823	.241
S66	.752	.450

G.7 Company A – Factor Analysis – My Manager Section

Rotated Component Matrix

	Component	
	1	2
S67	.419	.682
S68	.546	.653
S69	.850	.372
S70	.786	.501
S71	.873	.229
S72	.301	.918
S73	-.770	-.398
S74	.305	.917
S75	.199	.801
S76	.863	.199

G.8 Company A – Factor Analysis – Communications Section

Rotated Component Matrix

	Component	
	1	2
S77	.188	.879
S78	.597	.665
S79	-.003	.833
S80	.599	.508
S81	.661	.509
S82	.467	.664
S83	.895	.271
S84	.860	.136
S85	.709	.482
S86	.825	.011

G.9 Company A – Factor Analysis – The Organisation Section

Rotated Component Matrix

	Component		
	1	2	3
S87	.541	.394	.562
S88	.726	.403	-.023
S89	.313	.910	.130
S90	.194	.939	.085
S91	.668	.489	.169
S92	.616	.704	.206
S93	.889	.165	.132
S94	.883	.299	-.051
S95	.848	.184	-.148
S96	.564	.714	.236
S97	-.026	-.206	-.824
S98	-.100	-.006	.922

/End