Human Error Management

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Index

Abstract

The focus of this research is safety critical systems management set within the context of a series of Lean 'brown field' manufacturing case studies. The thesis is founded upon a human factors perspective of quality/safety management and the perceptions of over 800 workers drawn from 4 corporately owned aero repair & overhaul UK sites.

Traditionally, human factors and aviation research has focused upon aircraft operations, where pilots and to a lesser extent air traffic controllers, have increased their ability to make safety critical decisions based on improved levels of team situational awareness.

However by contrast, no available literature exists to demonstrate the same potential from a front line operations perspective of aircraft maintenance engine overhaul, especially, within the context of Lean operations[1]. This absence of a rigorous study from an aviation repair process therefore presents a major gap in the main body of knowledge, especially in contemporary times when efficiency ('leanness') and effectiveness (quality & safety) are both targets of operations management improvement.

The research hypothesis is "problem driven" and theory building using a cross-case comparative method involving both qualitative and quantitative data collection. The data was analysed using a non-parametric design and seeks to extract differences in quality attitudes. The results of the study show the most significant barrier to quality and safety effectiveness, originates from management planning and workplace control.

This is a condition that was found to be perpetuated by a lack of understanding for how to transition from traditional craft based engineering, towards a more lean approach within the context of Total Quality Management (TQM) literatures.

The study shows "corner cutting" is a precondition of system failure, when a gap in understanding exists between the organisational leadership and its front line engineering resource namely; self-managed teams.

The results also demonstrate that people do not intentionally make mistakes, but generally do, because of operations system pace/instability of material flow. The researcher therefore concluded with a challenge to design new ways of neutralising latent error conditions before the safety critical events breach the quality systems defence mechanisms at each case study concerned.

In parallel, the researcher offers a new model of operational management that reconciles the principles of TQM, self-management and leaner methods of working, for improved and safer business performance.

[1] Based on extensive literature reviews and expert interviews (2004 To 2010)

Acknowledgements

The researcher would like to dedicate this study to his late father, Mr Llewelyn Price who sadly died at the end of 2007 before its completion. Mr Price was an engineering apprentice-training instructor, who worked within this case study and was considered by his colleagues and friends as role model. Some of which now hold senior positions within the organisation, which like myself were taught to understand the true value of quality engineering, in terms of thinking and acting in the right way.

A special thank you must also be acknowledged to Rolls-Royce, for their financial sponsorship and confidence that enabled this research to take place, which was also carried out on behalf of the European Aviation Safety Agency (EASA)[2] Part-145.

Finally the researcher would like to thank the following list of people for their personal help and professional contribution at both Cardiff University and Rolls-Royce, who without their support would not have made this research possible.

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[2] The European Aviation Safety Agency (EASA) is a Maintenance Approval Organisation, which is part of the European Union (EU) whose headquarters are based in Brussels, Belgium.

Declarations

CARDIFF BUSINESS SCHOOL

STATEMENT 1

This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree.

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Date **September 8th 2010**..........................

STATEMENT 2

This thesis is being submitted in partial fulfilment of the requirements for the degree of **PhD**...........................(insert MCh, Md, MPhil, PhD etc, as appropriate)

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STATEMENT 3

This thesis is the result of my own independent work/investigation, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references.

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I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

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List of Acronyms Used

ARO	Aero Repair Overhaul
AROP	Aero Repair Overhaul Procedures
BPS	British Psychological Society
BPM	Business Process Model
BPD	Business Plan Deployment
CAA	Civil Aviation Authority
COE	Centres of Excellence
CRM	Crew Resource Management
CNC	Computer Numerical Machine
CONQ	Cost of Non Quality
CFM	Cross Functional Management
CPA	Critical Path Analysis
CQP	Central Qualification Plan
DBR	Drum Buffer Rope
EFQM	European Foundation Quality Management
EASA	European Aviation Safety Agency
EOQ	Economic Order Quantity
FCL	Front Combustion Liner
FAA	Federal Aviation Administration
FIFO	First In First Out
FMT	Fair Market Target
GEMS	Generic Error Modelling System
GQP	Group Quality Procedures
HSE	Health Safety Environment
IATA	International Air Transport Association
JSF	Joint Strike Fighter
JIT	Just In Time
LPT	Low Pressure Turbine
MEMS	Maintenance Error Management System
MEDA	Maintenance Error Decision Aid
MRP	Manufacturing Resource Planning
NTSB	National Transportation Safety Board
SMED	Single Minute Exchange Dies

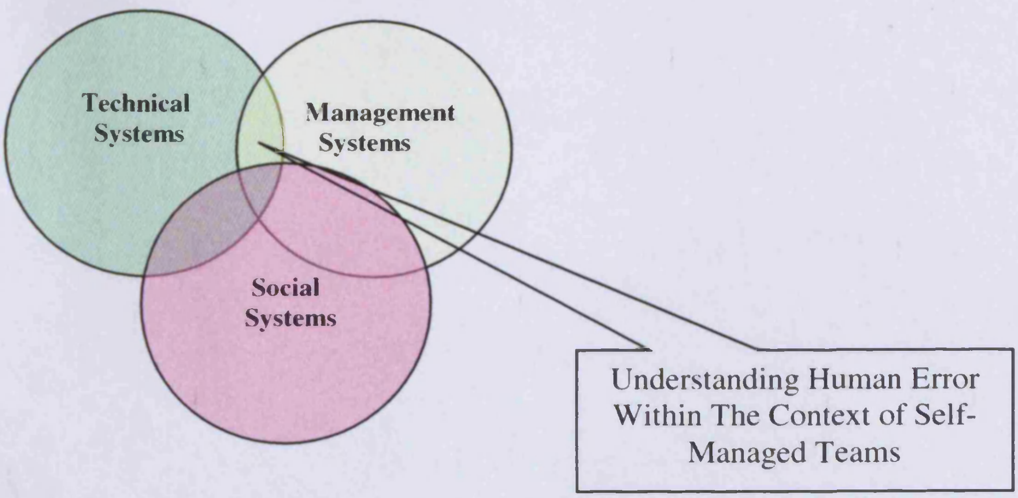
PLC	Public Limited Company
PS	Production System
QCD	Quality Cost Delivery
QMS	Quality Management System
RADAR	Results Approach Deployment Assessment
RCM	Reliability Centred Maintenance
STST	Socio-Technical Systems Theory
SPC	Statistical Processing Control
SAP	Systems Application Processing
SMED	Single Minute Exchange Dies
SPOA	Single Point of Accountability
TPM	Total Productive Maintenance
TQM	Total Quality Management
TOC	Theory Of Constraint
UK	United Kingdom
USA	United States America
VSM	Value Stream Mapping
TBW	Team Based Working
WIP	Work In Progress

Chapter 1 Introduction

1.0 Chapter Introduction

Few industrial sectors, beyond nuclear and pharmaceutical production, face safety regulations to the extent of those that control aerospace manufacturing and repair. Since July 2004 the European Aviation Safety Agency (EASA), under regulation part-145, has worked extensively with psychologists and quality managers alike to develop what is more commonly referred to as human factors engineering as a means to prevent system failures and potential human fatalities. Practically, this approach often contradicts the commercial pressures faced by businesses to improve quality/safety against the need to reduce lead times, offer quicker turnarounds and operate leaner ways of working. Furthermore, within some industries there is a belief that poor quality and safety lapses are 'person based' and to control these potential failures it is necessary to engage traditional forms of direct supervision. This school of thinking represents what is referred to as the 'classical approach 'that traditionally relies upon increased levels of management control (Reason, 2003). This approach is therefore perceived by the researcher as being contradictory to the general trend of Total Quality Management (TQM), where Lean/Sigma businesses such as the one found in this study are promoting a more autonomous and team based approach (Womack and Jones, 1996). The model shown below in figure 1 represents this position and presents three different perspectives of literature themes, which will be used to frame the main research question within the wider context of 'self-managed teams' level of control. Also referred to as critical to quality characteristics (CTQC) the model draws attention to the importance of 'systems thinking' as a philosophy to improve business performance and mitigate the risk of non-quality under the autonomy of team control.

Figure 1 Critical To Quality Characteristics Model



Source: Researcher

1.1 Introduction To Human Factors

At the time of writing this thesis, parallel research carried out by Maurino (2006) identified a gap in the main body of knowledge concerning flight operations and demonstrated that the over-attention to individualistic forms of human error research was an incorrect focus. He argued that a better contribution to the body of operations management knowledge would be gained by an alternative focus, claiming that; *"There is little to be gained by further pursuing individual-oriented avenues of action. In the best of scenarios, the profit will not be commensurate with the investment of resources"*. Scholtes (1998) an American human factors specialist reinforces this view arguing that safety systems research provides a more fruitful avenue of study based on the claim that 95% of all human error problems could be attributed to 'management system' failures, with less than 5% blamed on people committing errors.

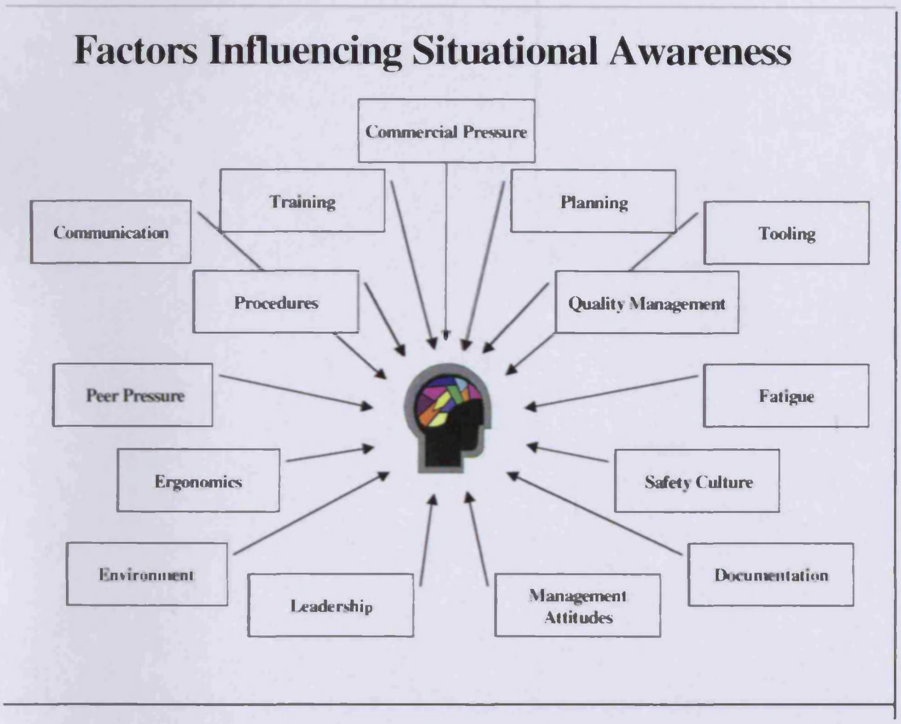
In spite of this widespread agreement, a divide still exists within the main body of human factors literature as to which methods are best suited to resolving specific types of quality / safety related problems. In this respect the researcher proposes that human factors research cannot be described as a unified disipline and like engineering, medicine and most other professions, there are many different and individual 'schools of thought'. For example some studies of pilot behaviour have specialised in 'cognitive' approaches while others measure psychometric aspects of trait behaviour as a means of assessing the suitability of individuals to interact with safety critical systems. As such, there are different views of how best to assess individual actions and management system behaviour. Such a gap in the body of safety critical knowledge offers an opportunity for this study that few research initiatives have sought. The purpose of this research is to combine approaches, including TQM & Lean methods of working, from a socio-technical systems design perspective (the individual and the system). In other words the study will provide a level of understanding as to which barriers enable a system to fail or prevent the successful deployment improvement activities in businesses that have few supervisors and instead rely upon self-managed teams. The purpose of the research is therefore to know what is 'going on' inside an operations management design in terms of what system factors require action to improve business and quality of performance.

The approach is compatible with the work of Adam (1993) who argues that the primary objective of meaningful human factors research is an approach to *"knowing what is going on so you can figure out what to do"*. Whilst researchers and practitioners approach safe working systems from a variety of backgrounds, they all share this common belief system, based on what the researcher describes as a comon goal to improve human performance through the concept of *"shared situational awareness"*.

It is now widely accepted amongst authors in the field of safety critical and organisational management that low levels of team situational awareness is a condition which can be described as a failure to understand the importance of 'awareness' over a 'situation'. In other words those individuals who function as part of a team need to understand and manage factors affecting human behaviour which may result in failure or breaches of safe practices Reason (2003). Endsley (2000) proposes *"The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future"* His elaborate definition implies that organisations which have not engaged in the design of the workplace/workflow using human factor methods will be unaware of causation factors that, if left unchallenged, will disrupt the capacity for clear thinking and breach safety defenses. These aspects of the work system are shown in Figure 1.2. At best, any failure in these sub-systems of safety management will result in a poor quality product and, at worst, these failures in the context of the aerospace industry will result in the fatalities of hundreds of civilian aircraft passengers.

The researcher's argument this far has been that systems design is more important than control and supervision of the individual, although according to Rasmussen (1998) some errors are accepted in terms of individuals acting alone and in isolation to the system. In other words Rasmussen is claiming that most quality-related problems are caused by individuals who fail to be functioning as part of a team. This argument is reinforced by Artman & Garbis (1988) who argued that properly supported team working enables the individual to build a common view of how best to improve the quality of their work, based on team work of shared understanding. In this context they propose that improved team situational awareness is based on *"Two or more agents in active construction of a situation which is partly shared and partly* *distributed from one part to the next"* As such, whilst the individual may make mistakes, it is generally believed that teamwork serves to catch issues and prevent their escalation into major catastrophes. The model shown below in figure 1.2 highlights this position for the purpose of this study and questions the validity of the current and most favoured approach to team work from a Lean perspective, which is at odds with main stream human factors thinking as it fails according to Liker (2004) to consider sufficent attention to human factors redesign.

Figure 1.2 Model of Key Human Factors

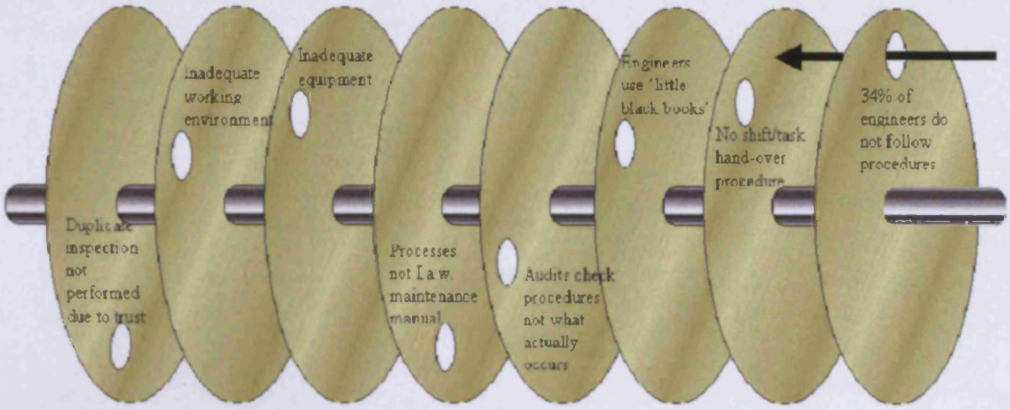


Source: Researcher Literature Review

It was decided to accept the work of Prof. James Reason (2003), who is one of the most influential British authors in the field of safety management, as a base line model upon which to ground this study. Reason's work provides an expert review of human factors, within complex environments such as the aviation industry and his model underpins the current EASA position (especially the 145 regulation). Reason called for a design of systems such that safety and cost effectiveness are balanced as a means to ensure robust quality, safety systems can prevent or capture a catastrophe before it takes place. One of Reason's major contributions to the design of effective socio-technical systems is his contention that methods should be designed to provide a successful defense mechanism to failures, although Reason stops well short of entering a debate upon the subject of leaner ways of working. The researcher therefore noted that Reason's model implicitly accepts failures will happen based on the belief that all individuals are fallible and random events will happen – hence his view is that defenses should be the focus of both compliance and control. Reason's model (figure 1.3) illustrates how a successful defense mechanism is able to capture problems within the system before they escape to result in major catastrophe. Conversely an unsuccessful defense is therefore one where the error passes through the multiple 'holes' and lines of defense resulting in a full system failure (as illustrated in figure 1.4). Reason proposes individuals are quite capable of contributing to the safety of any given system, provided it is 'well-guarded', which refers to the way rules and standards are designed in terms of capturing mistakes in real time situations. It should be noted that such issues are not well addressed within operations management literatures. Instead operations management authors, such as Shingo (1986), tend to advocate mistake proofing to eliminate sources of error, but rarely do they address the environments where product variation is high and the technical ability to mistake proof is low.

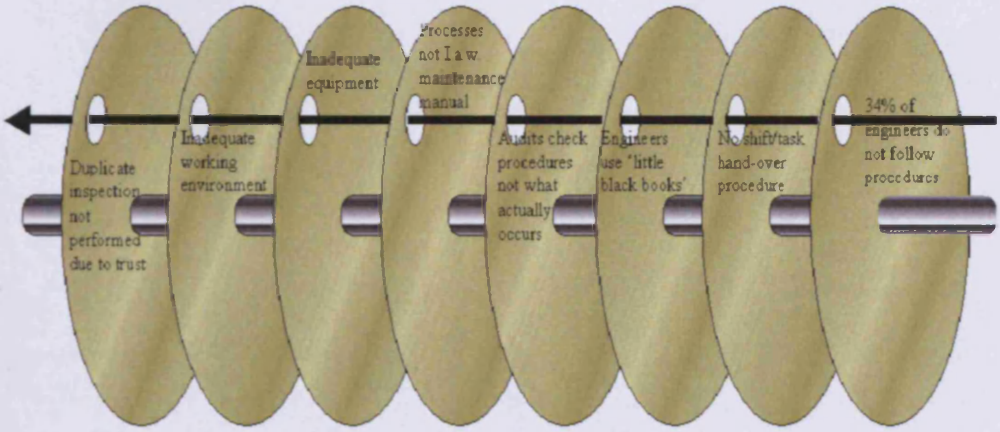
Errors and failures are not always visible and in many cases remain hidden within the operations system design and are described as either 'active or 'latent' forms of human failure. Latent failures can be described as a deficiency within the technical operations system, which according to Maurino (2006) can be analysed and used to evaluate the effectiveness of safety related concerns. In this manner, latent failures originate from poor system design where designers and system decision-makers are most remote from the actual conduct of the process, yet make assumptions in their designs, about how workers will perform tasks/control safety and quality based activities. According to Reason, latent errors present the greatest threat and are likely to be generated by those who are most remote, such as designers and high-level decision makers (2003).

Figure 1.3 Successful Defence Against Human Error



Source: CAA CAP716 (2003)

Figure 1.4 Failed Defence Against Human Error



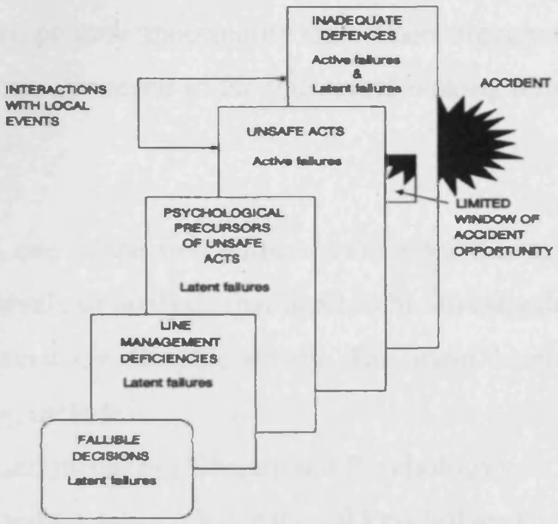
Source: CAA CAP716 (2003)

Latent errors are those associated with poor systems design and control of the work environment. It is these errors, under conditions of TQM and leaner ways of working that will, in non-linear production flows (complex parts and processes), critically impact upon the safety of the socio-technical system designs. For the purposes of this study, a non-linear work process is considered to be one whereby there is high variety, low volume work environment whereby one engineer does not generally process engine product quickly from one place to another. These types of socio-technical systems are therefore according to Reason (2003) the most complex and the least characteristic of modern Lean ways of working (Liker, 2004). Further Reason argued it is also possible that systems, which are designed to make the process safer, can also be seen as its greatest point of weakness. His view is based on two aspects, which are usually defined by the transparency of a system itself, in terms of team knowing and team understanding. These are:

1. Not knowing what is happening.
2. Not understanding what the system can do.

The way in which active and latent failures contribute towards the cause of human error (figure 1.5) shows a clear pathway through which a mistake can penetrate a process and, take advantage of what Reason conceptualises as the 'limited window of opportunity', resulting in catastrophic system failure.

Figure 1.5 Reason's (2003) Window of Opportunity



Source: Taken From Reason (2003)

Reason (2003) argues systematic errors are *"Opposite sides of the same coin, there are relatively limited numbers of ways in which errors actually manifest themselves, which are inextricably bound up with the computational primitives by which stored knowledge structures are selected and retrieved in response to situational demands"*. His argument is that a rare combination of poor defences and a limited window of opportunity will escalate into a major catastrophic system failure. In complex environments such windows of opportunity increase substantially and it is unclear why the Lean method of working in safety critical environments has not been well explored in the operations management literature and aero repair businesses in particular.

Rasmussen (1998) argued that inadequate situational awareness could be the cause of organisational inefficiencies that accounted for between 70-80% of all quality related problems. Ramsussen's work adds a new dimension to the study of human factor failures and he exposes the importance of 'collective knowledge' of a team that is needed to maintain high levels of defense. Kosmowski & Kwiesielewicz (2000) reinforce this view and support the need for good team engagement with safety management and argue that an aggressive and competitive environment, inadvertently, creates poor team performance that more often than not; results in high levels of active errors. If left unchallenged, poor teamwork and poor integration of individual knowledge, induces high levels of system risk and potential sources of failure. In this regard, previous studies of team working within complex and commercially-pressured work environments, show poor team work is associated with greater risks of a mistake process abnormality that, when triggered and with a window of opportunity, will eventually result in the individual making a mistake of potentially catastrophic proportions.

Rasmussen (1998) was one of the first authors to explore this aspect of human error and he proposes three levels of analysis that need to be investigated to build a system of robust defences against catastrophic errors. The main levels of error creation, according to Rasmussen, include[3]:

1. Skill-Based mistakes (Educational Psychology)
2. Rule-Based mistakes (Occupational Psychology)
3. Knowledge-Based mistakes (Cognitive Psychology)

The three different forms of mistake challenge the individual and team concerned at different levels. A mistake that has been seen before and requires less diagnostic skill is likely to be the result of a well-rehearsed or learned knowledge form of automatic response by the person concerned (skill and rule based mistake identification).

The opposite to such a condition is where a complex problem is presented to the individual and they must use their long term memory/stored knowledge to conceptualise/diagnose what they see and how they can solve problems around them. Much of the Lean operations management literature concentrates on simplistic

[3] These three levels of analysis are instrumental to the focus and major theme of this thesis.

operator routines in a repetitive operations management environment (vehicle assembly). The aero repair sector has neither of these conditions and by contrast requires a conscious effort by the individual to diagnose and repair aircraft systems. Such an environment has standardised work processes but there are much greater levels of variation in parts and systems than in the traditional operations systems of Lean production/assembly.

The aerospace repair process, the subject of this thesis, is altogether more complex and individuals are presented with problems that are not easily solved. These problems require deeper levels of cognitive skills and application of specialist knowledge to solve technical problems. The model put forward by Rasmussen is based on the opinion that individuals prefer to problem-solve at lower levels of cognitive function and will only move to the higher levels (knowledge based approaches) when encouraged to do so. The implication of Rasmussen's view is that a production system design should be mistake-proofed as much as possible because individuals will always take short-cuts to resolve problems, rather than problem-solving at a conscious and knowledge based level of awareness. His model was later adapted by Reason (2003) and developed into what is more commonly referred to as the 'Generic Error Modelling System' (GEMS).

GEMS is based on an implicit assumption that individuals solve problems in terms of schematic representations of real world experience, the model accepts that individuals will always maintain a consistent cognitive representation of events, even when contradictory evidence exists to suggest the opposite logic should be applied. In this manner, individuals will continue to apply ineffective solutions and also forget to actually define the problem The GEMS model was used by the Air accident Investigation Board (AAIB) during 1981 when a Boeing 727 crashed at Tenerife because the flight crew devised a procedure based on incomplete and incorrect information. The flight crew ignored the information concerning their position and minimum descent heights and instead flew the aircraft into high ground, using an incorrect mental model. The implication for industrial managers is they must identify the gaps in current levels of thinking and socio-technical systems design to ensure that there is compliance between engineers and the design of the process to prevent and ultimately eliminate what Reason (2003) referred to as the limited 'window of opportunity'. A further implication is that, even where a team approach is used, a common mental model that prevents re-questioning of the problem will lead to a catastrophic failure. For this study and in contemporary times, when businesses are engaging in Lean processes under commercial pressure, it is vitally important that attention is paid to the alignment of the social system and individual engagement within the process itself. Simply applying Total Quality Management (TQM) methods will not correct the situation of individual errors, team mistakes, and inappropriate models of safety management, especially under conditions of high complexity (Bicheno, 2000). As such, new models of worker engagement must be designed and simply migrating an automotive socio-technical system and its practices vastly underestimates the complexity of aero repair businesses and can accelerate catastrophic events.

So far, this chapter has argued there is very little evidence of Lean and human factors research in safety-critical processes like aero repair and has concluded that the dominant models of TQM and Lean are relatively unknown in this sector thus creating a gap in the body of operations management knowledge. The next section will therefore focus on the types of conditions that give rise to human error and how insufficient attention to the socio-technical operating systems, causes problems. These problems are exacerbated when increased loading is put upon an operation as Dhillon (2002) argues, *"There is a significant link between work place mistakes and the economic conditions"*. As such, pressures for delivery schedule adherence, aircraft on ground, and other commercial pressures can increase the stress in a system causing a rise in the number of 'windows of opportunity' for error.

1.2 Examples Human Error

In the majority of instances human error is captured and remains within a system, but in very rare cases, failures result in catastrophe. Whilst this thesis focuses on the aerospace repair sector, the application and principles of error management are not confined to this field alone and they can be applied to any situation where the cause of poor quality is complex and unknown. Informing better safety management has often resulted from high profile catastrophes and the countermeasures enacted to prevent reoccurrence but this form of learning is reactive and unsatisfactory when dealing with operations systems that fail and can result in many hundreds of deaths.

A landmark case that has shaped recent thinking concerning the importance of human factors was cited in 1987 when the 'Herald of Free Enterprise' a roll-on-roll-off ferry sank with the loss to 192 lives. When the initial investigation into the cause of the accident was carried out, blame was apportioned to the person who failed to close the bow door. But after further deliberation the prosecutor of the case in question, stated that because the management team of 'Townsend Torresen' had ignored previous safety recommendations for warning lights to be fitted to the bow doors, the main contributing factor was in fact attributed on the organisation and not the person who committed the error. What appeared to be an accident caused by basic human error was in fact the inevitable consequence of, what human factors specialists now refer to as, a classic case of system-induced error. In this manner the management responsibility of a system design has now become a major element of modern human factors research and much has been learned by the aero sector from these disasters. Of critical importance to this study is the role of management and their liability.

According to Sheen (1987) the acting chief prosecutor summarised the Townsend Torresson disaster in terms of *"Inadequate procedures that were found to be endemic throughout the organisation, infected with a disease of sloppiness"*. As a direct result of this case, the law commission introduced an amendment to the legal framework by which all corporations within the UK, aviation or otherwise, can now be held accountable and criminal charges can be brought if negligence is proved. Changes to the law, including tighter corporate manslaughter penalties, have also forced a greater need and investment amongst safety critical industries to accept the underlying cause of poor quality, in terms of compulsory human factors training and a new attention to system design. Following on from what is described as the 'failed system of defence' (Reason, 2003) the examples that follow below (listed in Appendix 1), typify what can happen when people fail to follow basic procedures even when under well-established methods of quality control. The first of which is taken from the official French accident report that described the crash of Concorde in Paris during July 2002[4]. During take-off the tyre on wheel number 2 was cut by a metallic strip of metal

[4] Concorde was a supersonic passenger aircraft and was a product of British & French manufacture.

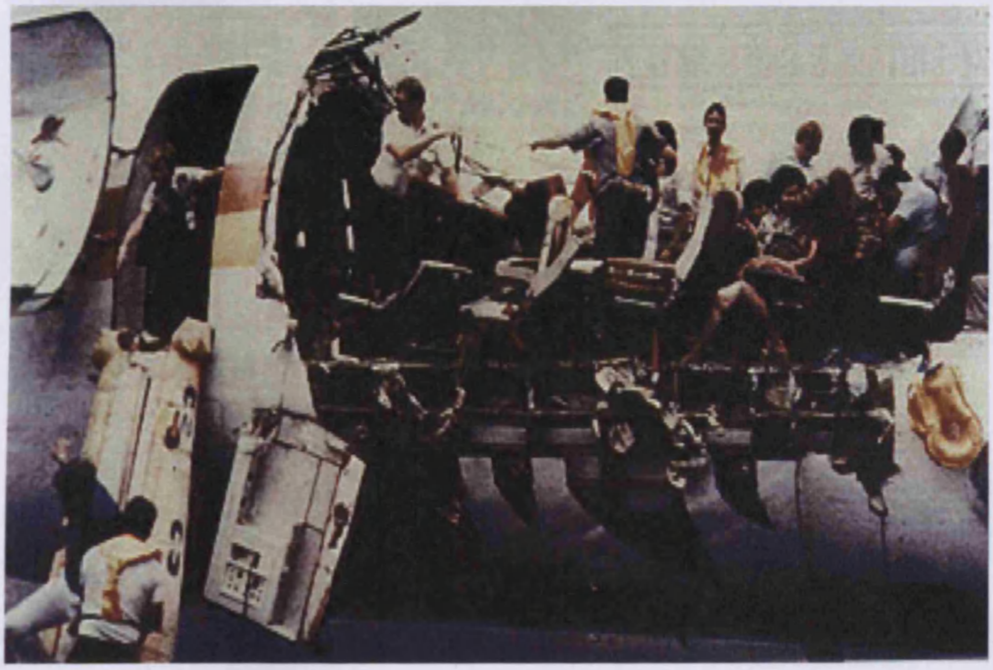
left on the runway. The metallic strip came from the thrust reverser cowl door of engine 3 on a DC 10 that had taken off just five minutes before Concorde. The metallic strip had been replaced in Tel Aviv in June 2000 during aircraft maintenance and then again in Houston on the 9th of July. The strip installed in Houston had neither been manufactured nor installed in accordance with the procedure as defined by the original equipment manufacturer.

Figure 1.6 The Failure of the French Concorde.

Source: Taken From Google Imaging

As a direct result of human error and non-compliance to procedure, the actual crash, taking approximately 2 minutes, killed 9 crew members, a 100 passengers and 4 people on the ground. The researcher has also identified with the findings of a well-documented case study that linked the cause of human error to the negative effects of commercial pressure to meet deadlines. The case in question was blamed on Aloha Airlines (1988) for not providing adequate maintenance procedures involving the accident of a Boeing 737 aircraft, which experienced a massive explosive decompression on route to Honolulu. The accident resulted in structural failings at 24,000 feet causing the front end of the fuselage to break away. The aircraft was carrying 89 passengers and 6 crew members at the time. The decompression injured 7 passengers and killed 1 flight attendant, after which the pilot performed an emergency descent and landed the aircraft on the island of Maui. The National Transportation Safety Board NTSB (1984) reported the cause of the Aloha Airlines accident as inadequate maintainenance checks. An inspection process that was considered as non-value adding was removed from the maintenance schedule in order to reduce the time the aircraft was out of serviced. The operation in question would have otherwise detected the presence of a significant outer skin cracking, which subsequently led to the separation of the fuselage in the upper lobe. Apart from very poor maintenance standards the underlying and most significant factor that led to the accident was financial pressure. The investigation concluded that had Aloha management permitted the necessary fuselage inspections as per Boeing recommendations, the accident, with its devastating consequences, as shown below[5] in figure 1.7 could have been avoided.

Figure 1.7 Aloha Airlines Structural Fuselage Failing



Source: Taken From Aloha Airlines Disaster Report (1988) Appendix 1

[5] Aloha Airlines Boeing 737-297, registration N73711 at Kahului Airport on April 28, 1988 after part of its fuselage was torn away in flight.

With this catastrophe in mind, Ostrom (1990) argued *"Airlines have a great interest in shifting some of the inspection activities from inspectors to the mechanics performing the work. The reasons for doing this are increased productivity and decreased cost"* and whilst these actions seem commercially logical they ultimately change the dynamics of human factors within an operations management system a fundamental change to the socio-technical system design.

Whilst air accident statistics underline how exceptionally low by comparison to all other forms of travel the aviation industry really is, the fact remains that public perceptions through media representation may be construed very differently by the year 2010. The significance of which is now considered by the authority Flight Safety (2003) as a global problem based on a statistical trend that measured civilian aircraft accidents during 2006 at an all time high of 35 crashes, of which 50% is attributed to human error (resulting in 702 fatalities worldwide). According to Sears (1986) research showed that of 93 aircraft accidents the major contributory factor was engineering maintenance mistakes that amounted to 12% of all aircraft accidents to date. This contradicts the popular view that pilot error is the critical failure source.
Later research carried out by Hobbs (2000) supported the claim that engineering repair processes are critical and found such errors accounted for 12% of all accidents, with a further 50% of this statistic blamed on engine/flight related delays. The Civil Aviation Authority (CAA)[6] also predicts that unless the current trend is reversed, the accident figure will increase and the number of aircraft crashes will rise to 52 by the year 2010. The CAA claim the industry will have 600 million more passengers and 7 million more tonnes of cargo than today therefore making aero repair a critical subject for improvement. The International Air Transport Association (IATA) support this need and argue that the chances of being killed in an aircraft accident in 2005 was less than one in every 10 million take off and landings, against a figure of just three in 10 million in 2003[7].

[6] Civil Aviation is regulated by the United Nations through the International Civil Aviation Organisation and subsidiary National Aviation Authorities such as the European Air Safety Agency, United Kingdom Civil Aviation Authority and the United States Federal Aviation Administration.

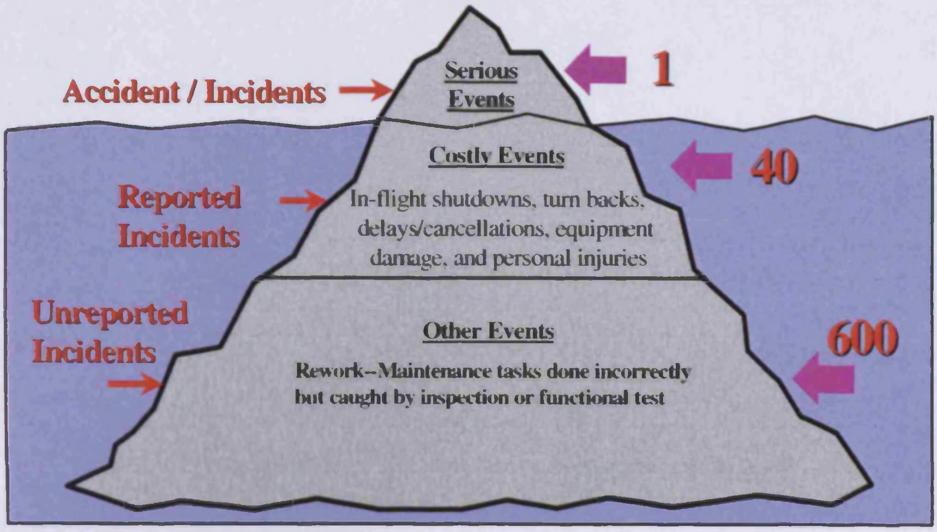
[7] For the purpose of clarification, Ranter (2006) categorises all of these problems in terms of: *"A commercial multi-engine airplane, which, in certificated maximum passenger configuration, is capable of carrying 14 or more passengers."*

The contemporary study of human factors within the sector of aero repair represents a timely insight especially as businesses are facing greater commercial pressure to improve the flow of work whilst maintaining the safety and integrity of the socio-technical elements of the operations management system.

1.3 Motivation and Background to the Research Problem

Comparing previous statistics against the main gap of operations management and TQM knowledge that underpin this study, the researcher conducted a preliminary literature review and found a trend whereby four out of every five major quality/safety failure investigations (an initial pilot case study) were attributed to human error with commercial pressure as a constant feature of the investigations. This finding, together with the lack of detailed investigations/models of best practice, reinforced the researcher's interest in studying the practices of the sector. It should also be noted that the researcher himself is an error management investigator and has significant 'knowledge', which has stimulated his desire to study the repair & overhaul sector as a means of contributing to the professional practice of human factors for improved business performance management. Thompson (2001) reinforces this need for research and proposes that maintenance errors are now the single biggest cause of in-flight engine shutdowns at £350,000 per failure of which a mere £35,000 is the cost of a cancelled flight. Other evidence, from the European Aviation Safety Agency (EASA) claims the need to study repair processes and research evidence presented by the agency showed that for every single serious event there were 40 additional costly events and over 600 other more minor hazards that were all present at the time of the breached defence. Figure 1.8 provides a visual representation of these problems based on the ratio of minor events ('beneath the water line') and major accidents. The 'hidden' system failures and minor events were considered by the researcher to be the key issues that require understanding in order to influence the professional practice of process excellence thinking.

Figure 1.8 The Safety Error Iceberg Model

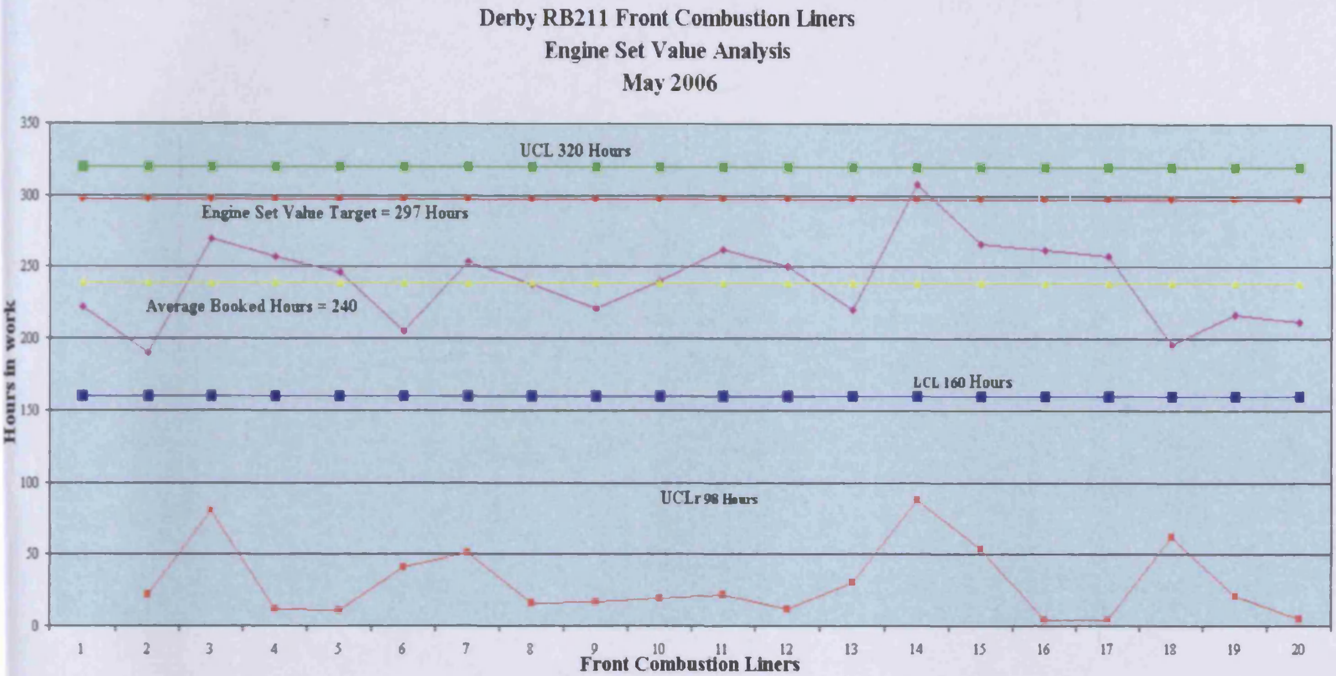


Source: Taken From Flight Safety Airworthiness Notice (2003)

The Error Iceberg model summarises the major elements of this study, which originally was developed by Heinrich (1980) but was later adapted by Reason (2003). The bottom end of the iceberg model provides a summary of the key factors that are most likely to influence the 'windows of opportunity' or aspects of operations management design that need to be identified and countermeasures introduced to prevent a major air catastrophe from taking place.

A major factor that motivated the researcher was the inadequacy of the existing operations and quality management literatures. These bodies of knowledge have focused on the problems of new manufacture, but ignored repair engineering processes, which have often addressed the issues of all other forms of manufacturing, but not that of repair environments (the characteristics of the aircraft engine repair & overhaul sector). The researcher therefore believes a study of repair engineering processes, based on understanding common cause variation would be a vital area of the team's behaviour in accounting for the severity of risk factors that may or may not exist 'beneath the water line'. The statistical process control chart (SPC) shown below in figure 1.9 typifies this position in terms of highlighting the existence of wide variations of work content, based on the UCLr value, i.e. the moving range of 98 hours. The chart is also considered as important as it represents an area of operations management thinking where a preliminary study showed that problems with repair processes are often resolved in the form of trade-offs between safety, quality, speed, and cost effectiveness across the entire aero repair & overhaul sector. It should be noted that these are untypical 'trade-offs' and are not identified by Slack et al (2004) due to his focus on unregulated and high volume operations systems.

Figure 1.9 Statistical Process Control Chart (SPC)



Source: Bristol Site Performance Management Output Metrics

These contradictions and trade-offs warranted further investigation and theory building for which this study is founded upon. Further, the commercial repair sector – both military and civilian, are under pressure to improve performance and increase process flow, whilst at the same time maintaining safety systems that prevent what Reason earlier described as the windows of opportunity and vulnerability.

It was therefore determined that the best approach to this study would involve a realist[8] approach supported by a multiple and longitudinal case studies drawn from a single organisation. The chosen corporate organisation was selected because it was engaged in the repair of aero engines and had an extensive improvement system (based upon Total Quality and Lean ways of working) with an operational context of 'process excellence' based upon autonomous team working. These factors were considered to offer the best possible insight into the performance of safety systems and the 'beneath the water line' issues that had been identified in the literatures.

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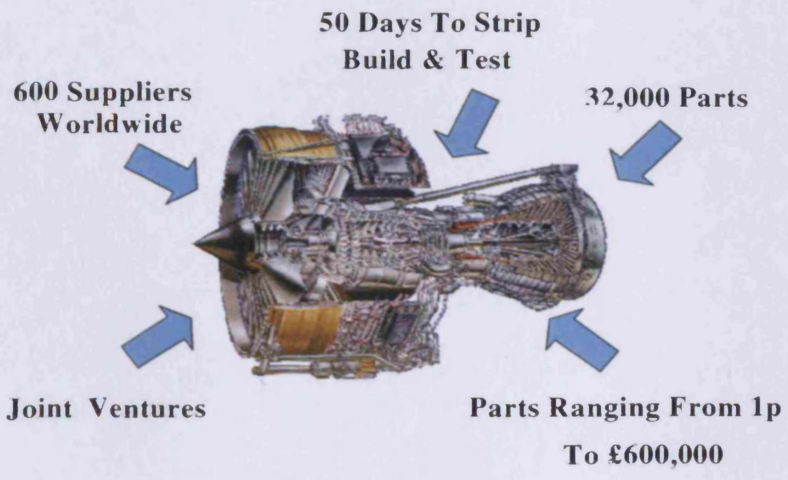
[8] The realist approach is a point of reconciliation that sits between the extremes of positivism and naturalism. Realists such as Giddens (1985) & Wass and Wells (1994) argue that a synthesis of extremes is possible and occurs naturally during most field research.

The case study business was also considered appropriate because it was a commercial operation, which is subject to global levels of competition. As such the focal business also provided an opportunity to extend the work of Reason (2003) and assess the contradictions of contemporary organisational models with high levels of safety defences as well as to test the limits of TQM when translated from less safety critical environments (Hayes & Wheelwright, 1984). The literature concerning TQM is heavily reliant upon repetitive and simple processes that are dominated by rule based decisions whereas the aero repair sector is complex and team members have much more skill variety, job enlargement, and a reliance upon knowledge-based skills. An aero engine is therefore regarded as a complex product and, based on a series of diagnostics will need a customised repair path and an approach to TQM that differs considerably from other sectors where one engine type can be very different from the next. The aero repair environment is therefore characterised as high variety and low volume production, which is furthermore complicated by infrequent orders of uncommon repair processes. Figure 1.10[9] illustrates the complexities of this position, based on a typical repair & overhaul engine type, which, for each of the 4 case studies under investigation, are performed under the responsibility of self-managed teams.

Figure 1.10 The Complexity Of Jet Engine Repair & Overhau



Source: Taken From Case Study Production System

[9] The cut away of the gas turbine engine shown above is a Trent 900, which achieves around 13000 flying hours between major overhauls, thus demonstrating the reliability of a typical big civilian aircraft engine.

The engine type (figure 1.10) is known as a turbo fan and represents the most common type of gas turbine technology used in the most popular airframes such as the Boeing 747 and Super Jumbo Airbus A380. Military and civil engine variants are of a similar type and are typically refurbished using a unique timing concept described as 'power-by-the-hour'. This concept uses a customer engine 'lease' agreement as opposed to the traditional option to buy (repairs are part of this lease agreement). Such an approach creates many commercial pressures to return engines back to the aircraft as soon as possible. 'Power by the hour' has redefined the business model at the case company, within the context of TQM and Lean principles have been engaged to ensure quicker turnarounds of engine repairs that has fundamentally challenged the cultural/traditional way of thinking and working. From a theoretical perspective Berry (1991), proposes a TQM culture transformation requires a *"Philosophy for total corporate focus that exceeds customers expectations and significantly reduces costs resulting from poor quality by adopting a new management system and corporate culture"*. From a TQM perspective the most effective and efficient approach to operations management advocates decentralised decision making, self-management of quality/safety routines based around the investment of empowered team working, which is the model adopted by each case company across multiple Aero Repair & Overhaul (AR&O) sites.

However, the practical application of TQM or Process Excellence from a case study perspective differs from the traditional definitions drawn from the practices of companies like Toyota on the basis that the automotive approach uses a highly structured team model with a distinct team leader/supervisor whereas each of the case studies in this study, is fundamentally different in its uses of a self-managed team approach.

For the purpose of this study, the achievement of TQM at the case company is described as a journey and self-management provides the main building block of the approach with a new style of management directed towards improvement and large-scale organisational change transformation. The deployment of the new socio-technical strategy and system has resulted in significant change from the traditional craft based engineering 'job shop' approach and towards a more customer driven approach of Lean production systems. The combination of both TQM and Lean production systems at the case company share the same principles of consensus management where low levels of demarcation and investment in human resources thinking has resulted in a learning environment that performs well and retains a safety consciousness approach. Such a socio-technical approach has been termed by Peters (1993) as a *"Simultaneous loose-tight properties of organizational change, where the awareness of organisational values can provide the glue for holding companies tightly together"* In other words TQM in conjunction with self-management is seen by the case organisation as an all-encompassing approach that is capable of engendering organisational quality through a collective responsibility, based on 10 principles of TQM as declared Saylor (1992)

1. Leadership
2. Commitment
3. Total customer satisfaction
4. Continuous improvement
5. Planning
6. Training and education
7. Ownership
8. Reward and recognition
9. Error prevention
10. Co-operation and teamwork

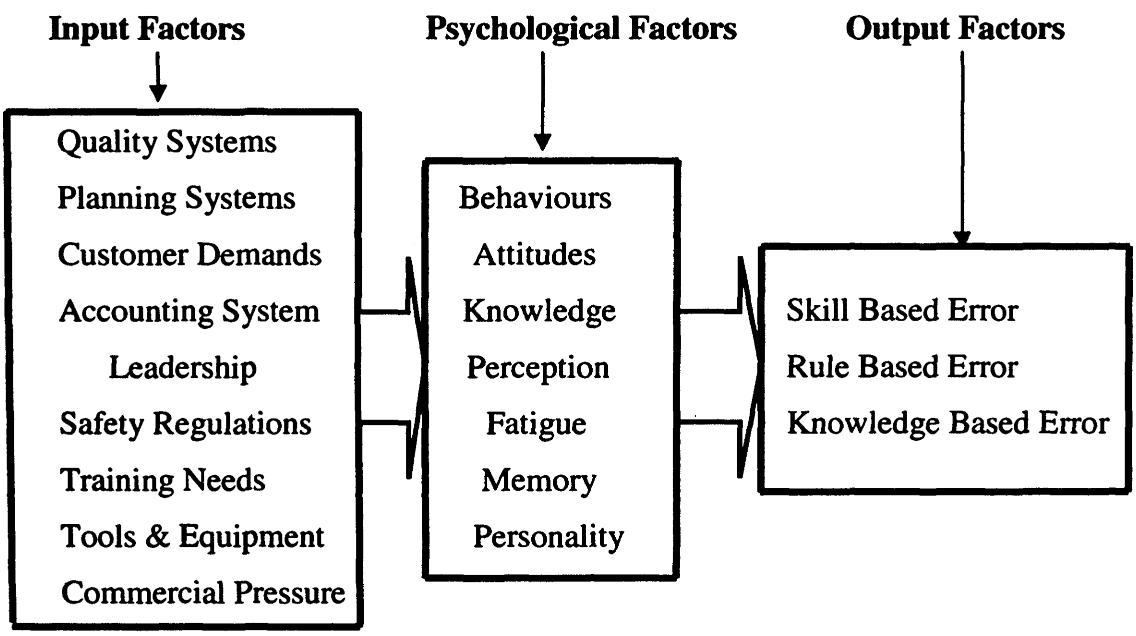
Given the recent events within the aero repair industry, access to a business in a process of large-scale transformation and the team/system approach to human factors created a unique opportunity to study how a complex operations management system adapts to new conditions using Lean and TQM approaches to adaptation. The potential contribution to the body of knowledge by researching such an organisation were considered a valuable means of adding to the body of knowledge in the fields of operations management and human factors engineering.

1.4 Research Aims & Objectives

The focus of this study is aimed at identifying these barriers and constraints that limit the extent to which self-managed teams are able to meet the real world challenges of achieving high quality engineering within the context of TQM. In order to test the compatibility of self-management within an existing framework of TQM, the researcher has identified a number of potential areas of quality risk, where the cost of non-quality is described as complex and unknown. The types of benefit sought from this study include the identification of the factors that have prevented teams from engaging in safety management and the development of a model of use for managers and academics alike. The chosen context of aerospace repair and overhaul was a deliberate decision, as this sector exposes one of the most extreme conditions, within Lean production/TQM. The case study is set within a harsh and legally regulated sector, where auditors have the right to withdraw operating licenses, based upon non-compliance to strict aviation safety law. Another set of factors that presented the aerospace repair sector as ideal for study, concerns the fact that a single error related event, which is the cause of an engine flight shutdown, or worse still a catastrophic failure can result in regulatory penalties and in the most extreme case corporate manslaughter charges. The context was therefore considered suitable for study because a conflict exists between the need for respect for individual/individual discretion and skills versus the traditional TQM structures of supervision and indeed the regulatory presented to the industry (EASA part 145). The principles of self-management & Lean are also at odds with the extensive research gained from more mainstream sectors of new production, which tend to follow traditional models of Lean that favour front line leadership, within the context of the Toyota Production System (TPS) itself. Figure 1.11 was created by the researcher as an initial framing of the research and to aid understanding and expose which gaps if any, might lie, within factors of efficiency and effectiveness of TQM based on the unique operating environment of repair & overhaul engineering.

Figure 1.11

Input vs. Output Model of Human Factors affecting Team performance



Source: Researcher

The model identifies the input, psychological and output error factors that could exist, as active, or latent modes of failure, should the socio-technical system become unbalanced or exhibit weaknesses that open 'windows of opportunity'.

1.5 Research Question

The exact research question that guides this study is declared as problem-driven approach based on the need to understand;

"To what extent can self-managed team working, facilitate the principles of safe Total Quality Management within the operational context of process excellence"

For this project, the researcher will seek to provide a level of understanding as to 'why' self-managed teams are at risk of making mistakes, within the context of established methods and procedures that could result in 'active error' within a working environment which calls for high use of problem-solving skills. Another objective of the study was to provide a level of understanding of 'how' some procedures might fail to provide adequate safeguard against long-term problems for both active and latent (system design) errors. The researcher acknowledged the historical concerns of previous studies and specifically decided to assess the volatile situations/systems issues that involve errors based on poor 'rule' based application of the latent issues of the operating system and the potential failures caused by poor operations management designs (socio-technical system). It was critically important that this study was not to investigate actual accounts of failure but instead to look at the perceptions of employees as a means to measure and analyse error related risks that are most likely to exist beneath the water line of the operational management system design. A study of narrative explanations of error management was considered as part of this investigation but discounted because, whilst contextually rich, were too individualistic to gain better insight into system design and management (Catchpole, 2010).

The selection of a corporate case study with multiple sites thereby provided an opportunity to statistically test differences of understanding and attitudes towards quality to help explain why such errors were able to penetrate the safety systems mechanisms of defense. Such an approach was considered to offer a beneficial extension of the seminal work presented by Reason (2003).

The final objective of the study is to provide a level of understanding of 'what' barriers exist to prevent high-level maintenance managers from creating a positive resolve towards the management of institutional and latent error risk within the socio-technical system. The purpose of this question was to look at system designers and how these 'remote' individuals could benefit from this study, in the form of a model to guide their decision-making, so as to optimize the socio-technical system of self-managed teams with TQM

1.6 Chapter Summary.

This chapter has set the scene and background to the study of contemporary safety management systems thereby outlining the main features of human error. It has also identified a number of potentional gaps for exploration between self-managed team working and TQM/Lean production especially in a low volume, high variety and high discretion workplaces where knowledge-based error prevention is undertaken. This form of workplace is considered to have the same compatibility as the quality philosophy of new manufacturers or first build, where human factors problems are resolved through the elimination of variation, reduction of waste, process standardisation and employee engagement. Features, of which remain questionable in the context of a repair environments, where operations management conditions are diametrically opposed to first build. As such, design for and sustainability of improved quality of performance for safer working environments in high variety environments is a major area of weakness in current academic thought. To date, the researcher would argue that no study or research programme has addressed the role of safety management, under Lean working conditions in high variety environments, such as those found in this study, namely; 3rd line deep strip aero repair & overhaul engineering. A study of high variability and low volume operations management systems and self-managed team working therefore suggest there is much to be gained and learned from a study in this type of environment. These operations management designs are by definition, poorly understood workplaces and their broader socio-technical systems designs also suggest they require an altogether different range of considerations that need to be optimised in order to result in high standards of safety and productivity.

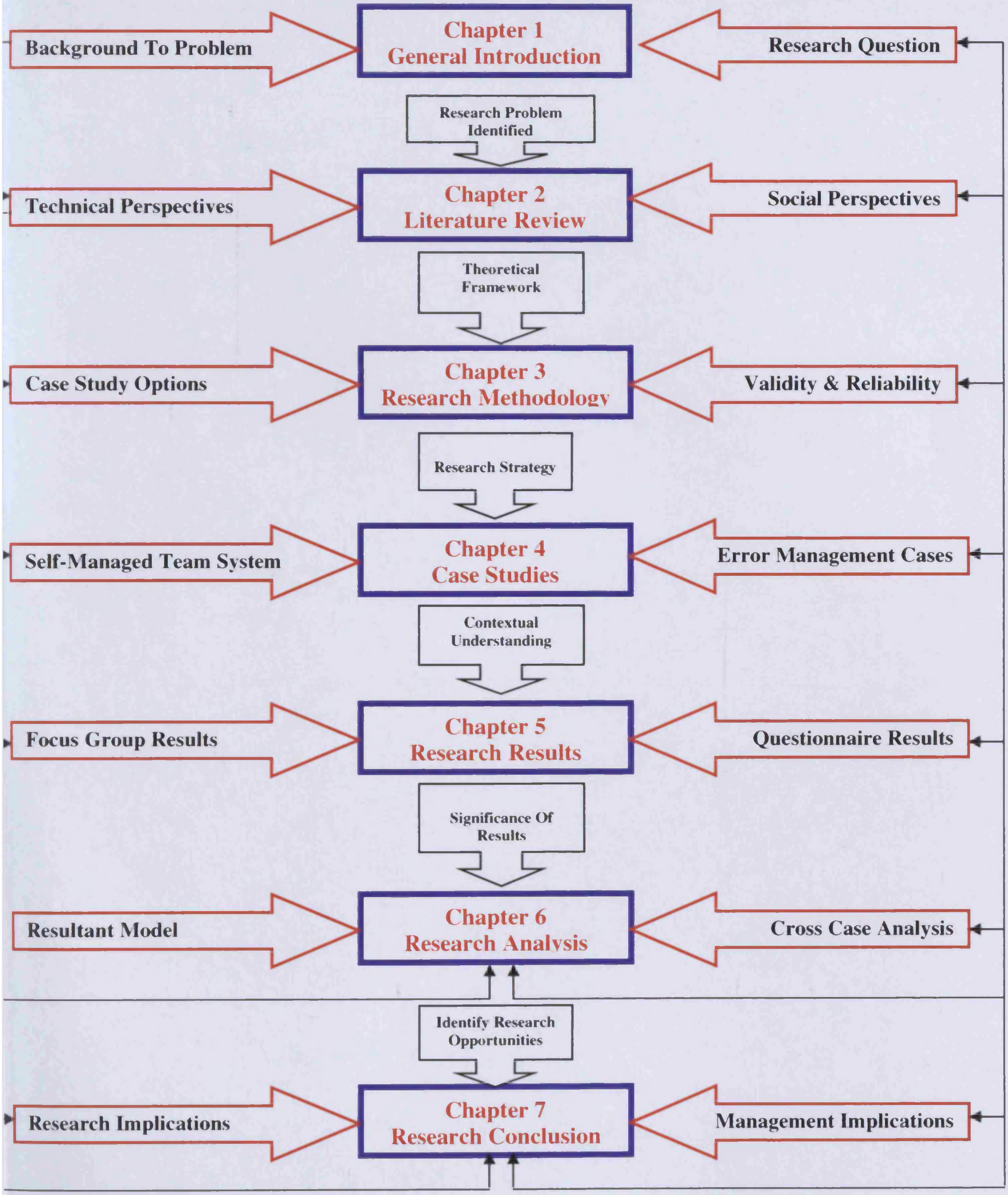
Chapter 2 will set the thesis within the context of the extant literature and show the many gaps that prompted this study. Operation management design issues, within the context of socio-technical systems theory (STST) will be examined. In so doing, STST will be used to expose the number of gaps in TQM literature and will also form the bedrock for discussion of the research strategy that will be defended in Chapter 3. Chapter 3 will àlso provide a justification for why the researcher decided to employ the pluralist methodology, the entire decision trail related to the case study selection, research, problems, and later data management, display and review processes. It will also show how 'quantitative' as well as 'qualitative' cycles of research were engaged to ensure a robust 'cross case comparative design'.

Chapter 4 will then explore, in more detail, the case studies and describe the recent changes/improvements of the case studies (within the legal framework of the European Aviation Safety Agency regulation part-145).

Chapter 5 will present an overview of the case study results and provide a detailed analysis of the research findings against the prescriptions of the literature review and original research question. In so doing the results will provide a broad framework of quality related issues that can be used for experiential and focus group research.

The analysis presented in chapter 6 will include a resultant model, which is intended to capture the findings of each case study, for future testing by researchers and managers from an aero repair and overhaul point of view. Finally, the conclusions and implications of the study will be summarised in chapter 7 together with the next set of most rewarding research activities in this field of human factors and operations management. The remainder of the thesis contains the supporting information, copy of the questionnaire and an audit trail for future cross-referencing purposes. To assist the reader, the researcher has created a schematic to show the flow of the thesis (figure1.12). The figure depicts how each stage of the thesis builds from its preceding stage and how multiple points of reflection were built into the process of research to add to the robustness of the study. The next chapter will set the thesis within the context of the extant literature and show the many gaps that create the need for this study.

Figure 1.12 Schematic Overview of Case Study



Source: Researcher

Chapter 2 Literature Review

2.0 Chapter Introduction

The previous chapter has presented a general overview of this thesis and has identified that the aero repair & overhaul of gas turbine technology is a critical context of operations management that is under researched especially within the context of human factor engineering and safety. The purpose of this thesis is to examine the operational management practices from a safety-critical systems perspective as a means to identify those practices that induce human error. In order to achieve this aim this chapter will ground this study within the organisational and operations management literature bases using 'systems theory', socio-technical systems theory (STST) and operations management (OM[10]) to provide the context of this review. In so doing numerous gaps in the main academic body of knowledge will be exposed thus justifying this study and showing why new theory is needed.

Set within the context of high product variability, low customer demand and low repetition of skills (including 'non-linear' product flows), the chosen literature will also explore the unusual operations management structure of self-managed teams and the relation of this form of structuration with seminal work of Reason's (2003) 'system induced' forms of human error conditions. The problem presented by the operations management literatures (which focus on high levels of materials flow) and human factors specialists such a Reason (which focus on system and individual causes of safety failure) is that much of the operations management work is located within high volume and low variety settings (such as car assembly). When the context is changed to high variety and low volume and also where there is a high level of individual discretion and self-management, risk factors grow and when commercial pressure is added, then failures in a safety-critical aerospace system may result in fatalities. This seemingly contradiction of structure, safety management and high materials flow/quality improvements is the subject of this study.

The research will therefore examine a new dimension to the field of human factors research that extends beyond Reason's work to embrace a broader church of human factor perspectives. The researcher will therefore consider a more eclectic approach to

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[10] The concept of operations management is, in the literature, called by a number of interchangeable titles. These include manufacturing management and production management. The title 'operations management' OM will be used throughout this thesis.

theory building that challenges the school of individualistic research with a more social psychological perspective which is considered to be better suited to understanding the limitations and performance of self-managed teams (Harshit, 2005).

Reason's human factors models have been applied exclusively in areas of front line supervision and therefore lacks due consideration of complex 3rd line aero engine overhaul & repair. As such, this approach calls for a broader range of considerations that will be discussed within the context of high performance management systems. In so doing the researcher will discuss a range of technical operations management approaches (such as Six Sigma[11] & Lean) and place into context the relevance of these 'hard system' tools/techniques against a range of social considerations that frame the main research question (Slack et al., 2008). The main research question is stated as:

"To what extent can self- managed team working, facilitate the principles of safe Total Quality Management?"

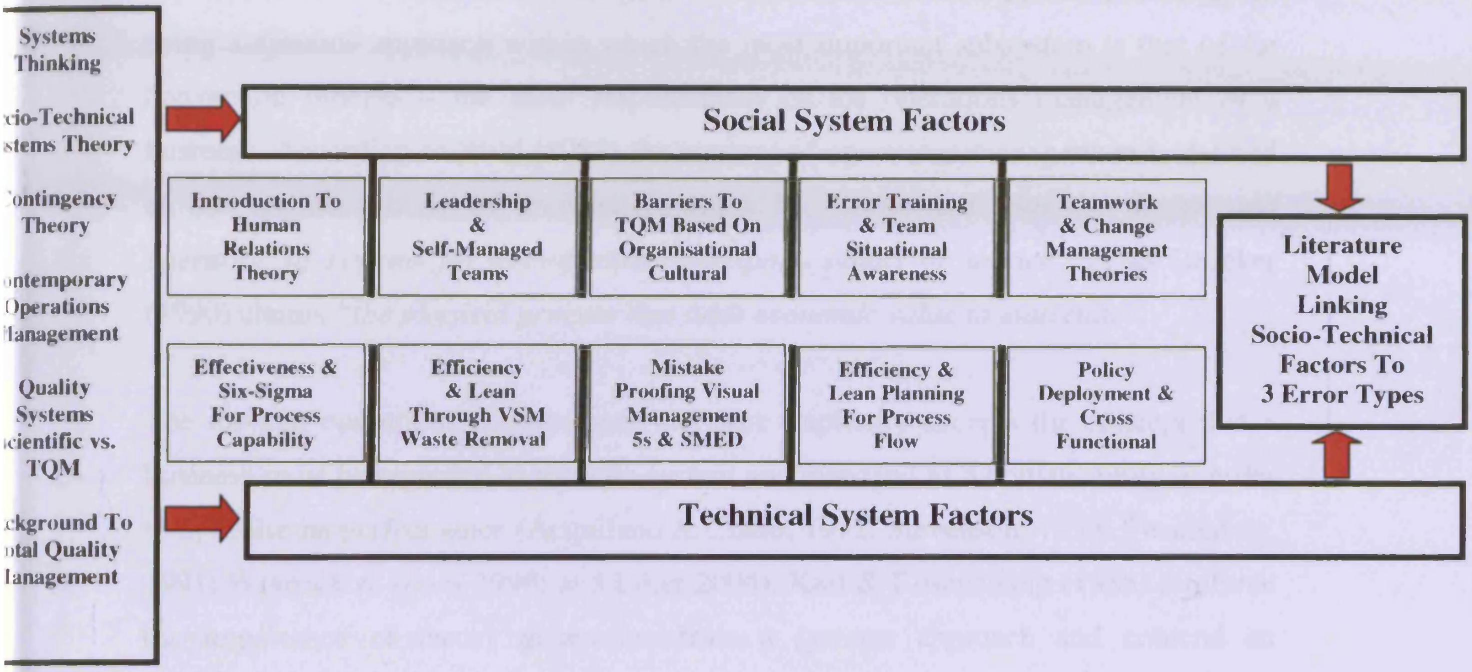
The research question and scope of this study concerns the investigation of a complex socio-technical system (an environment where safety is at its most effective through the careful design of technical and socio systems). To aid understanding a literature model was created by the researcher (Figure 2.0) and is offered as a means of contextualising the socio-technical systems perspective[12].

[11] The opportunity for quality improvement should be maximised through the application of six sigma & lean, which according to Chowdhury (2001) *"Is both a philosophy and methodology in which an organisation continuously improves its processes, with the aim of defect free manufacturing".*
Six Sigma is also credited as a statistically derived measure of a process that consistently produces no more than 3.4 defects or failures for every one million outputs.

[12] Socio-technical systems are those, which rely not only on technology but also on humans and social organisations for their adequate functioning.

Figure 2.0

Literature Components In Support of the Main Research Question



Source: Researcher Literature Summary

2.1 Systems Thinking In Operations Management

To place the relevance of the research question into context, the literature will begin with a historical overview of contemporary manufacturing management, which originated from the historical perspective of 'General Systems Theory' (GST) and the biological sciences. The purpose of selecting a systems view of human factors and operations management is that most forms of failure are actually the result of the system and its design rather than individual malpractice. As such, and in line with the protocols of theory-building research, a systems approach will be taken to the organisation and the major subsystem of operations management.

Bertalanffy (1951) was the first to formalise the systems approach and the need to take a systems approach to the design of effective systems that can adapt, survive, and grow. This early work, which argued that the system was greater than the sum of the parts, was later developed and adapted to use the systems metaphor with business organisations (Dunlop 1958). Ackoff (1971) Beer (1972), Garvin (1993), Goldratt & Cox (1998) and Seddon (2000) have since used it, to explain the performance of operational management thinking and have promoted the utility of system theory for application to management problems/new business designs.

Authors from the operations management field of study have also found utility in using a systems approach within which the most important subsystem is that of the conversion process – the main responsibility of the operations management of a business. According to Wild (1984) the concept of operations management is defined as the specialist body of knowledge which is; *"concerned with the design and operation of systems for manufacture, transport, supply or service"* or as Drucker (1990) claims *"the physical process that adds economic value to materials"*.

The modern operations management literature implicitly accepts the concept that a business must be regarded as a single system and managed as a holistic entity in order to optimise its performance (Acquilano & Chase, 1992; Stevenson, 1993; Swamidass, 1991; Womack & Jones 1996; and Liker 2004). Kast & Rosenzweig (1985) reinforce the importance of theory generation from a systems approach and contend an organisational system is *"an entity in its own right, with unique properties understandable only in terms of the whole, especially in the face of a more traditional reductionist or mechanistic focus on the separate parts and a more simplistic notion of how these parts fit" and they* go on to argue, *"The term system covers a broad spectrum of our physical, biological and social world"*[13]. In other words an engineering business is a system of numerous inter-related subsystems that include the socio-technical aspects of operations that reinforce effective human factors and high performance production. Central to the design of an effective and efficient operations management system is the conversion cycle of purchasing (input cycle), and distribution (output cycle), each sub system's performance can affect the overall business performance and the structural features that support the flow of materials. Support for such an approach is provided by Scott (1987) who argued that *"Previous definitions tend to view organisations as a closed loop system, separate from its environment and comprising a set of stable and easily identified participants. However, organisations are not closed systems, sealed off from their environments but are open to and dependant on flows of personnel and resources from outside"*.

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[13] For other definitions see Ackoff (1971). The broad range of applications and academic disciplines, to which the 'systems approach' has been applied has prevented the true unification of the theory. This lack of unification reflects the diversity of the approach rather than any internal conflict of logic or flaw.

Contemporary operations management theory stresses the importance of business designs that are considered to be 'open' systems (Dale et al., 1997). Such systems are capable of interacting with the supply and consumer environment and controlling the conversion process to meet its operational goals. Emery (1969), an eminent socio-technical systems author, formally defined this position as *"From the physical point of view, the characteristic state of the living organism is that of an open system. A system is closed if no material enters or leaves it; it is open if there is import and export and, therefore, change in the components. Living systems are open systems, maintaining themselves in exchange of materials with the environment, and in continuous building up and breaking down of their components"*. He further claims *"Human organisations are living systems and should be analysed accordingly management is concerned with the control of social systems, technologies, and markets therefore living systems are essentially 'open systems', not 'closed systems"* This was a definition that Pasmore (1988) later extended and codified as a model of high performance socio-technical system theory.

Pasmore argues the use of the biological systems metaphor is appropriate and states that researchers *"... find intimations of an exhilarating 'unity' of science, because the system models used by biological and physical scientists seem to be exactly similar. Thus, the system model is regarded as universally applicable to physical and social events, and to human relationships in small or large units"*[14]. The researcher therefore accepted that the systems approach to biology and organisational research were compatible. Furthermore, from within the Total Quality Management (TQM) literature base there was more support for a systems approach to management involving both social and technical elements of high performance businesses. This view was explicitly supported by the quality guru Deming (1993) in his system of 'profound knowledge', reinforced by Goldratt & Cox (1998), and explicitly recognised by the key authors of the Lean business system (Womack & Jones, 1996). As dominant models of operations management these authors reinforce the need for a systems view and Womack and Jones contend that high performance can only be achieved through an effective systems design. They propose, "manufacturing organisations, which have learnt to exploit the potential of the system through high

[14] 'Systems theory' has been applied by many academic disciplines involving modifications of the approach to better match the system under investigation.

quality and leaner ways of working, are more efficient and more likely to be successful than those businesses who do not". Womack & Jones (1996) go on to claim that *"when the competition also engages in the same models of open systems management, those organisations, which improve at the fastest rate will be more efficient and effective than those, which are time lagged"*. Such an approach to organisational ecology and the importance of good operational management processes implies that management choice and employee integration are fundamental building blocks of a successful business strategy and model.

The basic features of an organisational system are; an input-process-output cycle, management, a planning activity, and a means of system regulation through measures and monitoring (Pasmore, 1988). Katz & Kahn (1978) argue that of all these features, it is the planning and leadership processes that are most important because these processes are concerned with forming and 'internal fit' of the social and technological processes of the business.

Another aspect of systems theory is the achievement of a *'steady state'* of material flow within which outputs and inputs are balanced. The improvement of the flow processes requires engagement of employees to find ways of reducing waste and making the entire socio-technical system more adaptive. According to Deming (1986), this feature of systems theory is directly linked with the ability of individuals to exploit improvement processes and align all activities to achieving an optimised or 'waste-free' operations management system and do so by use of sophisticated monitoring of processes and customer requirements. The key assumption of Deming and other systems authors is that managers must design and maintain an efficient 'steady state' system to provide a measure of basic stability for the materials flow process and engagement of improvement activities to take place. Brown (1996) supports and extends this view by arguing that any high performance organisational/socio-technical systems design relies on effective management to create direction and focus, as an enabling factor for self-regulation to take place. The researcher duly accepted the utility of a systems theory foundation to this study and a means of framing human factors design and management of high performing businesses. In accepting this foundation theory the literature implies that effective human factors management results from an appropriate management design, engagement of employees and the 'right behaviours' of management to plan and direct efficiency programmes. Figure 2.1 provides an overview of the basic features of an open system and its impact on this study. Having provided a brief account of systems theory, the researcher investigated the different schools of thought that have emerged since the 1960s and found that contingency theory and socio-technical systems theory to offer many insights in to effective organisational design. Other management and organisational theories that were reviewed but later discarded included process theory (rejected because of the reliance upon following activities and decisions which was considered beyond the scope and ability of this research to conduct) and information, communication and control theory which each emphasize regulation, but not in a meaningful manner, to house a theory of human factors management. The next section will provide a brief review of contingency theory.

Figure 2.1: Summarising the Basic Features of an Open System.

Concept	Definition
Systems Hierarchy	A system, according to Porter (1985), is located within a higher order and is known as the supply chain. The actions of which involve the execution of tasks needed to meet system goals.
Steady State	To maintain a balanced fit within the environment the system must be regulated such that environmental change can prompt adjustments in the performance of the system.
Viability	To survive, a system must be contained within a larger system, which, according to Beer (1972), must be capable of organisational dependency to both customers and suppliers.
Input-Process & Output Cycles	According to Huczynski & Buchanan (1991) all systems exist to satisfy the goals determined by their designers and as such organisations represent *"social arrangements for the controlled performance of collective goals"* Open systems therefore engage in a conversion process that generates a level of throughput exchanges within the system.
Information Processing	An open system requires, according to Hayes & Wheelwright (1984), the concept of 'feed forward' management planning where routines are needed to guide the system under conditions of environmental uncertainty.
Regulation	An open system requires feedback of information concerning the flow of transactions with the environment. Negative feedback, according to Kast & Rosenzweig (1985), concerns information that deviates from the steady state and *"should be readjusted to a new steady state"*
Measures	The measures adopted and information processing within an organisation must be sufficiently sensitive to detect changes. These sensors must also be designed with standards to 'filter out' information in the form of decoding[15]

Source: Rich (1999) adapted for purpose.

[15] The 'Control Theory' (CT) literature was reviewed by the author, but the main tenets of ends (outputs) and means (inputs and the transformational process) analysis were deemed to be a subset of GST. Kast and Rosenzweig (1985), propose *"Control theory, like many other broad theories, is more a state of mind than any specific amalgam of mathematical, scientific or technological methods. ... The broad objective of a control theory is to make a system – any kind of system – operate in a more desirable way: to make it more reliable, more convenient or more economical"* (p.509).

2.2Contingency Theory: Organisational Structures & Performance Management Systems.

Having discussed the main features of general systems theory and identified its main components, this section will now explore the contribution of 'Contingency Theory' (CT). Contingency theory was selected as a potential literature base due to its concentration upon the management, planning, structure and improvement of organisational systems and also because of its fundamental tenet that organisations must be best suited to their environment and that organisational structure has a pivotal role in achieving this 'fit'. This 'fit' was considered to be an important aspect of operations systems design especially when the command and control structure of a typical business is replaced by self-management in faster moving environments, these design features also impact upon the safe working practices and resilience of operations management systems.

The basic premise of contingency theory is a rejection of the classical 'one best way' of managing (Taylor, 1947) and the proposal that an organisation must 'fit' its environment and that different environmental factors will shape the design features that make certain businesses successful whereas others fail. In this manner, contingency theorists attempt to explain why different business structures are more or less appropriate to certain product environments and therefore offer a superior advantage (Donaldson, 1995).

Theorists, such as Thompson (1967) and Pugh (1968), placed high importance in understanding contingencies that lead to different structures. They emphasised the role of management in properly designing operational and planning systems to maintain an organisation-environment 'fit'. Many of the contingency theory studies were based on empirical research that sought to explain the complexity of organisational systems by discerning patterns of relationships among subsystems, which resulted in improved business performance. Burns & Stalker (1961) summarise the approach by arguing there needed to be a switch in managerial philosophy from the scientific perspective of *'the one best way for all organisations'* to the *'one best way for each organisation'*. The main focus of contingency theory therefore concerns the alignment and fit of the business structure, which ultimately determines goals and organisational performance, which according to Child (1984) is important, because it focuses on; *"the allocation of roles and responsibilities, the grouping of functions, decision making, co-ordination, control and reward – all these are fundamental requirements for the continued operation of the organisation. The quality of an organisation's structure will affect how well these requirements are met"*

According to Pugh & Hickson (1976) there are severe penalties in terms of failing to maintain a critical 'fit' with the environment and each of these penalties has a negative impact on material flow and commercial performance of the organisation. The consequences of this mismatch is acknowledged by Hannan & Freeman (1989) and propose it will lead to a reduction in information processing efficiency that would inhibit the success of organisational learning and slow down change processes. Pedler (1992) adds to the argument that insufficient attention to the structures of the firm will lead to poor levels of organisational learning and higher states of functional demarcation, where an over reliance on specialisation within an organisation can create difficulties and lags when change is necessary and when managers seek to create a culture of consensus and co-operation. In this respect, the structure and adaptive processes of the firm are critical aspects of high performance and within this discussion, two 'ideal types' are presented, firstly the 'open' systems perspective, which is characterised as consensual or organic and secondly the 'closed' system which is more formalised that leads to what Child (1984) describes as bureaucratic, demarcated, and mechanistic approach to management. Under the 'closed' approach to management, control routines and supervision are used and where all workplace activities are based on rules and bureaucratic procedures. Within the management of the operations and organisational systems centralised decision-making is undertaken and challenge to the management prerogative is not permitted. Mintzberg (1983) proposes this is an appropriate management perspective suitable to relatively slow-moving environments.

The 'open' systems 'ideal type' approach is characterised by decentralised decision-making, based on styles of management, which create facilitation and ownership of the system itself. Both concepts which, according to the researcher, is of relevance to this study, where self-management, in the form of organic structures, assume the slow moving position of technology, which by its very definition, is characterised as a 'closed loop' system, within the context of gas turbine technology. To place this discussion into context Burns & Stalker (1961) were the first to propose that organisations fall into the mechanistic or organic models of structure and decision-making. They classified the 'mechanistic' organisation as a 'closed' system set within a stable mass production environment drawing from their study of a Rayon Mill. Whereas the second case study was set within a more 'organic' open systems environment of a high innovations electronics company, which was characterised as a turbulent manufacturing organisation. The main features of these two organisational designs are set out in figure 2.2.

Burns and Stalker (1961) concluded, from their study, that a stable environment created a more 'superior fit' within the mechanistic mass-production design. Whereas the other study carried out under conditions of environmental uncertainty and 'organic' design, was considered to be more appropriate. Both structures however, were described as rational designs that Burns & Stalker (1961) stated were; *"explicitly and deliberately created and maintained to exploit the human resources of a concern in the most efficient manner"*

Figure 2.2 **Organisational Forms**

Feature	**'Mechanistic'**	**'Organic'**
Market Environment	Stable	Uncertain
Goals	Defined, enduring & static.	Diverse and changing.
Production Mode	Mass production & Maximum output.	High Variety & Customer Service.
Technology	Established & uniform.	Complex & dynamic.
Functional Specialisation	High, static roles and bureaucratic methods. High number of job grades.	Fluid, low, informal and low number of job grades. Self-determination of methods.
Competence	Senior Management	With skills holder.
Decision-making	Routine & programmable.	Heuristic & co-ordinated.
Orientation	Means	Goals
Communication	Narrow & Vertical (Orders)	Lateral & vertical (Advice).
Control	Hierarchical (Superior)	Interaction (Networks)

Source: Burns & Stalker (1961) adapted for purpose.

However, later research carried out by Child (1984) exposed gaps in what is described as organic superiority, thus highlighting problems that concerned a lack of differentiation between the basic structure and operating mechanisms. In other words Child argues that Burns and Stalker failed to describe and reconcile the complexity of decentralised decision-making, in terms of a lack of understanding of how basic management planning and control processes could enable organisational change to take place. In view of this criticism Child (1984) proposes, regardless of the type of organisational design; *"a formal structure does not resolve these differences in a way that integrates peoples' actions in an effective manner"*. The rebuke offered by Child was duly considered by the researcher to be an important challenge to the superiority of the organic approach – an approach that underpins the TQM and Lean models of operations management. What is unclear is the extent to which an organic structure and 'hands off' management can control a workplace that must ensure the highest level of defence (Reason, 2003) and where mistakes can result in fatalities. The aero repair sectors are diverse they have come to rely on highly skilled methods of self-determination, which is of particular interest in use of organic and autonomous team structures. The association in the literature that high performance results from an organic structure was considered a very important issue with regards to this research and whether organic structures do lead to better performance.

The organisational structure school of thought is just one contingency associated with high performance. Technology is the common denominator that unites many other authors. 'Technological determinism' and the impact of 'technology' was first proposed by Woodward (1965) who argued *"It was possible to trace a cause and effect relationship between a system of production and its associated organisational pattern and, as a result, to predict what the organisational requirements were likely to be, given its production system"*. Such an approach has a natural fit with many operations management authors (Hayes and Wheelwright, 1984). However, Child (1984) again exposes a number of weaknesses with this approach. He argues that 'technological determinism' has a number of methodological flaws in defining technology itself and also in its testing. Based on testing by the 'Aston studies' of (1969), Woodward's theories were effectively discredited. This study was founded upon multiple definitions of technology[16] and a large-scale survey that proved no such deterministic pattern existed. As such, the concept of 'technological causality' remains questionable, yet for the purpose of this study such determinism could not be discounted and implies the technology employed by cases involved with the study should match as closely as possible.

[16] 46 companies were researched using 'technology' types of 'operations technology' (workflow activities); 'materials technology' was based on the study of inputs used in conversion and 'knowledge technology' which according to Hickson et al (1969) embodied the human organisation of production.

The concept of technological determinism has not received such criticism in the operations management literature. Authors such as Hayes & Wheelwright (1984) defend the view that technological design factors were more important than issues concerning the structure of human resources. Technological contingency theory offered a new insight into modern high performance organisations and demonstrated that technology would impact on the skills and numbers of employees needed, however contingency theory did not satisfy a basic need of the researcher to look at performance rather than structural design. The research into technology also did not exactly provide evidence for autonomous team working and the design of operations systems for high quality, high safety and high efficiency. This view is in contrast to operations management authors who directly relate team structures to higher performance (see Womack et al., 1990; Plossl, 1991; Grant et al., 1994, Levey and Monk, 2002).

Another contingency school and a common feature of all schools is the criticality of management in designing systems, also planning and dictating the learning approach of the firm. Contingency theorists therefore acknowledge the importance of management choice and the management prerogative. Donaldson (1995) first argued that *"strategy determined structure"* claiming that structural adaptations occur only when the success of business strategy becomes impeded[17]. Similarly, he acknowledged the existence of competitive penalties associated with a poorly aligned or a self-sustaining structure, ineffective management control and time-lagged decision-making that would ultimately threaten business performance, improvement and adaptation. Child (1984) acknowledges this position in terms of five such penalties and argues that planning systems, which fail to support formal participation, posed the greatest threat to organisational learning as illustrated in figure 2.3.

The design dilemma faced by contingency theorists is that of participation in self-management by employees. In other words a trade off exists in terms of slower decision-making between scientific formalisation of the operation management process and the inhibiting impact this has on continuous improvement. Later operations management theorists such as Schonberger (2002) Gregory (1990) Neeley (1994) and Womack & Jones (1996) accepted this position within the context of

[17] For a modern review of the strategy-structure debate see Donaldson (1995).

world-class manufacturing as part of the total quality management movement, which remains the most dominant approach in today's operational management structures.

Figure 2.3 Penalties of Poor Organisational Design.

Effect	Cause
Poor morale	The result of inconsistent decisions, no standardised rules, and lack of delegation, lack of clarity, poor prioritisation and stress caused by ineffective support systems.
Decision time lags	A function of interrupted information exchange highly specialised decision-making, insufficient delegation of decision-making power, lack of procedures to evaluate the results of historic decisions.
Poor Co-ordination	Resulting from poor and conflicting structure of goals, lack of synchronisation and regular information exchange and exclusion of key employees from the decision making process.
Low Innovation	Created by a lack of specialised jobs concerning forecasting, planning and environmental scanning, lack of senior management support for planned change, dislocation of departments with market intelligence and those tasked with change or technological responses.
Escalating Costs	The result of a long hierarchy and high amount of indirect to direct employees, bureaucracy requiring additional staff and the existence of some or all of the earlier problems.
Counter-measures	The operation of a formalised, regular, and participative process of decision-making. The use of a logical portfolio of performance measures for each goal established. A flexible business structure through which goals can be executed. Nurturing of consensus management, high levels of employee participation and widespread promotion of the 'need' to change, thereby establishing a culture of 'continuous improvement' as the norm for all employees in which to engage.

Source: Taken from Child (1984)[18]

Upon reflection, the researcher accepted that few studies since Child (1984) have delved deeply into the design and hindrances that face management even when the management prerogative for the design of the business is unchallenged. It was considered important that this study represents an insight into contemporary operations management organisations as an opportunity to improve efficiency and effectiveness in high variety/low volume/high worker discretion aero repair & overhaul engineering. Contingency theory was therefore regarded by the researcher as offering a valuable insight into successful organisational designs because it offered according to Kast & Rosenzweig (1985) *"important guidelines for organisational diagnosis and managerial actions in specific situations ... contingency views*

[18] The work of Simon (1959) and later Williamson (1975) reinforces the negative impact of decision-making delays on the performance of the organisation.

recognise that the environment and internal subsystems of each organisation are somewhat unique and provide a basis for designing and managing specific organisations". The role of contingency theory was therefore highly relevant to this study as it promoted the importance of management decision-making in planning processes that provided structural guidelines in the understanding and extent to which self-managed team working can facilitate the principles of TQM. In this manner, the structure of the organisation and its management processes were considered important to the management of company safety and the reduction of human/system errors.

In summary, while contingency theory provided a general understanding of operations management structures, it was not an appropriate means of housing this study. This was because the dynamics of human factors are considered more important than focusing on business process and structure alone, this is an element, which contingency theorists failed to address. In the opinion of the researcher, this weakness resulted in partial rejection of contingency theory, which is also associated with systems theory, later known as control theory as well. In light of this and other such considerations of contingency theory, each school failed to account for how the principles of self-management could be integrated into the TQM system seen as necessary for improved business performance encompassing technology under human factors control. Based on the need to satisfy the dynamic requirements of an error management system, it was next considered that the concept of socio-technical systems theory (STST) was the most appropriate framework to house this study, because it is able to account for the importance of flexibility in complex maintenance environments.

2.3 Socio-Technical Systems Theory: Work Organisation & Management System

Socio-technical systems theory (STST) emerged during the 1960s[19], at the same time as contingency theory. STST developed out of the need to understand and manage the complexity of organisations reliant on social systems. It was Trist (1963) who described STST as an approach, which is suitable for managing the balance between the needs of the technical system that would inevitably be affected by the social system and vice-versa. This view was also supported by Emery (1959) who emphasised this position by stating "*It is important to understand that when both the*

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[19] The Tavistock Institute, an ethnocentric and philanthropic organisation, was at the forefront of STS research into human resource management and issues concerning the 'quality of working life'.

social and technical systems are jointly optimised, peak performance can be achieved". In other words, one approach cannot be achieved without proper regard for the other. Ellegard (1992) describes this as an 'organic entity', *"...claiming that when both the technical and human elements of a system are used effectively, economic benefits will result, in terms of high productivity and improved product quality"*. In addition, both Emery & Trist (1963) argued that STST could be used to explain cause and effect relationships between the internal design of an organisation and human factors efficiency, which ultimately defines organisational effectiveness in terms of a whole type task driven environment.

The socio-technical systems approach therefore advocates both a systems and contingent approach to a 'designed internal fit' of the workforce and material flow processes, in terms of its interaction with technology. Later theorists such as Pasmore (1988) argued that STST emerged as a dominant factor because of its contribution to the relationship between organisational effectiveness and the quality of working life. Pasmore (1988) defined the socio-technical system itself as the " *Individual attitudes and beliefs, based on the implicit psychological contracts between employees and employers; reactions to work arrangements, company policies, and design features; relationships between groups, among group members and between supervisors and subordinates; cultures, traditions, past experiences and values; human capacities for learning and growth as well as for sabotage and collusion; power and politics; individual personalities and group norms; the potential for motivation or alienation; for loyalty or dissension; for cooperation or conflict; and remarkable, uniquely human emotions such as love, hate, charity, anger, joy, fear, pride, devotion, jealousy, compassion, and excitement"*.

At the core of the STST design is the concept of continuous improvement, a process that underpins both the Lean and the TQM approaches to operations management. Further the STST approach promotes the use of teams to create dependencies between 'whole tasks' of operational activities. STST also focuses on 'team-based' tasks, as opposed to the traditional mass production design of hierarchical tasks that Perrow (1974) argued would result in the process of de-skilling. As such STST promotes multi-skilling, job enlargement, and job enrichment under the banner of greater autonomy. Pasmore (1988) argues that organisations are natural socio-technical systems in that they are *"made up of people (the social system) using, tools,* *techniques and knowledge (the technical system) to produce goods or services valued by customers (who are part of the external environment). How well the social and technical systems are designed with respect to one another and with respect to the demands of the external market determines to a large extent how effective the organisation will be... The structuring and integrating of human activities around various technologies... affects the types of inputs into the organisation, the nature of the transformation processes, and the outputs of the system that determines the effectiveness and efficiency of the utilisation of the technology".* His argument is that optimisation can occur if management engage the correct design of hard and soft systems to manage production.

Pasmore (1988) goes on to argue that the quality of internal 'fit' with an organisation itself determines out-put results in terms of high output performance which can only be achieved by the use of a consensus management approach to the workforce and deliberate engagement of management and teams in a form of co-destiny relationship. STST also promotes cross-functional management where all employees and not just the decision-makers must engage in a process of optimisation by reallocating roles and work across different employee groups. He also argued that STST designs should place high importance on productive efficiency and satisfied employees, a point also reinforced by the work of Blake & Mouton (1964) and their managerial grid. As such, STST is a technology first approach, but supported by advanced human resource management practices to include support for the development and training of a multi-skilled team-working[20] activity. These features reinforce and extend the work of Burns & Stalker (1961) under the 'organic' business design.

Whilst Pasmore (1988) does not explore the management planning process in depth, he supports the work of Emery (1969) and characterises management as 'engaged', for the majority of their time, in the collective planning of the organisation, whilst operational management routines, are deployed to subsystem whole tasks of specialists within the team. Whole task designs therefore represent what the TQM guru Garvin (1993) refers to as interdependent, but self-managing teams who own specific tasks that form part of the conversion process and act within 'internal customer-supplier' relationships. From a structural position, the concept of 'whole

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[20] The introduction of autonomous teams is considered the means of aligning and balancing the economic, technological and individual requirements of work.

team tasking', according to Trist & Bamforth (1951), creates a series of 'boundaried subsystems' that form a range of control mechanisms based on input-process and output cycles at the part level of analysis.

The heavy emphasis on management design and engaged team work, in the major STST research literatures, offered many potential avenues of exploration for this research and the researcher considered that there were many design implications for this study including the role of the team, professional skills dependencies and commercial improvement processes. The context of 'whole-tasking' directly reflected the autonomous teams approach and held predictive utility as to what elements of aero engine repair would be enhanced under TQM, leaner working methods and high levels of material flow/safety. The concept of 'whole tasks' as the basic building block of the firm was also seen as a departure from typical definitions of teams and cellular type production methods as found in the operations management literatures concerning new manufacture and the role of the team leader.

According to Pasmore (1988) the STST approach is a structural type of logic that allows closer control of the production process and shorter 'conception to correction' routines through the development of team skills (defences to errors). In light of this position the researcher found a synergy existed between the positions put forward by the STST leading figure of Pasmore (1988) and that of the human factors expertise of Reason (2003). Both these authors advocate the principles of containment, in terms of effective human factors to prevent the escape of safety critical conditions. A position that was illustrated by Heinrich (1980), in his 'error iceberg' model, as factors hidden 'beneath the water line' where abnormalities and quality defects unless identified at the subsystem level of analysis are at risk of breeching the 'whole' organisational defence mechanisms.

Another dimension of STST of high importance to this study was provided by the work of Hackman & Oldham (1980). These authors argued that an operating system which focuses on whole tasks has both psychological and motivational benefits in terms of providing a sense of belonging and job enrichment, where teams are better placed to learn skills such as problem-solving, which are major features of contemporary operations management associated with high performance. These features also fitted well with the overall intention of the study to examine *"To what* *extent can self-managed team working, facilitate the principles of safe Total Quality Management?"*. The question also has a major linkage and dependency with organic operational management as described by Senge (1993) and Storey (1994) and more recently Liker (2004)[21]. These authors directly correlate high performance with whole task management.

Another aspect of STST which held a bearing on the design of this study was the need to integrate whole tasks with an integrated range of performance management that provide formal recognition for organisational learning and self-improvement. The researcher duly accepted these as an important factor in the process of continuous improvement, as illustrated by Hackman & Oldham (1980) in figure 2.4, for modern facilities especially those in low volume and high variety sectors.

Figure 2.4 Socio-technical Systems Job Designs

Dimension	Definition
Skill Variety	Concerns the variety of different activities that are encompassed in the work conducted which involve a variety of skills to be employed by the individual.
Task Identity	The degree to which the work of the individual, or as part of a team, encompasses a 'whole task' to produce, from an input, a recognisable completed output.
Task Significance	The impact on the performance of others in the organisation or environment as a result of the work being conducted.
Autonomy	The degree to which the work permits freedom, independence, to the individual regarding the timing and methods employed to complete the job.
Feedback	The degree to which conducting the work provides the individual with clear information concerning the effectiveness of the individual (or team's) performance.

Source: Taken From Hackman and Oldham (1980)

Such a structure of management practices was reinforced by Pasmore (1988) who claimed that when teams engage in more formalised management planning routines, the deployment of 'stretch objectives' both vertically and horizontally, will enable what Likert (1961) refers to as the 'linking pin' approach to take place[22]. Such 'boundary spanning' activities involve the championing of change, at the management

[21] STS designs were used by Volvo in Sweden at the Uddevalla and Kelmar plants, but failed to generate the productivity levels, needed to compete, with mass production assemblers.
[22] Team leaders and administrative personnel are those individuals who Likert (1961) refers to as 'linking pins' who act as company-wide representatives in problem-solving groups to improve the quality of organisational resource.

level through the use of a steering committee with a reliance upon the team leader to identify and engage in the overall improvement process. As such, the manager and team leader become engaged in organisational levels of learning whilst human resource policies and procedures ensure that all employees learn how best to improve their 'whole task' areas of responsibility. The approach therefore unites management-led planning and operational improvements within a single 'systems approach' without disturbing the autonomous nature of business 'whole tasks' and 'local' improvements. These STST design features correlate strongly with the concept of Total Quality Management TQM including the management of critical control points within the manufacturing process as advocated by Deming (1982) Juran (1944) and Pasmore (1988) as illustrated in figure 2.5.

Figure 2.5 STS Design Principles

Design Principle
1 The effectiveness of the whole is more important that the efficiency of the parts, the flow of materials and relationships between elements of the total production process govern 'saleable output' not throughput efficiency at cell. The latter shows how efficient the cell has been at converting inputs that may not be required for sale.
2 Variances must be controlled at their source and abnormality should be detected quickly – through standard operating practices – operators should be able to detect problems and to take proper corrective action.
3 Boundaries between teams should be set such that the creation of a variance and its detection occur in the same geographical department to encourage employees to work together to solve the problem.
4 Feedback systems should be as complex as the variances that need to be controlled such that signs of variance may be detected and corrected before failure occurs.
5 Inputs should be monitored as closely as outputs and the impact of variances should be isolated in order to prevent total system failure. Technical resources should be directed to those variances with the greatest potential for systems disruption.

Source: Taken From Pasmore (1988) pp 80 -94

According to Pasmore (1988) this process will determine the efficiency and effectiveness of each 'whole task' and should therefore focus upon the management of a product and its process quality. He argues that through prioritisation, defects and losses will be eliminated thereby allowing the continuous improvement process to take place, based upon detected and deviation between 'whole tasks' without the need for management intervention. Further to this Pasmore (1988) identifies the role of whole task in terms of 'stretch goals' where performance targets should focus on 'loss free' production[23] and perpetual adaptation of performance. In order to create what Pasmore referred to as 'internal fit', while other STST theorists advocated widespread investment in training for problem solving so as to increase the diagnostic skills of the team. This approach can be compared to that of Contingency Theory where the deliberate reduction of the command principle is associated with 'functional specialists' i.e. maintenance technicians.

STST goes one step further in the deployment of the specialist buffers of the organisation and proposes the integration and co-location of specialists within the whole tasks as a means of increasing the rate and extent of improvement activity. The purpose of continuous employee skill development serves to enhance the level of self-sufficiency, which also enables the decentralisation of management control. This involves the need for technical training requirements that parallels with the work of Perrow (1974) who suggested that training is a necessary process that will help to reduce levels of demarcation between technical specialists and team-based working. The combination of these planning, structural and training features are all factors associated with high performance team working, which typifies what Perrow (1974) describes as a 'learning organisation'. STST theorists, like contingency researchers, therefore regard training as a necessary function that will enhance the quality of the decision-making process. In light of this position the researcher considers this argument to be of vital importance to this study where consensus management is a major feature amongst self-managed teams as the main stay of the aerospace sector, whose investment is based on the strategy to solve complex problems in highly technical environments. STST theory was therefore accepted as a key body of knowledge upon which to found this study, based on the argument put forward by Child (1984) who claimed that TQM processes could be coupled with learning processes to ensure organisational performance is optimised. Again a contrast exists with the centralised, rule-dominated and time-lagged bureaucracies of the mechanistic production designs, which according to Liker (2004) provided a direct link between STST and the engagement of contemporary TQM. This approach is based on the assumption that TQM has emphasised the importance of the 'team leader' which according to Storey (1994) is associated with the high performance of TQM design. In light of these and other such similarities the researcher has accepted the main

[23] Pasmore's deign principles highlight local rationality at the team level and reinforce the principles identified in the general systems theory review.

framework of STST literature as it provides a major opportunity to review the components of TQM from a socio-technical point of view. It also acknowledged that there is a major gap between STST theory and the organisational design features of this study, where autonomous team working is functioning without the vital linking pin stage of the team leader. Such a consideration is therefore seen as very important to this study in view of the current problems facing self-management in relation to both safety and quality of all aerospace repair-engineering processes. The principles of self-management in relationship to this type of organisational framework therefore assumes a compatible relationship with TQM in terms of 'efficient' (Lean) and 'effective' (quality) socio-technical system.

However, whilst self-management is acknowledged by Ellgard (1992) as the highest form of STST system design, there is much confusion over this aspect of STST design. As far back as 1963 Trist proposed there is a high level of ambiguity concerning self management, the impact of commercialism and how best to research it. In other words Trist argued that more research is needed to explain how self-management can co-exist with the commercial pressures required to control business performance. Trist's work never embraced the regulated industrial sector and, to this day, few studies have attempted to theory build in this sector of the economy. One study that has addressed this area of management is Raferty & Tapsell (2001), but no one study has focused its attention within context of 3rd line aero engine overhaul & repair. The findings of the Raferty & Tapsell study does shed light on the pressures and contingencies of the regulate sector but does not explicitly address the contingencies of the aero repair sector.

The researcher accepts the fundamental principles of socio-technical research designs, the need for new theory to be built within the regulations of repair and overhaul and especially within the structural choice of self managed teams.

Whilst studies of self-management have not happened in the aero repair sector, similar empirical studies in other sectors have shown this structural choice to be associated with high performance, team working has been a constant feature of highly reliable and high performance businesses for over a twenty-year period, Delbridge (2000). In this respect, teams are potentially both the result of TQM and also the enabler for it to be successful and sustainable. However, it should be noted that in this study the role of high performance teams have in every occasion included the central and pivotal role of the team leader as a front line manager and local decision-maker Under the definition of self management within this study such a pivotal position is absent. However, the main expansion in the research of team-based working does coincide with the growing awareness and emulation of Japanese management practices and a renaissance for STST designs.

Researchers such as Buchanan (1994) focused on studies of Japanese practices in the context of TQM/Lean production and claimed that his results were able to provide an insight into higher levels of team performance in areas of quality and commercial indicators whilst also allowing for sustainable continuous improvement. This is regarded as a new form of team structure and is reinforced by a number of studies such as that of Storey (1994). The 1990s marked a new point in the definition of team working which was an evolution from the embryonic attempts to use such structures in the late 1960s and 1970s. The two time periods and the definition of the team leader are illustrated figure 2.6 shown below.

Figure 2.6 Contrasting Socio-technical Systems in the 1970's with High Performance Team Designs in the 1990s

Teams In The 1970's	Teams In The 1990s
Aimed to reduce costs of absenteeism and labour turnover and increase productivity.	Aimed to improve organisational flexibility and product quality or competitive advantage.
Based on the argument that increased autonomy improves quality of work experience and employee job satisfaction.	Based on the argument that increased autonomy improved skills, decision-making, adaptability and use of new technology.
Had little impact on management function beyond first-line management.	Involves change in organisation's culture and redefinition of management function at all levels.
"Quick fix" applied to isolated and problematic work groups	Could take two or three years to change attitudes and behaviour throughout the organisation
Personnel administration technique.	Human resource management strategy

Source: Adapted From Buchanan (1994)

Theoretically, according to Wellins (1992), the benefits of socio-technical systems were manifested in terms of autonomous team working and this he associated with the practices of many world-class organisations. He highlights the bias of Scandinavian businesses for this approach to management and presents a powerful, yet flawed, description of autonomous working practices found at Volvo during the 1990's. The central feature of the Volvo system was an improvement system based on human resource system to enhance quality standards by reducing the amount of defects. This, Wellins argued, resulted in performance uplift up to 90% good quality at first final inspection. Other success factors were identified, According to Gandz (1990) who also studied Volvo; these successes could be attributed to the process of co-responsibility, which included both the regulation and organisation of human resource strategy. This was delivered in such as way that quality and efficiency became an empowering process amongst self-management where business decision-making was encouraged as the main feature of autonomous team working itself. Gandz therefore argued that when self-managed teams were organised in this way business performance outputs would be improved to include ownership of quality in safety critical situations.

However, further research carried out by Gandz (1990) showed that managers can equally disrupt the most effective elements of STST design, by placing undue bias on productivity as opposed to the investment of conditions seen as necessary to support the empowerment of employees to take place. To counter-act this type of situation Gandz (1990), argued in favour of the maintenance of six general conditions, as listed below, these he saw as critical success factors in key areas of socio-technical designs.

1. Adequate training
2. A shared vision
3. Development of a set of a set of shared values
4. Development of a common set of shared benefits
5. Installation of managerial faith within teams
6. Development of an organisational culture, which supports risk taking.

Probably the most damning finding impacting on the 1990s passion for team working and autonomy was that, in productivity terms, self management and the Volvo system was found to lag far behind that of other mass production and Lean 'team leader' based models (Womack & Jones 1990).

In this manner, while many of the positive elements of STST features were considered as highly relevant to the practice of self-management, as opposed to team working with a team leader position, the application of such a structure in a high variety, low volume and high risk environment as found in the aero repair & overhaul business leaves many unanswered questions? The basic principles of STST researchers is that happy workers are productive and that autonomy is a higher level of Maslovian motivator and should enhance the quality and enjoyment of working life. However, deviations are easy to detect on a moving car assembly line yet they are masked on a complex repair schedule, work is repetitive on the car line and relies upon routines/standards but it highly variable within aero repair and productivity management is easier in standardised production environments with rework bays and not such an easy approach for repair businesses where work, work content and the hours needed to perform a task vary (even when conducted by the same person using the same tools/technology).

While the researcher accepts the broad arguments put forward by Gandz, he is also cautious of the dangers this promoted in terms of what Gandz saw as important within the teams role and function of risk taking. For safety reasons this position is highlighted as a contradiction to the legal requirements of EASA part-145 and the requirement for all work to be traceable and there to be a separation of work from quality assurance activities. As such whilst decision taking is seen as a necessary part of self-management the process of risk taking could not be accepted, within the context of aerospace engineering, without due consideration for a supporting risk management process. This was a concept that Wellins (1992) researched during the same time period as Gandz but Wellins highlighted the need to invest in depth and breadth of training to resolve the potential issues of quality risk. He claimed that an effectively educated social system would broaden the range of activities of self-management to properly take place. This approach highlights the importance of, what is referred to by human factors researchers as, effective situational awareness, which Peterson (1983) acknowledged in his model of interactive levels of analysis as shown in figure 2.7. These levels of awareness mark fundamental differences between the simpler awareness of repetitive vehicle assembly and the complexities of aero repair.

It is a great shame that Wellins did not develop his models of autonomy and team working and align his work with the human factor management issues as outlined by Peterson (1983) and later Reason (2003). The shame is that, at the same time mainstream management literatures were promoting team working and autonomy the human factors literatures, exemplified by Reason, had switched attention from 'blaming the individual' upon detection of a failure, to accepting it was an inappropriately designed system that created the potential for failure. An incorrectly designed system would therefore include all the problems associated with commercial pressures but equally the dysfunctions of an incorrect structure and unclear hierarchy of control/decision making. As such the two literatures of management and organisational behaviour never benefited from the human factors analyses of operations management and more general human psychology. In this manner it was the operations management field of study that lost the most and did not return to this debate until well into the new millennium as research shifted from high volume environments (such as car production) to low volume activities and repair work.

Figure 2.7 **Interactive Levels of Analysis**

Level of analysis	**Direct and indirect effects'**
1. Individual	Work design Productivity Self-perceptions Psychological contracts
2. Department	Role structure Physical layout Interaction patterns Management behaviours
3. Organisation	Relationships among departments Organisational structures Reward systems Organisational flexibility

Source: Peterson (1983)

Peterson may justifiably be claimed to be an STST researcher albeit with a psychological bias. His model shows what he considered to be the most important hierarchy of operations management systems design. These principles were echoed by the main human factors researchers of the time and were duly accepted by the researcher as critical areas of management that would influence the design of this study. In effect Peterson provided a framework of analysis that could be applied in order to understand the vagaries and contingencies of human factors within aero repair. Peterson's model therefore provided a general framework by which the researcher could test the position of other human factor specialists, such as Maurino (2006) who claimed that traditional approaches to human error had ignored a major gap in the operational management thinking – that of poor design and operational designs increasing the likelihood of failure.

Peterson's research draws attention to the relationships between technology and team working, which Applebaum & Batt (1994) claimed was a critical relationship shown by their researches with the world-class manufacturing case study of the Xerox Corporation. Their findings found a positive connection between its quality management system and self-managed teams, which resulted in high output performance. They attributed the improved performance to direct investment in team empowerment in areas such as safety management, work planning and control of products and processes. The benefits resulted in Xerox achieving reduced levels of management hierarchy; the elimination of supervision also resulted in closer and better working relationships and improved system performance measures (such as cost, quality and delivery).

Applebaum and Batt (1994) concluded that two key forms of STST systems existed; namely the American version of Japanese 'team led' lean systems and a Swedish version which "*Combines the principles of Swedish sociotechnical systems and self-managed with those of quality engineering*". The researchers describe the second model as a high performing system that favours an eclectic approach, involving a mix of Lean production and statistical process control. By contrast the former model represents a pure Lean approach that includes individual involvement through team participation in problem-solving events.

Thus far, this chapter has presented the power and seductive rationality of how a well designed STS can result in higher performance and how STST authors generally believe that the most evolved (European) form of STST organisational model is one of self managed teams albeit that empirical research stops short of providing design advice as to how to implement such a system or what features of the system will change and be contingent upon the extent of regulation experienced by the product/process of a regulated and non-linear type of repair business. The next section of this chapter will explore some of the weaknesses that were discovered during the literature review.

2.4 Limitations of Socio-Technical Systems

So far this chapter has promoted a movement away from scientific 'one best way' management towards socio technical systems perspective of high performance management. The review has highlighted the importance of an open systems approach to the study of manufacturing organisations and the need to assess both technical as well as social elements of work design to be studied. Whilst generally accepting the STST approach to integrating human resources with technical working practices, the literature also falls short in terms of enabling the researcher to extract the best design for this study.

The literature has suggested that the best form of study should include a business whose structures are organic in nature and involve whole task autonomous working. However, STST offers no direct design instructions and limited predictive utility for the optimisation of safety-critical organisations such as those found in the aero engine repair sector. The low volume, high variety and high employee discretion environments are not covered by any STST study since the initial work conducted in the 1960s. In parallel, those studies of human factors in regulated industries have promoted the need for supervision and multiple layers of supervision without really addressing the real structural issues of a business or indeed high commercial performance (Reason, 2003).

The STST approach recognises the importance of organisational learning[24] and the positive impact of such an approach on the adaptive capability of the business and continuous improvement activities. However, even Pasmore (1988) fails to advocate the methods of learning and effective organisational change interventions that support high performance. Indeed, even operations management authors have tended not to assess such structures or ignore these issues and present this aspect of change management as largely unproblematic (Hayes & Wheelwright, 1984; Brown, 1996).

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[24] This approach is known as 'single loop' learning

However, for brownfield businesses, such as the one found in this study, the emulation of high performing models requires a lot of learning and adaptation of existing systems and cultures to achieve the autonomous team-based structure. Further STST researchers have not truly questioned the work of contingency theorists and instead they have tended towards an organic structure even though contingency theorists might argue that the aero industry is slow, regulated, more bureaucratic and therefore more likely to need a mechanistic management model and a traditional structure. Even Emery (1969) offers no insight into how safety conscious management in his long-wall mining organisations structured their affairs and what level of decision-making was passed to the operations teams. As such, the little evidence shows how a business may change to become more autonomous but studies do not show the limits of autonomy.

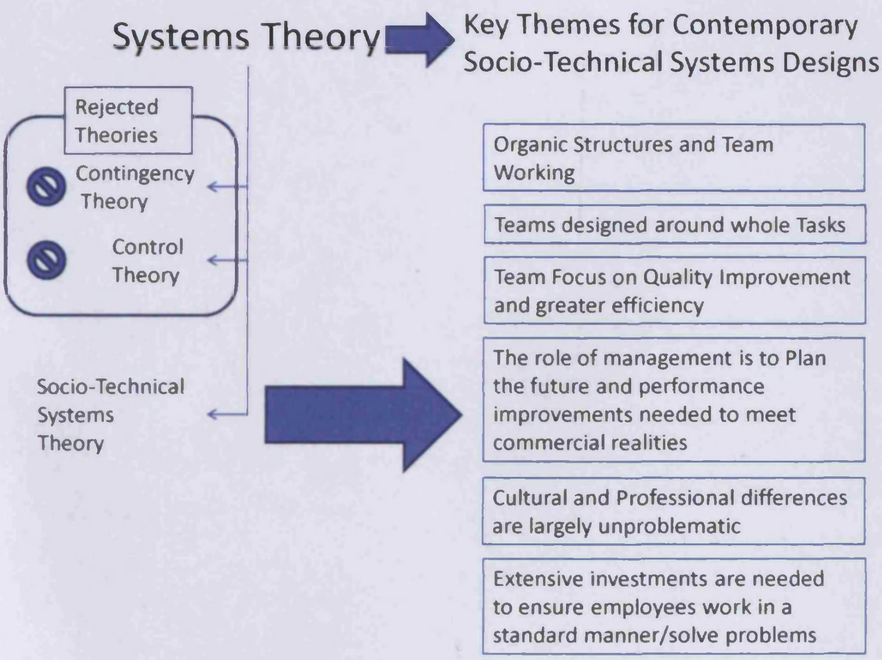
Where such team-based practices are described or explored, operations management authors tend to regard innovations (that originate from Japanese Lean and TQM systems) as easy to transfer from one country to another. Indeed, many authors argue that the techniques are simple enough to understand and therefore need only good leadership to implement (Schonberger, 2002). The implication is that there will be little resistance from the established leadership patterns and learning will ease existing leaders into a new 'enlightened' STST role. The models of self-management under conditions of TQM and Lean production will, according to Caffyn & Bessant (1996), experience the greatest learning challenges and generate much resistance even when businesses use the same methods and improvement techniques. In view of this situation Pugh (1968) notes that Japanese practices have "*...become part of the world-wide organisational convergence across cultures, and many organisations in different cultures are looking for further ways of benefiting from the Japanese approach as William Ouchi demonstrates ... while this convergence might apply to the formal management structures of the organisations, it does not apply to the actual behaviour of the organisational members in different cultures – even when the structure is the same ...there are, therefore, considerable cross-cultural differences existing between organisations. The issue is: are they moving towards convergence and, if so, how fast?*"

The STST school of thought therefore offers some insight into the processes of isomorphic change and the way in which Lean and TQM systems are translated from their essentially automotive origins to the aero repair sector. The approach also allows an investigation of how best to optimise or understand levels of sub optimisation as a result of management design.

The literature review has also exposed a gap in the body of knowledge concerning the treatment of high discretion work environments and how modern models of high performance have been and are being translated. The most significant gap concerns how human error factors are taken into account when seeking not to trade off between speed and safety. The model shown below in figure 2.8 illustrates this position in terms of those approaches. The features of this model will be explored in the subsequent sections that follow within the focal literature of high performance operations management designs practices of autonomous work teams.

Figure 2.8

Background Literature Audit Trail (Accepted and Rejected Theories).



Source: Researcher

After reflection, Contingency theory, and other theories such as control theory, were rejected because they described the support structural considerations of the firm rather than self-managed team structures, which is the subject of this study. Further most contingency studies showed that firms with structures that are similar to the norm will perform better than others yet this study is concerned with an innovative structural arrangement of shop floor teams. Whilst control theory was investigated it was also dismissed because it is essentially a model of monitored performance and team dynamics rather than a full human factor approach to TQM/high performance. It was difficult to disentangle much of the human relations theories from the human factors and socio-technical theories and the study, whilst cognisant of individual motivation, is more concerned with system factors of which individual motivation would be one variable/element. The most appropriate theory in which to house this study was considered to be Organisational Systems Theory and Socio Technical Systems Theory in particular. The latter presents a coherent body of knowledge that links structures, processes and technology in a manner that is associated with high performance. The researcher duly accepted socio-technical systems theory as the foundation for this study and concentrated on operations management as the focal literature set.

The next section of this literature will present a review of the operations management field of study to show how STST designs underpin modern models of high performance organisations and quality management practices, albeit in contexts of low variety, low personal discretion and the level of quality applied.

2.5 Contemporary Operations Management

Organisational and operations management literatures have remained largely detached since the study of industrial organisations and even today the most fruitful form of management study is to look at issues that position operations management within the business. Such a divorce is ironic given the impact of industrial engineering on the early models of organisational design under classical scientific management and how industrial engineering has been the critical success factor in Lean and TQM systems (Womack & Jones, 1996; Hellsten and Klesfjo, 2000; Escrig-Tena, 2004; Catchpole et al, 2007).

Neither the organisational or operations management bodies of knowledge deal effectively with high variety and low volume sectors or studies of safety/error management. Most academic studies of quality management have rarely ventured into this classification of production organisation. In the few occasions that studies have done so they have tended to concentrate on the tools/techniques used or the use of quality management practices from an employee and perceptual approach Clifford &

Sohal (1998). As such, a study of this sector presents a major addition to the body of knowledge in this difficult industrial sector.

In spite of well published literature by Hill (1987) & Slack (1991) the concept of 'manufacturing sub-systems' has not been fully integrated into the organisational literatures and safety literatures have not explored the application of lean ways of working. Within the operations management field of study, working practices often run ahead of academic models and this is particularly true of high performance operations management which has continued to study working practices and their emulation rather than looking deeper into the design of the system – the biggest culprit of this lack of study concerns the emulation of Japanese TQM systems by Western businesses. However, the researcher found that, unlike bureaucratic monopoly manufacturers, the evidence of studies of regulated industries that face commercial pressures to change is limited. As such, the combination of STST and modern operations management is timely and adds significant understanding as to how leaner and safe working practices can coexist. This study also sheds light on the design of safe systems and how an autonomous team structure is counter to the organisational literature of bureaucracy, there is a slowness of decision making resulting in a negative impact on performance, thus limiting the possible achievements of a system design.

In order to understand this operations management (OM) design dilemma further the researcher will now discuss the main features of 'manufacturing sub-systems' starting with the origins of contemporary management thinking based on the work of Skinner (1974). Skinner was the first researcher to argue that operations management could be a means of competitive advantage – if the operations subsystem was correctly designed and integrated within the organisation rather than treating operations management as a purely isolated activity conducted by insular industrial engineers (the consequence and legacy of the scientific management era). His model of manufacturing advocated a strategic elevation of operations management (away from a functional specialism and towards a strategically integrated executive decision-maker). His proposal was that, if well designed, OM should provide a pivotal role within an organisational structure and this mantra has guided operations management thinking for the last 40 years. Leading figures, exemplar practitioners and theorists have all, to a greater or lesser extent of explicit acknowledgement, held this view over the past 30 years (Hayes & Wheelwright, 1984;Womack & Jones, 1996; Schonberger, 2002; and Peters, 1993).

Skinner's work (1974) has also influenced the rise of *'quality thinking'* within operations management because he challenged the myopic attention to cost under the traditional model and he argued in favour of additional performance objectives for operations management – notably quality. It is also important to note that at the time of Skinner's work the codification of Total Quality Management practices by Deming (1986) was also happening albeit America remained impervious to these ideas until the late 1980s. It should be noted that at this time the works of the socio-technical systems theorists such as Emery & Trist (1963) were also gaining popularity amongst organisational managers in the UK and Europe, based on the introduction and business benefits of autonomous team working but in the absence of TQM. The combination of these authors and the general themes in the literature was a strong rejection of demarcated business functions (classical 'scientific management') and an organisation and operations subsystem that is based on greater participation, devolution of decision-making, and an awareness of process management.

Although Skinner never gave up his belief that 'cost' would always be the key performance objective for operations systems but that it should be joined by others, his thoughts have migrated through various other generations of operations management authors to resulting in a new 'no trade-off' approach to operations performance objectives (Slack et al, 2008). The new position suggests that when cost is seen as an outcome of an operations management system, the primary objective then becomes the focus of the product itself, in terms of achieving quality, and then delivery capabilities. In other words, traditional trade-offs would have included the cost of the product versus the quality of the product, such that managers would expect to charge a premium for higher quality products. Whereas when a higher emphasis is placed on quality as the key performance objective, the organisational performance results in lower waste and theoretically lower costs (figure 2.9).

Figure 2.9 Dimensions of Manufacturing Strategy

	Hypothesis
1	The operations or manufacturing function can be a strong competitive resource if properly designed and operated.
2	Cost, efficiency and productivity, while commonly accepted as the most important performance objectives, are generally too narrow and limited and, paradoxically, self-defeating to create competitive advantage. The following performance objectives need to be considered: Cost, efficiency, and productivity Flexibility for product change The investment required in the production system Delivery lead-times, Quality, Service & reliability. Flexibility for volume change
3	A focused strategic objective or 'manufacturing task' based on one or two of the above objectives is derived from the firm's competitive strategy, economics and technological opportunities.
4	To meet the strategic objective, operations system must be designed and tailored to focus on that task, with limited ranges of products, markets, technologies, degrees of process demands and order quantities.
5	The key job of high-level managers is the design of the supporting structure of OM. A strategically designed structure is the key to the operations function becoming a powerful competitive weapon.
6	The structure of an operating system is derived from decisions concerning 'make versus buy', capacity, equipment and processes, number size and location of facilities, what products are made in which plants, and the management systems for production planning, scheduling and control, information systems, quality control, organisational structure, and work-force management.

Source: Taken From Skinner (1974)

Schonberger (2002) was one of the first authors to contend the 'no trade-off' argument, claiming that when quality is considered as the first objective of an operational management system, almost all other key performance indicators (KPI) are affected positively. In other words, if quality improves then efficiency, in terms of flow, is increased thereby manifesting in less cost, and improved, lead-time performance that can be passed onto the customer in terms of increased customer satisfaction. The critical issue presented by Schonberger was the prioritisation of quality methods and its causal link to higher performance. This theme has continued to the present day and few authors have contradicted this new logic of operations system design. Although Schonberger clearly shows quality as a strategic and measured part of operations management, he proposes no further design advice concerning how best to structure quality management and sustained improvement.

The model as shown below in figure 2.10 typifies the 'no trade-off' position where quality and delivery are characteristics of a high performing operational management system.

Figure 2.10 Trade-off Selections for Manufacturing Strategies

Trade-off Proposition	Mass Production Logic	New Wisdom
Lead time vs. delivery reliability	Yes	No
Quality capability vs. quality consistency	Yes	No
Quality consistency vs. price	Yes	No
Quality capability vs. price	Yes	Yes
Design flexibility vs. price	Yes	Yes
Design flexibility vs. lead-time	Yes	Yes
Lead-time vs. flexibility	Yes	Reduced level of impact

Source: adapted from New (1992)

The main principle of the 'no trade off' school of operations management thought is the need to align operations structures with organic and flexible teams (Slack, 1991; New, 1992). Such an approach is reinforced by Roth (1995) in his empirical study of 782 British manufacturers. He discovered that high performing business which operated with multiple objectives were found to be more successful than scientific forms of manufacturing and that these businesses worked in a 'quality first' mode. Baker & Mapes (1996) also supported the quality approach and argued that, as a primary performance objective, it supported high performance and that when a quality first approach is taken *"Most measures of operating performance show a significant positive correlation's with each other"* There is widespread support for the concept that performance indicators can be mastered through a process of competency, which commences with quality management. However, less evidence was offered about the best structure with which to enact this process of mastery or how contingency factors impact upon the most likely design of the business. However modern approaches to improvement such as Lean and TQM have implicitly and explicitly accepted that all improvement commences with a mastery of quality methods/performance reliability. See figure 2.11.

Figure 2.11 Five Forms of Manufacturing Advantage

Market Advantage	Role of Operations Management	Key Performance Indicators	Supporting Authors
Quality	To make things right.	Internal & Customer defect levels.	Deming (1982) Oakland (1989) Garvin (1992).
Speed	To make things fast.	Value-adding ratio & throughput times.	Mather (1988), Plossl (1991).
Delivery	To make things on time.	On-time delivery, frequency of delivery & buffer levels.	Hall (1987), Plossl (1991)
Flexibility	Changing and updating what is made.	Changeover times & ability to late-configure products (customisation).	Shingo (1986), DeMeyer et al (1989), Hamel & Prahalad (1994).
Cost	To make things cheaply.	Cost of manufacturing, supplies & overheads.	Skinner (1974), Fine & Hax (1985).

Source: Adapted from Slack (1991) pp 7-8

2.6 Critique of Operations Management Performance Objective Logic

Having reviewed the operations management literature, the term 'safety management' is wholly absent from these models and is, at best, implicit in the term quality management and quality focus. This omission may well reflect the focus of the operation management researchers, within new and volume orientated production processes, which are characterised as linear in their design.

Interestingly, there is no mention of safety management as a key performance measure in the operations management literature (Slack, 1991). Further there is a dominance of studies from batch processes (Hayes and Wheelwright, 1984) and Hill (1987), which fail to show any clear indication of the optimal structure with which to enact or build the high performance organisation (regardless of whether that high variety/low volume business is within a regulated sector or not).

Under batch processes where volume is high, repetition is high and safety factors are comparatively lower than those of high variety and low volume production of safety critical devices – such as the context of non-linier environments for example, aero engine overhaul & repair. In highlighting this position the researcher contends that the human element of quality control falls short in its explanation of how to manage engineering activities within the context of TQM generally and that this lack of safety management has allowed a theme of 'delivery' to emerge in the literature or at best the implicit belief that safety is an element of the quality approach itself. Whichever view is taken, the current operations management literature is weak and potentially flawed.

2.7 Operations Management and High Performance Structures

Reflecting upon the operations management and socio-technical systems thinking literatures there is a common focus on organic and team based structures that enact the practices needed to achieve high quality performance. From the operations management it is not clear how such a team approach can work in a system of self-management, without a single person who is responsible for team quality performance. Within the STST literature there is a position known as the 'linking pin' (a supervisor), most operations management authors have named this position – the team leader (Womack and Jones, 1996; Levey and Munck, 2002; McCulloch et al, 2010). The position of team leader derives from the preferred structure of Japanese high performance businesses such as Toyota (Hampson, 1999; Haynes, 1999, Radnor and Boaden, 2004).

A team leader is therefore the front line of management who takes responsibility for the management of the team and operational controls such as safe working and human factors (Parker, 2003; Harshit, 2005). This role is much broader than that of the supervisor as defined by authors such as Mullins (1993). Within the context of self-managed teams – the team leader is absent by initial design or has been removed during an adaptation to the current state operations management structure. As such, there is no focal accountability even though systems will inevitably have latent failure causes and self-management relies upon an extremely high level of self-discipline by the individual.

Without this central role it is posited by the researcher that the team will lack focus, coordination and have no means of translating or directing efforts to improve quality performance. In this manner the team becomes exposed to commercial pressures as a group and manage their own human factors compliance of a process that most operations authors believe is critical to high performance.

The implications of the quality-first underpinning to performance objectives and the modern approach to highly performing systems are that accepting quality as a primary driver for business performance does not limit nor imply which structures are best in terms of a mechanistic or an organic approach (the strategy: structure debate to which this chapter will return). Furthermore, if self management is considered the most evolved stage of deployed decision making and the closest way to control the production process then the operations management literature confirms the need to research the high variety, low volume and high discretion/regulated operations systems. Again this cursory review of operations systems performance objectives confirms the importance of the main research question of this study and

"To what extent can self-managed team working, facilitate the principles of safe Total Quality Management?"

Within the context of the aviation industry and the management of life-threatening safety errors, this gap in the body of knowledge deserves to be closed as part of the contribution of this study.

The strategy (codified into operations management performance objectives) and the structure of the organisation to ensure high quality is a subject to which the technical safety literature has also paid insufficient attention. Reason (2003), the human factor safety guru, stops far short of acknowledging the role of improvement and quality processes in favour of a more technical view of safety and safe systems using bureaucratic supervision. Reason himself makes mention of team working or its impact, positive or negative, on safety compliance and high performance or high reliability. This thesis concerns effective team working for safety and high performance management. The term high performance is elusive and there are no measures of 'world class' standards. For the purpose of this thesis, the term high performance means a compliance with EASA regulation part 145 (the global standard) as well as local measures of quality, on time in full delivery and safety compliance indicators including reported accidents, near miss reporting, poor behavioural safety practices and the number of changes requested by operating teams to enhance the resilience of the operating system.

However, Reason does draw a causal linkage between the working environment, stress levels that result from commercial pressures to deliver product, and management weaknesses as key sources of system failure. He argues that these are contributory factors to individual breaches of safety. In this respect Reason implies that structure is more important than strategy and, to a high degree, commercial pressures and total quality management practices/learning how to improve processes by teams is secondary to enforced policing of the operations system by the supervisor/specialist. Self-management should be avoided on the grounds of the need to separate production from inspection. Reason's systems model therefore deals ineffectively with issues such as team working, responsibility and accountability for quality, and the role of the specialist as a system designer who will never work within it. Before building a model of safety management, the researcher will continue to explore the role of Total Quality and its impact on operations management designs.

To put in context the importance of structures for safety management and the importance of quality management practices (as a means of learning how to improve) it is first necessary to explore the evolution of industrial quality thinking. The Total Quality Management leading thinkers also present alternative models of organisational structures and stress certain working practices as associated with high performance. The next section of this chapter will review the evolution and contribution of Total Quality Management on contemporary management.

Modern models of high performance operations management rest heavily upon a foundation of technical TQM and also the soft 'human' aspects of TQM that determine the adaptive capability of the firm (improvement) and the ultimate determinate of performance (employees determine how optimally the technology is used). Various studies have confirmed this relationship with high performance and a process based view of operations management (rather than a functional view). As such business systems are treated as dependent and integrated processes, which are not reliant on individual activities; this is another significant parallel with STST theories as previously discussed.

2.8 A Brief History of Industrial Quality Evolution

Industrial quality management grew as a mainstream aspect of engineering knowledge when it began to be codified after the Second World War (and during the latter part of mass production and the scientific management era). From this point in history, quality management grew from the sole prerogative of quality inspectors to quality management practices vested in every employee. Total Quality Management is therefore 'total', all embracing and covers the activities of the entire organisation including the design of operations systems and their daily management (Hines et al, 2004). In this manner, it can be seen that TQM has a very critical impact on the skills of personnel, the robustness of processes and how learning results in improvement at the workplace

Early theories of operations management were based upon industrial engineering and the scientific management approach of Taylor (1947). This approach denied employees the engagement with process management where no skills were transferred to employees and all quality management authority was vested in engineers. As such, standardised work and close supervision, with the treatment of workers as automatons, typified this approach/ business model that saw employees as money motivated and untrustworthy (Mullins, 1993).

Safety failures were therefore considered not to result from the system but from the individual (carelessness, deliberate sabotage etc.) of an uneducated workforce. Indeed historical records show that safety management was a low priority with deaths being common in many workplaces. Similarly quality standards were designed by engineers, and quality specialists served as arbiters of good and bad using final inspection of the work produced – the employee was divorced from this responsibility. The job description of the operator reflected instead the quantity of work conducted often regardless of its quality (Fisher & Nair, 2009). Functional specialisation was commonplace with demarcated silo's and 'command and control' management practices. Another central belief was that if left unmanaged workers would stop all production through the concept of 'systematic soldiering' (Taylor, 1947), the countermeasure to which was greater levels of supervision. Taylor proposed, *"What workman want from their employers beyond anything else is high wages. What employers want beyond anything else is low labour costs"* and this statement shows the friction and alienation of the worker (a mechanistic design as outlined by the contingency theorists Burns & Stalker 1961).

Such a mechanistic approach to the design and structure of the industrial organisation worked well in many US and European aviation organisations and these businesses prospered from this approach. The UK by contrast, struggled to deliver the same standards of success, which Kogut & Parkinson (1993) explain in terms of a lack of investment in capital intensity and training to support a growing and formalised socio-technical system. However, the mass production approach and its logic underpinned the manner in which British businesses were managed, structured and controlled (Weber, 1948).

Burns (2000) claimed that scientific management still remains a dominant factor in most UK aerospace businesses today, owing to its heavily regulated systems of production, where written rules and procedures have proven successful in ensuring the safety requirements of complex aircraft system law. As such, the industry tends towards a system of rules and compliance and regulatory bodies that favour mechanistic approaches to operations management rather than creativity, learning and improvement. Further to this claim, Burns argues that the scientific approach also provides a wholly legitimate quality framework where managers can remain legally accountable for the safety implications of quality, based on what he termed as the rational system of industrial control. In this respect the study has encountered another phenomenon that is worthy of additional study – a further conflict between the traditionally dominant model of scientific management and that of self-managing work teams. The formalisation of the scientific method regime at least ensured quality standards through formalisation and direct supervision whereas self-managing teams lack these levels of defence and error management.

The scientific approach relies upon formalised rules and bureaucracy as first proposed by Weber (1948), who proclaimed that bureaucracy should remain a central feature of scientific management, because it eliminated what he referred to as 'human fallibility', based on following the principles of *'There is one best way for all organisations'*. Such an approach legitimised managerial authority and the management prerogative to design systems within a scientific approach to rationality whilst managing a business for profit.

The managerial prerogative was offset by a perception that the workforce was motivated only by money, and the fallibility of employees was an individual problem,

which, if it were to persist, should result in the termination of the individual's employment. In this manner safe working was considered an individual issue and not, as is currently the view, the result of a poorly designed or an adaptive system of latent errors. These financial motivations are increasingly questioned by recent organisational theorists who propose instead that the team is the fundamental building block of the modern 'consensus based' organisation (Kanter, 1989, Womack and Jones, 1996). These traditional values are contra to the principles of STST; a more modern approach to quality management has much greater empathy with the STST approach whilst still providing a rigorous method of quality control (Pasmore, 1988).
During the scientific management phase of management thinking, the dominant classical management model regarded quality management as a business function and not a process. A subsequent lack of investment in employee skills and a focus on quality in terms of specialist departments created problems for new business when the power of demand and supply switched away from the producer and on to the consumer. This switch exposed problems with the insular and functional specialist view of quality and placed a greater need to ensure process control and the engagement of more workers to support the specialists. In other words, quality became more of an individually owned concept rather than the problem of the quality department.

2.9 Moving From Quality Inspection to Quality Management

The switch away from functional quality inspection and control also suited engineers (those employees with the greatest technical skills) who were also dislocated by the system design in so much as they were ultimately held accountable for quality even though the performance of the operator was actually the causal activity that generated the quality output measure. The new move to process quality assurance therefore opened many new avenues for the engineers themselves and enabled a more proactive and cross-functional 'team' approach to be undertaken. Further, the move to the new era of quality assurance re-skilled the workforce and the pressure of powerful consumers meant that the cost of poor quality rose dramatically at the same time that the lead-times for products were reduced (Deming, 1982). The need for process quality assurance to satisfy consumer pressures therefore required a more organic and less 'functional silo' structure to the business and from the 1960s onwards markets became more competitive and required a much quicker response to market demands. By the 1980s businesses had evolved and emerged with organisational processes that were more adaptive, where the quality approach was one of total quality management involving all business processes. These innovations were stimulated and greatly accelerated by the exposure and publication of Japanese high performance working practices. Figure 2.12 shows the major differences between the traditional management methods of scientific quality management and that of TQM, which has emerged since the 1980's (Seddon, 2000).

Figure 2.12 Scientific Management vs. Total Quality Management

Perspective	Scientific Quality Management	Total Quality Management
Design of work	Silo Management	Flow Driven
Attitude to customers	Contractual	Value Driven
Decision-making	Separated from work	Team Work
Measurement	Related to budget	Customer Related
Attitude to suppliers	Contractual	Co-operative
Management ethos	Budgets & people	Learning Culture

Source: Taken from Seddon (2000)

It should be noted that even today where aerospace organisations have become more aligned with the concept of organic structures there are still working practices that resemble this earlier period of industrial history. Mullins (1993) contends that aerospace organisations have provided resistance to such a general trend of manufacturing and have favoured the practice of 'closed book' management, which is of particular significance to this study. Again Mullins' (1993) arguments provide a contradiction and gap in the body of operations management knowledge. Such a gap suggests either unwillingness or an inability to reconcile the contingencies of aerospace with the practices of TQM.

2.10 The Requirements of TQM

The newly emerging model of TQM for general industry required development of new internal relationships and a capability for improvement rather than management by 'rulebook' and command/control in isolation to a team approach (Bootzin, 1983). Bootzin claimed that as organisations grow they would also experience the need for improvement and for businesses to become more flexible/adaptive to meet commercial needs (an open systems approach to business). The impact of consumerism means businesses that cannot react quickly and provide customers what they want will, he argued, decline. From the literature review of TQM, the researcher compiled an evolutionary model of management thinking with five distinct stages of development (figure 2.13). The first stage of the summary model is most closely featured within the classical school of 'scientific' management, which as discussed previously is the oldest and most traditional form of a quality management system. As industrial systems grew this approach during the 1970s developed into a more mathematical and graphical approach that sought to measure and control processes using statistical forms of analyses. The responsibility for managing this approach rested with the quality department as opposed to the individual. Although, by the 1980s, the focus had once again changed towards a more compliance-based methodology that used organisational systems, which were formally documented and controlled through audited quality management systems such as BS5750 and ISO 9001 (the accreditation award was based on a third party audit of practices). The watershed point in contemporary TQM thinking occurred during the 1990's and reflected an approach to company-wide integration including the embedding of total quality language and mental models within the values and goals of the business (Storey 1994). By the early 2000s the view of total quality management had for all businesses, and the aero industry in particular, met with major problems in terms of a system that was failing to deliver the quality assurance performance levels that were expected by consumers and set by competitors (primarily Japanese businesses).

The last evolution presented in the model is the 5th stage, which has not been proposed by any other operations management or human factors author, is the concept of TQM management practice that is extended to cover the quality of the entire process from repair to returning the aircraft to service (an integrated supply chain approach). The fifth stage therefore integrates human factors engineering with decentralized management and autonomous teams as a natural extension of the management 'best practices' in the structure, execution and improvement of work.

As can be seen in figure 2.13, the precision and seductive rationality of the classical approach and all of its management benefits conflict with the modern approach to team based improvements. These frictions have not 'gone away' and modern models of high performance operations management continue to wrestle with the human resource issue. Many studies show how businesses have engaged team structures and yet still failed to generate the level of improvements necessary to compete Wellins

(1992) and even more show a clear correlation of success with a 'top down' management approach (Womack and Jones, 1996).

Figure 2.13 Historical Overview of Quality System from 1950 To 2009

Identifying Characteristics	Stage 1 Inspection 1950s	Stage 2 Statistical Quality Control 1970s	Stage 3 Quality Assurance ISO 9000 1980s	Stage 4 Total Quality Management 1990s	Stage 5 Human Factors In Quality Management 2000+
Theoretical Perspectives	Scientific	Scientific	Scientific & Humanistic	Humanistic	Scientific & Humanistic
Quality Perspectives	Problems To Resolve	Problems To Resolve	A Problem To Be Resolved Proactively	A Competitive Opportunity	Problems To Resolve
Concerns	Detection	Control	Coordination	Strategic Impact	Safety
Theoretical Authors	Weber (1948) Taylor (1947) Drucker (1990)	Shainin (1957) Deming (1960) Shingo (1985)	Ishikawa (1984) Herzberg (1987) Akao (1990)	Juran (1944) Maslow (1987) Goldratt (1994)	Rasmussen (1998) Reason (2003) West (2004)
Emphasis	Product Uniformity	Product Uniformity With Inspection	Engaging The Entire Production System	The Market Based On Customer Needs Removing Waste & Variation	Quality Based On Socio-Technical Equilibriums
Methods	Gauging & Measurement	Statistical Tools & Techniques	Programs & Systems	Six Sigma & Lean	Maintenance Error Decision Aid
Role of Quality Professionals	Inspection Sorting Counting & Grading	Troubleshooting	Quality Measurement & Quality Planning	Facilitation Educators Goal Setting	Analyzing Input vs. Output Human Factors
Roles & Responsibilities	Inspection Departments Rift between creating problem and detecting it	Manufacturing & Engineering	All Departments	Self-Managed Teamwork Based On Quality Being Everyone's Responsibility	Psychologists Engineers & Managers
Orientation & Approach	Inspects In Quality	Controls In Quality	Builds In Quality	Managers In Quality	Human Factors In Quality
Human factors system	Deskilled operators controlled by specialist (Reactive)	Closer monitoring of operators using charting (Reactive)	Compliance to formalized and established processes (Reactive)	Shared knowledge Process controls and designed-out failings Personal responsibility for quality	TQM features but with addition of Defence mechanisms and reintroduced inspectors

Source : Researcher Literature Review.

2.11 Inspiring the New TQM Model

The position of the *'founding father'* of modern TQM is accredited to the American, W Edwards Deming (Bicheno & Catherwood, 2006) who, after the Second World War, was sent to Japan to help recover the country's shattered industrial economy his work continued the general theme of human factors and system performance by management design. Despite the age of his work and theories they remain pertinent to modern businesses and few businesses have actually implemented all of his recommendations in order to achieve a highly effective socio-technical system. Deming rose to fame because his views were quickly adopted, in the 1960s, by the Japanese Union of Scientists & Engineers (JUSE)[25] who were keen to use both his knowledge and experience in order to raise the quality levels of their industrial products and also to make the most of the scarce natural resources available within the country. However, Deming's philosophy did not become popular in the UK until the early 1980s, when British businesses began to emulate Japanese working practices to 'Lean' their business/organisational models (Rich, 1999; Bicheno and Catherwood, 2006).

According to Womack & Jones (1990) early attempts of TQM gained global popularity amongst academic management literatures based on the success of industries such as Toyota, Honda and Panasonic. As a direct result of this success, Japanese ways of working were being adopted in many other western consumer markets, there was a rise in Japanese exports to countries like the United States, which in turn lost up to 50% of its automotive manufacturing as a direct result of the philosophy of total quality management movement.

Although, TQM may appear a relatively translatable concept, it should also be noted that a number of variations exist within the main body of TQM literature. The definition extracted from the International Organisation for Standardisation (ISO) that claims TQM as, *"As a management approach for an organization, centered on quality, based on the participation of all its members aimed at long-term success through customer satisfaction, benefiting all members of the organization and society"* (ISO BSEN 9001, 2008).

[25] JUSE is widely known as the Centre of Quality Control in Japan, who is responsible for managing the Deming Awards process.

Oakland (1989) takes a socio-technical view and defined TQM as "*An approach to improving the competitiveness, effectiveness and flexibility of a whole organisation in such a way that brings everyone into the processes of improvement*" He also proposed "*TQM programmes promote quality as a strategic business imperative that requires re-evaluation for how organisational members can address the quality of their work and production /service processes*". These views show a high level of consistency and this is true of operations management and TQM authors as well as between TQM gurus themselves who tend to emphasize its different facets rather than mark a fundamental departure in thinking.

When a comparison was made of the various definitions of TQM, by the researcher, it was found that a common denominator was the use of TQM as a strategic direction-setting device that also stimulated daily improvement processes. These two concepts are embodied in the Japanese phase of TQM, which followed Deming's application of TQM at companies like Toyota. Ishikawa (1984), one of the Japanese academics to be influenced by Deming, argued that managers must learn to both lead and facilitate an effective change control process, based on quality education for all as part of Deming's widely proclaimed 14 points of management. Ishikawa's approach promoted a process based on organisational structure, which has little similarity with the classical and mechanistic management designs associated with Taylor (1947). It favoured a process-based structure, although Deming did accept the scientific methodology and controlled approach to managing businesses. The main techniques offered are based on controlling processes and creating greater transparency in human behaviour.

Another quality management guru to influence modern models of thought was Joseph Juran (1944). Juran was a work colleague of Deming's who was also was promoted by JUSE and is credited with the 'Juran trilogy'. The trilogy is again an attempt to increase the dependencies between teams within a business by promoting the concept of the internal customer and shows how high performance results from an attention to quality between internal business teams. His work also promoted the importance of management in planning 'system transforming' improvements and 'breakthrough projects' to enhance the flow of production by STST redesign. Juran is also credited for adding a human dimension to the field of TQM theory, based on a philanthropic approach that reinforced the STST principle that quality and human resource management are synonymous and only effective designs result in higher performance.

The researcher therefore accepts Juran's contribution based on the philosophy that quality must acknowledge the responsibility for satisfying the complexity of human factors, based on maintaining a balance of resource for social and technological needs. In other words both Deming, and more significantly, Juran believed that quality problems should not be confined to the limitations of hardware system redesign, but extended to the management system of knowledge and skills. A concept, which is duly accepted as a critical factor in the consideration of the main research question where barriers to efficiency and effectiveness amongst self-managed teams could be seen as a direct result of inadequate socio-technical systems design. Juran was not alone in his line of thinking and as such the importance of effective socio-technical systems was closley associated with the work of Ishikawa (1984) within the context of 'quality circles'. Ishikawa's contribution was therefore accepted as relevent to the design of this study, based on Lean methods tool and techniques that sought to enhance problem-solving skills between the manager and his or her self-managed team. Despite the apparent difference in approaches between TQM theorists, Storey (1994) argued that there is a commonality between what they recommend in terms of enablers for successful implementation.

Whilst much can be learned from the application of TQM and its impact on performance and internal relationships there is another set of studies that suggest the ideals of TQM are very hard to apply and even harder to sustain. The failings of TQM will now be reviewed.

2.12 The Difficulties of Implementing TQM

Total quality has grown to become the dominant logic of businesses in all sectors of the economy and quality improvement is now, in the modern operations literature, a precursor to high performance and leaner ways of working (Womack and Jones, 1996). However, the reality of TQM implementation and successful exploitation in terms of performance objectives shows the application of TQM may well be much harder than portrayed by the quality gurus. Research carried out by Usilaner (1993) focused on the failings of organisations to change from the previous regime of scientific management to the TQM model (figure 2.14). His research showed a number of major differences that exist between organisations who had succeeded with TQM compared with those who had failed.

Kearney (2002) confirms Usilaner's view and provides research that showed in approximately 80% of all TQM programmes, none had been able to demonstrate any form of statistical success. For example 30% of the companies who took part in their study failed to report any significant improvements and furthermore 50% had no available information to demonstrate the quality of their business performance, although there was good evidence of the use of quality systems such as ISO 9000. But most, if not all, companies who took part in Kearney's study experienced difficulties in adapting to the implementation of TQM especially when moving to the higher stages of business evolution (those features shown in the researcher's model presented previously).

Figure 2.14 Characteristics of Failing TQM Programmes

Characteristics of Successful TQM Programs	Characteristics of TQM Programs That Fail
Active top management leadership and commitment	Minimal top management support
TQM is considered to be in a state of permanent change based on culture, structure and processes	Failure to recognize the need for fundamental change with accompanying emphasis on TQM training, tools, and techniques.
Well defined and widely communicated organizational strategies	Lack of overall organisational strategy.
TQM concepts integrated into the fabric of the organization with well-established reward and recognition programs.	Minimal integration of TQM with existing processes, and strategies
Persistent, long term objectives and results	Expectations of quick results not achieved or sustained over time.

Source: Taken From Usilaner, 1993

Contributing to this discussion, Seddon (2000) argues for the existence of structural rift when some organisations attempt to practice scientific management in conjunction with the philosophy of TQM. The resultant factor being that these two systems were diametrically opposed and could never co-exist. Although Seddon says nothing of the 'soft' system literature concerning TQM failures that has been highlighted by other

TQM theorists, who claim that a general lack of investment is more likely to represent the root cause of TQM failure itself.

Arumugam (2005), using case research, revealed the significance of the implementation and sustainability of the soft aspects in TQM organisations. He considered that the correct design of these issues and the engagement of staff was essential for sustainability and long-term success. His study, based on a large Malaysian semi-conductor organisation, investigated the effects of soft issues when sustaining TQM from the perspective of employee's attitudes to quality. The results, taken from 230 employees, revealed a significant relationship between individual attitudes towards quality that correlated with the organisational commitment of safety related factors.

Eskildson (2004) provides further support for the need of a bias for softer elements of the STS design and concluded that those management teams that used greater engagement techniques and available attitudinal measures when implementing TQM had fewer difficulties with lasting change.

In summary, the literature review has identified many aspects of quality management literature which suggests that, in the majority of cases, problems with quality, scientific or TQM are centred on the existence of gaps in social dimensions. It was Emery (1969) and later Pasmore (1988) who contended this position from an STST perspective and acknowledged it as a vital consideration in the successful application of operational management thinking. Ineffective socio-technical designs are likely to have created an environment, which is not conducive to the role and function of teams (self-managed or not). The OM literature has therefore shown that to become a world-class business or perform at the highest level possible, the mastery of quality must be applied. The first stage of which is duly accepted by the researcher from the approach put forward by Schonberger (2002) who argued that change management must be an integral feature of quality practice as a means of engendering a more efficient and effective range of methods to improve operational performance of material flows.

2.13 TQM and the Aerospace Sector

With reference to the aerospace sector, the direct results of the changes over time to management thought have not always resulted in emulation of 'world class' models, even though the industry may want to engage in such practices, and have often been the subject of regulator scrutiny. The changes to the management of quality prompted legal intervention in the sector, which has been constrained by prediction of future accidents and the need for more defence mechanisms to be introduced (separate inspection departments) to maintain a divorce between quality responsibility and operations/commercial responsibility). In other words value is not just a customer concept but should be considered as trade-off between the customer and the industry regulator. As such, any safety critical organisation such as the one found in this study must comply with regulator constraints that may limit what can be achieved from a quality and delivery point of view. The role of EASA therefore acted as a mediator to this position on behalf of CAA member states, major changes were enforced during the early part of 2004, and quality and productivity management were deliberately separated thus forging a new safety driven approach within TQM. Under these regulations the organisational structures through which operations and quality staff reported were deliberately disconnected to avoid any chance of conflicts of interest and the sacrificing of safety/quality for production performance. This intervention therefore added a new dimension to the organisational puzzle as to how best to structure the software and human aspects of the aerospace socio technical system. This single move therefore served to question the extent to which TQM could really be engaged by aerospace companies and, more germane to this study, whether self-managing operations teams could actually survive under these regulations.

Since July 2004, it is now a legal requirement for aero repair businesses to engage with new safety regulations that emphasise greater levels of control of quality operating management systems. Previously the management of product and process safety was seen as a key and integral facet of quality management, which in spite of the best interests of TQM researchers, had, to a large extent been completely ignored the lack of human factors thinking in the operations management literatures has added to this lack of management guidelines for effective TQM in repair businesses.

However, as previously noted this model does not rest well with the regulated aerospace sector and is a deductive model based upon trends in the organizational management literatures. These conflicts have not been explored in the academic literatures that focus on the organisation unlike the abundance of psychological literature regarding the pilot; even here the literature focuses on errors rather than quality management aspects of operations. The previous section has addressed the role of quality (TQM) as the first stage on the development of an operations system that performs well and enagages all staff in the improvement process. The next section will address the technical and hard aspects of high performance STST designs.

2.14 High Performance Management: Exploring the Focal Literature of Modern Total Quality Management & Lean Operations

The linking literature between the background systems theory, especially STST, and the focal operations management literature is that of the body of knowledge concerning organisational Total Quality Management (TQM) and the harder process flow enabling innovations known as Lean Manufacturing (LM). The technical attributes of high performing systems Nave (2002) describes as Lean/Sigma methodologies that provide the current evolution of quality thinking and the interface between quality and delivery performance objectives. In simple terms, these improvement processes blend:

1. Efficiency – The Lean Approach[26] and Sigma Approach[27]
2. Effectiveness – Customer service and cost effective operations

Bicheno & Catherwood (2006) provide a comparative background of the two approaches (shown in figure 2.15) and these features are now accepted as the key features of world-class organisations. According to Bicheno (2004) these improvement systems are both reliant upon consensus and process based management, for a modern technical systems design and a migration from mass production to the exploitation of TQM.

[26] Lean according to Ohno (1985)*"Improves performance and leads to leaner operations, which in turn highlights poor quality and the need for change"* Based on the concept of PDCA.

[27] Six Sigma is a methodology that relies heavily on statistical techniques to reduce defects using a methodology known as DMAIC (Define, Measure, Analyse, Improve and Control).

Figure 2.15 **Lean and Six Sigma Methods**

Area	Lean	Six Sigma
Objectives	Reduce Waste & Improve Customer Value	Reduce Variation & improve Customer Value
Framework	5 Principles (Not Always Followed)	DMAIC (Always Followed)
Focus	Value Streams	Project Focus
Improvement	Many Small Improvements	Small Number of Large Projects
Goals	Cost – Quality – Delivery – Lead Time	Improve sigma Levels 3.4 DPMO
Time Horizon	Long-Term – Continuous	Short Term Project By Project
People & Improvement	Team led at different levels	Black Belts Supported by Green Belts
Tools	Often Simple But Complex To Use	Complex & Statistical
Typical Early steps	Map the Value Stream	Collect Data On Process Variation
Impact	Large & System Wide	Cost saving Project Approach
Problem Root Causes	5 Whys (Weak)	Design Of Experiments (Strong)

Source: Bicheno & Catherwood (2006)

2.15 Lean & Six Sigma

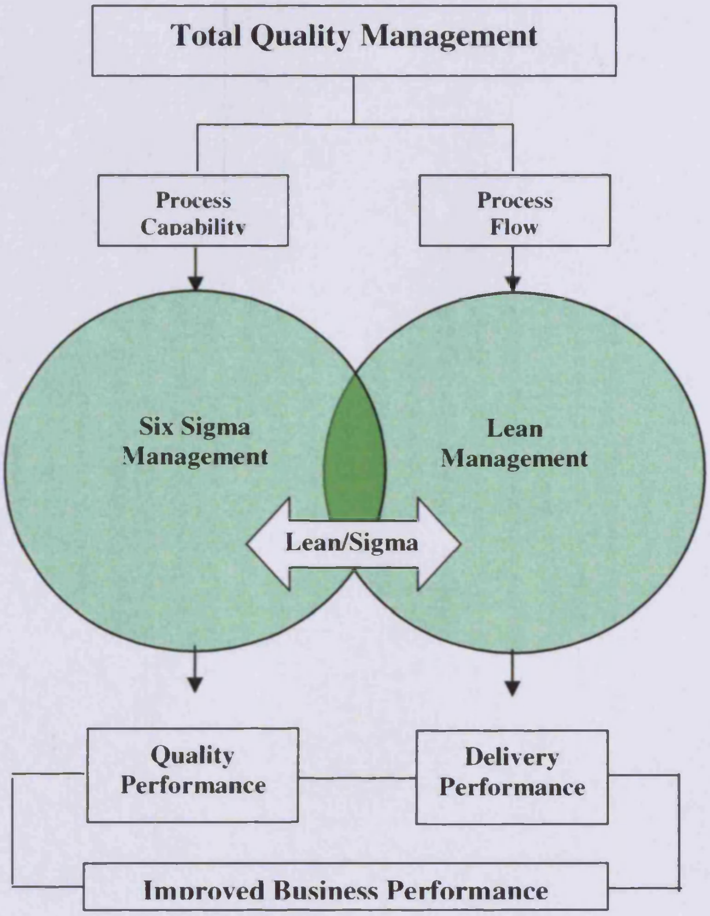
Over the past 20 years, these two improvement schools of thought have emerged concerning high performance operations management. One approach favours the understanding of process variation and its strict control by management and worker and is known as the 'Six Sigma' approach. The second approach, drawing from empirical studies of the demonstrated high performance of Japanese businesses (such as Toyota, Nissan, etc) focuses on eliminating waste and solving issues by exposing them as inhibitors to material flow. The latter approach is known as the 'Lean approach'.

Whilst these approaches have a common foundation involving better performance they do have differences that are worthy of exploration in this study. Both these approaches have a distinct logic and approach to management, structures and improvement processes. Indeed, to many authors, these approaches can be integrated and Drickhamer (2002) proposes the merger of these two approaches to form the Lean-Sigma hybrid offers *"...the solution to many complex and long-standing* [quality] *problems"*. This view and approach is reinforced by other authors including Bicheno (2004) who draws a direct correlation between Lean Six-Sigma and world-class performance. The main features of this approach are shown in figure 2.16.

In effect, the Six-Sigma approach is based on the mastery of Slack's (1991) quality performance objective and then the delivery of products using the material flow focus of the Lean approach. These approaches were first combined by Japanese companies such as Toyota who used quality management as a means of engaging just in time innovations in material flow systems (Ohno, 1985; Monden, 1993, Liker, 2004).

Figure 2.16

The Technical System Model of contemporary TQM



Source: Researcher

2.16 Improving Process Capability - The Six Sigma Approach

Chowdhury (2001) claims, *"Six Sigma is both a philosophy and methodology in which an organisation continuously improves its processes, with the aim of defect free manufacturing"*. The term Six Sigma itself is a measure of near-perfect performance (3.4 defects produced in one million units produced). However, many authors propose that it is merely a modern reinvention of the earlier quality tools associated with gurus such as Juran, Deming, Ishikawa and others (Rich, 1999) and a means of catching up with the levels of performance already achieved by the Japanese high performance businesses.

Figure 2.17 **Capability Conversion Chart**

Sigma (6σ),	Defects per Million
6	3.4
5	230
4	6,200
3	68,000
2	308,500
1	691,500

The Six Sigma approach was first popularised by the US company Motorola. Its chairman, at the time, Smith (1998), first introduced the concept of Six Sigma and this was later refined by the General Electric Corporation. Chowdhury (2001) argues that the Six-Sigma approach is an approach to statistical problem solving using a range of tools and techniques to understand and improve process variation. He proposes that the approach will enable much less variation to happen through a better understanding of the relationship between inputs and outputs. He further states that the approach uses a rigorous methodology to systematically address defects and the potential for defective production. This approach is known as DMAIC (Define, Measure, Analyse, Improve and Control) and represents the five stages of project execution, it is an approach to reduce the complexity of problems and lead to their resolution.

According to Bicheno (2000) Six Sigma is a *"hard nosed approach based on facts, which are easy to communicate and works well in process driven structures"*. However, Bicheno stops far short of explaining what a 'driven structure' is but he implies that the structure is a pyramid of Six Sigma experts located throughout the business with the intention of lowering process variability.

This approach uses a staged qualification with levels known as 'belts' commencing with 'Green Belts' and ending with 'Black belts' 'Master Black Belts'. Six Sigma therefore promotes a 'management by fact' culture based on the belief that all improvement projects should be kept simple, measurable, agreed to, realistic and time-based. (SMART) In light of this it is known to place a very strong emphasis on the measurement phase of process problems, based on data, which is quantitative rather than qualitative in its approach. It can, therefore, provide a methodology, which systematically addresses the root cause of many chronic or long-term quality related problems. In order to demonstrate this position a level of process stability is established based on numbers of 'Defect Parts per Million Opportunities' (DPMO)[28] For example, measuring process variation through statistical processes control (SPC)[29] is a process by which end users, or more importantly engineering teams, are able to measure the performance of a process in terms of defected parts per million opportunities. The term Six Sigma, derives from a statistical measure where a process spread or its standard deviation consistently produces no more than 3.4 defects or failures for every one million outputs. For example the higher the Sigma level the lower the defect rate becomes.

Standard & Davis (1999) argue that Six Sigma is one of the most powerful approaches to improving quality; this view is based on the belief that improving process capability is centred on measuring and reducing variation. Such an approach therefore aligns well with the strategic intentions of competitive performance objectives (Slack, 1991) and tools for all grades of personnel based on a 'master Black Belt' expert technical specialist to operator/practitioners known as Green Belts. The difference between grades concerns the advanced statistical and hypothesis testing skills of the master black belt and the less quantitative skills (simpler statistics) of the Green belt. The main strength of this method, with respect to human error and mistakes, is therefore centred on statistical probabilities, where specially trained experts can systematically reduce process variation as a means of creating a culture of continual improvement activity. Other authors have suggested that it relies less on TQM and more on expert mathematical interventions (it avoids the pitfalls of a total engagement of all workers in a consensus TQM approach). Albeit Six Sigma may also be used by businesses that are themselves experienced in TQM methods, structures and softer personnel skills (Cowdrey 2002)

[28] The process was pioneered by Bill Smith at Motorola in 1986 and was originally defined as below 3.4 Defects Per (one) Million Opportunities (DPMO)

[29] Statistical Process Control (*SPC*) is a method used in quality management that measures a process during its operation in order to control the quality of the product or process behaviour itself.

2.17 The Problems of Six Sigma

The problems with Six Sigma again concerns issues of applicability to high variety/low volume production/repair and sustainability of improvements. Further issues include the amount of money and time needed as an investment in training personnel. Such training may also not translate into cultural change but result in employees who religiously follow methods rather than the implicit 'thinking' and problem understanding associated with less mechanistic approaches to TQM. The entire support structure of this approach is inherently complicated and can alienate those who are not 'black belts'.

Another complication concerns the over reliance on statistics Hinckley (2001) warns of the dangers for those organisations that rely on statistics alone, as this approach will not guarantee the highest quality levels. In other words given the extremely rare events which often impact on quality where data is not evenly distributed about the mean the vital few are often ignored. It is therefore important that while controlling what Hinckley refers to as the 'trivial many' the variation paradigm is acknowledged as a means of preventing the dangers of over focus. In other words while Six Sigma is very effective at controlling small variations, it has a reputation for classically ignoring the chronic consequences of 'skewed' data, which often result in the most serious causes of major quality failing. As such it may be impossible to achieve the virtually defect free process performance of the statistical level of 6, Eckes (2001) also notes these dilemmas and states the well-publicised successes of Six Sigma Black Belt practitioners often miss the obvious and therefore such organisations suffer from lack of confidence in what is assumed to be a data driven quality strategy. In addition he notes, some projects can take up a year to complete, which often become very costly. This point is reinforced by Pande & Holpp (2002) in their study of General Electric where project costs in 1997, exceeded 600 million dollars with just 400 million dollars of return. The situation worsened in 1998 with 1 billion dollars of investments, based on 400 million dollars of return. In light of this evidence Velocci (2002), who also studied GE, claims that the underlying failings of Six Sigma for GE were caused by the following list of factors.

1. Lack of focus on the customer
2. Projects are skewed internally
3. Implementation objectives are not linked to the business objectives
4. GE used Six Sigma as a tool for quality and not as a management methodology

5. Lack of involvement of suppliers and customers
6. Lack of benchmarking to promote understanding of competitor performance.

Also, in parallel with the criticisms of TQM, Nicholas (1998) goes on to claim that Six Sigma fails to deal adequately with the issue of sustainability. In other words Nicholas believes it places an over emphasis on technical issues to the detriment of human factors and the problems people have in understanding and managing organisational change.

2.18 A Review of Six Sigma

With so many criticisms of Six Sigma (Seddon, 2000), the researcher is cautious of accepting its full value, based on the argument that statistical analysis in the form of DMAIC (Define, Measure, Analyse, Improve and Control sequential method) is best suited to those environments where processes are already stable, in control and high enough in volume to warrant statistical analysis. It would appear that the short term results, following the investment in training, are usually successful, but in the long term, improving processes will usually involve organisational change and unless fully understood by everyone improvements lose momentum. The latter is a major issue – such changes and confusion in roles, changes to practice etc. are all cited as major causes of human failure and error.

During this study, the researcher has discovered that to be an effective improvement process, Six Sigma organisations must perform at a standard, 3 Sigma or repetitive performance. Such a level of performance is beyond the ability of aerospace repair processes that often operate with a lack of measurable performance data owing to low product volumes that are rich in high process variability, which this approach is not intended to control. In light of this concern, Standard & Davies (1999) also argue that Six Sigma itself has a very limited role within the area of addressing human factors problems. In other words, measuring mistakes through the use of statistical tools can often lead to reductionism, based on what these researchers claim: *"There is no reason to expect the familiar statistical techniques used for controlling variance to have any effect on mistakes. The occurrence of mistakes is not even well modelled by statistics. For example, the probability distribution of screw torque cannot predict whether or not the screw has been installed."* Standard & Davies go to describe this problem in terms of two classes of mistakes (which mirror Reason's latent safety and human factor errors):

1. Mistakes waiting to happen.
2. Mistakes that actually happened

A further concern identified in the literature was the clash of improvement methods that competed for the same resources (money and people) and how programmes like 'Lean' manufacturing are based on teamwork whilst Six Sigma, on the other hand, has promoted an elitist hierarchy of experts who work alone on projects with the aim of improving quality in relation to cost Zairi, (1991) Overall, the researcher reflected that the above approach is an extension of the TQM method which has many elements of TQM but it lacks a suitably 'total' approach to intervention with all employees. A second improvement approach that has gained popularity in many manufacturing sector is Lean manufacturing and leaner ways of working. This will now be reviewed before returning to a discussion of aligning Six Sigma and Lean ways of working.

2.19 Removing Waste & Making Value Flow - The Lean Approach

The second dominant model of industrial improvement has become known as Lean production it emanated from Japanese automotive production and the successful exportation of these working practices to the West. Womack & Jones (1996) claim that this approach is not Japanese but instead based upon the innovations of the car assembler Toyota. The approach to manufacturing is premised on the elimination of waste from any and all manufacturing processes via a process of continuous improvement and business system redesign. These wastes are activities and practices that add no value to the production process or represent any form of added value that the consumer is willing to pay for. Waste is therefore seen as a barrier to both efficiency and effectiveness. Ohno (1985), the innovator of the approach to Lean waste reduction, argues that improved material flow results from fewer delays, less duplication and needs fewer resources to operate the system. Shingo (1986) argues that quality defects are in fact waste he recommended an engineering approach to Lean where *"the only way to achieve Zero Defects is to discover the conditions that give rise to defects or process change and eliminate them"*.

2.20 Measures of High Performance

The primary measures of high performance for Lean businesses tend to focus on cash and material flow (and length of time inventory is held) – the leanness of operations Kaplan (1990). In order to keep material flow rates high it is important to maintain very high levels of quality and to ensure no defects are passed onwards for further processing Ohno (1985)

There are seven key areas of waste which again are used as Lean indicators:

1. **Overproduction** disrupts flow and results in excessive lead-time, which conversely affects quality by hiding defects through mass storage. Sometimes compounded by bonus systems which inadvertently 'push' unnecessary products down-stream in order to satisfy short-term gain.
2. **Waiting** is waste that highlights the misuse of time and within production environments can result in either people or products that, for a variety of reasons are not working, or being worked.
3. **Transport** and the movement of products should be reduced to the bare minimum as over handling leads to wear and potential damage.
4. **Inappropriate Processing** is linked to mass production and discourages responsibility of ownership. The ideal situation is that small machines are substituted within cells that are situated next to their respective down-stream operations.
5. **Unnecessary Inventory** hides problems, reduces floor space and most importantly incurs unnecessary costs.
6. **Unnecessary Motion** is waste that relates to the ergonomics of production. For example the unnecessary use of labour intensive activities, such as manual lifting or any physical tasks that could be made easer or more cost effective through automation. Waste therefore is likely to manifest itself in low productivity which in-turn leads to poor quality.
7. **Defects** in productivity are cost incurred off the bottom-line profit. These occur for a variety of reasons, which according to the Toyota production system should be treated as an opportunity to improve quality through urgent Kaizen reviews.

During the time the product is within a facility the typical level of value added activity is between 1% & 5 %. (Source: Researcher pilot studies at Cases). The aerospace industry, unlike automotive and high volume/low variety products, does not have fixed and standard performance measures that are published. In many respects these sector indicators would be meaningless because the sector does not have standard lead times, customers will place orders ahead of time and change delivery schedules, and products have long R&D processes (with added adjustments to the product once it has been sold and is in its repair cycle). For the aerospace industry, the core 1

Lean principle of 'Value' is not a static concept as it is in sectors with high volume and low variety (where the customer engagement with the product is also low). The latter is not true of the high engagement and high complexity of aerospace products.

2.21 Features of Lean and High Material Flow Performance

There are many features of a Lean system, many of which are drawn from Japanese innovations at the Toyota Motor Corporation. Figure 2.18 shows these innovations, their purpose and how they contribute to high levels of material flow (The definition of a lean system is adapted from Slack et al., 2004 – see appendix 3).

Figure 2.18 Features of Lean and High Material Flow Performance.

Feature	Impact	Indicator	Authors
Value Stream Mapping (VSM)	Visualises waste and delay in the operations management system	Value added%	Rother and Shook (1999) Mackle (2002) Womack and Jones (1996)
5S	Workplace organisation enabling standards and 'process basics'	Accidents Availability of materials	Hirano (1995)
Visual Management	Enabling easy identification of items in the workplace or team performance	Quality Delivery Cost Safety	Schonberger (1996)
SMED	Quick changeover of assets	Flexibility Variety of production	Shingo (1987)
Standard Work Instructions	Standards for conducting operations and timings of tasks	Standards and compliance	Ohno (1985) Monden (1993)
Andon	Line stoppage by personnel on detection of an abnormality or defect	Defect avoidance	Monden (1993)
Takt Time	Pacing of an operation to conduct at the rate of consumption	Enables flow and synchronisation Drum beat for customer	Ohno (1985)
Pull Systems and Kanban	Use inventory to allow perfect availability of products as an enabler for just in time production and pull materials rather than to forecast work	Material flow	Monden (1993)
Single Piece Flow	Producing only one piece at a time rather than large batches of inventory (large queues)	Reduces lead time Enhances quality failure detection Eliminates systems variety, inventory and waste	Schonberger (2002) Suri (1998) Spear (2008)

Source: Researcher

Lean techniques provide a self-reinforcing system whereby any waste or interruption to material flow can be identified and eliminated/controlled. The purpose of Lean ways of working is to align activities and 'make what is required when it is required' (Ohno, 1985). The achievement of high levels of material flow is not just a question of good quality but entails a very coherent and process based approach to management. Quality problem-solving tools are used widely by Lean businesses to ensure learning and continual improvement of material flow rates and as such the design of the material flow system is critical to high performance. In this manner these designs are attractive to aerospace businesses because of the long lead times, long process times and the repair of single units (an aircraft or an engine at a time). Customer demands to get repair work conducted quickly and return aircraft back to earning money are high, these commercial pressures are changing the industry and growing the sector's interest in leaner ways of working. Indeed Boeing, Rolls Royce and Airbus all have Lean and Six Sigma programmes which have been portrayed to the workforce, shareholders and customers as successes), Rolls- Royce News letter 2005)

However, practically, the Lean approach has been used in new manufacturing of products, and the regulated repair sector has only just begun to conceptualise and emulate these techniques (Reference: RAF Marham and repair of Tornado aircraft with RB199 engines). The repair sector has many more levels of engineering and supervision than would be seen in automotive Lean cases even for first build aerospace products (such as bodies or wings). These issues will be returned to later in this thesis. The next section will provide a brief review of the combined and hybrid approach known as Lean Six Sigma, which is now beginning to be the dominant model of world-class operations management in the aerospace repair sector.

2.22 Lean / Six Sigma

It could be argued that when Lean and Six Sigma are applied together, faster results are achieved; this was supported in the study of Kaandebo (1999), which was carried out within Lockheed Martin. For example the organisation initially used the principles of Lean to identify and implement process flow, which enabled the foundations of quality to move into a second phase of Six Sigma. Similarly BAE systems in Fort Wayne North America according to Sheridan (2000) also used a blending of both Six Sigma with Lean as a means to reduce the total number of in flight shutdowns to 0.7

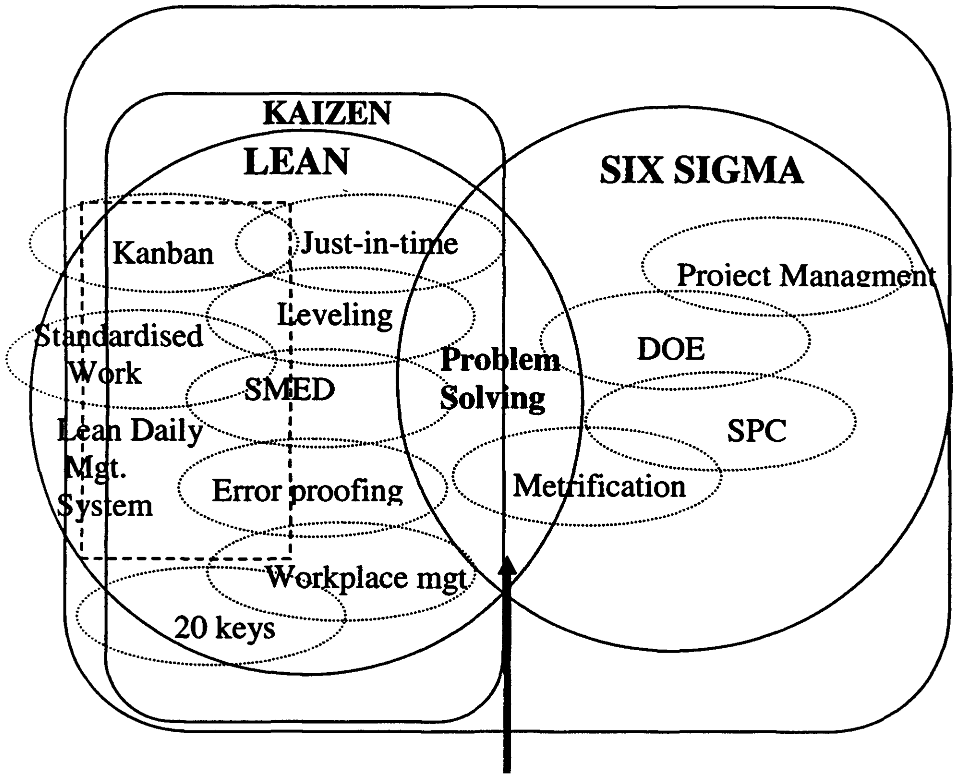
incidents per million hours flown. According to Basu (2001) the successes found amongst those organisations that have adopted this approach have taken place on the basis of what he described as a road map based on three waves of development, which led to what he referred to as *"fit Sigma"*

1. The first wave moves to TQM base on a companywide program of quality improvement.
2. The second wave takes TQM to Lean Sigma emphasising the importance of structured training.
3. The third wave develops into the 'fit Sigma' approach that includes 4 additional features compared to Lean Sigma:

    1. A formal senior management review similar to the S+OP process
    2. Periodic self-assessment with a structured checklist – as per EFQM model
    3. A continuous learning and knowledge management program
    4. The extension of the program across the whole business

In light of what can be described as a revolutionary approach to TQM, Drickhamer (2002) claims that combining both approaches can deliver faster results when Lean techniques are used to initially to *"lower the water to expose the rocks"*
In other words Lean is seen as an enabler for Six Sigma to solve these more complex or long-term process issues. In light of this criticism, both approaches, according to Bicheno (2000), share a common belief system, in that each perspective within the broader framework of TQM accepts that waste reduction is seen as the first step to address organisational waste, which Kaufman Consulting (2000) argues is not unique but derives from industrial engineering practice of 'scientific management'.
In respect of this position they argue in favour of a synergy of common problem solving tools such as, process mapping, 5 why's and cause and effect or Ishakawa tools, all of which have been illustrated in terms of a complete 'overlap'as illustrated in figure 2.19 shown below.

Figure 2.19 Overlay of Lean & Six Sigma



Source: Kaufman Consulting (2000)

However the merger and overlap of Six Sigma with Lean, Imai (1997) claims *"improvement should be gradual and continuous, building on the gains"*. He goes on to argue in favour of that Kaizen Blitz activities that should be used as a means of 'continuous improvement', which is key to TQM and long-term business success. In respect to this position, Imai (1997) explains that Kaizen is central to the Lean philosophy, based on the PDCA Cycle, 5s housekeeping, 5 Why's and most importantly of all the systematic identification and removal of waste.

Armed with the knowledge of the material flow and quality dimensions of the technical operations system design, the key question facing managers who wish to design effective and efficient organisations remains how best to engage the people who will determine the actual performance of the system. The next section will present a review of the social designs of high performance businesses including the role of leaderless teams. The review is important because in the aerospace sector much importance is placed on individual certified skills. The production systems produce high dependency between employees, managers to plan production (environmental and operations management support) and the application of knowledge based decision making (the highest level of human factor decisions).

2.23 Change Management and High Performance Social Systems

The social and technical elements of high performance have been explored in previous sections of this literature review. Central to this debate has been the influence of the interventionist approach taken to engage the workforce. Early management studies showed mixed results in terms of management designing operations systems for high performance (see Mayo 1930 and the bank wiring room or 'Hawthorne experiments'). Whilst Mayo may not have successfully proven, with his experiments, that it was possible to directly control performance levels by manipulating the work environment, he did set a general trend of understanding/improving the psychology of workplace design. Such facets of workplace design are vitally important to a study where safety engineering and human factors need to be controlled.

Mayo's work rejected the de-humanising workplaces associated with the earlier approach to scientific management and promoted the 'sense of belonging and job satisfaction' achieved through treating workers well (as much as motivating them with productivity pay incentives). His contribution to high performance studies was that the human resource management approach to the workforce was an enabler for effective team working and a new quality of working life. His major arguments for managers included:

1. Managers should be friendly to employees
2. Individuals should be asked how they feel about their work
3. Humanistic management design improves morale and productivity

These principles of high performance management are contrary to Weber's bureaucracy and suited to the concepts of motivation (Maslow, 1987) and conditions for successful improvement (Deming, 1993). Mayo's ideals are integral to Deming's 14 points for 'profound knowledge' management (the policies of TQM businesses). These points are summarised in the figure 2.20 below.

Figure 2.20

Deming's 14 Points of 'Profound Knowledge'

The 14 Points

1 Create constancy of purpose and continual improvement. Long term planning must replace short-term reaction
2 Adoption of Japanese philosophy by management and workers alike.
3 Do not depend on quality inspection, but rather build quality into the product and process
4 Choose quality suppliers over low cost suppliers in order to minimise variation in raw materials and supply.
5 Improve constantly to reduce variation in all aspects of planning, production, and service.
6 Training should be provided for workers and management, to reduce variation in how the job is done.
7 Leadership not supervision gets people to do a better job.
8 Eliminate fear and encourage a two-way communication to improve organisational interest.
9 Break down internal barriers
10 Eliminate slogans and recognise that processes make mistakes not people.
11 Eliminate numerical targets through management targets that encourage low quality.
12 Remove barriers to worker satisfaction including annual appraisals
13 Encourage self-improvement and education for all
14 Everyone is responsible for continual improvement in quality and productivity particularly top management

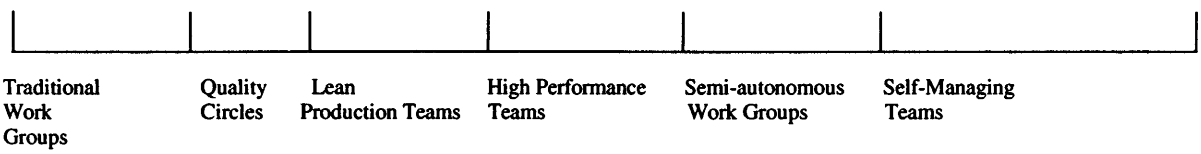
Source: Deming (1993)

2.24 Leadership & Self-Managed Teams

Thus far the literature review has identified the importance of a team-based structure when enacting the changes/interventions that lead to high performance. The study of Rafferty et al (2001), drawing on the work of Banker et al (1996) model, identified a number of different types of teams, as highlighted in figure 2.21 shown below.

Figure 2.21

Team-working Model of Continuum

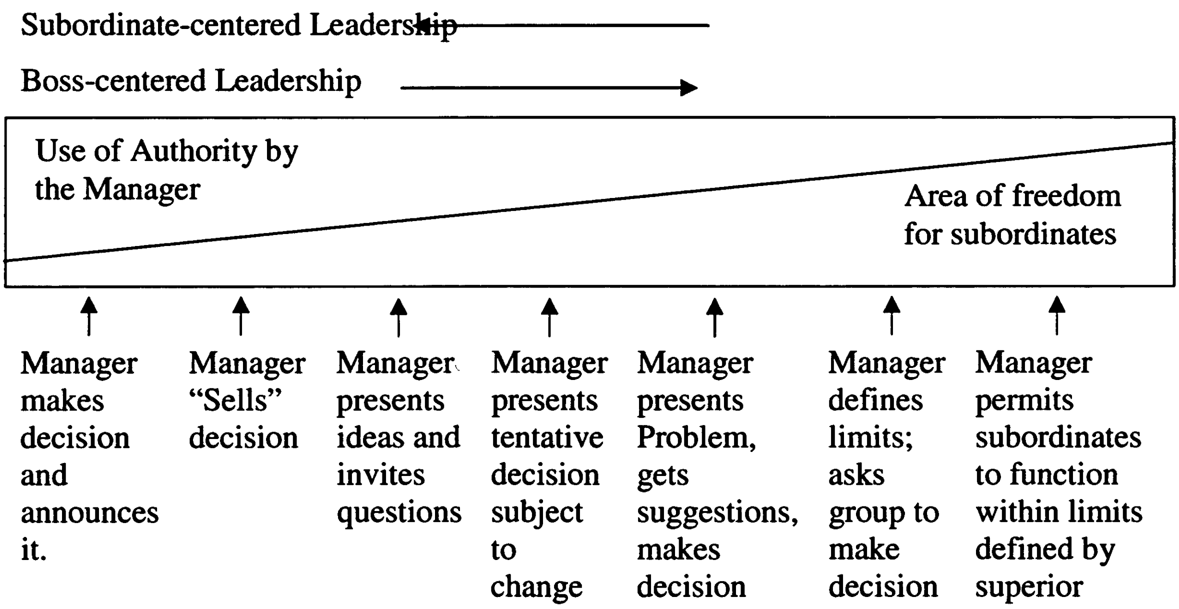


Source: Banker, Field, Scroeder & Sinha (1996)

The team-working continuum begins with an approach referred to as traditional work groups, where individuals are expected to perform core production activities, while other work groups are responsible for support activities, such as quality control and maintenance. In this context traditional work groups have no management responsibility or control. But on the other hand Lean production teams are characterised as those members who work collectively to achieve a standardised set of processes and at the same time expose opportunities through the involvement in problem solving situations. Under this model, as teams become more involved in organisational activities they can be considered in terms of 'high performing' thereby taking an active part in the management decision-making process and the 'just in time' philosophy, thereby enabling the facilitation of TQM principles to take place.

Further development of the mature teams, along the continuum, shows greater responsibility for management and the execution of major production activities including quality control and equipment maintenance. In effect, this is self-management through an empowered approach to self-regulation of the team's own work. In respect of this position Scholtes (1998) argued that through the application of goal setting, the move towards self-management must be management led and must also require changes in working practice that are primarily aimed at improving the quality of performance in complex situations. In order to illustrate this position Scholotes (1998) presented a 'continuum model of leadership' where the development of teamwork requires a rigorous process of high-level management support based on recognition and feedback as illustrated in figure 2.22 shown below.

Figure 2.22 Continuum of Leadership Model

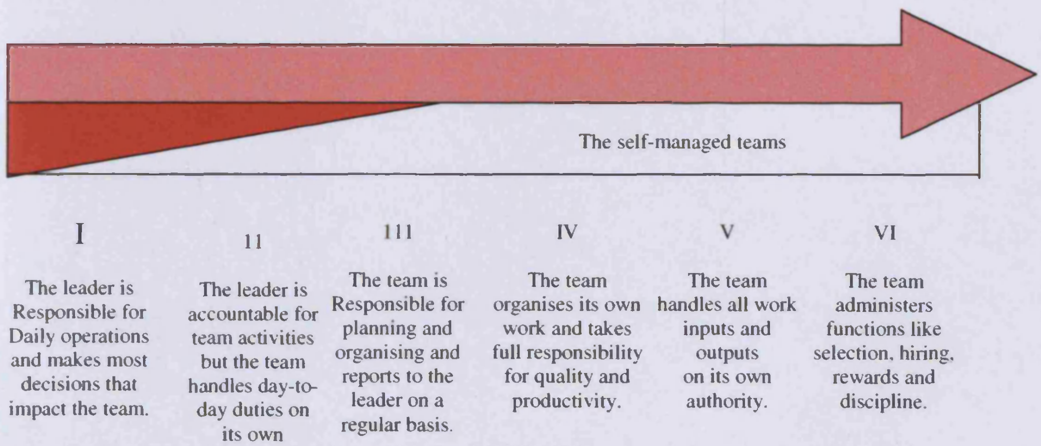


Source: Taken From Scholtes (1998) p 385

The effective design of self-management has also been addressed by Dawson (1994) who carried out a study within a cellular manufacturing unit at General Motors, claiming that when redesigning an organisational system a number of change initiatives should always be required, especially when linked with the introduction of new technologies and changing working practices.

These views were important in shaping this research and all authors agree that traditional leadership styles are a challenge to successful 'self-management' and that, in full support of an STST approach, the management systems and policies must be aligned, operated under a policy of trust within the context of continuous experimentation/improvement of working practices. Further, Thompson (2000) argued for a 'well designed team' with the right people in the correct positions accompanied by intelligent leadership that is capable of facilitating human resource through a number of transitional phases, which Holpp (1993) has illustrated in figure 2.23 shown below. Holpp's model is based on six stages of development that teams must progress through in order to become fully developed as a self-managed unit.

Figure 2.23 Moving towards self-managed teams



Source: Taken From Holpp (1993) Six steps to self-management

Beginning with formalised leaders through to empowered teams the model put forward by Holpp illustrates that as teams mature they also accept more responsibilities and should be encouraged to develop both planning and quality responsibilities. For example if a team decides to choose its own structure it can provide advantages for both, the members of the team and the organisation as a whole, which according to Bodwell (1999) creates the following business opportunities.

1. Increased morale
2. Authority to do what is necessary
3. Provides information and knowledge
4. High involvement in decision-making
5. Ownership of product quality

It should be noted that no model of team structures actually shows how a business can redesign itself or use business process re-engineering to jump over points in the leadership or team evolutionary stages, this presents a potential for failure as management leadership or team structures evolve at a faster or slower rate than each other.

2.25 The Limitations of Self-Management: Implications for High Performance

The researcher accepts that the claimed advantages of self-managed teams are not necessarily the most appropriate design for all types of organisations. For example, Lucas (1998) argued that if the type of work carried out does not require small groups of individuals with similar skills, self-managed teams are often seen as counter-productive. Lucas goes on to claim that in the event of a team member who fails to be adequately empowered to receive enough decision-making authority, conflicts can develop in terms of how the team can function as a whole. Other factors within this level of weakness include problems associated with attitudes towards self-managed teams by senior management. For example Lucas found that managers in many instances were reluctant and sometimes unwilling to engage in the change process from controlling to supporting.

Other disadvantages of self-managed teams are focused at the individual level of analysis, whereby sometimes team members are unwilling to make personal adjustments seen as necessary to comply with the structure of other team members. As a result some individuals often become fearful of change and experience difficulty with certain expectations. Establishing the foundations for self-management is therefore about managing a process that should be introduced in a series of incremental steps, so that everyone will understand the vision and philosophy of the organisational aim. Failure of organisations to introduce the principles of self-management in this way could result in hostility or worst resentment, thereby eroding the fabric and structure of the team dynamic, this situation will ultimately lead to chronic team failure.

According to Moravec (1997) a lack of empowerment for the complexities of autonomous team working is reflected by a lack of management, where the importance of leadership is often underestimated and very often assumed or taken for granted within the team itself. In light of this situation West (2004) argued that a common mistake, made by over 95% of all companies engaging in the process of self-management, is the definition of team empowerment in relation to daily control. In light of this claim Darling (1996) argued *'There is a significant gap between the perception of empowerment as viewed by management and the reality as viewed by employees'*. In other words as argued by De Ment (1996), team members in general have a better understanding of and are more sensitive to business requirements when the principles of cross-functional working are adequately supported and applied.

De Ment (1996) went further to argue that empowering self-managed teams to function as part of a cross-functioning unit will, in many cases, reflect a diverse range of sub-cultural norms that challenge belief systems at many different levels and unless managed with strong leadership could result in the potential for conflict and strategic misdirection.

In light of this position, Thompson (2000) criticised the principles of self-management because it lacks due consideration for the cultural and political issues it failed to explain. The latter is of particular importance to this study when operational management models such as TQM and Lean production have originated from models in other sectors and often other countries.

2.26 Cultural Barriers to Self-Managed Teams

The style, structure and activities of self-managed teams are affected by a number of factors and self-management represents a complex management design issue. At the heart of the debates concerning self-management is the issue of culture (national but more importantly organisational culture). These discussions are critically important to businesses that are adapting and implementing new working methods within an existing business with existing practices. For many of the authors reviewed thus far, the concept of culture is almost ignored or seen as unproblematic with an implicit belief that when the technical dimension of the operations management design is complete, the human resources will evolve to a new culture that is sympathetic to the operations design (Delbridge et al, 2000). .

According to research conducted by Jeffries (1996) the key to managing change is an understanding of a variety of social values of the factory and team – these values being *"All the interactions, which take place between people, their relationships and the feeling engendered by their behaviour".* The importance of understanding this complexity concerns understanding individual differences within the context of organisational culture, a phenomenon that is oversimplified by the management literature and many change models. Such insufficient attention is understandable when academics have failed to test models in a variety of settings. Also, for commercial reasons, where buy-in is used amongst culturally complex organisations there is often failure to consider resources required to manage change within the philosophy of TQM

In many cases the alignment of different sub-cultures is an intervention approach that is not best suited to non-linear processes, where teams have highly individualistic and specialist knowledge and where change can disrupt the business model and its safety management processes. In other words a quality culture is formed by acknowledging many different attitudes and perceptions within teams and using these differences to create opportunities to learn and evolve to higher levels of performance (Padman and Zhou; 2006). Again, if this logic is followed then it may be possible to have different teams operating at different evolutionary stages within a single factory setting. Economics, customer requirements and general management trends in organisational design may well lead to one way of thinking but the needs of the local teams will determine what is needed and how quickly it can evolve. The latter is not discussed in the management literature despite the pivotal role of team working and the enhanced reactive capability of businesses that deploy the greatest amount of self-management to teams in the workplace.

The complexity of these design considerations is exposed by Handy (1981) who claimed, *"Organisational culture is greatly affected by its history, size, involvement with and level of technology, goals, and its environment and people. When the expectations and assumptions within that culture are met and reinforced, the* *psychological contract is fulfilled, leading to satisfaction at work"*. Further Schein (2002) claimed industries that ignore the power of organisational culture are also unaware of how it can in turn, be shaped to change attitudes and behaviour for improved quality of performance. This reinforces the need to design all practices and operations systems to contingently suit the organisation and not to accept a modern day 'one best way' of team working using Japanese Lean and quality methods. The latter is a situation that Burnes (2000) believes *"The search for excellence does not reflect a unified discipline and in particular different styles of management in one country may not be easily translated to the next"*. Such a view is reinforced by Hofstede (2001) who demonstrates the existence of a variety of cultures at the national and organisational levels.

Figure 2.23

Hofstede's Model of National Cultural Differences

Focus	**Country**
• The Market	USA (driven by the individual)
• Power	France
• Order	Germany
• Efficiency	Poland, Russia
• Consensus	Netherlands
• Equality	Nordic Countries
• Systems	UK (driven by hierarchy and complex systems)
• The Family	China
• Japan	Japan

Source: Taken From Hofstede (2001)

Hofstede's model was purposely selected for discussion because it outlines the importance of differences at a social psychological level of analysis. There exists the concept of national identities for example British and Japanese; it is questionable as to whether innovations in one part of the globe can be embedded in another. The assumption being that British people are inherently dependent on a systems approach to work and require a procedure and process that is typically linear and based on logical reasons. British society has shaped workplace designs around structured hierarchies and deference to specialists, which are classically aligned with scientific management. By comparison, the Japanese, according to Hofstede, are less dependent on hierarchy and have a greater empathy with the needs of the total organisation thereby exhibiting traits such as flexibility and good will. Such an approach is much more sympathetic to the human relations and TQM approaches to management/improvement. In other words the national paradigm model put forward by Hofstede, suggests that in Japan, there is only Japan, thereby harnessing a collective consciousness that is aligned to the requirements of TQM. This approach is therefore based on achieving open systems thinking, which is characteristically non-linier and more easily aligned to the principles of Lean standardisation and not conducive to the practice of aero repair & overhaul engineering. In this manner it is possible to indentify a major gap in the body of existing knowledge and question as to whether it is possible to import innovations designed to generate high performance from another culture and to embed them successfully in another. The literature review so far also has not yet fully concluded that there is one best way, TQM and problem-solving, teams may begin to look more similar and global regulations may force businesses to adopt the same structures in order to comply.

In order to fully evaluate the impact of theoretical transportation consideration should be given to Hofstede's approach, which places, into context theories about management with proper regard for the values context in which these ideas were developed. Kono (1992) supports this view and argued that Japanese styles of management differ for a number of reasons. Japanese people are conditioned from a very early age and exposed to international events through an education system as early as pre-school. At work high expectation is placed on employees to integrate within company culture and coupled with decentralised trade unions, enhanced communication has resulted in better standards of industrial relations. The Japanese, unlike their British counterparts, have also benefited from government support, which shows a greater involvement in company business, by working with industry to create common goals through support agencies, such as the Ministry of International Trade and Industry. Hofstede created a further model with four dimensions that shaped the quality of human performance in terms of:

1. Power v Distance
2. Individualism v Collectivism
3. Uncertainty v Avoidance
4. Masculinity v Femininity

According to Reason (2003) an expert in the field of applied human factors research, the new model is more useful to a study of general human factors. Hofstede's work has parallels with the current focus of study in the aerospace sector. The new model has great significance, which is particularly relevant to the field of aircraft operations where behaviour in different cultures changes considerably. For example Asian cultures are based on encouragement of interpretation of published procedures, especially in situations where those procedures include the use of Flight Reference Cards. For example in Far Eastern and Asian cultures a rigid application of procedures is followed and applied in all cases irrespective of its relevance and ineffectiveness to aircraft safety. As such this has resulted in a larger number of in-flight emergencies that are treated quite differently between Eastern and Western cultures. On the one hand western pilots work around flight deck problems by analysing and improvising while Asian crews immediately engage the autopilot sequence and refer to procedural checklists.

According to Helmreich & Merritt (1995) the impact of individualism in Asian cultures can be perceived as detrimental, since self-reliance is seen as an indication of strength and seeking help implies weakness. Within Western cultures Harrison (1972) described organisations in terms of four 'ideologies', this becomes of practical interest when explaining the culture of maintenance organisations that relate to task-oriented activities as illustrated in figure 2.24 shown below:

Figure 2.24

Harrison Typology Model

Power Culture	The organisation depends on trust and empathy Few rules, little bureaucracy Political organisation Dangerous structure for large organisations
Role Culture	Logical and rational Procedural communications Personal and expert power held back Slow to react to threats
Task Culture	Team culture Difficult to control Revert to a power or role culture when resources are limited Gets the job done

Person Culture Socio-technical Systems
Control by mutual consent
Shared influence.
Social groups

Source: Taken From Harrison (1972)

The preceding models add insight into how cultures, at the national and organisational levels, influence performance and the willingness of individuals to interact and achieve/sustain high performance. The UK has been portrayed as resting at an uncomfortable point between harnessing creativity of teams and tendency towards centralised and scientific management regimes. The latter is counter to all models of high performance operations, the use of organic structures and the deployment of responsibility to teams. Furthermore, the practices in the aerospace sector are shaped by the historic approach to management and the use of highly regulated processes which may limit the degree to which TQM and self managed teams are able to co-exist within a safety-critical work environment/operations system design.

2.27 Cultures and Safety Management

It is widely accepted that accidents are caused by inadequate performance of people who had the capacity to perform effectively and yet failed to do so. Reports from the Confidential Human Factors Reporting Programme (CHIRP) and the Aviation Safety Reporting System (ASRS)[30] support this view and argue that attitudes play a significant role in aviation safety and by modifying attitudes through training is one way to effectively improve a safety driven culture. Helmreich & Merritt (1995) carried out research into attitudes and values amongst pilots, who like many other professions within the aerospace industry place high value on the nature of their work. The findings from their study are based on the interaction of three levels of analysis:

1. Professional Cultures
2. Organisational Cultures
3. National Cultures

The survey concluded that job satisfaction levels were largely determined by the organisational culture and the subsequent conditions that individuals experience in

[30]Aviation Safety Reporting System (ASRS) is a national program, which is part of the Confidential Human Factors Incident Reporting Program (CHIRP)

their particular area of work. For purpose of understanding Helmreich & Merritt (1995) define the culture as: *'The values, beliefs and behaviours that we share with others that help us define a group, especially in relation to other groups'.* Helmreich and Merritt reported a strong correlation between the strength of organisational culture and its performance, with coherence and stability of attitudes as the defining features that determines what is understood by a strong unified culture.

For example a comparative case based study between two successful airlines, namely British Airways and Virgin Atlantic, revealed that whilst each organisation's culture was significantly different and its good safety record was dependant on consensus of opinion that included everyone within the same organisation (Helmreich and Merritt, 1995). The authors compared two American airlines and measured respectively the relationship between safety and its organisational culture. In the first case 87% of Pilots interviewed were found to have high levels of morale, when compared with the second case study, which represented just 3%. The reason according to Helmreich and Merritt is explained as follows. Pilot's cynicism about the motives of their managers, were based on a response rate of 12% that agreed with the statement *"Management never compromises safety for profit"?*

However, the most concerning finding came from the statement *"Crews I fly with adhere to standard operating procedures."* In case study one 93% agreed with the statement compared with 73% in case study number two. The findings therefore indicate an important link between attitude and behaviour, thus underlying the point that high levels of professionalism displayed by pilots are easily undermined by the influence of negative organisational culture, which in turn leads to poor compliance of standards operating procedures (SOP) According to Helmreich & Wilhelm (1997) the safety critical nature of the aviation industry in general must include due consideration at the individual level of analysis. Increased productivity without proper regard for safety is perceived as the principle measure by which the majority of employees gauge their employer's commitment to safety.

Regardless of which team approach is undertaken, the evolutionary models reviewed show how teams become more effective as management decision making is deployed to them. Notwithstanding the importance of national and organisational cultures, the relationship of teams with high performance and effective safety management still exists. The next section will continue the analysis of how individuals, within established operations management socio-technical systems, regard and react to safety processes and abnormality.

2.28 Team Situational Awareness & Human Error Training

A critical element of the above discussion and team design is the concept of 'team situational awareness'. Team situational awareness refers to the collective ability of a team to understand what is going on at any point in time and to determine where an abnormality is happening that requires the team to react and restore the process to control. Situational awareness is therefore a skill held by the team which acts as one of Reason's (2003) barriers to system failure.

Human factors authors propose that it is vitally important to improve the quality of decision making between one employee and the next by redesigning the workplace and interactions of employees to enhance situational awareness and safe working (Spear 2008). The decision making process is therefore considered as an important part of self-management, based on the fact that individuals can only process information effectively if they have a safety and quality 'team situational awareness'. According to Salas (1995) the concept of team situational awareness is seen as a necessary framework that can be used to facilitate effective cognition. Stout (1994) goes further to describe it as a contributing factor, which defines the performance of a safety critical organisation. Stout argues that team situational awareness is composed of each team member's situational awareness and based on a pre-existing knowledge base of shared mental models.

Stout proposes that skill based activities represent about 25% of all errors, which are learnt and in some situations do not require a conscious level of awareness. Based on learned cognitive thinking, skilled activities require a level of awareness that relies on thinking programmes at the conscious level of control, for example the most common failing which is associated with the incorrect selection of a thinking program, could be undoing a nut, rather than doing it up. This is often referred to as a 'slip, completely missing out a programme is called a 'lapse'. Skill based slips are linked to the problem solving activity, while rule based and knowledge based mistakes arise during subsequent attempts to find the end result in terms of a solution to the problem. A pre-condition for the occurrence of a slip of action is the presence of attentional 'capture' from either distraction or preoccupation. Whenever attention is misdirected it will not be focused on the routine task in hand.

Stout argues that normally individuals like to operate at the skill-based level because it requires little conscious mental effort (referred to by Reason as a 'ready to run' programme where individuals will normally revert to a rule-based activity). For example when individuals have no prior experience of a particular task he or she may opt to pursue a written procedure without necessarily understanding it. The researcher refers to those influences, which may lead to a person, making errors or mistakes, which are also described in terms of violations, where barriers to effective teamwork are known to frequently take place. Referred to in terms of 'internal' factors, these considerations would typically include influencing conditions such as fatigue and noise distraction. Research has shown that the effects of this have not only resulted in decreased human performance, but it is also seen as the underlying cause of many workplace mistakes that often result in catastrophic accidents.

The effects of interruptions are especially significant in complex and dynamic situations of which 50% are due to poor levels of situational awareness where human error is cited as the main contributing factor. Research into the effects of this problem was carried out within the context of noise distraction by Banbury (1998) who suggested that the most significant cause of human error in the workplace was due to poor communication. The context relies on good speech both formal and informal without interruption and distraction from background noise. His research showed that the most frequent complaint was linked to difficulties with concentration when background conversation was taking place. In addition research carried out by Boyce (1974) measured the impact of noise distraction amongst 200 open plan office workers of which 67% were most affected by telephone ringing. Secondly 55% were concerned with background noise of talking and approximately half of the sample reported problems with concentration because of air conditioning and office machinery. Banbury (1998) also found that office noise either with or without speech significantly impaired memory performance in complex decision-making situations.

Despite the large number of empirical findings most studies concerning the effects of interruptions are centered at the individual level of analysis in terms of information processing. The cause and consequence is often attributed to ineffective communication where access to information is sometimes unavailable or denied. In some cases information can be immediate or prolonged depending on its availability or urgency of the task in question. While the costs of delays and interruptions are often calculated to the nearest minute, research from the perspective of the repair and overhaul sector is largely overlooked in terms of unexpected delays. The results create a series of stop/start situations where process delays occur because of unidentified sources of variation (conditions that are contrary to Lean and Six Sigma ways of working). Described as a planning problem, the consequences of system variation often results in a discontinuation of a current task or activity and is linked to the negative effects of impaired thinking processes (researcher pilot study and historical incident investigations (see Banbury, 1998).

Research carried out by Broadbent (1989) argued that the consequence of interruptions during the early stages of task involvement is seen to be more disruptive than those occurring toward the end of the task. The parallel with aerospace repair activities is pivotal and stop/start operations add to the confusion and potential for system error. In light of this consideration the researcher argues that an important role and function is played by management in creating a transparent environment conducive to information availability and human factors awareness. The point being made by the researcher is that if individuals can be conditioned to the practices and implicit values of TQM they will be less likely to be 'at risk' to, what human factors specialists call the 'error zone' (Reason, 2003).

Within the error zone, if the position of Rasmussen (1998) is accepted, then rule based mistakes represent about 60% of errors. In the aerospace repair sector, such events could occur when an engineer selects a package of procedures, which are inappropriate to the task in question. Such an event could influence behaviour to apply what is normally regarded as good rules, or conversely, bad rules which can take the form of shortcuts that lead to mistakes. It should be noted, many other authors cite commercial pressures as aggravating this situation thus leading to more fundamental risks as individuals cut corners as a matter of 'norm' (rule based errors). When rule-based activities fail to provide the expected answer to a problem, individuals are more likely to refer to knowledge-based procedures. A concept that represents 15% of human error, based on experience of analysing a problem as a means to finding a solution, or rejecting a problem until the required task is complete

(Rasmussen, 1998). According to Cannon-Bowers (1993) the quality of team situational awareness will therefore impact on a commonality of factors, not just 'rule breaking', this can be more akin to the quality of individual decision-making based on the system's ability to:

1. Set Team Goals
2. Assign Individual Tasks
3. Identify Team Member Roles

These activities are often the responsibility of management, especially under the regime of scientific management, and lapses in the effectiveness (quality and timeliness) can result in errors. Furthermore for autonomous teams, it is not clear how these activities are conducted and the previous 'team evolutionary' models presented earlier offer no insight into what is the appropriate structure, behaviour, situational awareness and human factors that must be taken into consideration when working with such teams and deploying goals. The latter area is a major gap in the organisational literature and a subject of immense insight for regulated industries such as the one found in this study. As such, a lean team based organisation without the features of evolved team working, as described above, could generate safety errors rather than absorb or eliminate them.

Converse & Kahler (1992) extended this line of research and proposed an approach that considered shared mental models based on three different types of knowledge structures. Firstly considering what is referred to as declarative knowledge, where individuals process information in terms of 'knowing that' about the system, which according to Stout (1994) is described as," *Containing knowledge of facts, rules, and relationships, and include knowledge: of the overall system, task goals, the relation among the system components, equipment/hardware, positions/roles, and the team members themselves"*. Secondly 'procedural knowledge' contains information regarded in terms of 'knowing how', which Stout (1994) describes as: *"Stored information about the steps that must be taken to accomplish various activities, and the order in which these steps must be taken"* According to Converse & Kahler (1992) each approach contains similarities, in that both models contain elements of knowledge-based and rule-based concepts. Accepting that self-managed teams must share knowledge about the situation and system in general the model put forward by Converse & Kahler (1992) is important as it provides a holistic explanation in terms of support of a developing socio-technical system. During the development of shared mental models Converse & Kahler (1992) argued in favour of understanding the importance of 'strategic knowledge' since this approach underlines the importance of team situational awareness in terms of 'knowing why' that Converse & Kahler (1992) describe as: *"Are comprised of information that provides the basis of problem solving, such as action plans to meet specific goal knowledge of the context in which procedures should be implemented, actions to be taken if a proposed solution fails, and how to respond if necessary information is absent"*. In this context 'strategic knowledge' is seen as an important consideration of self-managed teamwork in the application of selecting an appropriate task strategy. In other words declarative and procedural knowledge can be considered as 'static' whilst strategic knowledge is a 'dynamic' feature in achieving the educational requirements of problem solving for TQM.

The introduction of training strategies and relevant methods applicable to changing knowledge and situational awareness can therefore be enhanced to include training for shared knowledge structures that promote improved human factors performance within teams for enhanced 'shared cognition' According to Jonassen & Tessmer (1997) this is important because teams *"Contain knowledge about the overall system or task domain where shared cognition can help facilitate the active participation between team members themselves"* The rationale behind this approach is based on the concept of the group dynamic in terms of, that which is learned can be reflected by means of how and when a particular strategy can be most appropriately deployed. Collins (1991) supports this approach and claims that the advantages of this type of training encourage team members to learn how to react to future problems in relation to a social context. Collins also acknowledged that cross training of the strategic type could provide a unique mental representation in relation to learning about responsibilities of other team members in situations that require job rotation.

Training of this particular type is highly relevant to this study, because it permits the different roles within self-management to experiment with their shared roles and responsibilities that require test actions in an environment that is both safe and encouraging, thereby underlining the position that team situational awareness must be seen as an enabler to empowerment. Rogers (1994) argued in favour of developing a natural drive for self-actualisation, based on a humanistic perspective of motivation for learning. He makes the important distinction in terms of cognitive processing between meaningless information and experiential or significant information. The former relates to semantic processing such as learning vocabulary and the latter refers to applied knowledge such as technical information by means of evaluating the reasons 'why'. Rogers claimed that experiential learning is necessary for personal change, growth and development, which should include the following conditions:

1. Setting a positive climate for learning
2. Clarifying the purposes of the learning
3. Organising
4. Making available learning resources
5. Balancing intellectual and emotional components of learning
6. Sharing feelings and thoughts with other learners

According to Rogers, learning can be facilitated only when individuals feel part of the learning process and have control over its nature and direction. In light of this claim, Holland (1986), like Rogers, suggested that mental modelling provides the basis for all reasoning and learning processes, which he described in terms of:

1. They are incomplete and constantly evolving
2. They are usually not accurate representations of a phenomenon; they typically contain errors and contradictions
3. They are parsimonious and provide simplified explanations of complex phenomena
4. They often contain measures of uncertainty about their validity that allow them to used even if incorrect
5. They can be represented by sets of condition-action rules.

Evidence supporting this approach can be cited from Orasanu (1990) who investigated decision-making performances amongst aircrews. The case study looked at the decision-making strategies in relation to problem situations during flight simulations. The results demonstrated that high performance learning reflected twice the levels of situational awareness when compared to poor performing teams with 50% more accuracy in task requirements. Cannon-Bowers et al (1993) refer to this point and argued that high performing teamwork depends on the interaction between individuals. The process by which TQM can facilitate the systems thinking philosophy is intended to meet a wider range of environmental conditions, in complex surroundings. According to Johnson (1993) this approach provides strategic management within a context of shared understanding which is primarily a cultural and cognitive phenomenon. In other words Johnson is claiming that individuals have a unique representation that is linked to social conditioning. The point being that if organisational change contradicts an individual's cultural belief system, the process will be slow and difficult to manage.

2.29 Team Working & Change

In understanding the complexity of a situation it is important to consider the implications of change in terms of Burnes's (2000) 3 different approaches as shown below;

1. Incremental model of change, which is carried out incrementally taking one goal or problem at a time. This process is also carried out by a number of other sub systems that act independently based on achieving long periods of stability for incremental change to occur.
2. Punctuated equilibrium of organisational transformation, which is based on long periods of stability with short bursts of fundamental change.
3. Continuous transformation model of change is usually deployed where business environments are considered as unstable

Burnes goes on to argue that when selecting the correct model for managing change both the individual, group and system as whole would be affected in terms of the correct choice model to be applied as illustrated in figure 2.25 shown below.

Figure 2.25 Change Management Model

	Incremental	**Punctuated**	**Continuous**
Individuals	Learning	Promotion	Career development
Groups	Kaizen	Team building	Changes in composition and task
Systems	Fine Tuning	BPR	Culture

Source: Taken From Burnes (2000) pp-304

According to Burnes the management of change is broadly assumed to fall within one of two categories. The oldest, of which is the 'planned' approach that Lewin (1958) believed should be managed through 3 sequential steps. This approach is based on Gestalt psychology concerning the understanding of how managers should react to environmental change. Lewin argued for the importance of resolving social conflict stating that the best way to achieve this was to facilitate learning so that individuals could understand and restructure their perceptions. Lewin was heavily influenced by the Gestalt psychologists within the context of team dynamics and argued that a group to which an individual belongs is the foundation of understanding resolution of conflict and managed change, within a 3-step process as shown below.

1. Unfreezing by encouraging the reduction of causal relationships that maintain attitudes and traditional belief systems.
2. Movement through the development of new attitudes or behaviour that will re-define the problem.
3. Refreezing through effective communication based on understanding the need for change that should be identified and made clear as soon as possible.

However, critics of Lewin such as Dawson (1994) argued that the group dynamic approach is over simplistic where organisational change is a continuous and open-ended process. Thereby claiming that freezing and refreezing states were not possible since organisations are dominated by power and politics, which inevitably restrict the group's potential as an effective method of change. The 'emergent' approach therefore challenged the 'planned' approach and claimed that change should be part of a continuous process that is both open-ended and unpredictable. In favour of the emergent approach Kanter (1989) claimed that the role of change agents is unnecessary and instead considered the process of change as an integral element of the business strategy. The assumption being that when individuals are managed effectively a clear understanding of roles and behaviours will naturally align with the organisational systems aims and objectives. Accepting this position the emergent approach, as illustrated in figure 2.26 shown below, claims that most people fall into two categories: Firstly the unconscious incompetence grouping in which knowledge is described in terms of 'not knowing what the individual doesn't know'. Secondly, as the human relations approach unfolds, a new way of thinking is communicated whereby individuals start to recognise and to engage in a process of 'knowing what they don't know' For example as managers start to empower teams to accept ownership of process they realise how they are expected to perform. As new roles and confidence grows a level of conscious competence is developed whereby individuals become aware of knowing what they know. As new roles are learnt and become continuously practiced a process of learned competence is established and teams accept the 'one best way' thereby developing a range of skills or activities that can enable them to attain a level of 'unconscious competence' as illustrated in figure 2.26 shown below.

Figure 2.26

Competency Matrix

	Unconscious	Conscious
Incompetence	1	2
Competence	4	3

Source: Taken From Scholtes (1998)

However, in addition to the change management theories successful implementation of TQM should also consider a cultural level of analysis that West (2004) highlighted in terms understanding the importance of intergroup differences. For example West refers to subcultures that should always be exposed in order for open systems management to take place. West is critical of organisations that introduce team working without addressing this issue and argued that unless differences between teams are fully understood, inter team conflict will erode the stability and potential for businesses to perform properly. West claims that goals should always be made clear, with feedback on the effectiveness of performance or systems issues will not be solved. The modern equivalent solution to West's predicament has been termed policy deployment and it is a lean method used to align improvement activities (See Akao, 1990).

2.30 Chapter Summary & Literature Model

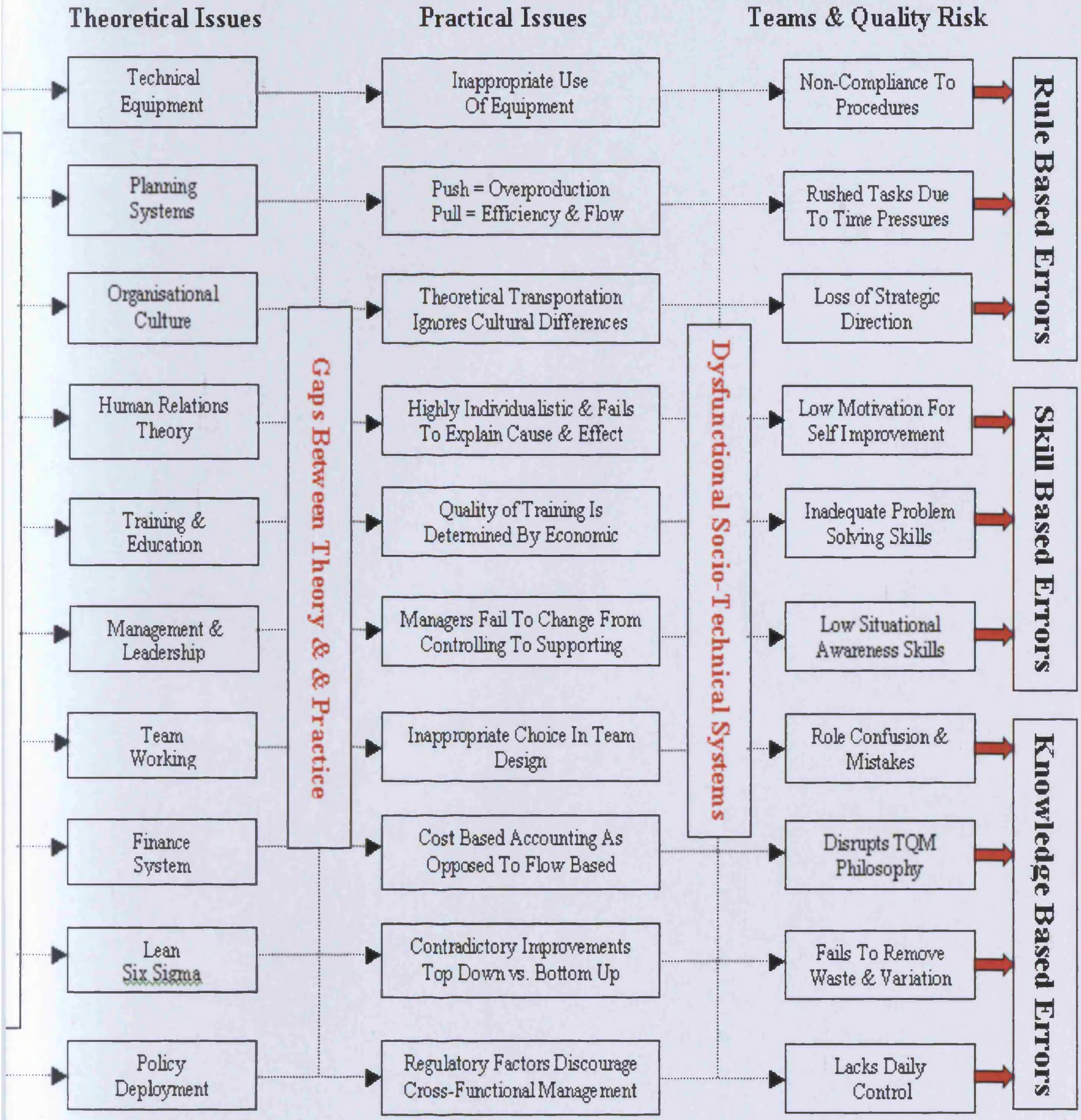
The preceding sections have built a picture of the inconsistencies between academic thought and the high variety environment of aerospace operations management. The literature has shown how a complex operating environment is subject to many latent risks, well beyond the simplistic models of TQM for high volume businesses, towards a blend of human factors that are contained within a safety critical and team based approach to high materials flow. The sections have also shown that inconsistencies in the socio-technical system design, especially the role of management and planning, can generate many interruptions to material flow, create team confusion (in identity and also in the priority of work) and allow/condone 'rule breaking' by individuals and teams thus compensating for poor planning and control (ineffective management practice). This chapter has provided an overview of socio-technical systems literature, which places into context the main research question. It began with an historical overview of 'general systems theory' before entering the focal literature concerning operations management within modern 'open' systems thinking. The review continued to explore modern approaches to team based improvement (Lean and Six Sigma) before presenting the challenges of managing teams themselves and how such structures can operate in an autonomous state under conditions of TQM

The researcher's choice of literature therefore extended beyond contemporary approaches of total quality thinking towards a more in-depth contribution from the human factors theories. These theories, pertinent to low volume and safety critical management practice, were also found to have significant gaps but were more closely aligned with the subject of study i.e. professional engineering teams engaged in aero engine repair. It is contended that contemporary human factors research can play an important part in explaining the possible risks associated with self-management, based on need for enhanced levels of 'team situational awareness'. These issues were duly built into the research methodology, which will be explored in the next chapter.

To conclude this chapter, the researcher compiled, and then tested, with an expert review (Dr Simon Banbury Human Factors Expert), the model for credibility. The literature-based model, which is shown in figure 2.27 below, is presented as a means of illustrating the key variables at play in a safety critical, constantly improving and team based workplace within which there is potential for human error. This model is a contribution to the subject of study because, to date, no such model exists it extends the seminal work of Reason (2003) bringing his work closer to the realities of working in a modern factory. Modern socio-technical systems have much evolved since Reason's time of writing and new improvement paradigms, such as Lean and Six Sigma, now dominate modern workplaces including those of a repair nature. However, academics with an interest in improvement have rarely ventured into the world of human factors thinking. As such, a gap exists between Reason's (2003) latent error risk models and 'windows of opportunity', Rasmussen's (1998) model of three different social types of error risk and modern leaner/TQM team-based working practices.

Figure 2.27

Linking Socio-Technical Risk Factors To Error Provoking Zones



Source: Researcher

In consideration of this position the researcher concludes this chapter by stating that factors such as those extracted from the literature review would be relevant to the process of theory building and more importantly will be used to frame chapter 3 of the research methodology, especially the measurement system used to collect and analyse data from factory teams and their management.

In summary the researcher has provided an overview of socio-technical systems literature and has explored the many different ways in which systems are designed and the influencing factors this has upon them. The chapter has also provided a review of high performance organisational designs and has identified the modern structural choice as that of team-based working. The gap in the body of knowledge is therefore expressed as:

"To what extent can self-managed team working, facilitate the principles of safety and Total Quality Management?"

It is expected that the outcome of the study will inform academic knowledge in these key fields of research and also influence the practice of management and the design of socio-technical systems. The importance of which cannot be understated in terms of the value this type of research can bring, based on prevention of mistakes or worse still, errors that result in the potential for catastrophic failure, which more often than not is the end result.

Chapter 3 Research Methodology

3.0 Chapter Introduction

The previous chapter has positioned and framed the research question within the body of knowledge and existing literature. It has presented a systems approach to the study of organizations and the management prerogative to design effective socio-technical systems in order tò generate higher performance yet it has also exposed many gaps in the current theory that, in the main, neglects any form of human factor management. The neglect of organizational, total quality or high performance operations literatures is a major weakness in the current management models of high performance. Indeed, it would appear strange that these issues have not been researched in the areas of regulated industries, the health service or in the automotive sector that has contributed so much to organizational theory. Whilst TQM and Lean authors would prefer the repetitive and low safety risks of repetitive manufacturing environments there is almost nothing written about Lean, TQM and high performance businesses in contexts that are safety critical, less repetitive and need high levels of individual skill.

This chapter will present and defend the research strategy, methods and overall design of this 'theory building' study of safety critical socio-technical systems. The chapter will outline, discuss, validate and defend the chosen research strategy and its associated methodology as an appropriate means of answering the main research question; *"To what extent can self-managed team working, facilitate the principles of safety and Total Quality Management?"*

In light of this statement the researcher will argue, from a realist perspective, the need for both inductive and deductive cycles of theory building in order to offer a greater probability that new theory can be generated. It will also show that the elements of the research strategy were crafted in a manner where qualitative observation was used to reinforce quantitative methods; it will also show those that were rejected and not included in the final pluralist methodology. As a synopsis, the final research strategy comprises of a multiple case replication strategy involving a pluralist methodology of questionnaires, focus group interviews, secondary data and observational analysis. These methods draw from the precedent of research STST methods and studies that have theory-built within operations management, the pluralist combination was considered 'fit-for-purpose' to evaluate complex human factors in a low volume brown field manufacturing setting[31].

3.1 Epistemological and Methodological Overview

Any piece of research should commence with a review of philosophical debate concerning exactly what is 'valid knowledge creation' is in order to craft and defend its chosen research strategy including the acknowledgement of the limitations of decisions to adopt or preclude certain approaches. This investigation is characterised as a realist perspective to the study of organisational management, based on a multiple case replication research strategy involving pluralist and triangulated methods.

Before exploring the methodology, the researcher will provide a review of the two main philosophical approaches to research, namely positivism and phenomenology. Positivism is a long-standing and traditional perspective that has a long precedent in the sciences and operations management and is reliant upon quantifying scientific observations and is a process that favours numerical and statistical manipulations of data and an observed reality. The phenomenology/naturalist approach, by contrast, is based on observational methods and ethnographic studies which have a much greater affinity to the social rather than natural sciences. The naturalist approach is subjective and rejects the ability to 'make sense' of collective behaviour preferring instead to support the view that reality is individualistic and within the person. Between these two diametrically opposed perspectives, is a middle ground or 'realism' school of thought. Realists blend both quantitative as well as qualitative methods, which, advocates argue, will enable a deeper insight into the subject of study and the messy issues of operations management (Rich, 1999).

The distinction between these philosophical perspectives reflects the degree to which the person/subject of study controls or is controlled by their environment. The researcher will therefore commence with a philosophical debate concerning 'valid knowledge creation' in terms of understanding the available choices of methods, within a framework of the two broad schools of research design. Easterby-Smith et al

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[31] A brownfield site is an area used for industrial, manufacturing or commercial use that has been long-established. As such it has existing culture/customary practices and work processes that must adapt to change rather adopt change as is the case of a new 'green field' site which has less resistance during such change.

(1993) argue that designing management research is often: *"A study of being that involves an ideal type of comparisons whereby "... in the red corner is phenomenology; in the blue corner is positivism. Each of these positions has to some extent been elevated into a stereotype, often by the opposing side"*. Such a positioning is, according to Layder (1994) a prerequisite for developing and justifying a research design, whereas epistemological research is an approach based on; *"how we know what we claim to know"* The relevance which according to the researcher, is whether 'reality' is external to the individual (positivism) or 'reality' is a function of an individual's consciousness (naturalism)[32].

3.2 Positivism in Operations Management

Layder (1994), argues that epistemological considerations define 'what' is an acceptable and valid source of knowledge based on whether the individual can be treated as a 'subject' or an 'object' of inquiry. In considering the positivist approach one can argue that 'reality' is external to the individual and should be the focus of researching patterns of behaviour. The assumption being that a structure of determinate relationships can be established, this, more commonly, is referred to as 'concrete structures' based on observed and measured objectively, without bias or 'value judgement'.

However, it is claimed that, even when all relevant variables of the study are identified and measured, the positivist approach lacked the necessary 'depth' needed to build theory from what Denzin & Lincoln (1994) describe as the 'messy' complexities of the Lean/TQM phenomena. Operations management authors tend not to fully reject positivism but there has been a greater trend towards qualitative rather than quantitative research designs as the field of study moves from merely testing theories to generating them. Meredith (1993) also argues *"The use of conceptual research methods based on descriptive, empirical investigation can significantly increase the external validity of OM research conclusions and thus their corresponding relevance to managers"*. Given the intention of this study to contribute to good management practice, Meredith's view was duly accepted and a purely

[32] There are many terms used in the literature as substitutes for the term 'positivism' (Easterby-Smith et al 1993). These include 'objectivism' (Morgan and Smircich 1980) and 'empiricism' (Burrell and Morgan 1979). The alternative terms used in the literature to describe naturalism (Wass and Wells 1994) including phenomenology (Easterby-Smith & Thrope 1993). For the purpose of this thesis the terms positivism and naturalism will be used to describe the extreme positions outlined.

positivist approach was therefore rejected as inappropriate to the development of theory needed to understand self managed teams. A positivist approach would therefore provide only a partial account of the phenomenon/reality of aerospace repair processes and would lack a depth of analysis needed to identify context and perceptions of error sources.

By contrast, the naturalist perspective regards 'reality' as a function of individual consciousness, subjective interpretation and grounded in personal experience. The approach is based on the attributes of individual creation where observed and measured reality is impossible and an undesirable activity. Naturalists are diametrically opposed to the positivist research approach but there is a 'middle ground' that seeks to reconcile the extremes such that observable events may be interpreted using both behavioural and observed forms of research. The latter approach was duly accepted (the school of realism) as a means of framing the main research study design. For the purpose of clarity, the realist approach is outlined in figure 3.0. The underlying ontological assumption is that reality is external to the individual and capable of objective forms of 'scientific' measurement.

Figure 3.0 The Deductive Positivist Research Model.

Researcher Tests a Theory
Leading To
Researcher Tests Hypotheses or Research Questions Derived from the Theory
Leading To
Researcher Operationalises Concepts or Variables Derived from the Theory
Leading To
Researcher Uses an Instrument to Measure Variables in the Theory

Source: Taken From Cresswell (1994)

However in accepting this position the researcher will not ignore the importance of individual interpretations, which Ajzen & Madden (1986), see figure 3.6, present in their model of human cognition, where levels of individual subjectivity cannot be removed from the social reality of the organisation itself. In light of this consideration it is also important to accept the argument put forward by Swamidass, (1991) also Scudder & Hill (1998) who advocate the position of the positivist school of research, which has a long precedent in the field of operations management. The latter suggests it is important to have a quantitative element to any study in order to generate valid knowledge within the operations management field of study.

The researcher therefore accepts that 'valid knowledge' is derived from quantitative research, which forms the basis upon which this study will take place. In other words a number of assumptions will be made based on hypotheses driven predictions, which will be used to test the principles of TQM within the context of cross-functional management. Also accepted is the position of cultural indifference within the case study itself, whereby attitude differences between the two main study groups are expected to exist as suggested by Hofestead (2001) earlier in chapter 2 of the literature review. The adoption of positivist research is therefore proposed as essentially unproblematic, as long as the researcher adopts objective procedures that Blaikie (1993) states are 'value-free' and supported by rigorous statistical testing. Proof of reality can be demonstrated using deductive forms of scientific logic. In other words a range of scientific procedures capable of providing a suitable range of tests procedures will need to be considered. The criteria which can then determine levels of statistical significance will include social data tests used for their reliability and validity, within a framework of positivist research design. This is a requirement that Ragin (1994), claims is a necessary consideration for any form of hypotheses driven research to take place. The researcher duly accepted this approach as a scientific means of discerning the existence of broad patterns of cause and effect relationships. In summary the positivist approach will provide a clear structure for the collection and testing of data, such that the differences between case study sites can be discerned and therefore prompt deeper investigations using more qualitative methods as a secondary form of research design.

However, the researcher makes clear that, for the purpose of this study, a purely positivist approach will be rejected, as it is more suitable for testing theory than developing new models of human understanding in areas, which are poorly understood and not yet fully established. This approach was also considered inappropriate to this study because of the complex socio-technical system of self-managed teams where cause and effect relationships can not be easily be identified, measured and extracted from the workplace setting. In other words the issue of data manipulation as used by the experimentalist would forcibly 'smooth out' outliers differences and promote 'similarity'. A concept that Parkhe (1993) considers important when identifying interesting deviations, the researcher will use this concept as the basis for prompting deeper and more qualitative levels of investigation. It is therefore considered that smoothing of data would be incompatible with the development of new theory building; this is seen as an important consideration when aiming to close the gap in the existing body of operations management. In light of this consideration the intention is to maintain the importance of positivism, within a non-parametric design, but to draw short of accepting what is referred to as parametric data, where any generalizations according to Norusis (2006) will always be statistically similar when comparing attitudinal differences, between and across case study groups. Therefore the extremes of positivist research and its 'smoothing' of data are not considered as a viable approach to the real world problems of human factors in safety critical operational management structures.

In rejecting the experimentalist approach the researcher is considering that the practical contribution this study can offer in terms of the limited number of time constraints that this type of research can bring to the field of operations management, thereby accepting the criticism and limitations that a purely positivist approach (experimentalists) would bring, in terms of solving the real-world problems from a safety critical and human factors point of view. In support of this position Swamidass (1991) states *"the scope of operations management (OM) cannot be captured and explained in its entirety by purely deductive tools...unlike mathematics or logic, OM is embedded in the empirical universe...the lack of an empirical dimension in past OM research is a reflection on the unbalanced research emphasis in the area, which is correctable and deserves correction by increasing the pace and quality of descriptive, empirical investigations"* In light of this argument the design considerations of Swamidass (1991) are accepted, he argues *"field based research can narrow the gap between practice and research because it takes the researcher to the field for dialogue and observation ...some OM topics that are too fuzzy and messy [and] ...are under researched because they are unsuitable for deductive methods of research"*

At the present time, human factors within the aerospace industry and TQM are not well understood and therefore, as Parkhe (1993) advises it must be studied using a subjective rather than positivist methodology. Parkhe argues, *"at a stage of* *development where phenomena are not well understood and relationships between the phenomena are not known, precise experiments that precede rather than succeed studies amount to being precise about vagueness"* Before the final cycle of the case research was conducted, and in response to Parkhe's opinion, a pilot study was used to precede phase 1, the main questionnaire. As such the balance of the study was blended and the design was structured to offer new insights into the phenomena of repair & overhaul of safety related risk factors in areas of effective and ineffective management practice. Such a viewpoint is reinforced by Meredith (1993) who argues *"The use of conceptual research methods based on descriptive, empirical investigation can significantly increase the external validity of OM research conclusions and thus their corresponding relevance to managers"*

3.3 Naturalism in Operations Management

Having reviewed the main features and propositions of the positivist school, a growing trend exists against experimental forms of research and calls for a greater depth of study (from a real world/problem driven point of view) of research designs that focus on quality/safety related problems. In light of this situation the naturalist approach is therefore seen as having a bias towards meaning and offers an opportunity to provide a wider insight in to how best to design this study. The importance of which is centered on qualitative levels of understanding which Morgan & Smircich (1980) claims that *"Once one relaxes the ontological assumption that the world is a concrete structure, and admits that human beings, far from merely responding to the social world may actively contribute to its creation, the dominant models become increasingly unsatisfactory, and indeed inappropriate. The requirement for effective research in these situations is clear; scientists can no longer remain as external observers measuring what they see; they must move to investigate from within the subject of study and employ research techniques appropriate to that task"*

The 'ideal type' naturalist approach is diametrically opposed to that of positivism, and represents a comparatively newer branch of knowledge that accepts subjectivity in human decision-making and behaviour. For naturalists, 'value freedom' cannot be assured and the ability to manipulate human systems, such as industrial organizations, in the same manner as the natural sciences is not possible according to Layder (1994). This approach therefore highlights the role of the individual within management research as providing collective interpretation, based on 'meaning', which according to Delbridge (1998) is bound up with the experiences of the social world. In other words the view offered by naturalists rejects anything that lies outside of this experience and therefore has no real relevance to the understanding of social groups.

As such, using data collected during specific 'snapshot' interventions, naturalism seeks to capture the dynamism of events rather than 'freezing' the social world. These techniques favour observation and interaction with individuals, following abstention from 'a priori' axiomatic structures built from previous knowledge and extensive literature reviews. As such, the approach is characterised by 'inductive' methods as opposed to the positive tradition (deductive approach), which implies that the researcher enters the social setting to develop explanations as a result of a research process based upon observation and reflection. In view of the purely naturalist approach to research, figure 3.1 shows a very different methodology based on a 'bottom up' research approach.

Figure 3.1 The Naturalist Research Process.

Researcher Gathers Information
Leading To
Researcher Asks Questions
Leading To
Researcher Forms Categories
Leading To
Researcher Looks for Patterns (Theories)
Leading To
Researcher Develops a Theory or Compares Pattern with Other Theories

Source: Taken From Cresswell, (1994)

However, the main criticisms of the naturalist approach concern the number of potential and almost infinite causal relationships that exist with, even simple, social phenomena. Such a variety of choices, according to Miles & Huberman (1994) is undesirable[33] and leads to difficulties during the interpretation of results, which Miles & Huberman (1994) go on to argue, *"Even advocates of the naturalist approach conflict in terms of reconciling epistemological issues and also practical considerations during research itself"* In other words the naturalist approach in its entirety was considered to be inappropriate methodology as a whole, since

[33] During the design of this research strategy the recommendations of Miles and Huberman (1994) were observed and a pre-structured literature survey was conducted.

organizations, such as the one found in this study function as part of a system. The researcher therefore rejected this approach as the single source of design, because of its inability to provide direction and structure, this is summarized in terms of two extremes as listed in figure 3.2 shown below.

Figure 3.2.

Theoretical Comparisons

Naturalist Approach	**Positivist Approach**
Assumptions	**Assumptions**
Reality is socially constructed	Fact and data with objective reality
Variables are complex and interwoven	Variables can be measured & identified
Event taken from informants perspective	Events taken from researcher perspective
Dynamic quality to life	Static reality to life
Purpose	**Purpose**
Interpretation	Prediction
Contextualisation	Generalisation
Understanding the perspectives of others	Causal explanation
Method	**Method**
Unstructured interviews	Testing and measuring
Concludes with hypothesis & theory	Commences with hypothesis & theory
Inductive and naturalistic	Deductive and experimental
Data reported in language of informant	Statistical reporting
Role of researcher	**Role of research**
Researcher as instrument	Researcher applies formal instruments
Empathic understanding	Detachment objective

Source: Taken Barnes (2000)

3.4 Realism in Operations Management.

In the light of these two extremes the realist position is accepted as a suitable means of framing and housing this study. The realist approach is a point of reconciliation that sits between the extremes of positivism and naturalism. Realists such as Giddens (1984)[34] & Wass and Wells (1994) argue that a synthesis of extremes is possible and occurs naturally during most field research. They contend that positivism, whilst legitimate only provides a partial account of reality and that no form of science can rely exclusively on empirical evidence alone. Instead, much of reality is implicit or hidden from empirical observation and therefore realists propose that valid knowledge

[34] Giddens (1984) was one of the first academics to propose that structure and action constitute social life.

should encompass both observable and non-observable forms of study. Central to this debate Bechofer (1974) proposes a *"...research process is not a clear-cut sequence of procedures following a neat pattern but a messy interaction between the conceptual and empirical world, deduction and induction occur at the same time"* As such he argues for cycles of investigation that move from observable studies to more qualitative approaches. Gummesson (1991) reinforced this line of thought by proposing *"...there is nothing to stop a researcher from adopting a positivistic paradigm in a certain research setting and a hermeneutic*[35] *in another, even in the same project"*. Such 'cycling' between quantitative and qualitative observation is, for Miles & Huberman (1994) a powerful means of exploiting the realist approach that allows for a greater insight into 'messy' and complex social phenomena. Other researchers within the field of operations management such as Gilbert (1993) Swamidass (1991), Meredith (1993) Fillipini (1997) and Liker (2004) agree with this whilst at the same time rejecting the purely positivist approach in favour of using realism that generates a depth of understanding best suited to more complex operation management environments. These researchers also caution against what is referred to as positivist 'snapshots' claiming that the purely positivist approach leads to artificial 'smoothing', of data that has, in many cases has been shown to result in an oversimplification of reality.

As a direct result of this criticism the researcher, for the purpose of this study, has cited the work of Bhaskar (1978) who promotes a realist approach and proposes that there are three overlapping domains of reality. The first is centred on the empirical domain and includes experiences and observations of reality. The second, concerns the actual reality and events either observed or not and the third the real structures and mechanisms that produce these events. As such the concept of 'realism' is considered both objective and subjective this legitimises the researcher's choice and position in accepting what is described as middle ground. Bechofer (1974) reinforces this position claiming that *"research processes are not a clear-cut sequence of procedures following a neat pattern, but a messy interaction between the conceptual and empirical world, deduction and induction occur at the same time"*

The realist perspective according to Maylor (1998) therefore permits a deeper exploration of issues and deviant outlier cases, which the researcher accepted as a

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[35] The term hermeneutic is used interchangeably with the term naturalism in the philosophical literature.

valuable research perspective for consideration. Consequently, the realist perspective was considered to be the most appropriate means of research design, Silverman (2000), Yin (2003) Miles & Huberman (1994) claim that it is the 'dominant' form of organisational and operational management research design.

The realist perspective also permitted the 'cycling' between quantitative and qualitative aspects of the investigation such that Crompton and Jones (1988) argue that "*quantitative data always rest upon qualitative distinctions*" In other words the researcher is prepared to combine both elements of interpretation and will not assume a position of mutual exclusivity and for this reason decided that a wide choice of methods could be used to analyse both qualitative and quantitative research findings (Oakland, 2003). In this manner, the realist approach was selected as the most appropriate grounding for this study as a means of identifying the main features and barriers of TQM as well as offering a deeper insight into the safer management practice of self-managed team working itself. In light of this consideration Easterby-Smith (1993) argued that a "*Failure to think through philosophical issues while not necessarily fatal, can seriously affect the quality of management research*" Wass and Wells (1994) argue that a research design is "*a technical decision whereby the strengths and weaknesses of various techniques, in relation to the research problem, are optimally combined*"

3.5 Main Research Design Model

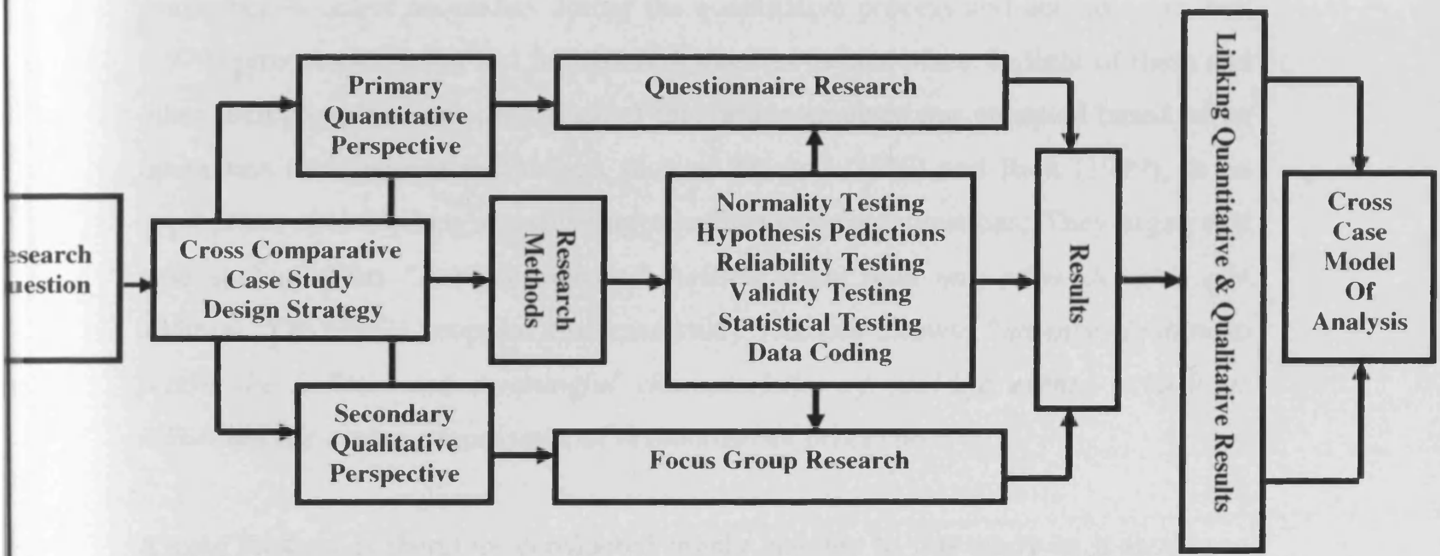
Having established the realist epistemology as the grounding approach for this study, this section will concern the selection and presentation of the research strategy itself. In achieving this aim a philosophical evaluation of investigative techniques that could be employed as a means of acquiring knowledge and manipulate data[36] has been included. Such considerations were integral to the selection of an appropriate strategy, whereby the methods used can be considered as more or less effective against the given objectives of the chosen research design. In consideration of the research question that guides this study, the researcher found that the chosen research design could not be explained by either a purely positivist approach, owing to vagueness of understanding, or a purely naturalist approach, which falls outside the perceptual boundaries of subjective interpretation.

[36] Source: Dictionary of Sociology 2nd Edition Unwin Hyman 1995

The chosen approach is therefore set within a realist, longitudinal framework, with cyclical phases of quantitative and qualitative research, involving a pluralist range and use of methods. The model shown below in figure 3.3 provides a schematic overview of this position, based on the researcher's design strategy that demonstrates to the reader a logical flow of research events.

Figure 3.3

Main Research Design Model



Source: Researcher

From a methodological viewpoint, this model allows for the widest variety of methods to be employed, combined with quantitative techniques, which will result in data expressed in a numerical format for the purpose of statistical manipulation[37]

In other words a 'qualitative observation' identifies the presence or absence of something, in contrast to 'quantitative observation', which involves measuring the degree to which a feature is present the latter of which according to:

Kirk & Miller (1986) *"Relies upon the emphatic skills of the researcher as an interviewer/observer".*

As previously noted Huff & Reger (1985) advocate the 'realist' approach and favour cyclical processes in which the researcher's role can be described in terms of

[37] The use of statistical manipulation is contingent upon a number of factors including the size of the sample and therefore it is not always conducted as in the conditions of multiple case studies using a common approach.

methodological pluralism. In addition, this position is accepted in terms of triangulation, with reference to the type of data to be collected, which according to Denzin (1978), Eilon (1974), Morgan (1983), Brewer and Hunter (1989), and Meredith (1993) will strengthen the validation process where the subject matter is ill defined and difficult to control. The recommendations of the above researchers were accepted, in terms of the methodological benefits that pluralism and cyclical approaches can bring to data collection and validation to this study as a whole. These advantages will ensure confidence in the results, are based on the ability of the researcher to detect anomalies during the quantitative process and according to Jick (1979) provides a critical test for different theories to take place. In light of these and other such considerations the choice of this design strategy was accepted based on an operations management researchers such as Massey (2000) and Rich (1999), as an appropriate choice when investigating manufacturing organizations; They argue that case studies offer: *"A more rounded, holistic study than any other design"* . In addition, Yin (2003) proposes that case study research allows; *"an investigation to return the holistic and meaningful characteristics of real-life events – such as individual life cycles, organisational & managerial processes..."*.

A case strategy is therefore considered highly suitable to this study as it is able to measure areas of human error risk, in environments that are poorly understood and as such are more likely to produce new theory, which is a key objective stated by Eisenhardt (1989), Leonard-Barton (1992) and Pettigrew (1992) within this area of operations management. Another argument, raised by Yin (2003) again supports the case study design based on its suitability for conditions where *"little is known about a phenomenon, current perspectives seem inadequate because they have little empirical substantiation ... In these cases theory-building from case studies does not rely on previous literature or prior empirical evidence"* [38]. He adds, the case approach is best suited to answering 'what', 'how' and 'why?' types of questions where the researcher cannot influence control over the subject as illustrated below in figure 3.4. As such, the case study process and strategy align well with the chosen research objectives that guide this study (as declared in chapter 1).

[38] Meredith (1993) reinforces the utility of the approach for poorly defined phenomena.

Figure 3.4

The Appropriateness of Different Research Strategies

Strategy	**Form of Suitable Research Question**	**Requires Control Over Behavioural Events?**	**Focuses On Contemporary Events?**
Experiment	**How and Why?**	Yes	Yes
Survey	Who, What, Where, How Many, and How Much?	No	Yes
Archival Research	Who, What, Where, How Many, and How Much?	No	Yes and No
History	How and Why?	No	No
Case Study	What, How and Why?	No	Yes

Source: Taken From Yin (2003)

3.6 Case Study Strategy Selection & Design

The term 'case study' covers many different approaches within the realist perspective and, as Yin (2003) claims, it offers three basic classifications namely; exploratory, descriptive and explanatory[39], their use is based on the intent of the researcher. Exploratory studies involve the identification of questions/hypotheses for later study, whereas, descriptive cases involve a comprehensive account of the phenomenon within its context, and finally, the explanatory case is used to test 'cause and effect' relationships as events unfold. Stake (1994) also provides three types of case study commencing with 'intrinsic' cases used to generate understanding of a phenomenon, 'instrumentation' cases used to test methods and the 'collective' form of cases, used to examine common types of research phenomena. Although, more recent studies have identified six classifications of case study which Shavelson (2000) identifies as.

1. Multi-case studies
2. Historical case studies
3. Observational case studies
4. Oral case studies
5. Situational case studies
6. Clinical case studies

[39] Explanatory cases involve the questions of 'how and why'. Descriptive cases examine 'how' subsystems interact and exploratory cases focus on 'what' questions before engaging further fieldwork to test the hypotheses developed.

Of the many different types of case study, a multiple-case replication approach was considered to be the most appropriate for this research, because it can align the main research question with contemporary events set within a framework of high mix low volume types of OM systems. Herriott (1983) provides strong support for this selection and argues that research of the type found in this study, will be able to predict patterns of results and theoretical replication to ensure a common approach across a multiple case study design. He argues that this is the strongest way of building theory and a multiple case approach allows consideration of the business problems as a holistic system. Such a view was accepted by the researcher and considered to be necessary when evaluating the major areas of error risk that require objectivity, thus avoiding focusing on one problem in isolation. In light of this and other such considerations the concept of multiple embedded case studies were considered because they are able to reduce the risk of misjudgment whilst at the same time exposing different levels of generalization, in terms of the practical benefits to a small populations of businesses sectors.

The multiple case approach permits, according to Eisenhardt (1989), greater levels of confidence and validity of emergent relationships especially when the results need to be compared between cases and/or when deviant or contradictory cases are likely to be found. For this reason the multiple case study approach offers the potential to refine and extend theory, suiting the purpose of this investigation, which Leonard-Barton (1990) argued in favour of, in terms of the benefits of developing the opportunity for theoretical replication to take place. In accepting this position the concept of a cross-comparative case study was considered to be a suitable choice, it will be used to measure the extent to which a quality problem may exist in terms of creating an objective reality, which according to Schramm (1971) *"Tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and what was the result*" To achieve the goal of academic rigour the researcher has therefore identified with the three guiding principles set out by Gligun (1994) & Ghauri (2002), based on the following prerequisites shown below.

1. A matching of method and strategy with the implications of the research question.
2. To allow deeper research and lower the ability of the researcher to control behavioural events.

3. The ability of case research to focus on contemporary events as opposed to reflections upon historical events at each case study site.

In accepting a case based approach it will also be necessary to define the 'boundary' of the unit of analysis for this research a case study is defined in terms of a single manufacturing site (a systems approach to safety management). The number of cases selected to determine this position was set at four and each case was a subsidiary repair facility of a multi-national corporate enterprise (Leonard-Barton, 1992). The selection of 4 cases is considered to be an effective number in order to offer an insight into human error risk, based on purposive selection criteria. A viewpoint, which is supported by other researchers such as Eisenrhardt (1989) who advocated using more than 3 cases and less than 12 based on the caveat of practical administration. This consideration was duly accepted, based on the doctoral factors such as time, access and finical pressure, set within the same parent organisation. The repair & overhaul business was deliberately selected because, it was operating a Lean and TQM approach to operations management, as such it was most likely to offer insights into safety management practice under conditions of human factors control. Each case shared a corporate culture and common ways of working under a single human resource strategy within the context of TQM and self-managed teams.

The informants were selected from common grades of employee divided by 'staff' and 'shop floor' groups at each case study location using a cross-functional management model. The selected informants were considered to be critical elements of the gas turbine repair & overhaul business process, which complies with the recommendations suggested by Yin (2003) as representative of all businesses in the aero-engine repair sector. The purposive selection criteria is shown in figure 3.5 below, which demonstrates a level of compliance, based on the recommendations put forward by Silverman (2000) concerning the ability and need for the researcher to generalize from a purposive or theoretical sampling point of view.

Figure 3.5

Purposive Selection Criteria

Selection criterion	Main Purpose
One corporate owner of the sites	To reduce the affects of cultural bias. All sites were part of an identical improvement, HR and quality strategy. Each site also reported to the same directorial structure.
Same engine type (Civilian Engine)	To ensure the technical system and repair processes were similar. Civilian engines were those where most air traffic accident data existed. All engines were of a similar and regulated complexity.
Established factory	All sites had an established culture and working practices based upon over 40 years of repairing engines. Each case is third line aero-engine repair (the level of engine supply that is at the base of the safety iceberg model proposed by Reason (2003).
Mature Improvement Programmes	All sites were experienced in the application of quality and lean working methods.

Source: Taken from Silverman (2000)

A pluralist approach to data collection instruments was selected during the design and execution of this research. These instruments included a pilot study to sensitize the researcher to each case site and to identify key issues within the field of error management itself. In view of this requirement a variety of background literature was drawn upon which was partially accepted for its contribution to theory building and was subsequently used as a suitable framework for testing the original research question. The assumption being that human error problems, for the most part, correlate significantly with defeats in systems thinking, this therefore provided a *"read-across"* with operations management thinking. While most human factors studies reflect the need to capture different kinds of data, the researcher states that no single method or way of combining employees' attitudes will be used alone as a means for measuring factors affecting human error risk[40].

In light of this consideration the study therefore integrated cognitive research methods, whereby the cohesion of knowledge structures can be assessed in terms of a

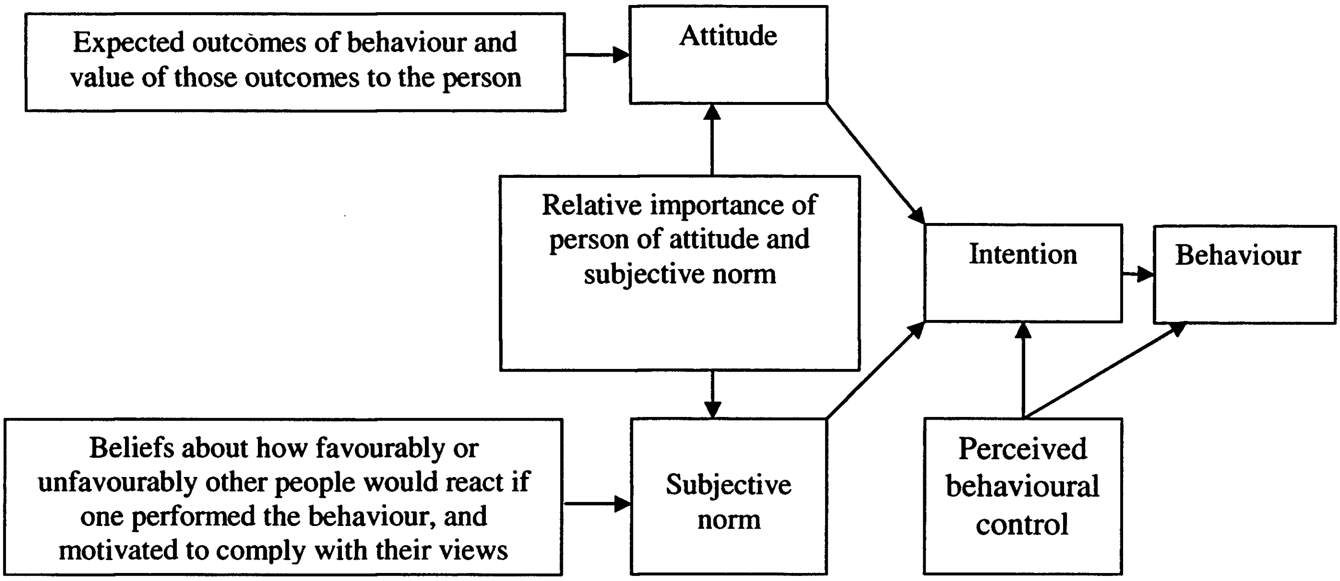
[40] Human error analysis and subsequent risk reduction are of significant concern for all type of human process tasks found in various industries.

measured response to what the individual thinks or believes to be representative about his, or her particular environment and their role and function within it. In so doing, part 1 of the study includes the deployment of a large-scale questionnaire as a method of effective data collection; it is based on how individuals relate to operational constraints it also measures the relationship between cause and effect thinking. Although, when nearly all conditions within the field of human factors research are defined by language, perception and meaning it is acknowledged that overt forms of measurement, without due consideration for naturalist forms of research would be reductionist in its approach (Saunders et al, 2000). Therefore a complementary secondary approach was added to the research design, whereby qualitative methods can provide deeper and more complex answers than quantitative studies alone.

Whilst understanding the significance of attitude research, the study could not ignore that individual problems are jointly defined by feelings that relate to objects, events and behavior as stated earlier in the literature review. To substantiate this claim further, the work of by Ajzen & Fishbien (1980), was considered, they developed a theory that was able to legitimize the relationship between attitudes and behavior, which was specifically designed to overcome this type of problem. The model is referred to as the 'theory of reasoned action' because it assumes that actions are best predicted by intentions and that these intentions will be determined by the attitudes of individuals who are able to express their concerns through experience of environmental perception. Ajzen and Madden's (1986) contribution is based on the premise that attitudes are heavily influenced by environmental control and for this reason a realist research framework was used and a researcher day book was maintained to capture reflections and informal aspects of the investigation (as per the recommendations of Yin, 2003). Considerations at this level of analysis underline the importance of the individual's belief as to whether he/she can or cannot perform a certain task against a given situation as outlined in their model shown in figure 3.6 below.

Figure 3.6

Model of Planned Behaviour



Source: Taken From Ajzen & Madden (1986)

3.7 Questionnaire Design

Following the literature review and expert interviews, the researcher has selected 9 common factors to include in the questionnaire, which form the general framework of quantitative human factor barriers. These barriers could affect the goal of achieving self-management with TQM as shown in the list below.

Factor 1 = **Planning**

Factor 2 = **Equipment**

Factor 3 = **Procedures**

Factor 4 = **Quality Management**

Factor 5 = **Fatigue**

Factor 6 = **Training**

Factor 7 = **Communication**

Factor 8 = **Safety Culture**

Factor 9 = **Management Attitudes**

In order to gain appreciation of each site, the researcher visited each factory and met with the management team to introduce the general context of the study based on the objectives of human factors itself. The visits included a tour of each facility, which also provided the opportunity for assessment of the uniqueness and the history of the culture of each site. Such an approach is widely favored by case researchers as a means of contextual sensitization and also as a practical means of designing and phrasing the questionnaire. A common questionnaire was therefore administered to all cases based on a sample size of approximately 200 employees per site location, including 20% of those respondents taking part in the secondary stage of follow up qualitative research. The structure formed a series of focus groups and semi-structured interviews as part of the secondary data/observational research cycle. Based on the logistical task of programme managing and processing large amount of data, the researcher committed approximately 12 months of full-time work across each of the four UK based sites. The data collection methods, which are taken from a standard Likert scale were used to collate interval data types, represent affective attitudes of error provoking factors through a single questionnaire design. The likert system is often used in operational management research, because each item on the measurement scale is not influenced by the researcher's intuition or common sense opinions.

Likert scales are usually designed around a single number that represents the sum and average scores respectively, thereby providing the researcher with a set of raw data scores as a broad indicator of human error concerns, as illustrated by the choice of design shown below.

Questionnaire Numbering System

1 = Strongly Disagree (No Problems)

2 = Disagree (No Problems)

3 = Unsure

4 = Agree (Problems)

5 = Strongly Agree (Problems)

The questionnaire was deployed to a central co-ordinator at the human resource department of each site's Learning and Development adviser and these personnel were used as the point-of-contact to receive completed questionnaires. It should also be noted that access to the sites was negotiated via the trade union and the trade union was content to support the human factors programme.

However, before the survey could take place the issues of variable selection and control were addressed in terms of understanding the validity of the questionnaire process itself. For example, the original research question, about the relationship between self-managed team working and the principles of TQM theory, was based on the experience and informed opinion of the researcher in his professional capacity as an error management investigator and the experts that had been interviewed. In order to test this relationship, a number of variables had to be clearly identified using established methods of social science that ensured statements based on assumption could be tested for their relevance and truth.

3.8 Questionnaire Validity

The scientific term 'validity'[41] refers to the process by which the researcher can confidently measure a range of human factor risks, against the original research design. In order to provide evidence of scientific generalisation a level of consistency should be demonstrated; the study should be robust and able to stand the test of time whereby this particular study could be repeated in other places and by other people. This study satisfied the first principle of external validity in the area of the process of expert sampling. This process included a cross representation of people from the department of error management research at Cardiff University School of Psychology along with industrial professionals from the field of aviation maintenance such as of quality, human resource and error management consultants. Their advice was duly accepted. In addition, the supporting literature was used as a checklist as highlighted by Thompson (2001) this is perceived as instrumental in shaping the design of the questionnaire, as agreed by the panel of experts. For example each survey was administered to a sample of staff and works groups; reference Appendix 1, which was estimated to take approximately 20 minutes to complete. The final evidence for content validity is indicative of how closely the results shown in chapter 5 are expected to correlate between and across all case study sites. Consideration in this context was therefore given to a range of factors within the design of the questionnaire, which aimed to understand the strengths and weaknesses at three levels of analysis. This was carried out by means of controlling and reducing employee's unreliability through standardisation of questions, within the context of its;

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[41]Testing the scientific validity requires development of a qualitative methodology for the measurement of behaviour

1. Wording
2. Content
3. Format

The testing involved examination of each section within the questionnaire, which was widely discussed with a number of end users (n=12) before the administration of the survey proper. After considerable debate it was agreed that every question in each section was equally relevant with no single question being more noticeably relevant than any other. Finally the advantages of carrying out the process of external validity is supported by the fact that the researcher is not acting alone and thereby able to defend decisions that justified the investment of resource during the second phase of the study. This was considered important in order to justify the investment of further time and resource when planning formative evaluations, as follow up research to stage 1 of the study based on the validation process as shown below.

1 Review the questionnaire by the panel of experts.
2 Carry out a think-aloud process with the cross sample of experts.
3 Engage 10 employees to write detailed responses of the draft questionnaire.
4 Invite employees to carry out a pilot questionnaire.
5 Compare the responses of high and low scores against background research.

Establishing external validity is therefore ultimately dependant on how the researcher is able to prove that the correct generalisation has been made. For example how can the researcher be confident that the results of the study, which will be carried out in the UK, will be consistent with the findings of other global studies, when according to Hofsteade (2001) different cultures often exhibit certain types of behaviour that may be culturally biased between one country and the next. For example Craig & Douglas (2000) found in their study of social acquiescence bias a strong correlation amongst some Japanese subjects who required a sense of 'togetherness' in their organisation and therefore did not want to elicit negative responses for fear of offending or causing problems. In other words Craig & Douglas argued that this type of situation could be explained in terms of a cultural bias, which is characteristic of many Asian countries where workers would be expected to respond positively to questionnaires as it would be considered rude to do otherwise. In some situations they also found evidence of research bias in redundancy environments where employees of one organisation felt that any negative comments found in their surveys might be used against them.

However, at the micro level of analysis the researcher is also aware of what social scientists refer to as response order bias, whereby the aim of a well designed questionnaire must be able to reduce the effects of error within the survey itself, starting from the rationale that human error can be attributed to many different types of stimuli, with some errors relating to carelessness, negligence or poor judgment. Secondly the researcher considered the concept of internal validity, which refers to the rigorous methods under which the questionnaire was carried out. For example it was noted that approximately 20% of subjects during the pilot phase of establishing validity were observed as not completing the questionnaire accurately. The researcher therefore concluded that (approximately 3/4 of the way through the pilot questionnaire) a satisfactory resolution would be to redesign the questionnaire and to simplify it. A number of inconsistent trends had developed and the original design of the questionnaire had induced a condition known as 'response order bias' whereby some subjects lost track of the a number of options and selected answers that came easily to mind rather than the options the researcher had intended for choice. To resolve this problem the researcher removed 33% of the questionnaire thus reducing the effect of response order bias.

3.9 Reliability Methods

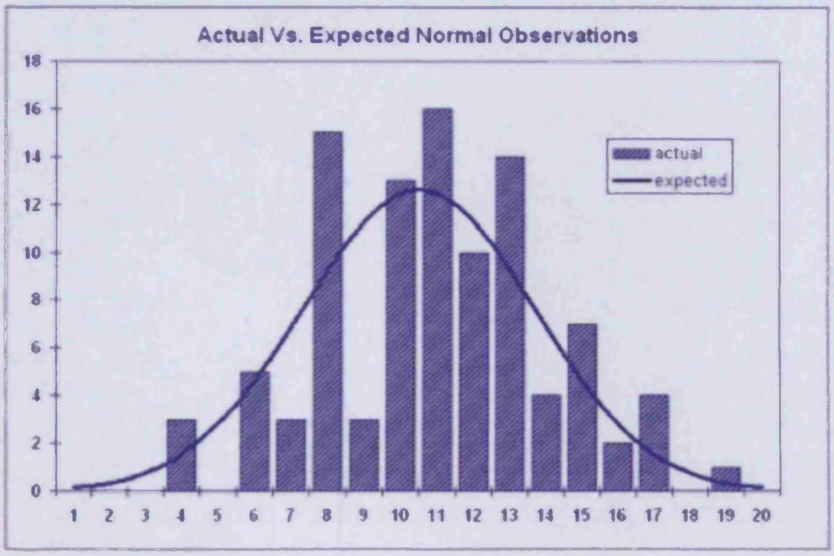
The concept of reliability[42] is based on the assumption that objective research must be able to demonstrate scientific rigour through a standardised range of methods that will reduce the chance of variation thorough what is described as research bias. A consideration that Yin (2003) formalised in terms of: *"A process by which another researcher should be able to carry out the same study, following the same procedures, making the same findings and drawing similar conclusions"* In compliance with this position the researcher will process the first stage of the study, namley each questionnaire response separately, to create a database of raw scores for the purpose of what researchers refer to as testing for 'normality' To facilitate this the 'Anderson Darling' best line of fit test will be used to establish the reliability of the data, in terms of its spread or standard deviation about the population mean. A probability value will

[42] Research Reliability relates to whether research results can be applied to a wider group than those who took part in a study.

then be established in terms of defining the type of data collected as either a parametric or of a non-parametric research design. The aim of the normality test will allow the researcher to compare response frequencies in terms of measuring the intervals of scores within a histogram against expected frequencies, if the distribution curve is assumed to be normal. In other words the researcher is concerned with how well the data fits a normally distributed curve, against an overlay of data as illustrated in figure 3.7 shown in the example diagram shown below.

Figure 3.7

Actual Vs Expected Normal Observations



Source: Taken from Min Tab (2007)

The test statistic taken in this example represents a probability value of 0.75, which is higher than the significance level of 0.05. In general terms any data, which fits a normal distribution profile, will be represented as a large probability value, thereby resulting in the acceptance of what is referred to as the null hypothesis. If the test statistic is equal to or above 005 i.e. the critical value, a level of significance will be established to guide the researcher in accepting the null hypothesis. For example if the test probability value is less than 0.05 then the researcher can accept the questionnaire as being of a non-normal outcome. Whereas if the data is greater than 0.05 the researcher can be certain that the data is of a normal distribution, this would hypothetically prove that each person who took part in the survey was in agreement with the same human factors concerns. In order to test the consistency of the measurement system itself the researcher must also be able to demonstrate the criteria of accuracy and repeatability. For example Miles & Huberman (1994) advocate the importance of taking actions to increase the reliability of a case study, such as clarifying the research questions and designing the study in congruence with them. The researcher therefore considers the measurement system as reliable if a person's score from one question is statistically similar to the next. By means of testing this element of reliability, the researcher adopted the principles of internal consistency that statistically measured the levels of variance between questions using a standard Cronbach Alpha test. This test will be applied using a computer-aided programme namely SPSS[43], which is capable of measuring correlation values based on a series of what is referred to as split tests. The rationale being that the closer the score is to one; the higher the reliability estimate is proven to be. The accepted social science cut-off point for any Cronbach Alpha test should be <0.70 or higher for a set of items to be considered a scale.

However some researchers insist on using 0.75 or 0.80 while others are prepared to accept as little as 0.60. For the purpose of this study the chosen statistical cut-off point is set at <0.70 based on an error of measurement declared at half the standard deviation.

3.10 Hypothesis Prediction

Once the researcher was confident that standards of reliability have been attained the next phase will be to utilise the principles of hypothesis testing. This approach is based on designing a model (as proposed by Rasch, 1980)[44] where the concept of interval levels will enable the researcher to make estimates that can be used to understand patterns of data for the objective of theory building. For example if there is a statistically significant relationship of attitudes towards human error risk between staff and works grouping the existence of team situational awareness will be assumed. Whereas if the alternative was found to be true the null hypothesis would be rejected, thereby claiming the existence of a disconnection between these two sample groups. In other words evidence would exist to demonstrate the principles of a silo mentality whereby each group is working in isolation to the next underlining what human factors literature describes as a lack of team situational control. In order to establish this position for the purpose of theory building a common one-directional test will be

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[43] SPSS, is a comprehensive statistical analysis package used for non-parametric testing

[44] The Rasch scale is based on the assumption that the probability of a particular response to a test item depends on two parameters that can be estimated independently.

used, as opposed to a two-directional approach where no prediction can be assumed to be made.

In general terms the significance levels of hypothesis testing relates to a fixed probability of either accepting or rejecting the null hypothesis if the prediction is found to be true. In other words the researcher expected the probability value to be as small as possible in order to reject the null hypothesis, based on accepting wide variations in attitudes to quality related problems of the two sample groups, namely: staff and works employees. The probability or p-value will be used to compare the significance levels and if the value is smaller than 0.05 the null hypothesis will be rejected and reported as $p = > 0.05$ thereby suggesting that the null hypothesis is unlikely to be true. For example the smaller the p value becomes, the more convincing the null hypothesis will be. In other words if the expected outcome is proven to be true, attitudes towards quality will vary significantly, underlining that both works and staff grouping are not the same.

For the purpose of this study the researcher has chosen to follow the convention of always stating the null hypothesis by means of demonstrating strict equality in the context of accepting or rejecting the alternative. The research question that guides this study is therefore accepted from what Henslin (2000) claims is a formalised approach to theory building, based on the deployment of either single or multiple numbers of hypotheses that will provide: *"A testable prediction about the relationship between two or more events with no logical interpretation"*. The goal of the hypothesis test is therefore aimed at providing strong enough evidence to reject the null hypothesis in favour of the stated alternative hypothesis. The exact hypothesis that guides this study is declared as one tailed, based on the problem statement shown below:

1. *The null hypothesis predicts that no significant relationship concerning quality problems will exist between staff and works groups across all sites.*

3.11 Statistical Methods Used

In order to understand more of this relationship the researcher will need to evaluate the significance of these findings that goes beyond the simple order of magnitude, towards a more in depth analysis in terms of understanding its shape or standard deviation. Typically the type of test used to measure this relationship is referred to as the 2 sample't test', whereby the differences between mean scores at each case study site can be analysed within the concept of what statisticians refer to as 'normal theories' The suitability and application relies on data known to be of a non normal shape and within close proximity to the standard deviation of its population size.

For the purpose of this study the exact probability value will be considered in terms of real-world research, which is expected to be slightly skewed. The rationale being, that field research of the type found in this study is far removed from the rigours of laboratory research.

Accepting this position, the researcher chose to carry out a mixture of both approaches, whereby the 2 sample t test will be used as a check measure to provide a general comparison of data sets which is closely distributed about the mean.
However, the main body of analysis is accepted in terms of utilising non parametric methods such as the Mann-Whitney test, whereby the researcher will measure the differences between average scores of one group against the next by counting categories, based on the median and not the mean.

The method used to assess this position is formally referred to as non-parametric statistics (Wass and Wells, 1994), whereby the range of data being analysed reflects very little about the parameters of the population mean. In other words when carrying out a non-parametric analysis the Mann-Whitney test is considered as being more robust because the researcher does not have to rely on the estimation of parameters, such as the mean or the standard deviation. The test statistic used for Mann-Whitney, is referred to as U and represents a value, which can be compared to a table of critical values for U based on the sample size of each population group. For example if the U value is larger than the critical value for U, a significance level or probability of $p= > 0.05$ will be established, thereby enabling the researcher to accept or reject the null hypothesis in favour of the alternative point of view. In summary the benefits of using this type of test instead of other parametric methods, will enable the researcher to predict generalisations, which are seen as more applicable to the real-world situation of problem solving from a human factors point of view.

However, when considering a more in-depth comparison of analysis involving multiple groups or more, the researcher will also be interested in measuring the effects of team performance against a particular condition, namely a 'factor' and in so doing will measure the interaction of this effect or influence. The Chi Squared test will be used for the purpose of this interaction because it has been designed to convert the differences between questionnaire scores by analysing the probability of chance when comparing the data being measured, against the number of variables referred to as degrees of freedom. For example the effectiveness of self-management in its ability to facilitate the principles of TQM maybe more or less effective when input factors such as bad planning or inadequate training result in high levels of system variation. In order to test this relationship the researcher will cross evaluate the actual results against a theoretical range of expected results. The Chi-Square test was selected because it is able to compare what is referred to as the 'goodness of fit' for 'independence'. In other words, the test will highlight paired observations, based on two or more variables, which have been defined through a contingency table in terms of each case levels of independence. For example if the p-value is high there will be considerable overlap between case study groups where the distributions of results are assumed to be the same. In some cases the chi-squared test can also be used for quantitative purposes as well, but in such situations the researcher will not be able to use t or f test because the data would be described as 'categorical' and thereby not of quantifiable origin.

In anticipation of such an opportunity arising, the researcher has accepted the argument put forward by Schaubroeck & Kuehn (1992) who claimed that:
"The majority of published studies are conducted in the field, although laboratory work comprises of nearly one-third of field research. Half of occupational research problems are experimental and compared to most other studies are based on common method factors by using diverse data sources. On the down side, a majority of field studies were cross-sectional in nature, as there is little cross-validation of evidence, such as psychological measures and archival records. Researches appear to invest in particular design strengths and compromise others"

3.12 Linking Qualitative & Quantitative Research

In general terms the use of quantitative research, whilst initially providing an understanding of where the problems areas might lie, fails at the same time to facilitate a meaningful account of what individuals are able to express in their own words. In order to address this position Bryman (1989) argued that qualitative research in the form of phenomenological studies[45] should take place, which for the purpose of this study the researcher will complete, within a time frame of 1 year, once the questionnaire process is complete. The concept of semi-structured interviewing will therefore be used in order to satisfy this aim based on establishing the principles of congruence[46] that Miles & Huberman (1994) claim are important, when establishing a triangular approach to a cross-case research design. In developing this position the researcher has adopted the methodology of focus group research, which was selected for its narrative value to include direct quotations from those persons involved. A concept that Greenbaum (1998) argued would also provide an opportunity for understanding and measuring the importance of attitudes that are not entirely available based on questionnaire results alone. In light of this consideration Tesch (1990) also proposed a number of different qualitative methodologies, based on four traditions and groups of classification a shown in figure 3.8 below.

Figure 3.8

Types of Qualitative Research

Characteristics of Language	**Discovery of Regularities**	**Comprehension of text or Action**	**Reflection of Research**
Content Analysis Discourse Analysis Symbolic Interaction	Grounded Theory Qualitative Evaluation Action Research	Phenomenological Research Case History Life History	Reflective Phenomenology Existential Psychology Heuristic Research

Source: Taken From Tesch (1990)

Tesch divides the main areas of her model into subgroups, arguing that it is not possible to define clear-cut borders between different groups. Instead she is suggesting that different qualitative methods should consist of many different shades and mixes. Tesch stresses that qualitative research may mean very different things to different people because analysts come from a variety of backgrounds, such as sociology and psychology, therefore each will bring his own bias to the understanding of the research.

[45] The results of phenomenological studies arise from interpreting analysis of texts.
[46] Referred to data analysis that includes within-case, within-group, across-case and across-group pattern matching

The researcher's decision to use the methods of a phenomenological structure was based on the need to create an environment that will encourage discussion of attitudes, feelings, beliefs and experiences in such a way that would not be available using single method studies alone. While the researcher accepts that focus groups in general are independent of their natural setting, an important factor remains that a valuable range of information can be gained in such a way that would increase the likelihood of an open and interactive debate. The rationale supporting this argument is taken from Morgan & Kreuger (1993) who claim that focus group research encourages the use of everyday language, which is of particular importance when exploring the degree of consensus in any given situation. In other words the researcher will consider the importance of individual viewpoints in order to confirm a level of validity against the information collated at the first stage of questionnaire design. For example attitudes and employee belief systems will be analysed independently of the workplace setting, this will necessitate the need for a carefully designed produce, based on the following checklist of criteria shown below:

1. Recruit participants using site human resources champions through human resource database
2. Make necessary arrangements to include training room and refreshment services
3. Introduce everyone with name badges if locally appropriate
4. Explain the purpose of the focus group, how long it will take and what feedback they will get.
5. Explain that what employees say will be treated as confidential
6. Each session to commence with an easy range of topics that ensure all employees have a basic understanding of the session aims and objectives.
7. A record to be kept, which summarises the consensus of group opinions and to be subsequently prepared in report format for research purposes.
8. Develop a framework of human factors criteria based on questionnaire design.

All of these factors were built into this study and in light of this consideration Miles and Huberman (1994) go on to argue that adequately sampled and carefully analysed information will illuminate a unique level of understanding, which is not limited to specific case concerns, but instead will enable the author to: *"Calculate where a given order of events is most likely to occur or not occur"*

However, the down side of this approach according to Morgan (1988) means that the researcher is sometimes faced with the difficulty of interpreting subjective data in the form of opinions, which highlight the issue of reliability in terms of social control.

Unlike traditional analysts the researcher for the purpose of this study has rejected the notion that focus groups will form the conceptual framework of study. Instead he identifies, with the model put forward by Tesch (1990) and uses the qualitative data methodology as a collection tool for clarification of primary research, within the context of her model of 'Types of qualitative research' In general, qualitative data is usually presented in words as opposed to numbers and whilst becoming the preferred method of human factors research, Miles & Huberman (1994) argue that the issue of numerical control is still problematic, they describe it as: *"Pervasive and not gone away"* In other words, presenting and arranging of information must be organised so that comparisons and contrasts can be identified. In light of this requirement Miles and Huberman (1994) argue in favour of linking both qualitative and quantitative approaches into one cross-case design, based on the premise that: *"We need a theory that explains what is happening- but a theory that does not forcibly smooth the diversity in front of us, but rather uses it fully to develop and test well-grounded set of explanations"* With this approach it is important that the researcher is able to categorise all information in such a way that a single cross-case design represents a pareto of relationships in terms of the most serious threat to the quality and safety concerns. In adopting this approach Dawson (1979) highlights this process as a highly labour-intensive activity that must be conducted in such a way that its methods do not 'cheapen' the quality of cross-case design. Miles & Huberman (1994) support this position and claim that: *"The most serious and central difficulty in the use of qualitative data is that the methods of analysis are not well formulated"*.

For qualitative data, there are clear conventions the researcher can use. But the analyst faced with a bank of qualitative data has very few guidelines for protection against self-delusion, let alone the presentation of unreliable or invalid conclusions to scientific or policy-making audiences. How can we be sure that an "earthy" "undeniable," "serendipitous" finding is not, in fact wrong? In view of this consideration, the actual methods used and the results obtained for the purpose of analytical evaluation are based on the framework suggested by Rossman & Wilson (1991) who claim that linking primary with secondary forms of research will:

1 Enable conformation or corroboration of each other via triangulation

2 Elaborate or develop analysis providing richer detail

3 Initiate new lines of thinking through surprises or paradoxes.

The researcher therefore compiled and documented information from the workshops held, the aim was to convert large amounts of basic raw data to a form of typed content summary. Next the principles of first-level coding were used for the purpose of structuring what is referred to as a contact summary of events. In so doing the researcher extracted what is considered to be key phrases and sentences reported from the findings of the focus group workshops, which are considered as error provoking factors cited from the main questionnaire concerns. This element of the analysis was carried out on completion of each workshop held, based on the advise put forward by Loftland & Loftland (1984) who recommended carrying out write-ups no later than one day after field contact is complete. By simplifying the content of events from each case study location the researcher is able to condense a large array of error provoking factors into 9 generic measures, whereby a methodology will then be established in terms of linking both data sets into one cross-case design. In acknowledgement of the complexity surrounding this requirement, a method was designed whereby a set of codes are used to assign units of meaning, which relate to key words, sentences or paragraphs as a whole. The assumption being that the researcher will be able to examine, identify and highlight similarities of findings, within the context of different error trends, by linking the results of the questionnaire and focus group concerns. This approach in principle was taken from Ragin (1987) who argued in favour of a method that will enable the development of: *"Dialogue between ideas and evidence"* The researcher has therefore structured the following model, for the purpose of this study, that will reflect a range of error provoking factors, which will be highlighted by patterns of reoccurring themes as listed in figure 3.9.

Figure 3.9 **List of Error Provoking Factors**

Focus Group Factors	Codes	Tally
Commercial Pressure..........	CP	111111111111111111111111
Leadership......................	L	11111111
Communication.................	C	111111111111
Individual Accountability....	IA	1111
Attitude Differences...........	AD	111111111111
Role Ambiguity................	RA	11111
Peer Pressure	.PP	1111111
Responsiveness To Change...	RC	11111
Team Responsibility...........	TR	111111111111
Problem Solving...............	PS	111111111

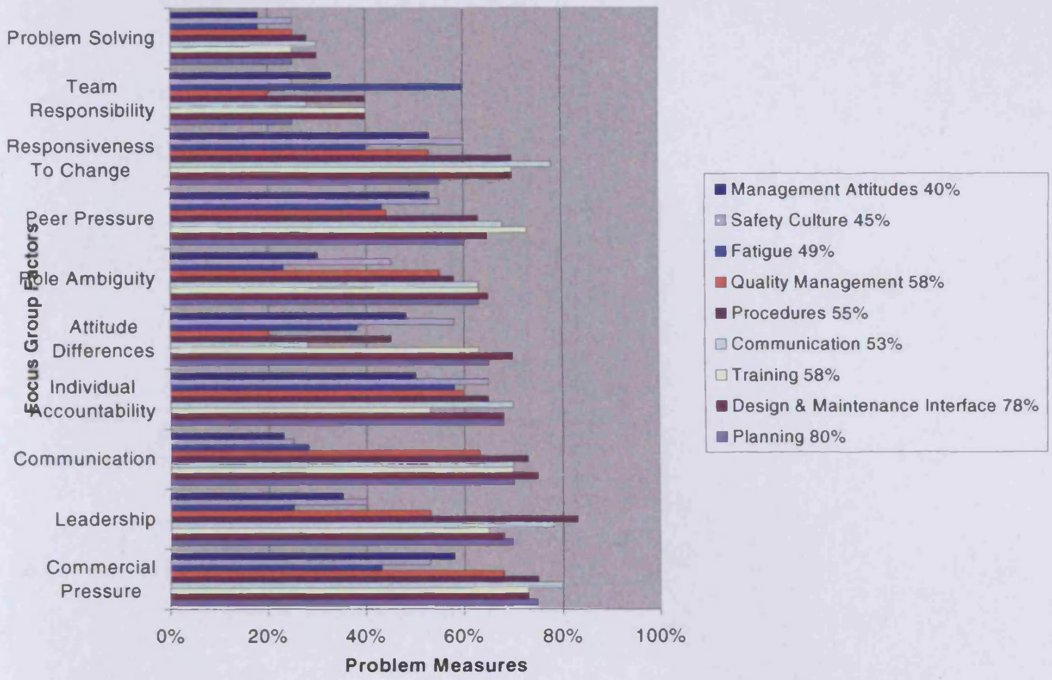
Source: Researcher

In the first instance a numeric tally was used to provide an overall percentage frequency against each set of focus group results, which will be arranged in chronological order against a pareto of questionnaire scores.

The model in question has been designed to analyse a range of generic input factors, based on configurations and associations of historically grounded patterns of information, extracted from the focus group results. The researcher therefore assumes the position of data reduction, whereby the methodology itself cannot be separated from its analysis and will serve to validate and interpret quantitative findings in such a way that final conclusions can be made, based on the principle of 'data condensation' In other words the proposed model will enable the researcher to analyse interrelationships and thereby highlight gaps between the social & technical system that other researchers, within the field of human factors research, have not yet explored. A matrix analysis was therefore created, based on literature taken from Miles and Huberman (1994) who point out the benefits of linking quantitative as well as qualitative results into one cross case design. This position was accepted and a model was created, which is able to analyse interrelationships based on extrapolating multiple explanations, as highlighted in what has been described as a model of cross-case analysis[47] as illustrated in figure 3.10 shown below

[47] Cross-case analysis is central to the process of constructing generalisations

Figure 3.10 Model Linking Qualitative & Quantitative Results



Source: Researcher

The model is intended to provide a deeper understanding within the context of cause and effect relationships, as opposed to the qualitative and statistical approaches that are either too factual or highly subjective when analysed on their own. For the purpose of clarity, only the highest three factors will be presented for analysis during chapter 5 and compared to the background literature of chapter two and, more importantly, to highlight gaps against the organisational strategy as declared in chapter three.

3.13 Limitations of the Case Study Design

In any type of research design a trade-off exists between theory and those practical considerations, which has been accepted in terms of a number of limiting conditions. Given a greater amount of time and access to the organisation the researcher would have increased the numbers of focus group sessions as a means of testing the questionnaire model derived from the quantitative phase of the research design.

In selecting the exact type of case study strategy to be deployed, many alternative courses of action were both considered and rejected, these included, amongst others, grounded theory. This approach was deemed as inappropriate because of ethical issues when aligning ethnographic research with certain questions and outcomes that relate to the uniqueness of this study in particular. For example it was considered that such issues were impractical to manage owing to the economic and political nature of human factors surrounding the role of the trade union and local management which typifies the nature of this study in terms of a repair-engineering environment, although these issues were deemed not to affect the ability to generalise from the findings of the study as a whole.

However, it should be noted that the number of Bristol cases is comparatively small compared to the other three sites and for this reason the results could be slightly skewed in comparison to the sample sizes used across the other sites, albeit that the actual number of cases was still within the advised number stated by Leonard-Barton (1992) Other limiting factors concern the comparability of the different UK sites themselves that, whilst chosen for their overall compatibility, differed slightly in terms of the type of product and processes themselves. Whilst similar in the nature of product repair type, each engine project differed slightly in content and volume.

Finally, no account is made of the differences in design processes, which could have impacted on error management because of considerations that failed to account for the impact of mistake proofing devices. Although it was believed that older engine designs would have benefited from greater problem solving even though errors may have been 'designed out'. The researcher therefore proposed that there are few differences between old and new designs, and that the study would focus on TQM practice and not design effectiveness. Furthermore the supplier network, though considered to be an influencing factor, was not taken into account because it was outside the scope of case study control and therefore did not form part of the socio-technical system design. Data is controlled and subject to official secrets act. Limitations are: the timing and the allowance of the unions to do this work, also the focus is on civilian and not military aircraft, however these were seen to be comparable processes by the researcher.

3.14 Issues & Ethical Considerations

The researcher could not ignore the rules of scientific convention and therefore ethical considerations were integrated within this study at a very early stage in its design by means of establishing a number of guidelines that were be communicated as a matter of policy to protect the anonymity of those persons concerned. While the highest ethical standards will be followed at all times, the issue of complete confidentially was difficult to maintain as this particular case study involved sharing of information across and between each of the case study sites. As such, individuals were given the option to refuse to participate in this study. Some of the problems have already been resolved through direct contact with those individuals where the problems were most apparent from a safety critical point of view. In spite of this position the research promotes the standard rules of convention that that protect any individual from the sensitivity of data contributions. In addition, the researcher must also be aware of the effect of his bias and with this viewpoint in mind the Research Ethics Framework[48] established in 2006 was duly followed,. For example, the interests and rights of all employees involved or affected by the study have been assured of their anonymity, through a number of agreed criteria shown below:

1. Consider the social and psychological impact of people affected by the research
2. Offer anonymity and confidentiality to all employees.
3. Verify data collected through interviews with employees and provide feedback on findings
4. Select research methods that are fit for purpose.
5. Report research findings with integrity
6. Establish rules on intellectual property rights and reporting restrictions
7. Consider the consequences of research findings for air passenger safety
8. Acknowledge that some of the research may be open to interpretation.
9. Consider the consequences of research misuse by other interested parties.
10. Ensure approvals are granted before publication and presentation of findings

To further demonstrate a level of confidentially all persons associated with the study are protected through what is described as a non-disclosure agreement (NDA)
The NDA process was created by the organisations corporate legal team that was duly granted by Cardiff University Business School, which is aimed at protecting the intellectual property rights and commercial sensitivity of the organisation as a whole. The agreement is also applicable to the requirements of the Ministry of Defence (MOD) thereby conforming to the requirements of the Official Secrets Act (1971)

[48] The Research Ethics Framework (REF) is intended for social science research and was formally introduced by ESRC in January 2006 to protect the dignity, rights and welfare of the individual.

3.15 Chapter Conclusion

This chapter has outlined and defended the chosen research strategy by declaring a range of tools and techniques, within a framework, which is able to facilitate the original research question declared during chapter 1 as; *"To what extent can self-managed team working, facilitate the principles of safe Total Quality Management?"*

The design of this strategy included a range of scientific methods from both qualitative and quantitative perspectives of social science, which formed the overall flow of methodological design. Based around the concept of 'realism', the methods deployed were selected for their flexibility, in being able to facilitate the real world gap between theory and the growing consequences of human failing as outlined during chapter's 1 & 2. By adopting a cross-comparative case study design, the researcher was able to provide a strategy that will highlight quality problems, which are in-put driven and not easily resolved at the individualistic level of team control.

In order to substantiate this claim a statistical process will be used to formalise the content of the research question in terms of several hypothesis driven predictions. To legitimise this approach, it was also seen as necessary for the researcher to follow strict rules of scientific convention, whereby the principles of both validity and reliability could be demonstrated. The design and methodology, which was subsequently accepted, was based on the assumption that other human factors specialists would be able to follow, in terms of a capable and repeatable process.

In spite of the statistical methods used, the researcher was also heavily influenced by the literature made available by Miles & Huberman (1994), who underlined the importance of linking qualitative as well as quantitative data sets into one cross-case design. Therefore no one single approach could be accepted in its entirety, based on the premise that research into the problems surrounding socio-technical systems, require an eclectic strategy that should centre on the design and use of a flexible range of research methods. This study therefore shows a design common to those STS studies of Emery and Trist based on a modern approach to systems investigation.

In summary, the model put forward at the beginning of this chapter, provided the reader with an overview of the strategy and methods used, which are seen as capable of measuring what is currently referred to as 'unknown areas of human error risk'.

The rationale being that attitudes when measured through a carefully constructed process, will be perceived as a credible account that business leaders can assess for the purpose of improving current levels of out-put, based on improved quality and safety of control.

Chapter 4 Case Study Details

4.0 Chapter Introduction

The previous chapter has explained and defended the research strategy and has also detailed the appropriate methods required to measure the extent to which human error risk may, or may not, exist within an industrial system. This chapter will provide a background of business understanding set within the context of real-world problems across four corporately owned UK sites. The chapter will begin with an overview of the business strategy, providing the reader with an appreciation for the organisational factors that have challenged the entire PLC business (from which four cases of similar process types have been selected) in relation to risk factors affecting the performance of TQM. Each of the case study sites is owned by a single corporate parent and can be described as entering a transition period where its customers are demanding change, which in turn has pressurised each of the repair & overhaul sites to adopt the philosophy of TQM by corporate dictate. The goal of adopting a company-wide TQM approach included improving process quality as well as output, within a highly complex and technical environment that is committed to the repair & overhaul of civilian & military aircraft engines. The business groups in question are part of a public limited company that was first registered in England by the registrar of companies in 1971. In 1991, the aerospace repair business was formed to combine all civil and military engine maintenance activities under one director and by December of 1993, Aero Engine Services Limited gained the approval as a JAR-145 maintenance[49] organisation and in 1998 it was re-organised into customer-facing operational units. The aero customer-facing businesses now consist of, Aero Repair and Overhaul, Airline business and Defence Aerospace, including a global profile as shown below:

1. Interim order book of £16.7 billion
2. Sales of £8.3 billion
3. 38,000 employees world-wide in 15,000 different job types
4. Services include more than 4,500 customers across 500 different Airlines.
5. Over 53,000 gas turbines in service in over 150 countries

In order to meet demand for an additional 23,000 new aircraft types ranging from light to short haul also wide body jets, the organisation forecast that 48,000 engines, valued at £61 billion, will be needed.

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[49] This is an approval, which allows the company to maintain aircraft engines in line with civil aviation law.

However, now that the market share has grown, a maturing portfolio has demanded a new emphasis from offering every application, to concentrating on investing in the applications where there is the strongest business case. In order to facilitate this approach the business has therefore concentrated on the principles of Lean engineering, which ensures that all new product introductions are considered in terms of life cycle profitability. This approach is both specific and functional aimed at adding customer value to meet predefined standards in terms of improved business performance under the global template of TQM. This has helped consolidate the organisation as a leading manufacturer in gas turbine technology across 5 market sectors, namely: Defence Aero Space, Aero Repair & Overhaul, Civil Airlines, Marine and Energy. In 1991 the aero repair & overhaul business was formed to combine all civil and military engine maintenance activities under one director.

This business now has the capability of meeting customers' needs for engine overhaul and component refurbishment across 17 global facilities. The organisation has its headquarters in Derby, which is the original centre for large civil engine overhaul. Other facilities include Ansty, Bristol and East Kilbride, with completed portfolio of wholly owned subsidiaries in Brasil, Canada, Deutschland and Oakland. The aero repair & overhaul group is also complimented by joint ventures in Hong Kong, Dallas, Singapore and Germany as illustrated in figure 4.0 show below

Figure 4.0

Geographical Map of Case Study Location

Fig 4.0 Source: From Case Study Customer Business 2008

Set within a volatile market place aero repair & overhaul business is becoming increasingly important to fleet operators now that traditional risk and responsibility of the fleet operator itself has reverted back to industry where on-wing-care[50] agreements are managed with the help and wider support service of plc. In addition to these types of contracts, aero repair & overhaul also carry out repairs with customers directly who require traditional 'time and material' contracts, thus providing all types of maintenance for what can be described as a 'legacy' type repair.

Many commercial pressures affect the case study business. The majority of customers prefer fixed price contracts, which not only assist in helping them with their budgets, but also because they believe it provides aero repair & overhaul with an incentive to become more efficient in terms of an opportunity to develop more of a market share. In order to demonstrate the principles of operational efficiency; the organisation has therefore developed a standard range of business methods that measure operational performance of advanced repairs, within the manufacturing philosophy of TQM. In line with the corporate Rolls-Royce business improvement strategy (2003) the company has therefore focused its attention on: *"Promoting locally managed facilities that specialise in performing advanced*
repairs in support of multiple engine types, within a management philosophy of TQM

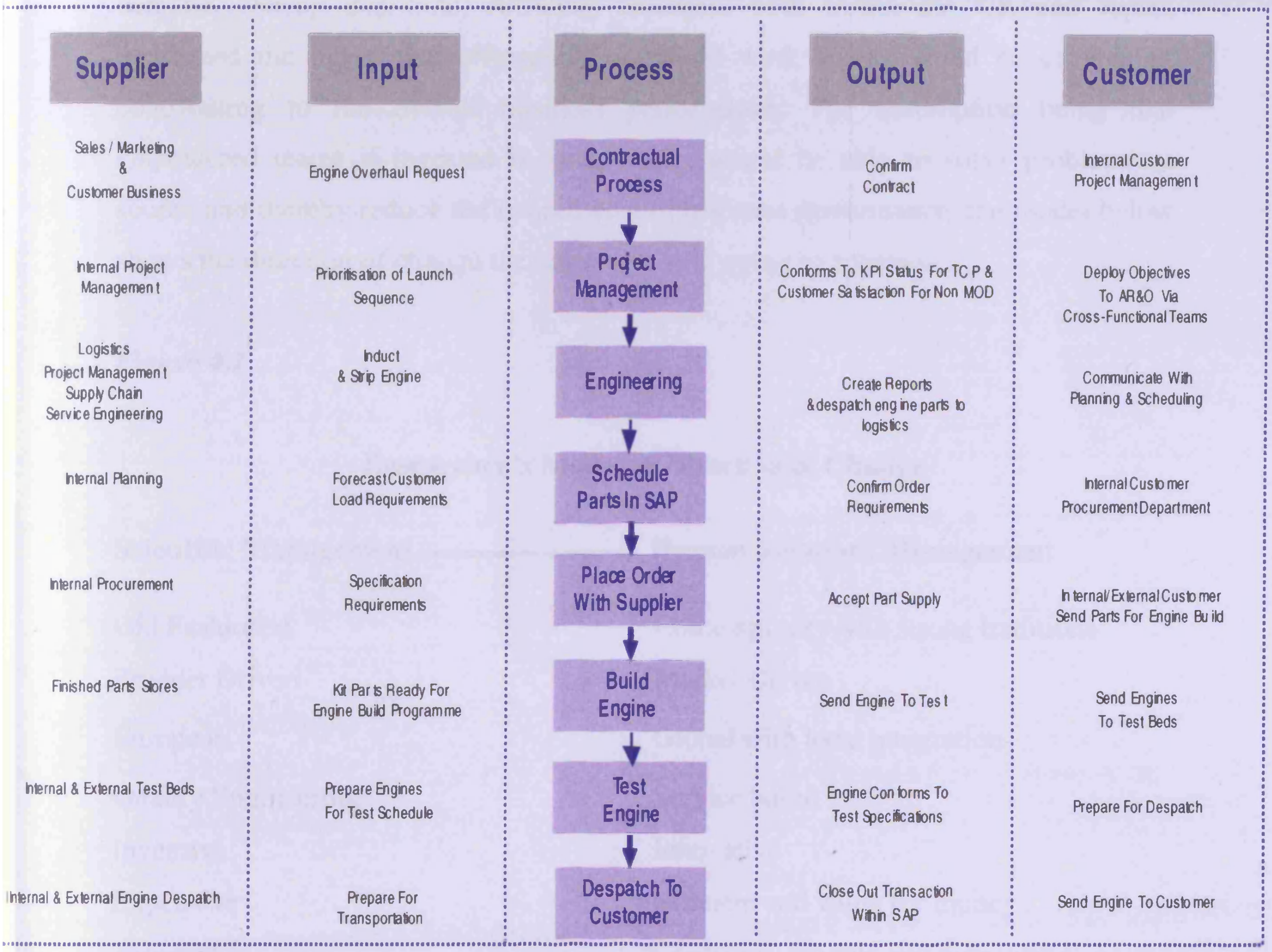
4.1 Repair and Overhaul Processes

In order to sensitise the reader to the process of aero engine repair, the researcher has prepared the following SIPOC (Supplier-Input-Process-Output-Customer systems analysis) figure 4.1 which demonstrates an end-to-end view of the process stages from supplier (induction) to despatch (Customer).

[50] On-wing care provides 24/7 aircraft on ground service

Figure 4.1

Aero Repair & Overhaul Supplier-Input-Process-Output-Customer (SIPOC)



Source - Researcher

4.2 Introducing Self-Managed Teams

Prior to the implementation of self-managed team working the AR&O organisations followed a typical hierarchical structure with each site being managed by a head of site that reported to the regional Director. A typical pyramid structure was made up of production shop managers, supervisors, foremen and team leaders. The management team made all decisions and very little decision-making activity was devolved to the shop floor.

However in trying to achieve the goal of TQM the new focus of attention was taken from the school of human relations management and in 1998 recognition of the values of autonomous team working was accepted as the new way forward in terms self-managed teams being able to make a greater contribution to the needs of customer demand. During this time, sufficient examples both within the UK and Japan, confirmed the belief that effectively organised work teams would be capable of contributing to the overall business performance. The assumption being that empowered teams if invested in sufficiently, would be able to solve problems at source and thereby reduce the overall cost of business performance, the model below shows the direction of change the organisation is trying to achieve.

Figure 4.2

Researcher's Model of Direction & Change

Scientific Management ⟶	**Human Relations Management**
Old Fashioned	Contemporary with strong traditions
Product Driven	Market Driven
European	Global with local integration
Quality Engineering	Service based
Inventive	Innovative
Expensive	Efficient and value for money
Arrogant	Confident, reliable and responsive
Inflexible	Flexible
Production Environment	Service Ethos

Source: Researcher Secondary Data.

In 1998 a joint working committee introduced the principles of self-management under a collective bargaining agreement between the management and the works unions. This agreement was part of a wider re-organisation of the business structure, which centred on the business functions and key process that were needed to deliver increased customer satisfaction. The model, which was agreed to, required the dismantling of the existing management structure, this was characterised by supervisory forms of front line control management within a working environment of cells under the overall control of production managers.

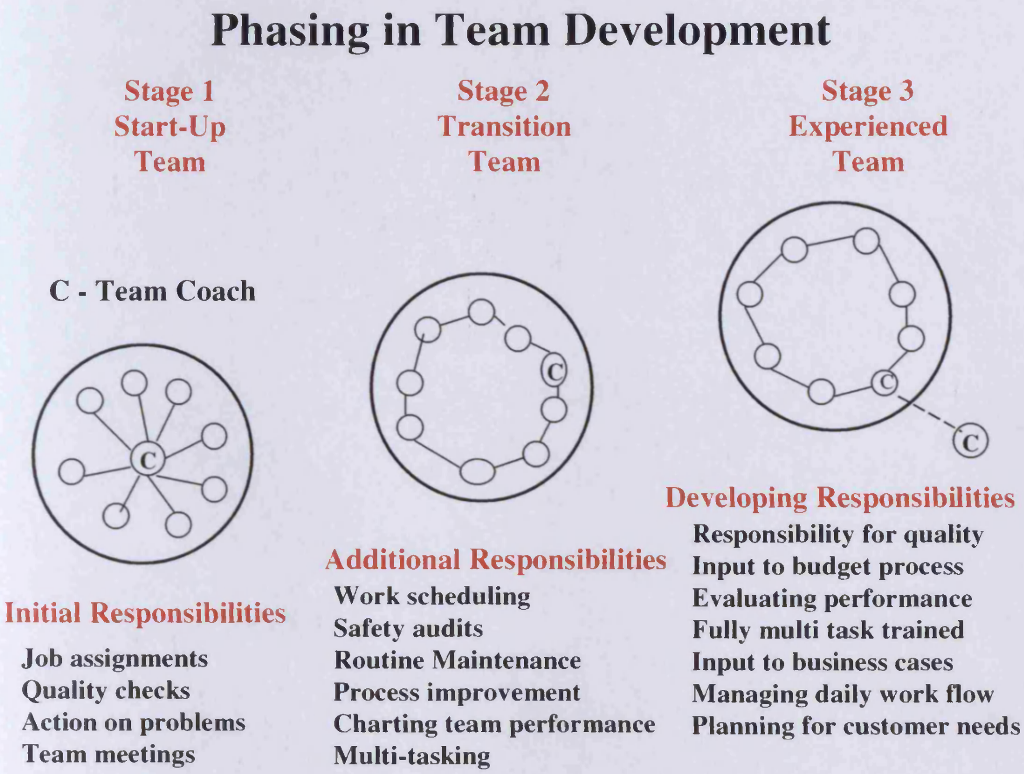
The new organisational model was substantially different; it saw the replacement of supervisors with team coaches on a ratio of 20 to 1 to facilitate self managed teams through two key stages of development. The team coach was required to lead by example rather than direct, he or she had no disciplinary powers or authority in a traditional management sense. The purpose of the role was to support the team as far as possible until each could become autonomous thus ultimately removing the necessity of the future existence of the team coach. The typical benefits and expectations of which include the following list of criteria shown below.

1. Improved performance through increased employee involvement
2. Customer focussed objectives owned by the team
3. Team alignment to business performance measures
4. Teams planning and carrying out their assigned work task
5. Increased flexibility through multi-tasking of team members
6. Greater involvement in problem solving and decision-making
7. Team members developing their personal skills portfolio
8. Leadership and coaching style of management

The culture of leadership prior to this point was one of command and control which given the processes of repairing and overhauling gas turbines, is characterised by huge amounts of problem solving decision points. New manufacture is therefore seen as significantly different from repair and overhaul where non-standard processes make the process of flow very difficult to achieve; therefore it is not easily translated to the philosophy of TQM.

A huge opportunity to reduce cost dramatically and improve satisfaction and quality to the customer was the driver behind the reason to adopt the business model of self-managed teams. The model that was used to develop this strategy was first introduced in 1998 by a consultancy organisation named AT Kearney, whose primary vision was accepted on the basis of their model shown below. The model put forward by A T Kearney (2002) is considered to be consistent with the theoretical approach of socio technical system theory, as discussed earlier in the literature review. The philosophy of self-management was therefore introduced based on the premise that teams would make a natural transition towards theory Y from theory X. Figure 4.3, shown below, illustrates this position. Based on a shared value system it was phased in and allowed to develop naturally, aligning itself with the principles of self-management with TQM. The assumption being that experienced teams at stage 3 would foster awareness for extra curricular activities, such as engaging with the tools and techniques for improved business performance.

Figure 4.3



Source: Case Study Production System

Whilst not rejecting the value of these claims the researcher is also interested in understanding how successful the model has been since its introduction in 1998. In respect of this requirement many different sources of information have been drawn on including a recent postgraduate study carried out by Simkiss (2004). The study was carried out within a cross case framework to include both Ansty and Bristol sites, it measured the affectivity of managers in supporting the development of self-managed teams. It was found that 40% of the staff population believed that line managers often failed to listen or consider ideas for change compared to the results of shop floor engineers, who believed that 70% their managers did. The inference being that white-collar managers were less prepared to listen to new ideas and improve the business. The survey also revealed that only 20% of staff members believed that their managers were good communicators, compared to the belief of 55% of shop floor workers. Again, the suggestion being that investment in resource is primarily aimed at the shop floor and not the white-collar community as a whole. This raised concerns about the implications of attitude in terms of the way morale has influenced behaviour in promoting the organisational goal of cross-functional team. When asking employees across both groups their thoughts on how they viewed the communication policy in general, the survey showed that the majority of white-collar staff valued the quality communication as less effective than the same groups who took part in the survey from the shop floor.

The conclusions drawn from the survey suggested that the frequency and quality of communication correlated with the lack of cohesion and buy-in between teams, which is one of the reasons why the researcher has factored the issue of cross-functional management within the main research objectives. However, in spite of these findings the benefits that self-managed teams have brought to the business, far out weighs the drawbacks and, in line with other large industrial companies, the relationship between the management and the trade unions has significantly improved because of this.
Because of self-management, team working has reduced the cultural barriers that historically existed between the management and shop floor, which in turn has also helped in the transition to a more customer driven approach. The unions, who provide representation, are considered as business partners. The main unions are:-

1. Transport and General Workers Union (TGWU),
2. Manufacturing Science and Finance (MSF)
3. Association Professional Executive Staff (APEX).

The TGWU represents the shop floor engineers and the MSF represent the white-collar engineers, whereas APEX is aligned to the clerical population leaving the management grades unrepresented.

Now that the chapter has set in context the recent changes for the business, the next section will present a review of each case study site. Every site has the same process stages although engine types will vary between sites.

4.3 The Derby Case Study

The case example is located centrally within the UK, the Derby AR&O site is the largest of all the repair businesses. It includes whole engine strip, build and test facilities for modern large fan engines, based on a typical operating life cycle of between 25 to 30 years. It is anticipated that the majority of these engines will visit the Derby overhaul facility at least 5 or 6 times during their lifetime, to receive regular scheduled maintenance, product upgrades and performance improvements.

The Derby overhaul facility saw investments of £80 million during 2007, these were based on the adoption of modern working practices following initial experiments with self-managed team working (1998), which resulted in a 25% improvement in productivity. The result was increased satisfaction for some 40 different customers and air service providers. The site at Derby utilises 18,400m of workshop incorporating an integrated quality control and inspection system to support multiple engine projects, within a Lean concept of one-piece flow. This process includes the stripping and rebuilding of engines to module level, where, engine teams function as value streams for the overhaul of engines such as the RB211-524, 535, Trent 500, 700 and 800.

However, the term 'maintenance' has much expanded with the introduction of new technologies; the context of 'total care' is beginning to challenge the existing production system through what is described as an engine health monitoring service. For example a typical aircraft can send real time data to the control room in Derby where the engines' performance is constantly being monitored for problems in areas such as vibration, temperature and engine speed changes. This means that any issues, which arise in-flight, can be analysed and understood before the aircraft lands. The consequence of this approach has set new challenges to business whereby scheduled load & capacity planning for flow is often disrupted by the need for emergency overhaul repairs.

Recently, the magazine business 'Aviation Maintenance' representative visited the new Aero Repair and Overhaul facility at its Derby and spoke with the company's director of service delivery, Kontich (2006) who was quoted as saying: *"The facility has embarked on a very different kind of world in what we call Total Care. This new environment puts tremendous pressure on the highest levels of reliability,* *airworthiness and safety at the least total cost. Doing a better job of managing the cost structures of delivery is a key challenge in the face of huge growth"*

However, at the beginning of this study, the case site was experiencing great problems with the accommodation of improvement methodologies and self managed team working. These problems were manifest in the ability of self-managed teams to facilitate the principles of TQM. The teams were experiencing challenges to their autonomous decision making as Lean initiatives and commercial pressures had combined to challenge the speed of work, responsibility for work and how teams interact with their support functions. The new pressures created a suboptimal allocation of decision-making responsibility, Lean initiatives had eroded the ability to work overtime, it had leveled scheduled the production programme and increased the need for team flexibility including the redeployment of labour. The removal of the night shift also occurred and production pressures grew to complete all work during a two shift operation. The removal was justified because of human factors issues associated with such late working where the body clock of the employee was affected thus there was at risk of making many mistakes. In this respect Derby can be positioned as a level of stage V of the Holpp (1993) model and current pressures, imposed by the business, were reducing team profile towards a level II stage. The case is therefore was at a 'stressed' stage whereby pressures influencing the team provided a good insight into human factors, team working and TQM. The site was duly accepted as a research partner as it would provide a good insight into the research question.

4.4 The Bristol Case Study

In support of the whole engine strip and build process at Derby, the Bristol facility is a specialist component refurbishment centre which supplies repaired combustion chamber units. The role of Bristol is to work as a service provider to other AR&O businesses as well as Derby. The facility is situated in the south west of England and produces an annual turnover of 20 million pounds and specialises in fabrication overhauls to the hot end of gas turbine technology for both military and civil engines, such as the Pegasus, which powers the Harrier Jump Jet. The facility also produces the EJ200 engine, which is a fast jet used in the Eurofighter Typhoon, and it also services the Trent engine portfolio that provides power for long haul and wide bodied civilian aircraft.

The type of customer contracts entered into by the business is considered to be diverse and includes some of the latest concepts such as 'power by the hour'. These latest generation contracts service customers with lease engines as opposed to the purchase of an engine – in this manner the service package for total support care generates an income for every hour an engine is worked on an aircraft. As such the site has many pressures to return repaired engines to the service of the customer as quickly as possible (so they can earn an income again).

The complexity of the case is illustrated by the many different types of engines and customer demands, which are further compounded by variable operating conditions defined by different customers through their choice of aircraft and application for which the engine is used (short haul – many take off and landings versus long haul with fewer takeoffs and more flying hours). The differences between applications can vary from between 25,000 flying hours seen in a typical civilian long-haul aircraft, to a fast military jet, whose engines can be removed from service every 250 hours. It is this level of product variance, which characterises the current production system in terms of the classic 'jobbing shop'. The low volume, high engine type conditions and variable repair/process mix (routings through facility) calls for skills which emphasise predominately hand craft experience, knowledge based diagnosis of engine needs and experienced decision making.

In light of these and other such complex conditions, the core business metric is still committed to the concept of turn-round-time performance that should not exceed more than 21 calendar days. This is the manifestation of the lean approach to working and the service level agreement to supply units to customers.

The case is described as a non-linear production type because all components are repaired through the deployment of self-managed teams, which currently consist of 86 permanently-contracted individuals. The breakdown of these teams shows 67 'works' engineers consisting of a skilled fitters, machinists, welders & inspectors. The white-collar population, referred to as 'staff', consist of 19 people of whom 7 are technical engineers and 7 are administrators. The controlling element of the system is made up of 4 managers, whose role is to provide leadership and support for all aspects of civil

& military aircraft front combustion chambers[51]. An illustrated example of the product application is shown in figure 4 below.

Figure 4.4

Euro Fighter Typhoon

Source: Case Study Library

The pressures facing the Bristol facility have included 'quality escapes' or errors that have passed through the organization's lines of quality and safety defence and been detected by customers' goods receiving inspection processes. An investigation was conducted and found that 'corners had been cut' because of poorly defined procedures where teams were ineffectively working between one department and the next. The procedures for handovers were found to be informal and the teams, through poor industrial relations, made a series of errors, which could have been prevented if reference was made to technical specialists. The Bristol teams were assessed at the stage V level of team engagement and self-management according to the Holpp model (1993)

4.5 The East Kilbride Case Study

East Kilbride is geographically situated in Scotland, within the city of Glasgow and currently employs approximately1000 skilled engineers (similar in size to the Derby facility). East Kilbride provides whole engine refurbishment programmes as illustrated from the engine and airframe portfolio below.

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[51] A combustion chamber is the part of an engine in which fuel is burned to produce thrust when directed out of a nozzle in jet engine.

Engine	*Application*	*Aircraft Type*
Civil	AE2100A	Saab 2000
Civil	AE3007	Embraer 145
Civil	Dart Rda7	Fokker F27
Civil	Spey 511,512	BAC1-11
Civil	Tay 651-54	Boeing 727 re-engines
Civil	V2500-A1	Airbus A320
Civil	V2500-A5	Airbus A319, A320

The level of product complexity is high and the portfolio is wide with many engines that are very old and some that are very new (learning curve implications). Further, some of the engines are joint venture products but, due to the location of the design authorities, access to data and knowledge sharing is difficult. The site is further complicated because of export control regulations (United States of America) whereby communication has to be managed strictly (so that no communication can be intercepted), Such an activity slows the decision-making process also improvement projects are difficult because, under export control, engine test run data cannot be collected (and will not be released without authorisation and special permission). Older engines that are not regularly maintained are a problem because consistent quality data is not available. Further some customers will not allow 'inter-changeability' of products – the same product that came from an aircraft must go back to it (this is known as repair by repair working). For customers who 'pool' products this acts as an inventory buffer and means some products operate with shorter lead-times (these engines go back to different aircraft but to the same original standard – known as repair by replacement working).

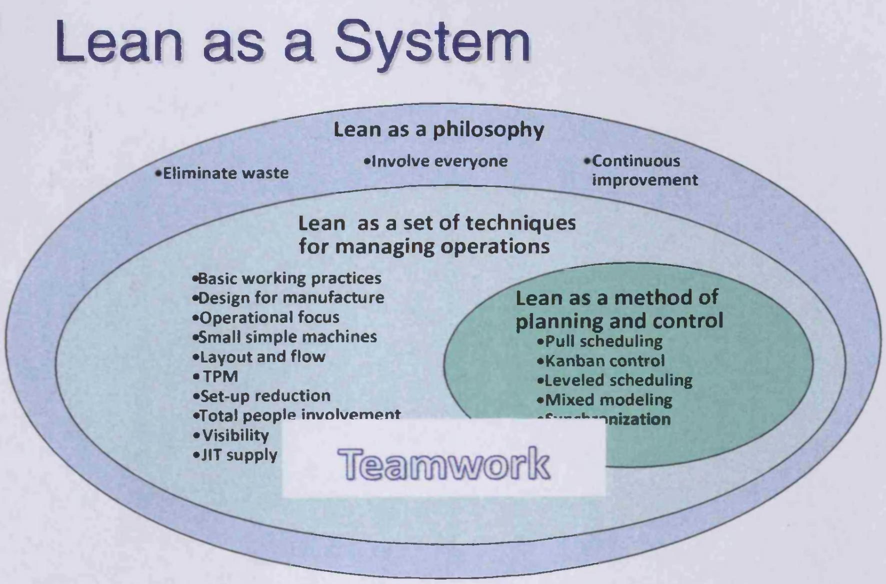
Traditionally this area of the business, like many other AR&O sites has adopted a top down approach that was historically compromised by a distinct lack of customer satisfaction and confidence which tarnished the reputation of the facility and its teams. To illustrate this point, the turnaround times prior to 1996 were in excess of 130 days for component refurbishment, which is excessively long (very low value adding from a lean perspective). The long time involved suggested failings in the material flow systems at the facility and highlighted a potential lack of management control and unacceptably high levels of operating costs. In turn, this had led to discussions about the future viability of the site and discussions about subcontracting the work to other businesses. During this 'burning platform' for change, the business introduced self-managed teams even though the initial stance of the trade unions on site was to reject this form of working.

Appendix 3

Definition of the Lean System

There are many different definitions of the lean operations management system. After extensive literature review, the diagram below proposed by Slack et al., (2004) was accepted as a means of housing and framing this study and to answer the question 'what is lean?'

Figure: The Lean System



Adapted from Slack et al., (2004)

The business therefore found itself under major threat of closure, owing to the growing dissatisfaction of its customers and in particular the inability to meet engine delivery dates. To counteract this problem East Kilbride launched a programme similar to all other case studies called 'Better Performance Faster' whose primary aim was to review all processes including the way management led its people, in all aspects of the repair & overhaul activity.

One of the most significant outcomes of this process was the introduction of self-managed team working, which resulted in a radical management-restructuring programme that saw the introduction of business leaders as facilitators as opposed to the traditional approach of managers & supervisors. The new 'bottom up' approach to management was based around the introduction of team coaches, whose role was to facilitate new codes of behaviours where the following of strict rules was substituted by a value driven system for wanting to 'get the job done'. The latter was a principle used by Volvo during their experiments of the 1980s.

The philosophy behind this approach is based on the investment of empowering teams to improve product quality through ownership of TQM principles. The new challenge for East Kilbride was aimed at delivering an improvement strategy, which is Lean enough to meet the demands of reduced customer turn-round-time (TRT), whilst not undermining the importance of EASA safety compliance in pursuit of the organisational goal of self-management & TQM.

Using the Holpp (1993) model see figure 2.2, the East Kilbride teams were assessed at a level of self management which does not rate on the scale and at best were positioned at Stage 1. It should be noted that during this research the teams have progressed at different rates but were assessed at the level V – equivalent to that of the other AR&O sites.

4.6 The Antsy Case Study

The Ansty facility is located in The Midlands of the UK close to Coventry. The site is described as a military repair & overhaul facility with a core business process specialising in overhauling military engine types (fixed aircraft wing, rotating helicopter wing and naval engine types). The products are very complex and equivalent in structure to those of the other sites.

The business has major contracts with the UK Ministry of Defence to repair & overhaul engines for the Tornado and Euro fighter programs. Approximately 70% of this work is taken from the UK Ministry of Defence (MoD) whose yearly budget is has been cut in half through government spending reductions. These reductions have placed significant commercial pressures on the Ansty facility to reduce its costs and embrace leaner ways of working. According to an MoD official *"The MOD will either cut their cost of ownership or reduce its fleet size, but either way we will achieve the objective of cost reduction".*

One could argue therefore that self-managed teams have by default provided the Ansty business and MOD alike with an easy opportunity to reduce costs by virtue of its head count reduction. Within the last 10 years the management structure has become leaner or more flattened, this was achieved by the removal of 2 full layers of managers. Such restructuring has implications for the layers of business defences (Reason, 2003) and also reduces the co-ordination of material flow processes provided by these managers/reallocating roles and responsibilities to other workers. These actions are, as noted in the literature review, positively correlated with increased errors and potential system failures.

From secondary data, the pilot study and interviews, the researcher established that problems with human factors have in fact not changed since 1998. The introduction of self-management has created new pressures for the business in terms of a lack of management where the majority of teams have a reporting structure, based on a ratio of approximately 50 to 1 (in some cases 100:1). This means that structures are very flat but that many people report to very few employees in management positions (the equivalent ratio at the customer sites was 6:1 at the time of writing this thesis). Based on a series of informal interviews, the researcher established that pressures on key people, such as engineering inspectors, was very high and incurred great stress. These inspectors were found to carry out their responsibilities, based on inadequate levels of team situational awareness (ability to work across departments) and faced many interruptions to their working day. Again this scenario is equated with a higher potential for failure of safety systems using the Reason (2003) approach.

The researcher found that some areas of team working are lacking in investment, leading to conditions where tooling is either broken, poorly designed or not available, this problem is within financial levels of management control. As a direct result of this situation production managers are of the opinion that a negative peer culture is slowly developing, implying that teams do not feel accountable for their work and processes they were supposed to own.

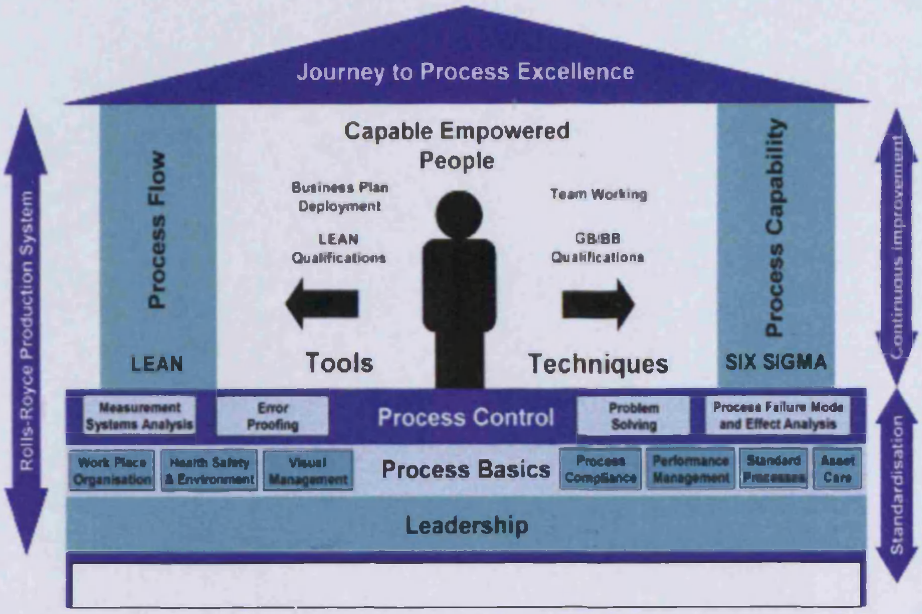
The review of the Ansty site, using the Holpp (1993) model, despite its issues, was rated at a level V. Not surprisingly therefore the transformation and ownership for TQM across most engine projects is well below the process excellence performance measures expectations of the site by corporate indicators. The performance of the sites will be reviewed and highlighted later through the assessment journey as shown in Figure 4.5

Having reviewed each site, the discussion will now focus on the corporate organisational strategy for improvement referred to locally as 'process excellence' and being a hybrid TQM model involving both Lean and Six Sigma ways of working.

4.7 Assessment of Total Quality Management Strategy

With these site problems in mind, the focus of the corporation has concentrated on developing and executing a strategy through a corporate production system. The production system adopts a standard approach to managing material flow, it ensures that high-level business goals are aligned with the correct tools and techniques within the context of TQM (to meet commercial needs and the expectations of a broad customer base). The methods employed by the model are based around the same model as that of new production and provides a wide range of 'how to' documents within a framework of both Six-Sigma & Lean. The model below provides a schematic overview of this position based on satisfying 5 key performance indicators (KPI), within a framework of capable and empowered work teams.

Figure 4.5 Case Study Production System

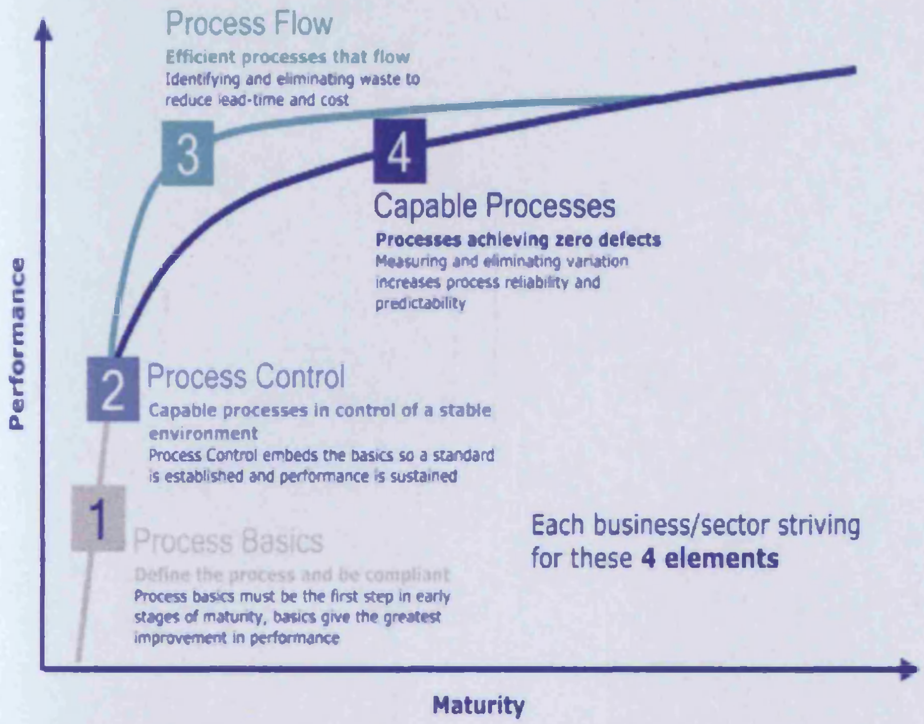


Source: Case Study Production System.

In spite of the business commitment to the principles of TQM, a recent customer satisfaction index during 2007 measured the performance of quality at just 76% effective. Such a figure was well below the expectations of the corporate business. The statistic reflected a wide range of manufacturing concerns, for example, factors such as quality complaints and non-conformance costs that exceeded a total of £427million pounds. The report showed 'non-compliance' to the business processes is therefore responsible for 80% of major quality investigations and almost 100% of product quality 'escapes'. Although, it is believed that the real cost of non-conformance is approximately 2-3 times greater than directly measured, amounting to over £1bn per year. The organisation has stressed the importance and need for change by embarking upon an improvement journey where self-managed teams are assumed to be compatible with the organisational improvement strategy of TQM. The method, by which the organisation has set out to achieve this aim, is based around a 'one size fits all' approach, within the organisations 10-year Business Plan Deployment (BPD) programme that all business groups, aftermarket and new are expected to follow. Figure 4.6 below provides a schematic overview of this position, which is based upon a 4-step process for how to deploy the fundamentals of TQM.

Figure 4.6

The Deployment of the Fundamentals of TQM

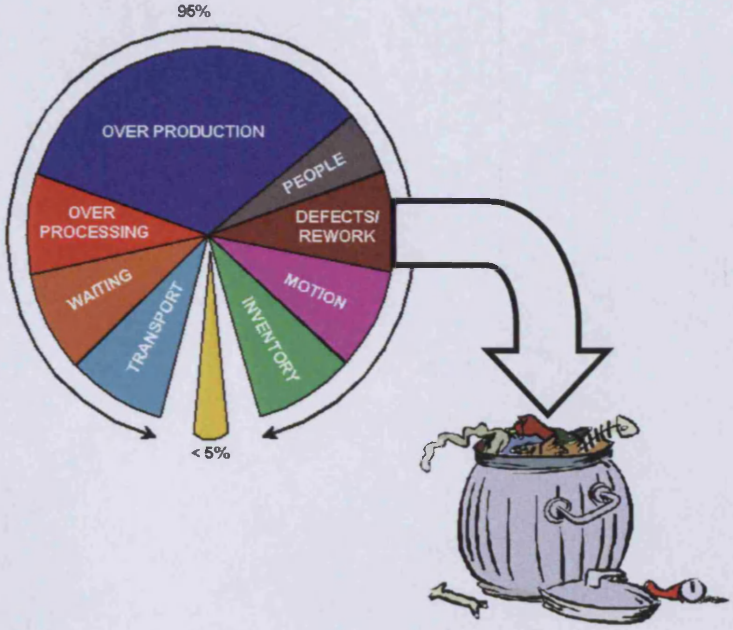


Source: The Case Study Production System (2008)

Drawing from secondary data, the improvement journey was found to be made up of four key processes, together with supporting tools. The first two steps (Process Basics and Process Control) concentrate on building the foundation of TQM, based on standardisation and stability. Continuous improvement is then sustained through Lean or Six Sigma techniques and in the third and fourth steps 'process flow' and 'process 'capability' Once the basics are in place and controlled, the use of all the steps together will remove waste, reduce variation and help facilitate improved quality which will ultimately help to make value flow. To sustain the progress of TQM it is important that every individual adopts the principles; even basics such as keeping a clean and organised desk or work environment help contribute to this success and minimise waste. For the ease of the reader, using the four-stage model, the sites are positioned at stage 1 'Process basics'. The reviews by the researcher found no site with the features of a stage 2 organisation. The process basics stage is the basis of management before improvements, which lead to the following of a quality or a Lean route towards stage 2. From the perspective of a Stage 1 case, the production system is the recipient of high levels of training and standardisation which is a prerequisite before the TQM strategy can be embedded. Figure 4.7 below is taken from the corporate training manual and shows that only a small percentage of work is value adding whilst the majority of work incurs business costs - just 5% of all engineering activity is shown as 'value adding'.

Figure 4.7

Showing Proportional Value Added Work



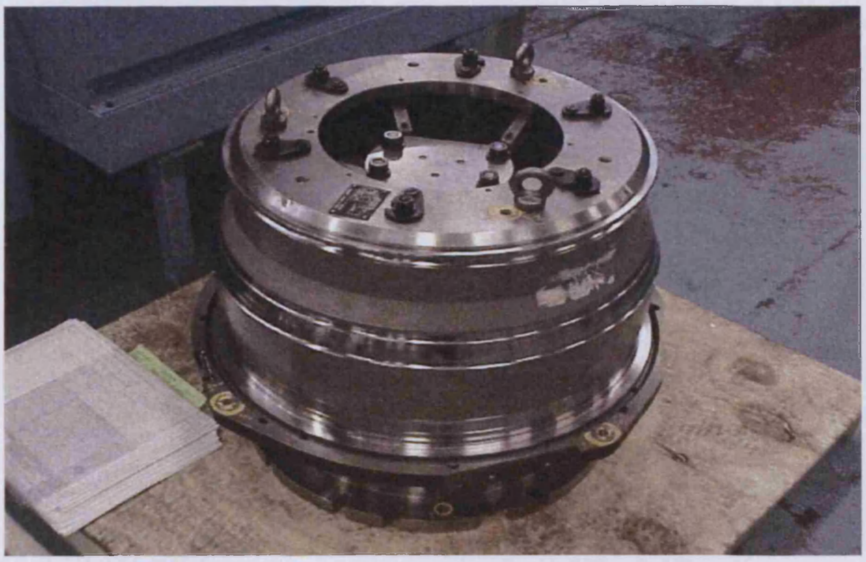
Source: Taken From Case Study Production System

This approach has fundamentally challenged the principles of TQM where some engines depart from a critical path of repair in line with a bespoke process, which is non-standardised and ultimately interrupts and disrupts production flow. Which in-turn has redirected the business strategy to adopt the practices and principles of both push as well as pull manufacturing (Lean ways of working). This position contradicts the plc strategy for improvement where Lean tools & techniques were developed in line with the success of Toyota, whose practice and techniques are based on standardisation of high volume automotive manufacturing.

Figure 4.8 shows an application of fixture designed at the case studies and how multiple operations have been combined into one fixed process (standardisation). Such a device is a concept that has carried over from automotive production and has been used to reduce waste. Such practices have also included quick changeover/SMED activities and the case companies have all benefitted by reduced mistakes and reduced visits to the tooling store (by combining two fixtures into one). Further, organisational learning and process improvement activities mean that new innovations have moved to the aero repair sector from automotive – such as one-turn bolts with pear shaped holes in clamps, so as to make fitting and removal of aircraft engine components a less time consuming and more error risk free process.

Figure 4.8

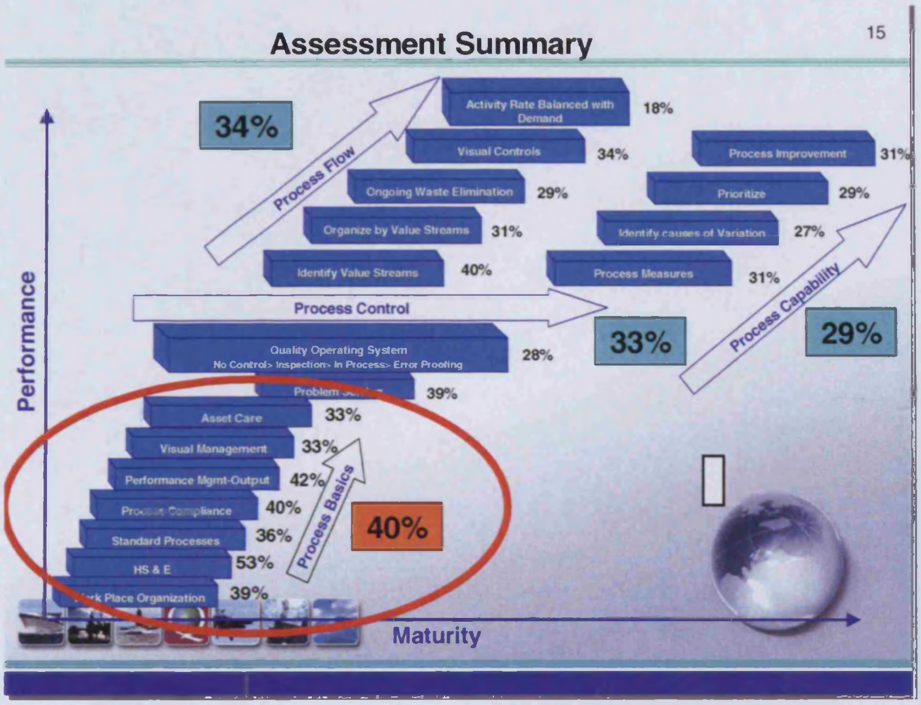
Multi Purpose Fixture



Source: Taken From Case Study

The corporate business has also engaged in a process known as the 'Active Risk Manager' (ARM). This is an electronic database where improvement projects and best practice can be viewed for improved learning. The purpose of which is to avoid the duplication of effort and speeding up improvement processes at the sites. At the time of the study there were over 2,500 improvement projects registered onto ARM (including those conducted by experts of whom 400 Black Belt projects were registered, 900 Green Belt projects and 800 Yellow Belt projects). The information stored in ARM is available to all employees interested in sharing best practice and learning about what is happening with TQM throughout the entire plc business. Each site has access to this system. To help business leaders and self-managed teams to understand where their respective businesses are, along the improvement journey, a global assessment tool has been formulated that provides an overall set of results against a number of key building blocks shown in the model below (fig 4.9). Over 300 assessments have been completed during 2008 and the overall score for aero repair & overhaul is currently averaging 40%. The objective is that all business areas must score at least 50 per cent at Bronze level in process basics.

Figure 4.9



Source: Taken From The Case Study Production System (2008)

The red circle on the figure shows the activities on which the teams were working during the course of the study. These activities concern a host of material flow issues and, most importantly for this study, a series of unknown factors related to risk mitigation and team engagement. It is the purpose of this study to understand, in more detail, the severity of risk that the current improvement strategy and the socio-technical systems designs, have imposed on teams by implementing/sustaining TQM. In effect, the poor scores achieved by the sites (against corporate audits) provided a timely opportunity to delve deeper and identify the limiting factors in these safety critical working environments which may go some way to explain what factors inhibit progress against expected business performance.

4.8 Quality Management System

Alongside the production system and its evolutionary journey is a quality management system (RRQMS) that must be independent, by regulation, of the production system. This is a parallel system defence mechanism (Reason, 2003) that sits alongside production audits and is designed to meet international quality standards of ISO 9001 / 2000[52] and EN/AS9100. Unlike traditional Lean production systems found outside this study the aerospace model differs considerably this is based on the need to separate production from quality where value is jointly defined by the customer and regulatory authorities.

The implicit assumption behind the maintenance of a quality reporting structure and a production structure i.e. the joining of the two defence mechanisms (with associated audits) is that commercial pressure will undermine aviation safety if people cut corners. Under regulation 145 and to avoid commercial pressures lowering quality standards, the company must maintain independence in these two control systems. A corporate quality manual has therefore been created to satisfy this position; this is maintained by the director of quality as the top-level document in the quality system and deployed to all business groups throughout the plc group. The quality management system provides a consistent approach to achieving customer satisfaction thereby improving quality performance and satisfying both its legal and regulatory requirements. In addition the RRQMS consists of business quality manuals, which are supportive of the quality policy within the context of group quality procedures (GQP).

The RRQMS is designed to provide a statement of how quality should be managed across the entire plc group. For example planning is one of the group's most important quality procedures (GQP) and encompasses all activities involved in: *"Realising the ambitions, objectives, targets and commitments of it people through the delivery and management of an integrated set of strategies".* It also includes the activities associated with risk management of quality and product safety. In this sense one could argue that all levels of the organisation are provided with a clear view of what they need to achieve, with each business sector committing to a set of affordable plans that support the corporate objectives and targets. For example; under the GQP 3 Aero Repair & Overhaul must be able to react to unexpected events that, in some cases, will

[52]ISO is the world's most established quality framework, currently being used by around 897000 organizations in 170 countries worldwide

require a full or partial review of their strategic and business plan. Measuring and eliminating variation mitigates to some degree certain levels of quality risk and therefore increases process reliability based on the 4 points as summarised below.

Process Capability is:

1. Measuring how well the outputs of a process, namely quality, cost and delivery, meet the requirements placed on it by customers and stakeholders
2. Understanding key process output measures that reflect the needs of all stakeholders
3. Measuring process capabilities
4. Identifying root causes of poor capability, prioritising and then improving processes to meet capability requirements

It is necessary to understand which processes need to be improved first, using the concept of a Pareto analysis to establish the 80:20 rule, e.g. 80% of problems caused by 20% of the processes. The methods used to achieve this approach are based on the following criteria:

1. Compile databases of all improvement opportunities
2. Develop a weighting process based on business needs
3. Process all potential improvements through gant chart or priority plan
4. Provide an improvement database or 'project hopper'
5. Provide a project selection matrix

It is important to note that points 1 to 3 relate to establishing and embedding process basics through the building blocks of good housekeeping, visual performance management and adherence to standardised processes.

In summary the improvement journey is built upon a solid foundation of standardisation through process basics and stability through process control. Continuous improvement is therefore sustained through both Lean and Six Sigma to enable process flow and process capability, based on the summary of the objectives highlighted below.

1. Achieving good housekeeping as a quality basic throughout the organisation and establishing 5S (see Hirano, 1995) pilots to give impetus to this.

2. The introduction of 4-box charts at all levels for the quality metrics of customer complaints, defective Parts Per Million (PPM) escapes, concessions and net savings to drive local, data-driven problem solving and continuous improvement.
3. The reinforcement of process thinking and process adherence through effectively governed process deployment.

Having reviewed the cases and the corporate overarching approach to quality and production, the next section will review the standardised and formalised approach to human factors undertaken by the business. The human factors management is another defence mechanism for the business and the case sites.

4.9 Background to Human Error at the Case Company

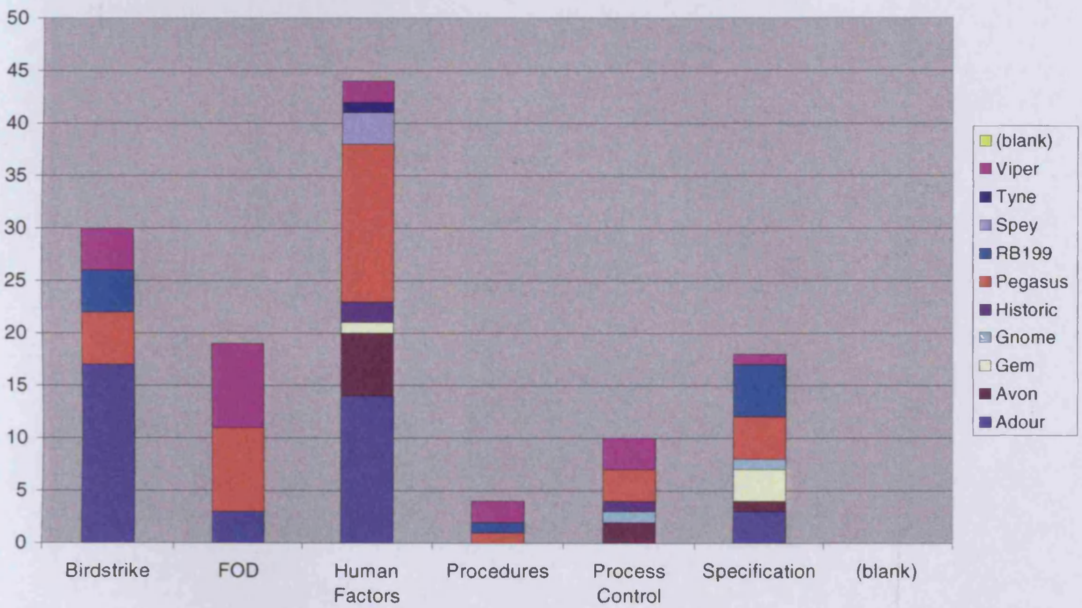
During the 1990s, there were a number of high-profile accidents and incidents, as outlined earlier in chapters 1 & 2, consequently during the early 1990s a number of national aviation authorities became concerned at the level of human errors in aviation maintenance. This motivated extensive research carried out on behalf of the UK CAA, FAA, JAA and Transport Canada that led to the eventual development of new requirements for a Maintenance Error Management Systems (MEMS) – the case company has, as a legal requirement, complied with the MEMS system.

The system is designed to address contributing factors as a means of reducing the likelihood of error occurring themes. The MEMS regulations were first published under JAR-145 amendment 5 and subsequently superseded by an annex to the EU regulation, which is now referred to as EASA Part 145. The regulation requires that maintenance organisations, such as the one found in this study, are able to demonstrate a level of competence, whereby all of its personnel have knowledge of human factors compliance and are able to demonstrate an acceptable level of quality control that would otherwise not be considered under more traditional approaches to TQM.

At the heart of the MEMS system are social issues, such as the organisational safety culture, as well as technical issues. These might have been missed by typical quality management systems audits, which address only procedural compliance. From initial pilot studies and data collected by the researcher, the MEMS database was found to be a useful resource especially as it correlated with Harrison's Typology Model. The research evaluated the severity of problems that had been experienced by the case company; using secondary data covering all aircraft crashes (known as 'red tops' with engines from the case company) between 1981 and 2006. The graph, (fig 4.10) underlines the importance of human factors as the number one quality related concern.

Figure 4.10

Causes of Aircraft Crashes 1981-2006



Source: Taken From Case study Red Top Crash Statistical Database 2007

It can be seen that, by far the greatest amount of recorded red top incidents are caused by human factors. However, from an operations perspective, the details of what system factors cause these 'escapes' – the bottom of Heinrich's (1980)'iceberg model'- are unknown. He posited that for every one of these incidents the researcher would find 600 elements of breakdowns in the socio-technical systems under study. These issues will be reported in the next section of the thesis. The next section will provide information to enable the reader, using the maintenance error management tool, to appreciate the types of failures in the socio-technical system.

4.10 Maintenance Error Management System

British Standards (1984) BS 3811[53] defined the work of the case study states as unplanned and planned tasks. Unplanned maintenance is regarded as either corrective or emergency in nature and occurs when a component breaks down. Planned maintenance is a preventive and time based approach of periodic intervention including servicing or repairing of an engine to an agreed standard. The quality of maintenance is heavily dependent on schedules, which are controlled through the use of records that must comply with a legally accepted and pre-determined plan. EASA part – 145 determines that all maintenance procedures should be designed to reduce the probability of failure from a time based performance design plan[54].

When considering the operating conditions from one aero engine carrier to the next, no one maintenance procedure can be described as being exactly the same. For example on-wing engine life expectancy for long haul aircraft will be significantly higher in terms of engine run hours compared to short haul flights. In addition, reliability centred maintenance (RCM) processes are used to predict failures when a condition falls below a specified standard of economic or safety related performance. Cases of maintenance error are in forms of events or potential hazards (within the iceberg model). Human factors engineers across the organisation refer to hazards as an occurrence that can be identified through any number of existing processes such as customer complaints, major quality investigations and safety alerts. Some hazards are potential occurrences, which could, if left unreported, lead to a maintenance error or a safety related concern. From secondary data, collected from the company's quality management system, the researcher found 122 documented cases involving human maintenance related errors, the following categories were revealed:

1. Omission of parts to be fitted 56%
2. Incorrect installation of parts 30%
3. Wrong parts fitted 8%
4. Other 6%

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[53] BS 3811 (1984) defines maintenance as:
'The combination of all technical and administrive actions intended to retain an item or restore it to a state in which it can perform a required function'. British Standards Institute. BS3811 Glossary of Maintenance Management (1984)

[54] In the aviation world of maintenance the original equipment manufacturer (OEM) may recommend the removal and repair of certain engine parts that must conform to a maintenance plan in terms of the number of 'take off's' and 'landings referred to as engine run 'cycles'

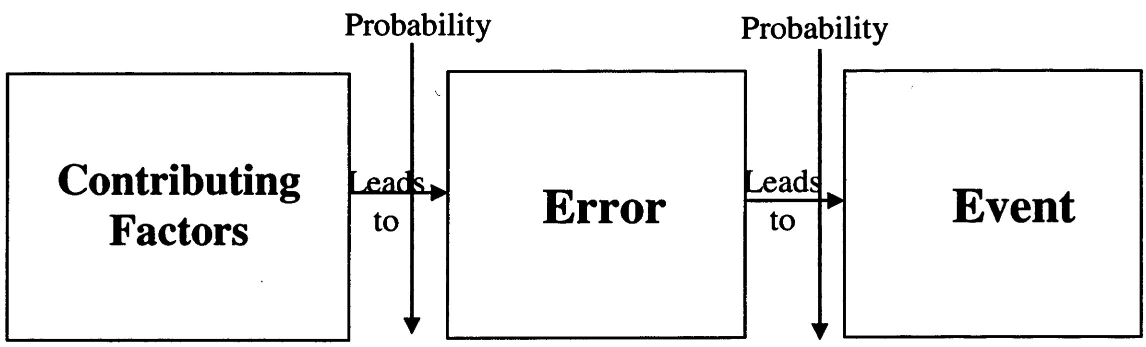
These results are compatible with others found in the sector and EASA have forced, through regulation, a greater transparency and need for socio-technical considerations through the introduction of an all-encompassing 'maintenance error management system; (MEMS) The MEMS system is currently intended to be used as a reporting mechanism that focuses on investigation, prevention of mistakes and actual practices that could lead to a maintenance error based on identifying:

1. Conditions that could result in the practice of unsafe factors that will seriously hazard flight safety.
2. Understanding of issues that have or could lead to a maintenance error.

The success of the system is based on what human factors engineers refer to as a 'just culture', where maintenance errors and situational violations are not punished but reported for investigation so that all contributing factors can be identified and countermeasures introduced (a learning/improving cycle). The number of reports raised is not regarded as a measure of quality standards, but more importantly it is intended to be used as a tool for formally raising and addressing potential safety and quality concerns. In its simplest form the error management model shown below in fig 4.11 illustrates the problematic relationship between contributing factors and errors that could lead to hazard or accident event.

Figure 4.11

MEDA Error Model



Source: Taken From Case Study Quality Management system 2006

For the MEMS to be successful all persons within the AR&O business must feel that occurrences and errors can be reported openly without fear of punitive action, however this does not advocate the need for a 'blame free' approach. To ensure the credibility and success of MEMS, a robust and clear discipline policy is essential. The CAA recommended AR&O utilise a model contained within CAP 716 produced by

Professor James Reason, which ensures that a consistent approach to discipline is made available and maintained as a quality management standard. It is also proposed that to enable the effective recording of reported occurrences, AR&O adapt the Maintenance Error Decision Aid (MEDA) system as developed by Boeing, and is widely used throughout the aviation industry. The model, which provides an effective and structured method for the recording and investigation of error related events, is described in detail below. At each case study site, and corporately, there are over 100 employees trained to carry out investigations and it is assumed that these investigations will be carried out by either the quality or process improvement departments. Following a 'best practice' visit to Monarch Airways, it is also understood that training in the use of MEDA investigations and its subsequent techniques are critical to the success of an occurrence reporting system. In support of this approach David Hall, deputy regional manager in the British Civil Aviation Authority (CAA) Safety Regulation Group, recommended that users should consider the broader potential for improvement by using MEDA system as a tool to track the cumulative effects of less-visible errors.

Dr. Jim Reason,(CAP716 , 2003), professor of Psychology at the University of Manchester, supports this view and claims that MEDA is *"A good example of a measuring tool capable of identifying accident-producing factors before they combine to cause a bad event."* As a consequence, the MEDA was introduced in 2004 at the time when the self-managed teams were engaged with the implementation of the TQM strategy. By 2006, the introduction of MEMS, the provision of Human Factors training for all personnel and process basics improvement programmes had been launched. The entire process is supported by operations and quality staff from all UK sites, who meet monthly to address a number of ongoing themes and key issues addressed so far. The MEMS process therefore provides a procedure where the realisation of a 'just culture', is facilitated through an open and honest reporting and investigation system where employees:

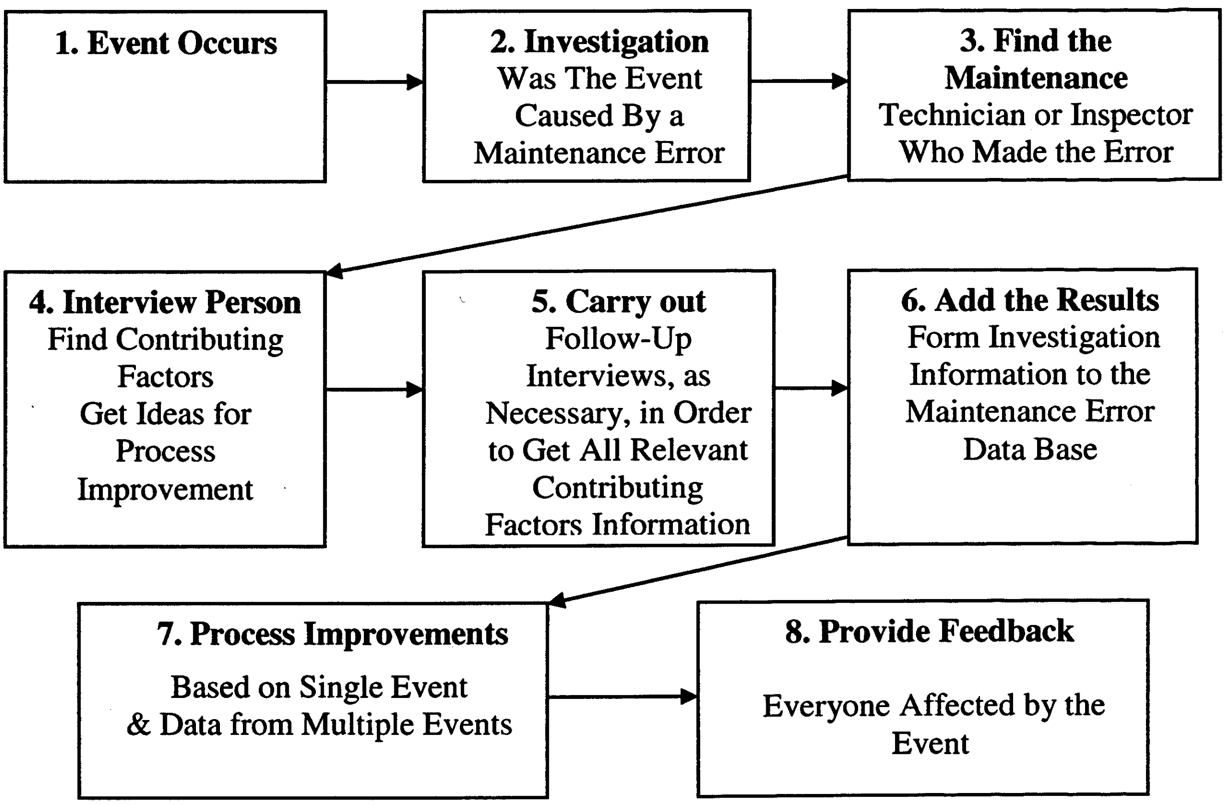
1. Can implement their right and duty to raise concerns that may lead to a serious safety and quality errors
2. Can report safety concerns without fear of inappropriate action
3. Can raise issues or concerns openly and honestly which will be listened to, with concerns investigated fully and actioned in a professional manner, without fear of being penalised for being honest about genuine mistakes.

MEMS also provides a mechanism to report, investigate and prevent human maintenance errors occurring based on factors such as procedural ambiguities and mismatches between required and actual practices. For example, if an error is made because a maintenance manual is difficult to understand then others using the same procedure are likely to make the same or similar types of error. Typically an error will not occur due to one single contributing factor and maybe the result of a series of contributing factors. For any safety critical business – these factors are critical to good management. The MEDA tool therefore supports a structured process for mapping and addressing the underlying causes of error related factors based on three key objectives listed below:

1. The AR&O organisation must be viewed as a system where the person is considered as part of the system.
2. Addressing the contributing factors at lower level events will help prevent more serious events from occurring.
3. The MEDA investigator should have a good understanding of the whole investigation process as shown in the decision making chart shown below.

Figure 4.12

MEDA Model



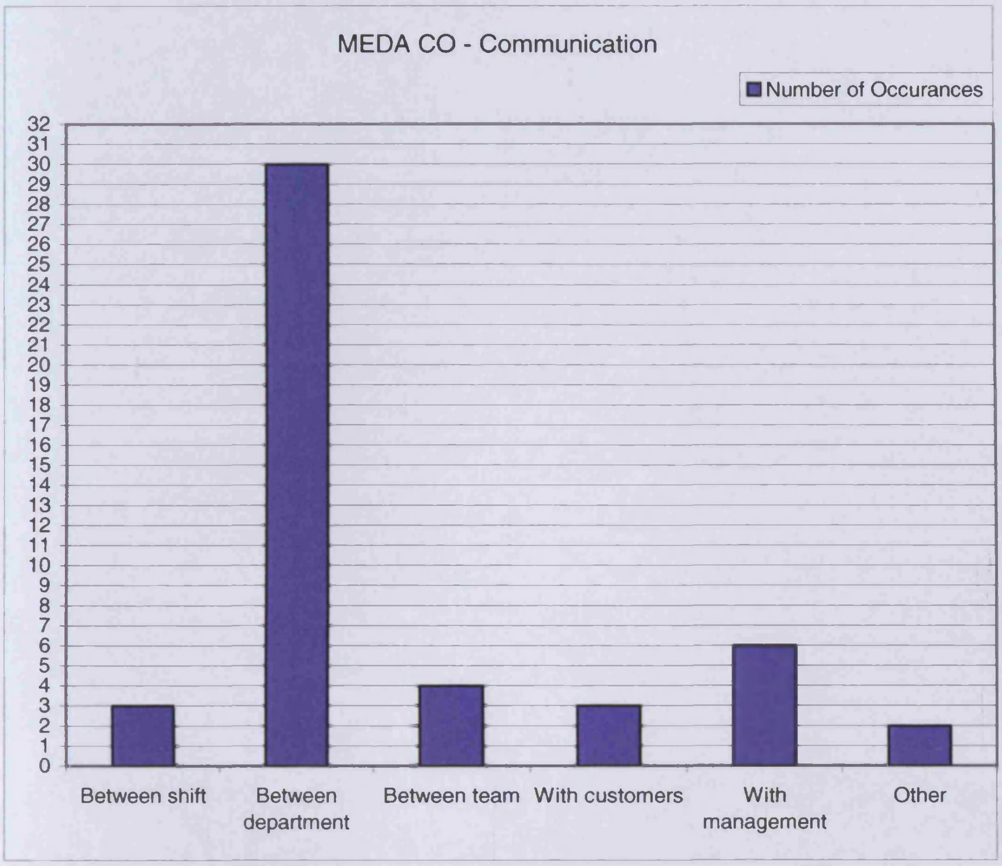
Source: Taken From Case Study Quality Management System (2006)

At this point in the review of the case studies, it can be seen that the sites and corporate HQ have designed a system to engage the individual, team, site management and all employees in a portfolio of human factors reporting that is coherent and based on openness and trust between those who perform repairs and those who support the operations system.

4.11 Error Case Study Investigation

To encourage employees to report incidents occurrence reports are recorded using the MEMS database. In turn this allows for the measurement and identification of patterns of contributory factors. The database was investigated by the researcher and this management process was found to have been active since 2004. Sufficient amounts of data have also been extracted and collated which suggest that interdepartmental communication is one critical element of human factor management and a potential for failure. For the researcher such a result gives rise for concern and is illustrated in the graph below (figure 4.13). A significant number of human error investigations showed a strong correlation between the role of self-management and failings in the support required by other cross-functional business groups.

Figure 4.13 Elements of Human Factor Management



Source: Taken From Case Study Quality Management System (2006)

To investigate the problems between departments, the researcher extracted a documented case study that typified this particular type of failure. It was found that a combustion chamber, which was despatched to a customer, was fitted with incorrect parts due to the complexity of the repair process itself and a general lack of understanding of how to comply with procedures. The root cause was found to be poor technical change control for service bulletin up-dates based on 5 contributing factors as outlined below:

1 Non-compliance to SAP Task list planning procedures ref AROP C4.62/2 [55]

2 Non-compliance to SAP Sentencing procedures ref AROP F3 5/2

3 Non-compliance to SAP Final view procedures ref AROP F.3.6/4

4 Poor communications between departments.

5 Poor knowledge surrounding SAP within the repair facility.

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[55] SAP is the enterprise computer system operated by the case company and AROP means Aero Repair and Overhaul Procedures (standard work instructions).

This research indicated that a lack of management within the process of planning tasks often resulted in poor quality work because teams could not work efficiently and effectively, these elements are prerequisite 'business process basics' in order that TQM can be exploited in terms of high quality material flow. According to EASA part -145 there is a direct link between management attitudes and expectations of a maintenance/build teams. EASA provide the following summary of criteria expected of management systems.

Planning of work

1. Remove excess downtime between tasks
2. Create adequate time for tasks to be carried out
3. Plan tasks that can be carried out in a logical sequence

Prioritisation of work

1. Engineers should be informed as to which tasks to carry out first
2. Important or safety related tasks to be scheduled last
3. Prevention of wide variances in workload amongst engineers

Delegation of work

1. Refrain from assigning the wrong person to carry out a task
2. Prevent inconsistency of processes when delegating tasks
3. Be wary of giving the same task to the same person consistently

These guidelines represent 'tests of goodness' for any socio-technical design of a safety system and are also measures of success at the case study organisations. These themes will form part of the review process during the Results and Analysis chapters.

4.12 Chapter Summary

This chapter has provided a contextual sensitization for the reader and an overview of the case study issues and corporate/commercial challenges facing highly regulated repair businesses. It has shown that quality problems have much deeper roots in socio-technical designs than would otherwise be considered from 'unregulated', higher volume businesses and organizations with team leader roles. In attempting to understand the difficulties surrounding self-managed teams a number of contradictions between theory and practice are apparent. This chapter highlights more fundament failings in management and more importantly across departments as a traditional regulated and functionally structured business (typical of the industry) wrestles with the traditional scientific management model and new TQM practices to meet commercial/regulator imposed pressures.

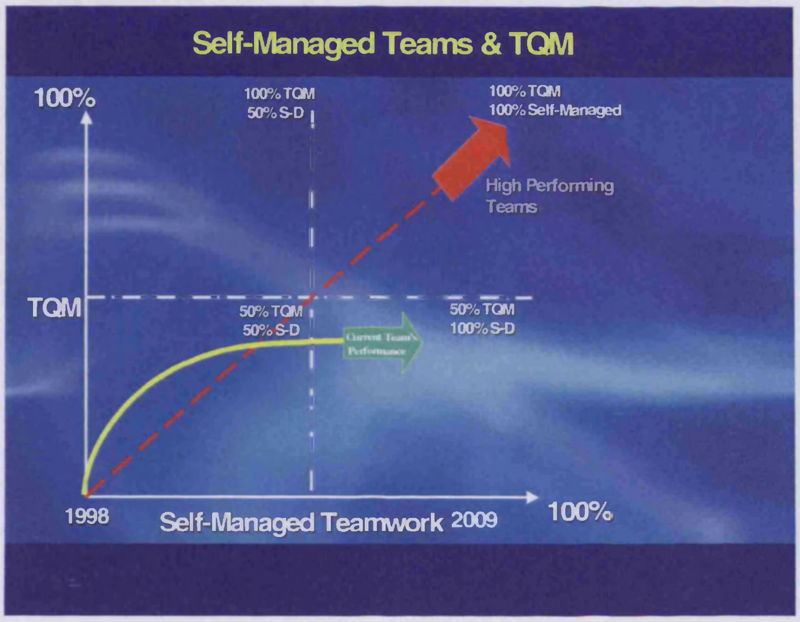
Some areas of the business can be described as successful in facilitating some elements of TQM, but by contrast, most areas work at the level V Holppe 1993 rating, and are slow to extend empowerment to support the evolution beyond the basic 'process basics' stage 1 corporate model of TQM. Since the introduction of self-management in 1998 each of the UK sites have experienced a rapid acceptance for, what is referred to as, modern working practices and have faced greater human factors transparency in their operations (such as the introduction of MEMS, MEDA etc). The cases have made progress in terms of positive improvements to material flow and have generated dramatic reductions in engine turn-round times (by as much as 50%).

However, in spite of these successes, the quality foundation upon which the drive for improvement rests (and is fundamental to Slacks 'no trade off' view of world class) has potentially eroded. The pursuit of cost reduction has included many changes to the structures and support that the team had previously enjoyed (such as the removal of the team coach). This may have been premature in the transition to self-management and signaled its success when, in reality, the teams were mature but poorly supported in the planning of work and broader socio-technical system design.

What should have been a positive substitute for traditional quality management thinking has therefore resulted in both confusion and loss of strategic direction for achieving the organisational goal of self-management (the embodiment of a TQM philosophy). The reality and current position of self-management is therefore somewhat different than expected and justified the in-depth study of this corporate case especially the socio-technical systems design that manages the relationship between self-management and TQM. This relationship is illustrated in the model shown below.

Figure 4.14

Assessment Model of Self-Management & TQM



Source: Researcher

In the absence of robust academic models that cover the industry or process type of regulated repair business, the researcher took a broad approach to socio-technical systems designs and their contribution to human factor failures. This chapter has shown how, through the use of the iceberg model, management issues and poor local designs of systems have been identified as potential causal factors that limit the self-management of TQM by teams. It has provided a cursory overview of how facility management has fallen short in its ability to lead teams through the stages of improvement, efficiency and effectiveness of the corporate TQM model.

This poses a dilemma – can self-managed teams safely facilitate TQM in the aero repair industry sector? The aero repair & overhaul case studies present an almost unparalleled and unique position for the investigation of the phenomena of self managed teams and the socio-technical systems that support them.

Even 'safety gurus' like Reason (2003) and Rasmussen (1998) have stopped short of engaging with repair businesses and have instead remained committed to pilot issues or focused on traditional areas of high volume regulation (petro-chemical etc). The case studies were therefore deemed provide a major opportunity to add significant value to the academic understanding of a regulated business within which the application of TQM which is conducted in a highly complex operations management process. The initial sensitisation stage of the study also showed that the business system did seem to struggle with safety system issues concerning the structure of the operational staff, how best to control safety/quality processes and which elements of the existing business design were inhibiting progress towards full self-management and fully deployed safety/quality responsibility. An overview of the businesses engaged with this series of cross-comparative case studies has been provided in this chapter. The cases involved with the study are high performance and critical repair centres with long established skills and customary practice. The cases have continuously adapted and have struggled to make sense of a craft based model of operations management and how best to change it to that of a leaner and more safety conscious way of working. The businesses are in a state of flux and have little guidance in terms of successful organisational models in this area (and a sparse academic literature). As such an interpretation of the lean and TQM way of working is needed and these cases were selected because they offer most insight into a safety critical environment. Many conflicts exist including the role of team working, individual autonomy, situational awareness and responsiveness of the operations systems to commercial pressures. The timing is right to study how the socio-technical systems designs are changing and how these impact upon human factors (in the absence of a supervisor and organisational structure which is structured for command and control and not TQM). It should be noted at the time of finally submitting this thesis and the last final adjustments to this document, Toyota (the archetype lean business) has recalled 8 million vehicles as a result of a safety concern and a catastrophic breech of Toyota's systems which makes this study all the more important and time critical. The next chapter will begin to distil the results of the study and build towards the analysis and contribution to the academic body of knowledge concerning human factor risk management and TQM.

Chapter 5 Results

5.0 Chapter Introduction

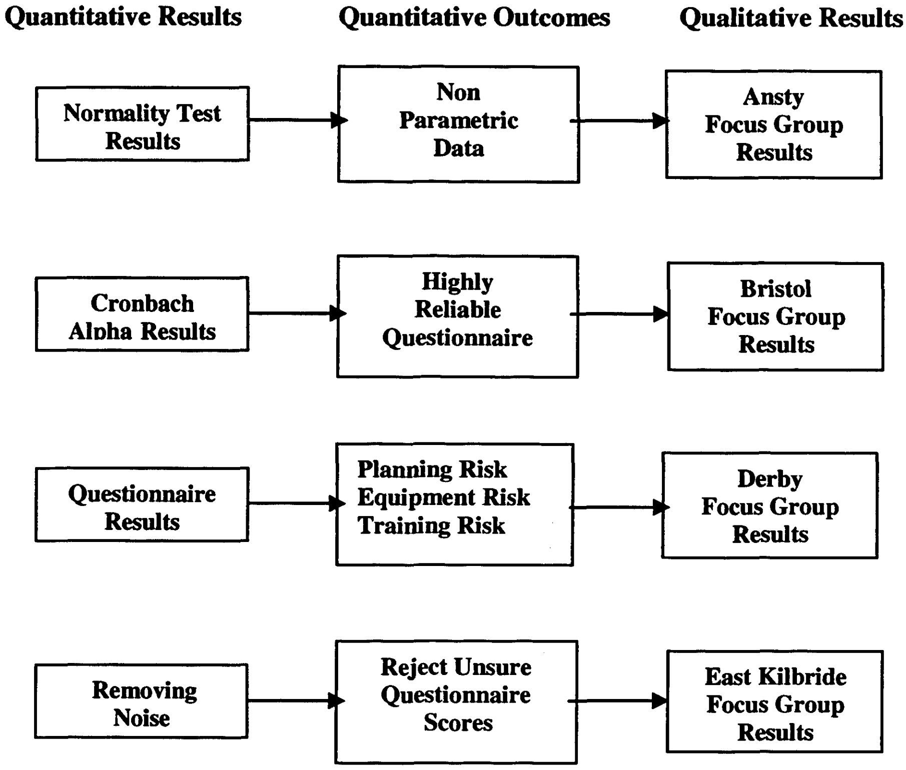
During the previous chapters many evolving themes have emerged and these have all had a common denominator - the importance of creating a positive human factors environment where self-managed team working is able to facilitate the principles of TQM. These preconditions are important if this structure is to be effective and many authors claim it is a step too far for a regulated industry (Reason, 1995). This chapter will present the results of the empirical field research of this study and will partially answer the guiding research question.

The chapter is divided into two parts that reflect the two key cycles of research – the quantitative analysis leading to a qualitative review cycle. Such a pluralist and cyclical methodology is conducive to theory building and the exploration of phenomena where little is known (Eisenhardt, 1989; Miles and Huberman, 1994). The purpose of presenting this material in such a way is to support the building of a model that describes the significant features that underpin mature improvement case studies within the context of, highly regulated safety management/high costs of failure, working environments.

Part 1 of this chapter provides the main body of results including data from the large-scale survey. This part of the research cycle demonstrates a generic range of error provoking trends that were found across 8 separate teams who are located across 4 different UK aerospace repair & overhaul sites. The results of the second phase (the qualitative cycle) support the main quantitative framework and this is presented as a summary of written narrative events (drawn from the research with focus groups and semi-structured interviews of actors in the system). In other words the majority of information presented throughout phase 2 provides an experiential account of error provoking trends and builds upon the critical mass of employee's perceptions (management, staff and teams). Whilst this is not purely an ethnographic study, employee perceptions were used and tested against secondary data collected whilst at the case studies. The following chart (figure 5.0) is representative of this position and provides a schematic overview of the main chapter primary and secondary source data.

Figure 5.0

Overview of Case Study Results



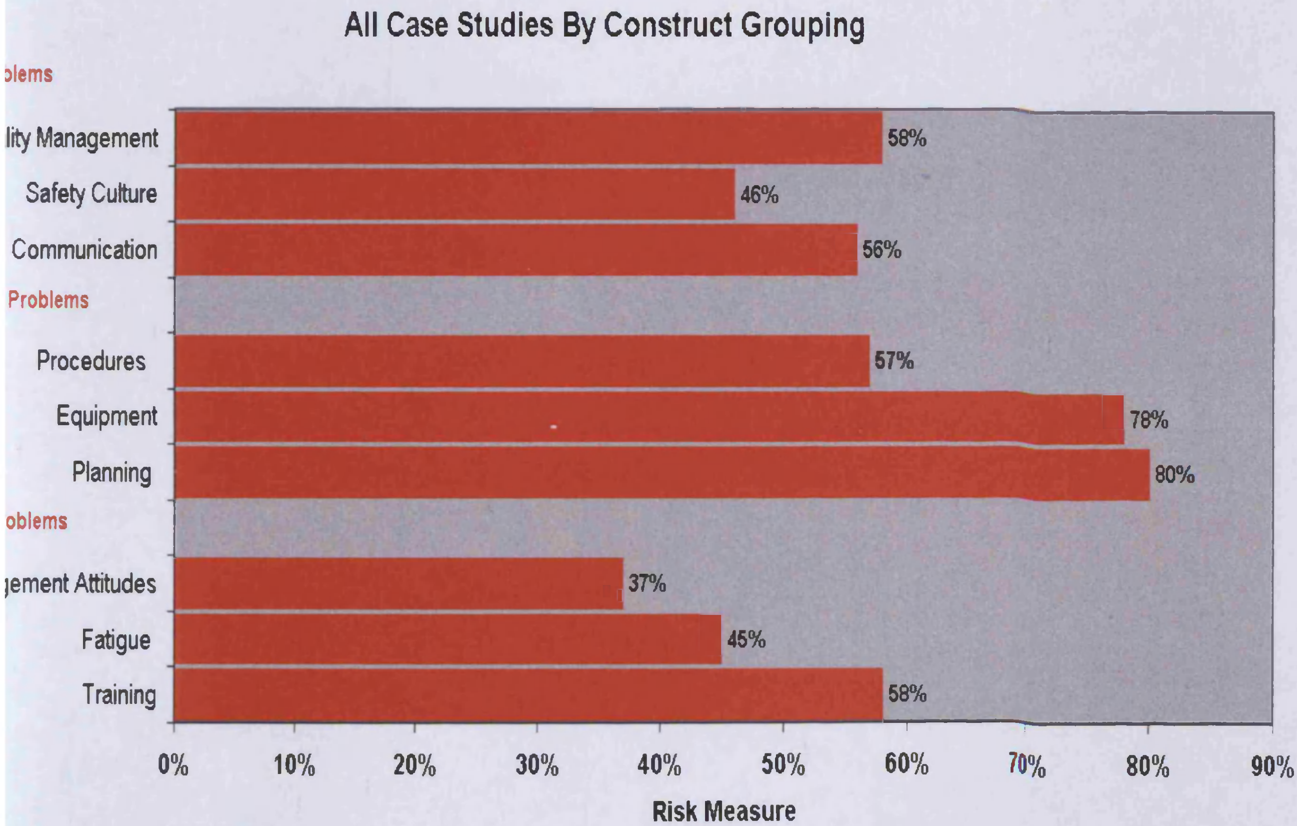
Source: Researcher

5.1 The Quantitative Review

The quantitative stage of results included the processing of raw data taken from total of eight hundred questionnaires that were distributed to approximately 30% of the AR&O population (across all four sites engaged with this study). By means of background data, the average in-service period (tenure) of the informants was 25 years and this result was regarded as significant in terms of the employee having experienced pre and post transition states of the business and also for the employee to be positioned effectively to comment on working practices and systems design.

The chart shown below (Figure 5.1) provides a percentage breakdown of the mean case study scores of all sites surveyed, based on the most significant three risk factors of the 9 central risk measures adopted by this study and extracted from the survey. The nine major factors were drawn from established works in the field of study, aviation human factors in particular. Planning is reported as the highest area of concern expressed by the informants in terms of safety-related problems. A score of 80% risk was associated with the process of management planning and material flow followed by concerns about equipment problems (recorded at 78% level). Next a series of inter-related activities are perceived as concerns for safety management namely: employee training problems (at the 58% level of significance), quality management and improvement processes (58%), procedures (57%) and communication (56%). This demonstrates an interesting result in that 3 of the most significant concerns are located within engineering (technical system) and reflect a concern for the management of technical processes. There are two major concerns in the cultural/social element of the repair system (quality and communication) and training at the individual level (social system). As such this study reinforces the importance of the socio-technical approach to research in this area as opposed to cognitive studies of individual error as has been traditionally adopted by authors in the field (Banbury, 1998).

Figure 5.1



Source: Researcher

However, the perspective called 'engineering problems' represent 42% of the entire survey data and such a result supports the main body of literature (Reason, 2003), which suggests that hardware problems are a major underlying cause of latent error concern (the technical system design) in the context of managing this 'hardware'. Secondly the perspective measuring individual problems was recorded at 27% and accounted for errors associated with cognitive information processing in terms of the way individuals react to specific problem situations (situational awareness). Because the system creates the way in which the individual will perform, this result shows that employees perceive poor system design to be manifest in personal fatigue, poor working environment control, poor team situational awareness and confusion concerning skill variety. As stated in the literature (Spear, 2008), the ability of an individual to perform at a higher level is a function of the team situational awareness of the employees around the individual (higher social system) and this result shows a concern that there is instability in the design of the operations management system at the individual and therefore team levels (deployment of responsibility for ownership and control of the repair process to self managed teams). Finally, the perspective measuring the company culture reflected an overall score of 31% and captured information, which is largely attributed to system in the form of latent error problems. This result shows significant concerns for the fundamental elements of TQM and communication between teams (team situational awareness and material flow performance). In the absence of TQM and high levels of team communication it is not possible to deploy responsibility for operations management/repair management to the level of the team. Viewed holistically, these preliminary results show gaps in the systems of all four sites and suggest the individual/teams have dysfunctional socio-technical systems designs.

5.2 Normality Test Results

Against the original survey design, the summary of results that follows is taken from 800 different data sets of questionnaire scores. These results were manipulated using Minitab and SPSS (by 8 different case study groupings). The use of the two systems was important due to the rigour of the tests designed for this study. These systems were considered appropriate for the reliability of the data collected and Minitab was used (a 'normality test') to show how the responses were spread about a mean and not biased by a pocket of informants with extreme views/perceptions. The type of data extracted from each of the questionnaires is defined as ordinal because it is 'count data' and for the purpose of scientific evaluation was recorded as continuous in statistical terms (see research methodology chapter). In the charts that follow, the researcher organised the data into individual data plots that characterise and sum mean scores. These summed mean scores represent a numerical question trend by site and case study grouping (works and staff views). The purpose of conducting this test is to determine the level of standard deviation about the mean (for staff/management and works/operational personnel). The significance of this test result is shown in the table below (table 5.2).

Figure 5.2

Normality Results

	Planning	Equipment	Training	Communication	Procedures	Quality Management System	Commercial Pressure	Complacency	Attention	Fatigue	Safety Culture	Management Attitudes
Bristol Staff	0.10	0.23	0.06	0.12	0.30	0.30	0.33	0.70	0.20	0.01	0.06	0.05
Bristol Works	0.23	0.00	0.63	0.01	0.72	0.06	0.63	0.03	0.07	0.01	0.50	0.61
Ansty Staff	0.01	0.23	0.10	0.70	0.20	0.23	0.09	0.10	0.31	0.01	0.14	0.40
Ansty Works	0.32	0.23	0.13	0.60	0.11	0.52	0.25	0.50	0.70	0.40	0.40	0.83
Derby Staff	0.20	0.23	0.50	0.30	0.50	0.21	0.62	0.10	0.23	0.10	0.30	0.13
Derby Works	0.61	0.23	0.50	0.32	0.60	0.01	0.61	0.40	0.71	0.10	0.10	0.90
East Kilbride Staff	0.62	0.23	0.60	0.40	0.32	0.50	0.11	0.80	0.22	0.13	0.50	0.30
East Kilbride Works	0.61	0.23	0.30	0.80	0.60	0.23	0.11	0.90	0.30	0.81	0.40	0.50

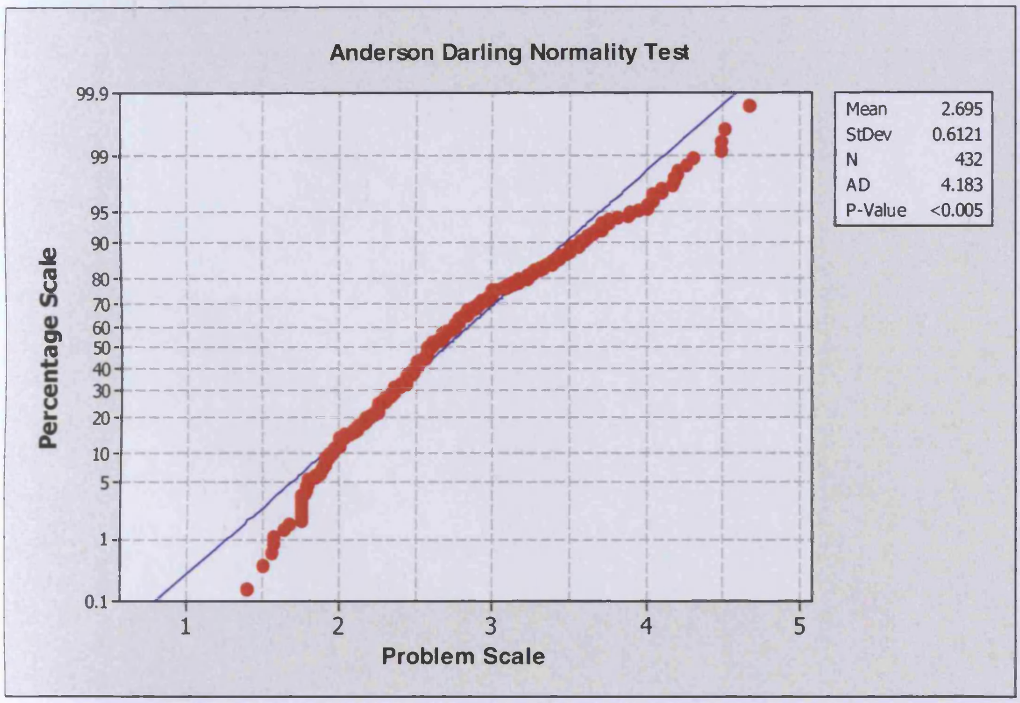
Source: Researcher

The purpose of this test was to define the type of data extracted from the raw questionnaire scores through what is termed as a normality test. Each statistical test defined the data as normal. The 'normal' outcome is achieved only if the probability value 'p' was equal to or greater than 0.05 (presented as green scores in the table). The opposite logic was applied to data that fell below 0.05 level and was duly defined, for the purpose of this study, as non-parametric. The classification as 'non-parametric' is considered 'non normal' (these are presented as red scores in the table).

To ensure the robustness of the study, it was necessary to stack the individual responses into a single normality test and the test selected was the Anderson Darling test, this is used to demonstrate the overall degree of standard deviation from the whole study (Henslin, 2000). The purpose of using this test was used to illuminate a general pattern or trend and the actual survey mean of 2.69 exposes proportional differences in terms of both safe and unsafe working practices as shown in the Anderson Darling 'line of best fit' test shown in the Figure 5.3.

Figure 5.3

Anderson Darling Normality Test



Source: Researcher

The graph shows a slight curve at the edges in the residuals, which indicates a preference from the sample size of 432 employees, which demonstrated that not everyone decided to score the questionnaire in the same way. In other words some individuals either 'strongly disagreed' allowing the researcher to transform a 'tick' response into a numeric code of 1and likewise when others 'strongly agreed' a 'tick' at this end of the Likert-scale was represented as number 5. Profiles of this nature are not uncommon in survey data, in this instance occurring owing to the expected variance the questionnaire was designed to extract. In summary the probability value of less than 0.05 has no bearing on the validity of the questionnaire itself, but rather exposes the research question from a non-parametric perspective where the data reflects wide variations of why different opinions about quality exist. In other words, if you give people a scale representing strongly agree/strongly disagree then it must be expected that extremes will be taken by individuals resulting in information that will not cluster around the middle value. Also, it should be noted that this study is non-parametric and as such defined the direction of the study, it also ruled out means based analysis of variance type tests (such as 2 sample t tests). The above test of normal distribution therefore was accepted as non-normal whereby any further tests will concentrate upon the median as opposed to the mean.

5.3 Cronbach Alpha Results

The next step in processing the survey results was to test the data for its level reliability. In other words of the researcher needed to provide evidence for standards of internal consistency by measuring patterns of scores from individual responses against each construct grouping. By measuring the survey's internal level of consistency the researcher was able to estimate the level of questionnaire reliability against a numerical 1-5-Likert scale, as shown in the example below:

1 = Strongly Disagree

2 = Disagree

3 = Unsure

4 = Agree

5 = Strongly Agree

After collecting the responses from each questionnaire a database was constructed by case study grouping to determine if the survey was statistically reliable against the perceived research design. The ALPHA option, used to assess the reliability of every subject's response to each question, was analysed through an SPSS computer program in the form of 72 Cronbach alpha split tests. Cronbach's α is defined as

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N}\sigma^2_{Y_i}}{\sigma^2_X}\right)$$

For example where N represents the number of subject scores, σ^2_X is the variance between those scores against the observed total test scores and $\sigma^2_{Y_i}$ is the variance of each factor, which is represented as component. The accepted social science 'cut-off point' for this test (Thompson, 2001) was set at p< 0.70 for a set of items, which are represented in the table of results shown in fig 5.4 below. The test data that failed to reach the probability criteria of <0.70 was considered as skewed and subsequently removed from the study in order to meet the standards of scientific norm (Ghauri, 2002). The actual number of human factor measures was therefore reduced to 9, based on the researcher's decision to reject the following factors (shown in red in Table 5.4) as listed below.

1 Commercial Pressure
2 Complacency
3 Attention

Figure 5.4

Table of Cronbach Alpha Test Results

	Planning	Equipment	Training	Communication	Procedures	Quality Management	Commercial Pressure	Complacency	Attention	Fatigue	Safety Culture	Management Attitudes
Bristol Staff	0.83	0.90	0.82	0.94	0.90	0.90	0.97	0.80	0.73	0.93	0.94	0.95
Bristol Works	0.92	0.70	0.97	0.86	0.90	0.90	0.50	0.80	0.62	0.80	0.75	0.70
Ansty Staff	0.72	0.82	0.77	0.81	0.74	0.70	0.50	0.80	0.70	0.93	0.80	0.70
Ansty Works	0.70	0.82	0.80	0.82	0.90	0.70	0.05	0.72	0.60	0.72	0.70	0.80
Derby Staff	0.70	0.70	0.78	0.80	0.80	0.78	0.50	0.70	0.63	0.70	0.85	0.70
Derby Works	0.82	0.80	0.74	0.84	0.90	0.80	0.71	0.62	0.70	0.72	0.83	0.80
East Kilbride Staff	0.74	0.70	0.70	0.74	0.71	0.72	0.42	0.60	0.42	0.70	0.80	0.70
East Kilbride Works	0.70	0.70	0.73	0.71	0.80	0.70	0.54	0.60	0.70	0.70	0.70	0.70

Source: Researcher

The internal level of consistency of the survey was confirmed as acceptable. The data was accepted based on the results of the Cronbach Alpha slit tests, which determined the exact measure of statistical reliability for all questionnaire scores. In other words the application of reliability testing was used to measure the effectiveness of questionnaire design based on rejecting data that fell below the values of p< 0.70, as highlighted in red. All other data shown in green was subsequently accepted for the processing of human error review. The quality of the questionnaire design was duly accepted as meeting the levels of social scientific statistical reliability upon which to build a theoretical model at a later stage.

5.4 Overview of Case Study Results

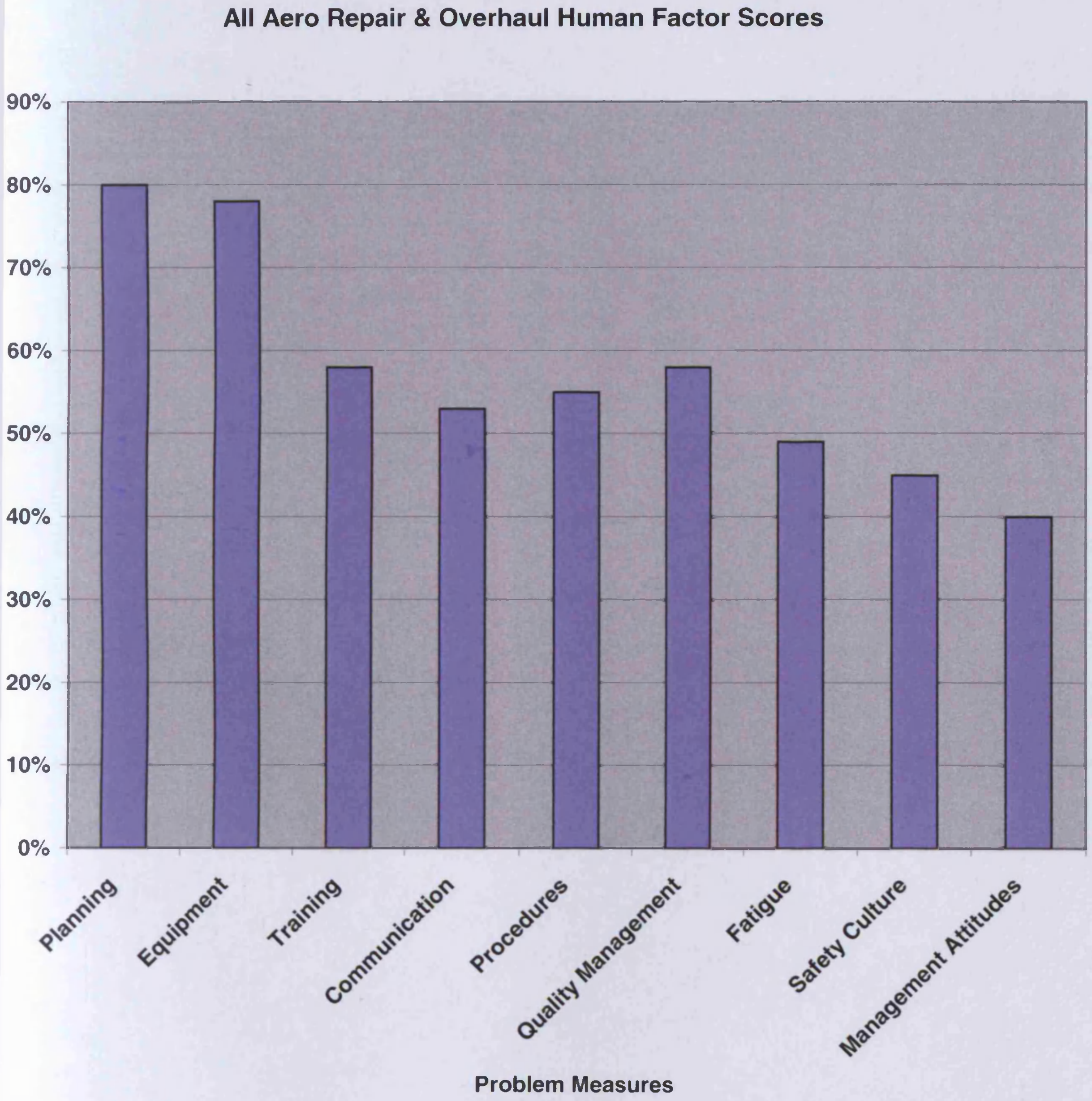
Having established the type and reliability of the data being used, the researcher recoded all questionnaire scores into a percentage scale that considered problem ratings between 0% and 100% (reference the list of examples show below).

0 to 25%	=	Strongly disagree i.e. no problems exist
25% to 50%	=	Disagree i.e. no problems exist
50% to 75%	=	Agree i.e. problems exist
75% to 100%	=	Strongly agree i.e. problems exist

In other words the researcher was now confident that the data available was of a level of quality that could be used to show robust trends. The chart shown below (Figure 5.5), includes a summary of all sites and group scores and clearly indicates the biggest representative problems by percentage scale, based on the highest order of concern are:

1. Planning 80%
2. Equipment 78%
3. Training 58%

Figure 5.5



Source: Researcher

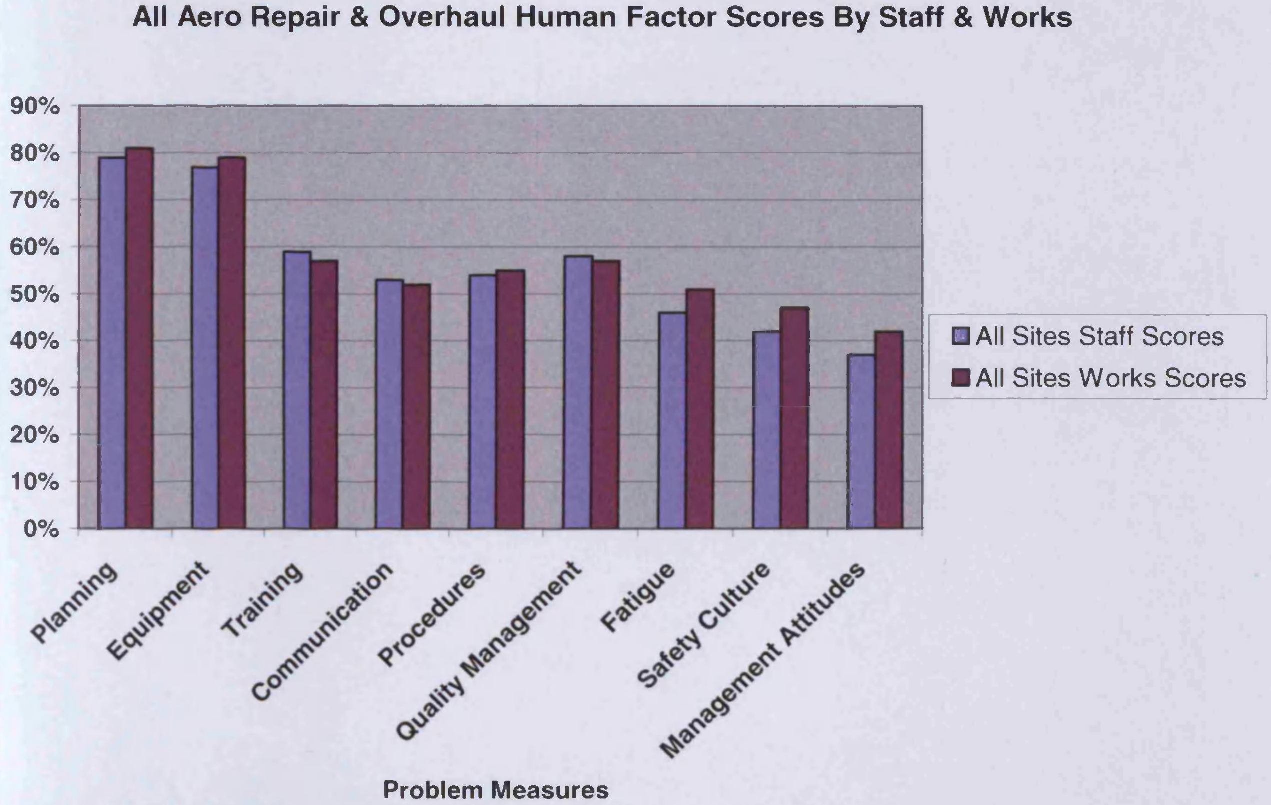
Interestingly, quality management ranks sixth in the series of problem measures. Again this result reinforces those found earlier and the view that there are problems with the management of the technical system.

5.5 Comparison between Works & Staff Personnel Groups

Figure 5.6 provides a cross case comparison of all sites to include differences between Staff & Works group perceptions, thus representing a mean percentage set of scores of construct measures. The purpose of which is to illustrate any trends and relationships between the two main groups of informants upon which this study of socio-technical systems designs is based (works and staff personnel). The trends discovered are significant and will be explored in the subsequent chapter. The bar chart reads from left to right, with the highest 6 areas of concern shown in the table below:

1. Staff Planning 79%
2. Works Planning 81%
3. Staff Equipment 77%
4. Works Equipment 79%
5. Staff Training 59%
6. Works Training 57%

Figure 5.6



Source: Researcher

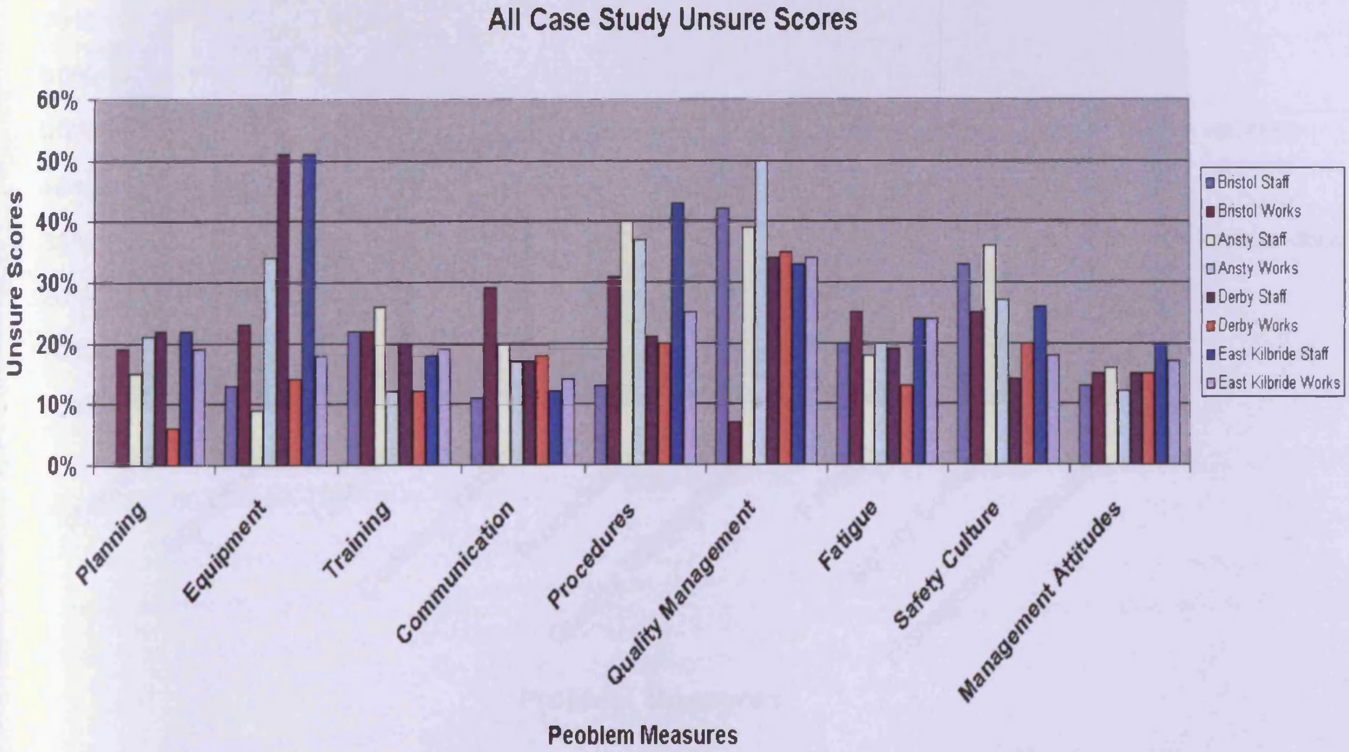
Again, such a result confirms how much in agreement these two types of personnel are in terms of the issues within the socio-technical system and its management. As such the hypothesis that there was a difference in the views of informants (by classification) was wrong and this result does inform the analysis presented in the next chapter.

5.6 Uncertainty Results

During the initial presentation and review of the case study results, the researcher was only concerned with data that represented problem areas and deliberately excluded all uncertainty scores of 3 (the middle option in the 1-5 Likert questionnaire response scale). The rationale behind this approach was based on the assumption that unknown scores of 3, as shown in the chart below, would represent a series of ambiguous interpretations based on the assumption that employees.

1. Did not understand the question?
2. Could not make a decision between questions?

Figure 5.7



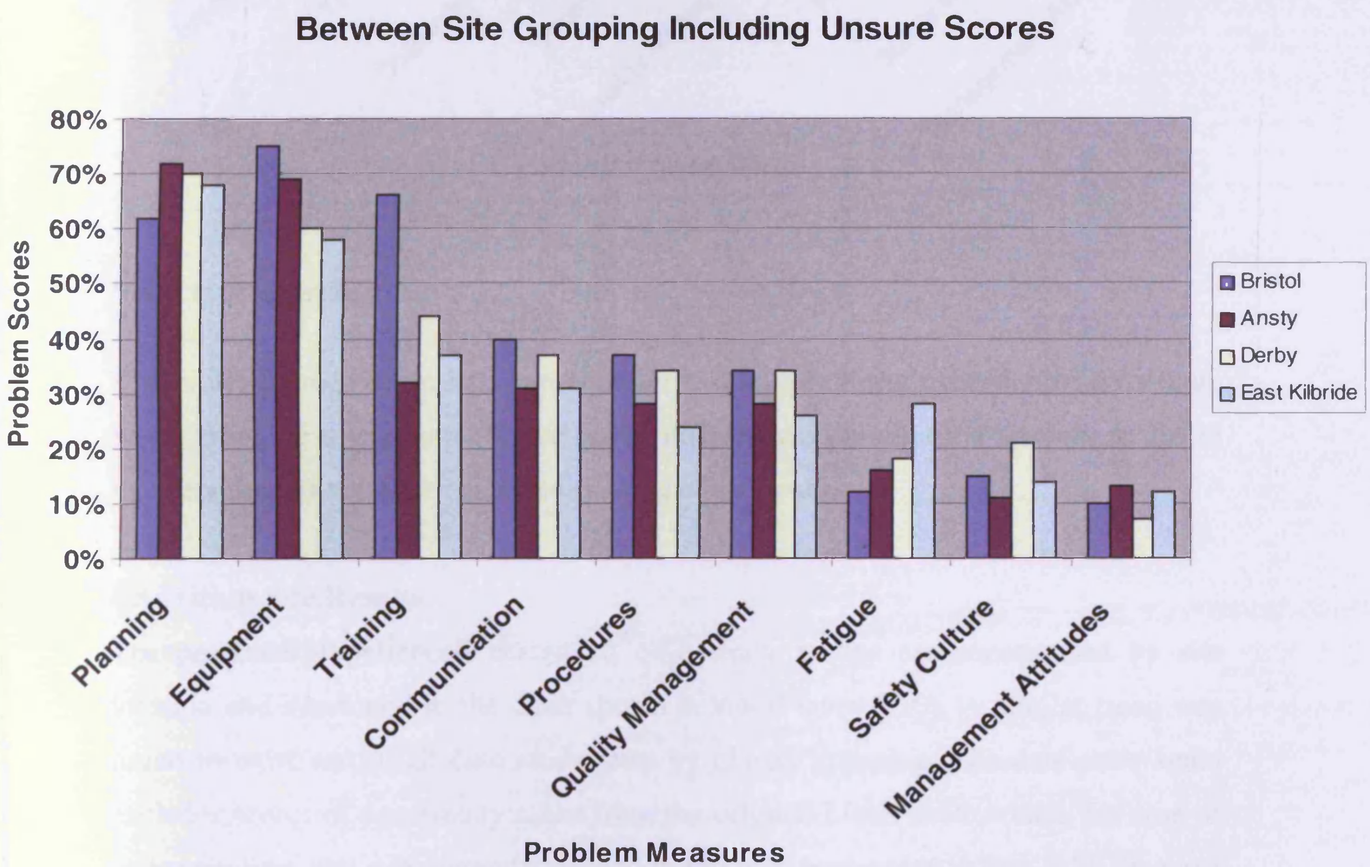
Source: Researcher

For clarity of understanding the researcher was concerned with the level of distortion the uncertainty scores might have on the overall trend of results. It was for this reason that the two charts were created as shown below, these provided the researcher with a level of understanding of which model to pursue.

5.7 Accepting & Rejecting Results

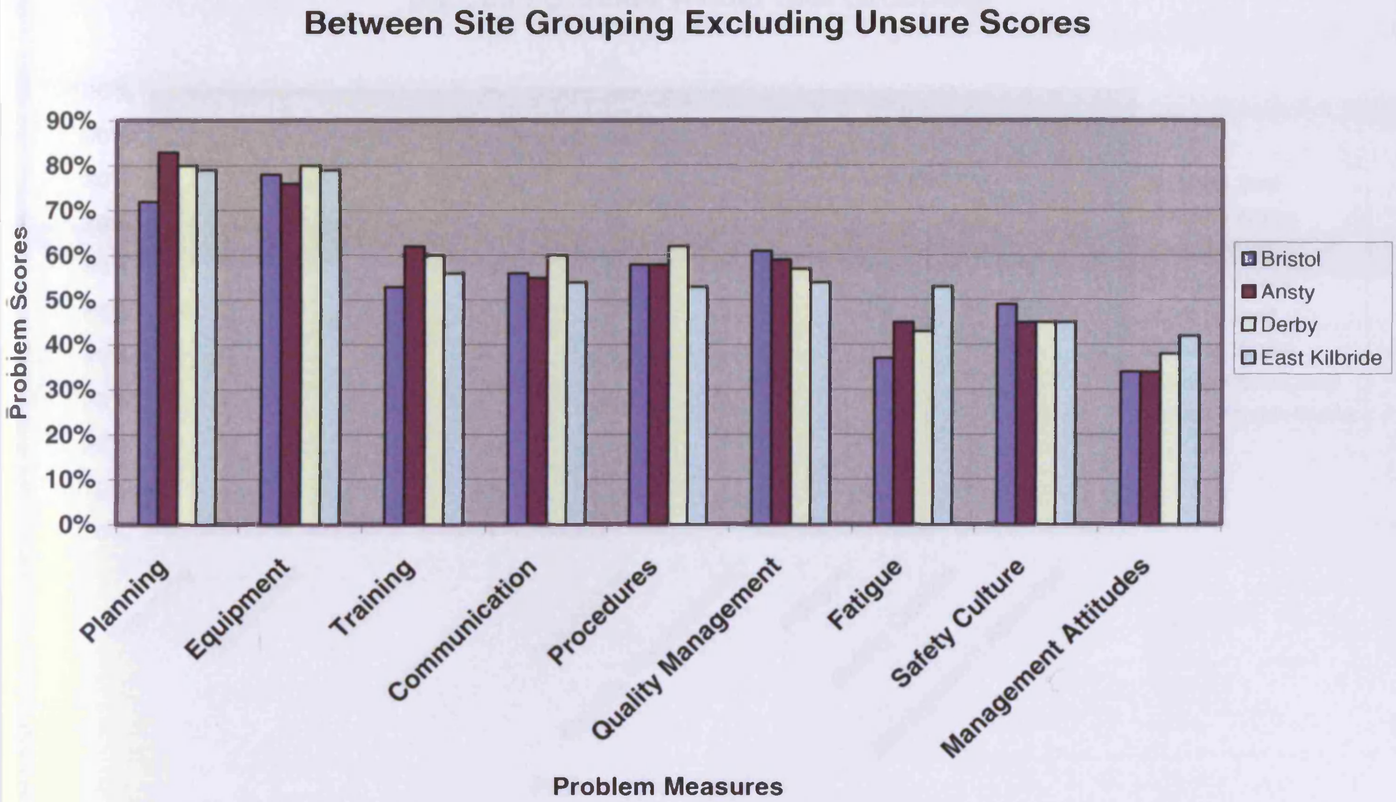
The chart below, (figure 5.8) provides a comparative measure of 'between site' scores, based on the inclusion of all unsure scores of 3. The second chart below, (figure 5.9) provides a considerably different trend, whereby the problem measure of management attitudes is approximately 3 times greater because of the exclusion of unsure scores of 3.

Figure 5.8



Source: Researcher

Figure 5.9



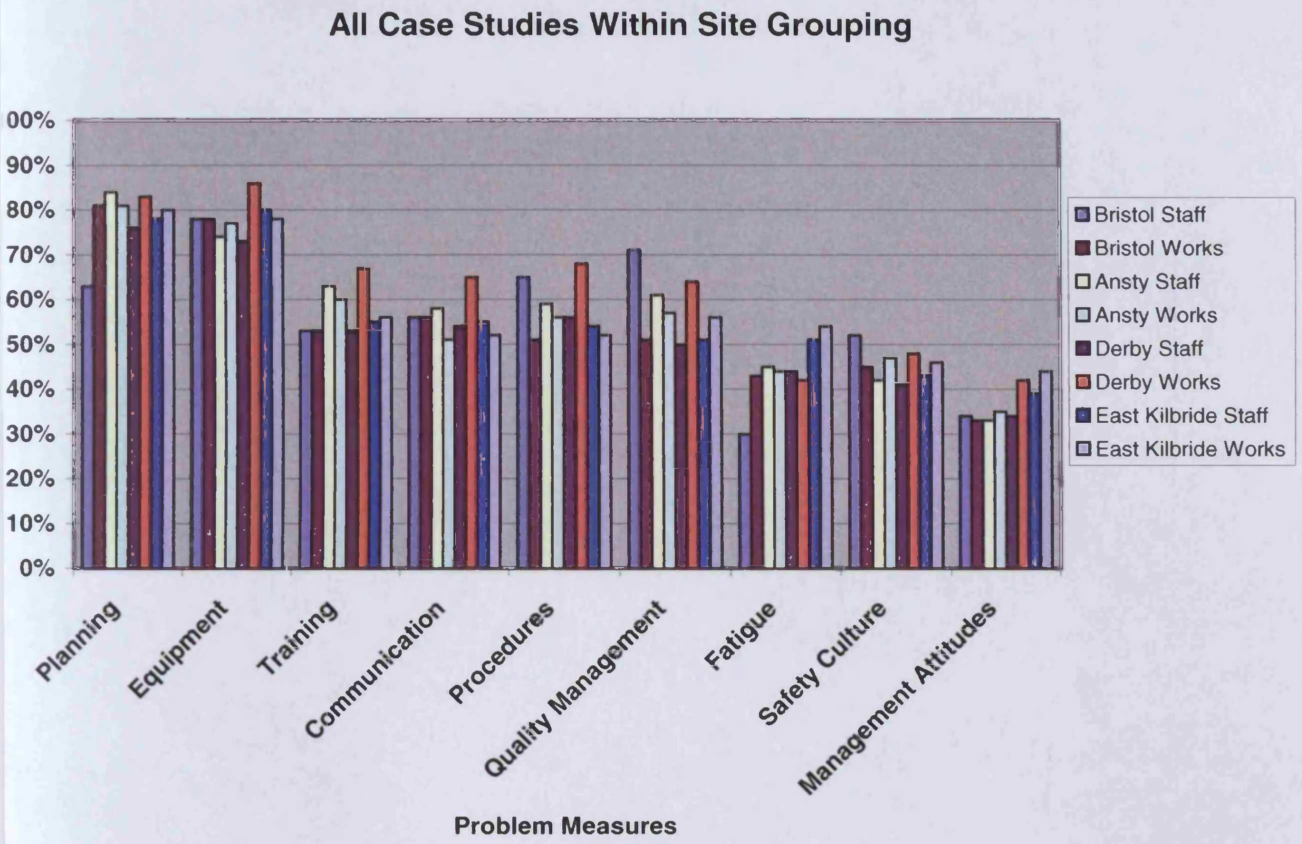
Source: Researcher

The preferred method of data presentation was based on the exclusion of all unsure scores from the entire survey based on the differences between these two charts due to its averaging effect and artificial smoothing of the results.

5.8 Within Site Results

The problems experienced across all case study groups are summarised by site location and illustrated in the chart shown below (Figure 5.10). A similar trend was found to exist across all case study sites by cluster grouping. The data once again excludes scores of uncertainty taken from the original Likert scale which, for ease of understanding, was subsequently recoded in terms of percentage values, with the most problematic area reading from left to right.

Figure 5.10



Source: Researcher

5.9 Summary of Quantitative Results Phase 1

From the evidence, and looking for outlier cases, problems associated with planning and equipment represented a higher percentage value amongst Derby works, with a similar trend between all other sites by sample grouping. It would appear that problems with training and communication are clustered very closely together, with Derby works measuring the highest order for concern across each construct measure. The situation regarding procedures and the risk of non-conformance to the management of the quality system is ranked highest at Derby and Bristol with East Kilbride and Ansty following a similar trend. In considering these findings it can be argued that because Derby and Bristol share the same customers the engine work scope, whilst different from one site to the next could, in principle, have an influencing effect on the same reported levels of human factors concerns. The finding suggests that these ‘commercial pressures’ from the same customers and similar technical product characteristics (engine types) induce similar pressures on the socio-technical system. So, despite removing the questions associated with commercial pressure in a previous test of the quality of the study questionnaire, it has been found that commercial considerations have been detected. This would validate the fact that the questionnaire questions were not robust but that enough questions in the questionnaire were present to detect the impact of commercial pressure (an important factor for latent errors as per Reason, 2003).

In consideration of the construct measure of individual fatigue, which has been previously highlighted as important, one could argue for the existence of the opposite situation (recorded as a low level between the Bristol and Ansty site). Since both of these sites share the same corporate management structure, the researcher has assumed that different styles of local leadership explain why the opposite situation exists between Derby and East Kilbride. As such 'local management' and indeed the responsiveness of local management to team/individual needs is considered important and a justification of the phase 2 (qualitative phase) of research to delve deeper into the socio-technical system design (Gummesson, 1991).

Apart from Bristol, each of the three other sites has demonstrated similar levels of risk that surround the general measure of their overall site safety concern. The ranking below provides a list of the aggregate questionnaire scores based on a pareto of 'most at risk' error provoking themes.

1. Planning 626%
2. Equipment 624%
3. Procedures 461%
4. Quality Management 461%
5. Fatigue 353%
6. Training 460%
7. Communication 447%
8. Safety Culture 364%
9. Management Attitudes 294%

Again, this test confirms the critical importance of planning and equipment as the key facets of safe socio-technical systems designs. Finally, 'management attitudes' was regarded as the least cause for concern, based on a consensus of opinion that managers are not consciously acting in a manner, which can be considered as unsafe. However, during the next section the qualitative approach has fundamentally challenged this view by exposing the underlying causes of error risk from a leadership point of view. In overall summary, the first phase of research clearly indicates the planning and equipment of the facility to be most important features in a safety-regulated environment. Again the multiple tests provide significant robustness as grounding for the resultant model that the researcher seeks as his major contribution to the academic body of knowledge and informed professional management practice.

5.10 Qualitative Results Phase 1

The researcher will now present, in the sections that follow, an experiential account of human error problems from a theoretical perspective as outlined by Miles & Huberman (1994). In these sections of findings a more humanistic approach is used to provide a more in-depth account of 'why' error-provoking problems exist from a socio-technical perspective. In the sections that follow a series of paraphrased reports will be presented by site-specific location, which summarise the opinions as to why certain areas of the business are perceived as being exposed to errors/risks. The researcher has limited the qualitative phase of investigation to planning problems, equipment problems and training issues alone due to the significance of these issues as shown by the quantitative research process.

Using the detailed summary of transcripts, the researcher has drawn a series of results from the follow up interviews with different managers at each site location. These informants were selected because they were 'system designers' and were identified, as being accountable for staff / works area of concern. The information and research findings will be presented from a staff and works viewpoint (operational employees) and Management viewpoint, which reflects a divide between personnel who work within a design and those responsible for the design of the operations system. With reference to this part of the study it should be noted that in nearly all cases a contradiction exists between the management and teams' account for why error related problems exist. Based on established research taken from the literature review, one can argue these and other types of indifference reflect the existence of a 'claim' & 'blame' or 'them & us' type of culture. In other words the ability for self-management to facilitate the organisational goal of TQM depends on the resolution of human factor problems cited at the leadership level of human factors control (design issues related to latent errors).

In spite of these differences, all participants of the focus group research were happy to engage in the analytical assessment of results; these will be discussed in more detail within chapter 6. In the sections that follow the researcher has utilised the support of 4 human resource professionals, based at each case study location, their expert skill in facilitating each focus group workshop was considered vital in providing an objective account to support the research design. These professional facilitators were engaged to ensure there was no bias in the collection of qualitative data and that the researcher's presence did not influence the willingness of the teams to be open and honest.

The interpretation of the qualitative results is based the methodology provided by Miles & Huberman (1994), Yin (2003) and within the recommendations of Eisenhardt (1991). These methods and guidelines were used for the purpose of measuring the value of both the written and spoken word but doing so without any crossover between these parts of the study (to ensure robustness and to eliminate further form of bias). Each of the HR specialists was trained by the researcher to conduct the research to the same standard and not to bias results or influence the research process.

The next sections will present; the narrative from the qualitative research, comments regarding the implication of the findings on the design, and errors in the socio-technical system design at each case study site.

5.11 Extracts from the Ansty Focus Group Transcripts

The first feature of socio technical systems design to be reviewed was the central issue of planning and the co-ordination of the material flow system. The review of planning is important because this feature of system management is central to deploying responsibility to self managed teams and it is the key part of the system that deals with commercial pressures.

Planning Problem 1: Commercial Pressures and Deadlines

Antsy Works & Staff Concern

The teams were interviewed for over two hours as a panel group. The most repetitive words and synonyms were all associated with commercial pressures as a source of problems which led directly to issues and conflicts with technology and materials flow. Comments from teams in general were raised about unrealistic deadlines being set for production targets, which create pressure and, as Reason (1995) states, raises the potential for barrier failure because of the chaotic confusion that such deadlines pose in an environment where routines are not standard and vary in time taken to achieve a quality outcome.

These issues were raised during the panel discussion about the working environment and the introduction of a new engine contract. The review of these experiences raised interesting findings about the potential for failure, role confusion at the team and individual level and the structural issues of accountability within the factory.

Ansty Management Response

In respect of the new engine contract and concerns from the works teams, the factory management responded by establishing an improvement team. The purpose of this team was to temporarily accommodate and understand the issues that would enable the business to meet the contracted hours and beyond. Such a temporary intervention was a modification to the existing business structure and an 'issue containment exercise' using TQM methods for the purpose of maintaining commercial material flow in a competitive market. The team therefore 'policed' the factory system and constantly reviewed its targets to ensure that engine overhaul projects remained competitive.

The differences between causal concerns of works staff and the reaction, by management, to protect short term material flow is interesting and shows a divide between the intentions of teams to solve problems with permanent interventions and temporary fixes by management teams to ensure customer service. Both approaches are TQM methods that are focused on the customer but they show a marked level of difference in the best long term and permanent solution to an identified 'safety' issue in the workplace. In this respect the strength of management response and willingness to change the system design is weak and implies a lack of leadership within the socio-technical system.

<u>Planning Problems 2: Task Uncertainty and Leadership</u>

Antsy Works & Staff Concern

The teams expressed major reservations that structural changes to the regulation of quality management would result from structural changes by management and that the current department for quality control would be devolved. The single point of responsibility for quality control was held by the inspection departments and fears over its removal were expressed in terms of an increase in task uncertainty due to unregulated practice. These concerns therefore reinforce the issues of a designed safety system and the use of barriers to ensure safe and quality working practices. Again changes to the existing system of accountability provide a major theme and concern for staff.

Ansty Management Response

The business management response was that the most effective ways of managing quality must be used and this implied the need to continuously evaluate the most effective way to plan and carry out work. Furthermore, the allocation of quality responsibility would reflect the best place to conduct the assurance and control routines based on achieving cost commitments and the delivery of a product, in line with customer contract requirements (commercial pressures).

The second response from the management team to the panel group concerns was that specific concerns involving the removal of operations should be raised with the technical department and not directed to management. Such concerns should be highlighted via the MEMS reporting system. As such, the factory management had *referred the issue to a functional specialism and would only react if the issues were proven to raise safety incidents or would be considered as a human factor failures.* Such a result is again surprising given the high priority that is placed on team working and multi-disciplinary working under the ideals of TQM. The approach to safety management shows a friction between classical business structures, deference to specialists and the modern approach to process management and the engagement of all stakeholders to solve issues and maintain the safety/quality of the production system.

These results raise further issues that commercial pressures and a classical management support structure is at odds with autonomous teams and that fears exist between the teams and what they expect (responsibility and accountability) of the staff around them. As such – this is a matter of trust – and trust is an implicit feature of all TQM models (based on consensus management) but, it would appear, the level of trust, in regulated industries where individual professional skills are high, is heightened. Again, a common theme associated with this discussion was the impact of role ambiguity, low levels of communication, fear of blame for safety lapses and poor understanding of the leadership within the system.

<u>Planning Problems 3: Low Morale and Boredom</u>

Antsy Works & Staff Concern

Whilst commercial pressures is one potential source of failure that catalyses many other failures in the defence barriers of a production system, the interviewees also expressed an alternative view of commercial pressures – this time concerning low utilisation of staff and equipment. The view of the team was that there was a lack of work going through the repair shops. The interviewees expressed concern that this was linked to low morale and boredom – these two features are also associated with poor human factors and inertia in the production system. Boredom tends to lead to lack of attention according to Rasmussen (1998) and a potential failed defence.

Ansty Management Response

The management response to the team following the panel interviews was that a lack of work necessitates individuals to become more flexible and assist one another to ensure that schedules are met by movement of labour and material, thus improving *morale and boredom.* Such an approach reflects a potential conflict in that workers would share jobs and that those unfamiliar with the work would learn. However, safety models suggest it is the repetition of learning and activities that add robustness to the defences of an individual (they learn what to look out for). Furthermore unstructured learning by watching another has a second and more severe penalty – without structured instruction it is possible to learn the short cuts of others (based on their expert and implicit knowledge) and this can put the learner at risk of adopting bad practice without knowing or question.

The production schedule, issued at the site, has on average 450 - 500 items released that require output on a weekly basis and typically only 250 are achieved. *The management response was also that the workload was present but that material flow system failures are the result of individual employees failing to assist material flow and move to areas of the factory that has work.* The management response is interesting and is a means of allocating 'blame' for the identified problem and is a means of absolving management from needing to take action by requiring teams to chase materials for their own productivity.

This shows another dimension to the concept of trust and dependency creating a breakdown in understanding roles within the facility. Such confusion is again a potential breech of safety barriers but also a significant degree of vagary in the design of the new production system. The levels of role ambiguity and potential for blame creates a system whereby workers appear unwilling or un-empowered to move to other parts of the factory to enhance their skills albeit that the management have the authority to request such transfers but it does not exercise this level of leadership.

<u>Planning Problems 4: Motivation, Low Morale and Poor Communication</u>

Antsy Works & Staff Concern

The team discussed the withdrawal of established and well-respected incentive schemes and their discontinuation when team based working was introduced at the site. The interviewed team felt that the bonus should be reintroduced in order to motivate people to communicate the potential for planning of workflow improvements. The incentive is an output driven reward and linked to the concern that less work in the factory was causing issues.

Ansty Management Response

The bonus replaced individual incentives as the business moved to team based working (the incentive was seen as incompatible with teamwork). The management response was that "*All individual suggestions for improvement to our business are important, but we need to ensure that collectively these suggestions improve business output and ultimately improve profit*". The management position was therefore based on a level of presumed collective responsibility for material flow and that individual bonuses did not necessarily equate to better repair turnaround for the business. Such a view suggests that there is an abdication of management responsibility for material flow and a belief that self-management must incorporate providing materials to the team by the team (role ambiguity). This response shows a clear definition of the management role by the management and an uncertain allocation of role by the team who believe management should provide materials for them.

Planning Problems 5: Knowledge Errors and Attitude Differences

Ansty Works & Staff Concern

Another major concern that was voiced by the interviewed staff and works personnel was that while there is a need to remain flexible, because of varying workloads, the teams felt under pressure and un-supported when having to cope with inexperienced, untrained personnel when extra resource is added to a team. This response again confirmed that the relationship between those who train (and may not be qualified trainers) and those who are attempting to be trained is strained (the direct presence of a person 'watching over' repair activities). As a root cause the concern confirms the earlier result that personnel do not feel qualified to train and potentially to risk training another in working practices that may not be wholly correct. Again this is a voiced reluctance to violate safety barriers within the production system design and a limit to the autonomy of the team.

Ansty Management Response

The site management response to these concerns was that "*We operate a successful transfer policy within the requirements of the competency structure. Review of on-the-job training shows that management support this requirement, allowing time for individuals to learn new tasks*". The response to this challenge appears to suggest that management is comfortable with existing structures and competencies even though the business has moved to a team based and autonomous approach. The management appears to have faith in the established bureaucracy and controls. However, the issue is not necessarily that clear-cut and it concerns both what is trained and how it is trained to other team members i.e. the quality of training. From a system design perspective, these issues concern the continuous improvement, standardisation and organisational learning elements of the production system design. These features are all key barriers to system violation and represent chronic latent failure factors that management seem unwilling to re-examine. It would appear that multi-skilling and multi-tasking are solutions to maintaining product flow as opposed to creating a standard way of working where abnormality can be detected by all (such deployed decision-making and ability to stop production based on the detection of a defect is critical to Leaner ways of working). The response also has parallels with other safety management issues such as a lack of empowerment, role ambiguity and the negative influences of peer pressures placed on individuals to train others when they feel incapable of doing so.

Planning Problems 6: Role Ambiguity and Poor Decision Making (lack of responsiveness to change)

Antsy Works & Staff Concern

Within the context of a facility that was under-capacity, concerns were expressed that the company was out sourcing production of certain components. It was felt that the quality oversight and routines for quality assurance of these subcontractors was not robust. As such, holes in the barrier defences of incoming materials could not be prevented and this would inevitably lead to shortages and stop-start production as defects were sorted and schedules breeched.

Ansty Management Response

The Ansty management response was that "All vendors are selected in accordance with GQP C.4.11 the process is robust and is in accordance with the Global Purchasing Policy and related processes, all of which are defined in the quality management system". This response shows deference back to a functional specialism outside of the actual facility and an acknowledgement that the local management were powerless to change such practices albeit that it could have introduced countermeasures at the factory to inspect materials that were inbound to the production system but did not do so.

<u>Planning Problems 7: Commercial Pressures and Poor Decision-Making</u>

Antsy Works & Staff Concern

Another issue raised by the team concerned the change in pace between initial stages of repair (where material flow was slow) and the final stages of engine shipment where the speed of the transfer to the customer was pressured and staff felt concerned that logistics bookings were happening without consultation with the teams concerned. As such, delivery promises were being made with inadequate knowledge and certainty that the date could be met and the engine despatched to the level of quality required. Staff, during the interview, consistently reported a 'last minute rush' to get work away and that this could lead to a compromise of safety and quality management practice.

Ansty Management Response

The management response to these charges was that "All ECU requirements are routed and communicated via the production manager and the team. All working arrangements are considered prior to any decision being made and passed onto the customer business". This rather formal response returned the decision-making authority and responsibility to a specialist department with the team informed of any outcome, rather than acknowledging this as an issue or formally addressing the role of the leaderless team in the process of agreement to ship the product. These responses reflect a management concern to allocate roles beyond the team whilst also promoting the corporate view of autonomous working. At the heart of this friction is therefore the very definition of what the team is – beyond a group of highly skilled engineers who share a common workplace. In the absence of a team member with responsibility to lead it is not clear how functional support departments can communicate effectively with the team and be confident that each member is working to the same outcome or at what point time constraints limit the flow of work to customers. The statement of this issue and the management response shows significant gaps in the safety system and TQM process to the point that it opens the potential for unknowing violation and role ambiguity (the latter being a well known source of safety system breeches – See Reason, 2003).

Planning Problems 8: Commercial Pressures and Ineffective Leadership

Antsy Works & Staff Concern

The quality assurance of contractors was mentioned repeatedly as a cause of team concern but additional comments and concerns were raised that related to the penetration of mistakes (into the repair site). The teams proposed there was a lack of vetting and quality output of some contractors as this had an impact on work done at Ansty. In this manner, the passing of a safety defence could happen and would result in the team attempting to repair the faults created by another business. In this manner the creation of the defect and its detection were separated and this posed problems for inter-organisational learning and the level of 'right first time' or value added production by the teams. This performance is directly related to all management and customer service measures, which, if performance was low, would result in management intervention. These concerns were presented to the site management and are breeches of the safety system with which the system itself is not resilient enough to cope without large amounts of rework or the condemnation of the product as defective (to be scrapped which causes production scheduling issues as team members look for other work to do that may not be on the critical path of the production schedule). It should be noted, from the Lean production literature review, it was found that this source of failure is treated very seriously and suppliers are expected to replace defective products at very short notice (a matter of hours) and to document how the problems will be eliminated in the future (See Monden 1993). Such a feedback mechanism was found not to be in place with the teams concerned.

Ansty Management Response

The response of the management team was that *"All Vendors are selected in accordance with GQP C.4.11 in accordance with the RR Global Purchasing Policy and vendor performance measurement includes Quality, Costs and Delivery elements"*. As such no further action would be taken. This aspect of management thinking is indicative of an organisation with a high level of task uncertainty aggravated by ineffective leadership (Sholtes, 1998).

The next section will continue to dissect the socio-technical system at Ansty by reviewing the equipment related issues that were shown as highly significant contributory factors in the initial survey findings.

<u>Equipment Problems 10: Commercial pressures leading to rule breaking</u>

Antsy Works & Staff Concern

Another subject of concern to the teams was a general lack of correct transport boxes/cases that did not prevent material damage thus passing damaged goods un-noticed by Rolls-Royce and the customer. These issues drew heated debate with the team who had been reporting this issue for a long time and, admitted, they had almost given up complaining because no change had happened and the 'product protection' issues of the current working method was considered to be the norm. These complaints are interesting and, from an operations management perspective, these failures of product damage represent a major concern because good production is lost as transportation causes damage that will need to be reworked or scrapped. Such events cause low customer satisfaction and high potential for safety breeches at the factory and at the customer sites.

Ansty Management Response

The response from the management concerning production damage focused instead on the quantity of transport boxes and not the quality of the transport device. The written feedback provided as part of this research shows the response that *"In general we have sufficient transport boxes to handle the current loads within the plant. We are beginning a project to look at improving our material handling processes over the next 6 months commencing with the RB199 project"*. Whilst the answer is vague, the implication of the statement is that management intend to design a system with specialists and impose this design on the teams. In effect the management have closed another window of opportunity for the teams to engage in learning and problem solving whilst opening a window of error opportunity. This response continues to suggest that the management have structural issues where roles and responsibilities are referred to the current organisational chart rather than looking to see which element of the organisation (department, team or specialist) should hold this responsibility.

Equipment Problems 11: Poor Decision Making, Rule Breaking and Ineffective Leadership

Antsy Works & Staff Concern

Another concern to emerge during the facilitated review sessions with the teams was the reported use of paper repair manuals, which are in poor condition with missing pages etc. These were regarded as safety risks. When queried, people are told that the system will soon be transferred to an electronic version, so there is little point in refurbishing the paper manuals. However this has been the case for approximately 18 months. The implications for procedural non-compliance are clear, in view of the fact that there is a potential for a catastrophe, an immediate and decisive action by management should have taken place.

Ansty Management Response

The response from the site management concerned a reference back to expert support function groups and proposed *"If you find a manual that is in poor condition or pages are missing then you should raise this with the Technical Administration Engineers. They will then re issue or replace the pages"*. Such as response shows a concern to refer the teams to the technical experts rather than show concern that an important control document was missing key technical pages it was therefore a potential source of error and a barrier that had been breached at the site. This response is a deflection to a functional specialist and a potential source of conflict in process-based operations.

Equipment Problems 12: Decision Making, Blame and Rule Breaking

Antsy Works & Staff Concern

A number of problems were reported with reference to documentation:

1. The Olympus and Tyne instruction sheets are hard to follow without experience
2. RTM322 (mark 120) has no strip or build manuals despite this being a routine task. Un-official digital photos are used.
3. There is a shortage of QAS (quality assurance standards) manuals despite regular referral being required. All the above missing data is being worked around as a Norm. Once again the teams have identified a clear breach in the defences of the site and have showed concern that a repair error may inadvertently be produced. Such a scenario – including unofficial workarounds should prompt immediate management

action. Such a situation should generate an appropriate response, according to Reason (2003), because the operational safety system has the potential for violation.

Ansty Management Response

After discussions with the inspector the management concerned felt comfortable with the process and have instructed teams to contact a Manufacturing Engineer if any further problems arise (deflection to a specialist). A further problem identified is that the palletisation sheets can get oily and damaged, so it has been agreed that engineering will issue the instructions in a plastic wallet which will ensure clarification of stamps & data etc, this will come into effect immediately. In this manner, management were clearly provoked into a countermeasure to restore the system to a controlled state. Whereas other system lapses were directed towards expert authorities, this breach prompted immediate corrective action which suggests the site management are concerned for the quality systems and the prevention of violations of practice. The potential explanation for this prompt action could be the ease of the solution and is not typical of the Ansty response thus far in the research.

Equipment Problems 13: Role Ambiguity and Rule Breaking

Antsy Works & Staff Concern

The team also reported that *"It is reported that task cards do not reflect the complexity or nature of the work as it is carried out and people are stamping for work completed by others, unseen. 'One-liners' are also common, where the task requires more than one shift/person but there is only one stamp"*. Whilst 'one liners' are not violations of system defences they are potentials for failure due to lack of detail about a job or a problem. Of far higher significance is the misuse of the stamping system, which is itself a disciplinary offence given the significance of the 'stamp' and also the certification standard that it confers on the individual. Such a scenario should provoke an immediate reaction by management.

Ansty Management Response

The management response was to demand that *"Specific examples of these should be raised with Engineering using an Operation Change Request in line with AROP C4.62/2"* and a return to the rule book. There appears to be a reluctance of management to confront these failings in the system design and shows a pattern of returning to the rule book or specialists. The emerging pattern of responses suggest that management have no means of front line control which traditionally was enacted by supervisors and, under other world class businesses, this role is performed by the team leader. It would appear the absence of such a linking pin in the management structure has created a vacuum or void within which the management default to expert specialists (and their codified rules).

Equipment Problems 14: Poor decision-making and knowledge errors

Antsy Works & Staff Concern

The team also reported that *"Data in use was out of date, inaccurate and reports of such have not been acted upon. Some new projects in progress had no manuals at all and staff regularly work with old revisions of data"*. From a human factors perspective these symptoms reflect an unstable safety system where the potential for failure is high. Again, from Reason's systems approach, these are breaches in the defences of the business and should prompt the redesign of the system (root cause analysis) to solve the cause of the problem. In this case, countermeasures should be sought to control the process documentation, its release to shop floor teams and the removal of obsolete working practices from the workplace. The management response placed the responsibility on the specialist to replace rather than control documents of a safety critical nature.

Ansty Management Response

The management team proposed *"If you find a manual that is in poor condition or pages are missing then you should raise this with the Technical Administration Engineers. They will then re-issue or replace the pages"*. The elimination of the issue would have been to find a means by which the documents are not lost and the latest revisions available to shop floor teams instantly – such as electronic solutions, mobile computer stations and hyperlinked work instructions that are linked to the master engineering database.

The next section will focus on the social system at Ansty and review a number of training related issues as the third area of human factors concern based on the initial survey findings.

Training Problems 15: Task Uncertainty and Knowledge Errors

Antsy Works & Staff Concern

During the discussions around training, concerns were raised about the frequency of temporary transfers and the opportunity this brings for errors as the level of training in these instances was thought to be insufficient. This is a view shared by Reason (1995) & Rasmusssen (1998) who claimed the temporary deployment of labour or rotated labour on short assignment is identified as a source of potential failure due to inexperience or lack of regular repetition of the task.

Ansty Management Response

The management response in consideration of this advice was that *"Due to the situation regarding workload and flow, it is necessary to move personnel to best utilise available resource rather than book diversions. As personnel move between projects on the job training is given and individuals are only transferred within their current competency"*.

The implication of the response is far stronger than the potential safety lapses, although these issues are commercial in nature. Such a response appears to represent a strategy of convenience rather than a deliberate attempt to multi-skill workers in a manner that would result in improved and safer organisational flexibility. In light of this situation it would have been better – from a team perspective – to multiskill members who would work together in the same part of the facility and for a longer period of time thereby retaining the teams' level of situational knowledge.

Training Problems 16: Commercial Pressure leading to Rule Breaking

Antsy Works & Staff Concern

During discussions relating to the need to work to standards, individuals reported situations where during sentence inspection, components, which would to their knowledge and experience, be rejected were instead requested by the customer to be accepted for further service (rather than being scrapped). Such an approach contravenes good practice and is a form of institutional 'rule breaking' (inducing a latent system error). In this process a skilled employee would look at what parts of the product should be filtered out of the product to be repaired and those that can be legitimately repaired and despatched back to the customer. The team argued that clarification is required, for the people involve, to explain why this is occurring because it is causing confusion and frustration for the working teams.

Ansty Management Response

The management response was that teams should do what the customer expects but to acknowledge the potential for failure – using the processes outlined in the existing rule book. The response was that *"The form 1 document states 'It is important to understand that the existence of the document alone does not automatically constitute authority to install the part/component/assembly' we should be doing what the customer states on the purchase order request but at the same time individuals have a duty of care to notify customer of any identified defects"*. Such violations or risk of violation should, in other industrial settings such as the automotive industry, result in an escalation of the issue to management for solution, Changes of this nature, or working to these standards exposes the business to external customer failures and the high cost of rectifying this scenario.

<u>Training Problems 17: Leadership leading to knowledge errors</u>

Antsy Works & Staff Concern

There was a general view amongst the team that continuation training of staff was not complete enough, with a large proportion of the group reporting having little or none. The shift and task handover document within the AROP for example was not known about, this appeared to be indicative of a wider perception of the lack of continuation training. These results are serious safety risks caused by poor process control (despite good situational awareness by the team). The issues with handovers could mean that issues with one shift were not corrected by another. In the medical setting such failures in handovers is considered a potential for patient harm and litigation (Vincent et al, 2001). These are serious breaches and latent error.

Ansty Management Response

The response was rather mundane and the management team proposed, *"Continuous training is part of the competency model which all trainers and assessors have been briefed on. This may not have been cascaded by those individuals to team members. Shift and task handover has been cascaded to all teams at various team meetings. It may be necessary to communicate further"*. The response to the concern about safety system design was to refer to company policy rather than engage countermeasures or even defend the business position by referring to the number of people who were actually trained; the management team did not refer to these facts. It did, however, seem willing to invest more skills in the leaderless autonomous teams.

<u>Training Problems 18: Task Uncertainty leading to Rule Breaking</u>

Antsy Works & Staff Concern

The main corporate computer system is known as SAP and the teams proposed that training in the use of SAP was patchy at best, with people feeling under confident in using the system. This situation was thought to be very likely to increase the opportunity for error, with people being shown, unofficially, how to 'get around the system to get by'. The data in the computer is the main 'police force' used to capture electronic stamps, material movement times and all manner of deviation control.

Ansty Management Response

The management team acknowledged this criticism and replied that it had been discussed at the business level training review. The response was a plan is to identify an infrastructure of super users and key users for each piece of SAP functionality. Once individuals have been identified for those roles they will be trained appropriately. This support infrastructure of super users and key users will then be able to support the end users at the work place embedding the use of SAP. Such a structural response shows the concern of the management to maintain the cleanliness of the data in the master planning system due to the fact that the system controls all aspects of material flow and safety. The creation of super users is a quasi form of generating a specialist but this time closer to the team.

<u>Training Problems 19: Poor Decision Making and Communication</u>

Antsy Works & Staff Concern

The teams identified further underlying issues of poor communication. Some individuals (n=12) reported not having had a production team weekly meeting for a considerable amount of time and thought that the revisiting this option would be of benefit, as it gives the opportunity for information to flow both ways. Comments such as *'there is no communication with management – only by exception when voiced'* suggested that there was a frustration with daily communication systems and dissonance with management also a significant allegation of disengagement by management.

Ansty Management Response

The Ansty management response was to direct the attention of the teams to the published communications policy of the site, which the management intended to review in the near future. The review was prompted by a recent Employee Engagement Survey, which highlighted similar issues. However no formal commitment to improve the effectiveness and regularity of communication was provided by the management team.

Training Problems 20: Commercial Pressures, Poor Leadership, Poor Decision Making, Knowledge Errors, and Rule Breaking

Antsy Works & Staff Concern

Within the AR&O division there is a set of behaviours and values, one of which is the employee is 'Encouraged to take rational risk'. Some individuals felt the use of the word 'risk' was not compatible with the message EASA are promoting in respect of 'always follow the procedure' and also felt a safety conscious organisation should not take risks at all. It should be noted that the company's 'behaviour statement' does not define in what context risk is being taken; however to the employees the statement appeared to be inappropriate in a MEMS system and safety conscious environment.

Ansty Management Response

The Ansty management response was to reiterate the need for all staff to remain compliant with procedures and that "no one within the organisation has the authority to take risks with regard to air safety". The response was a decisive reaction to staff concerns and suggested that the values associated with risk were not compatible with the way business is conducted at the Ansty site. Given the other responses by the management team and the reversion to the 'rulebook' this is a deviation away from that response. The message was that management would not tolerate breaches of any sort – especially at the level of the individual, where risks were at their highest.

Having reviewed the position of focus group results the researcher duly complied with the conditions laid down by Bryman (1989) who argued that qualitative follow-up studies should take place, within a time frame of 1 year, once the questionnaire process is complete. The concept of semi-structured interviewing at the Ansty site has therefore satisfied the principles of congruence[56] suggested by Miles & Huberman (1994) who claim they are important, when establishing a triangular approach to a cross-case research design.

In next section the researcher will present the results of the Bristol teams in the same format and will add to this review by showing whether the same environment and same commercial pressures facing a repair business create a common view of management and the teams.

5.12 Bristol Focus Group Transcripts

Planning Problems 21: Leadership and commercial pressures

Bristol Works & Staff Concern

The issue of 'overproduction' as described by Ohno (1985) was raised during discussions by the Bristol team. The comments were with reference to the management overloading of the repair shop with high and unconstrained levels of work. The general implication being that choke points (bottleneck constraints) were creating extended lead-times and this was being aggravated by local custom and practice which was more sensitive to selling hours to customers, based on the principles of 'cost plus' that had a negative effect on efficiency and disrupted material flow. 'Booking hours', as portrayed by the interviews was a process to satisfy the businesses management accountants rather than a means of generating external customer value. This practice, more often than not, created the situation whereby operators could not distinguish which components require the most urgent level of repair. Such confusion is a major break in the safety defences of the organisation and is a latent factor that could create a lapse in concentration resulting in error or mistakes.

[56] Referred to data analysis that includes within-case, within-group, across-case and across-group pattern matching

Bristol Management Response

The management response was based on satisfying customer demand and the accountants need to meet target demands of good hours sold against monthly key performance indicators. The view held by the management team is contradictory to the practice of human factors thinking and highlights an organisation which is at odds to the principles of TQM where a silo mentality is evident in terms of a 'them & us' type of culture.

<u>Planning Problems 22: Commercial Pressure and poor leadership</u>

Bristol Works & Staff Concern

The teams raised the concern about the removal of certain Non Destructive Testing (NDT) inspection operations from the process, which they argue is causing a potential problem with quality control. This activity is vitally important as it provides a final check against process errors. The team claimed that by removing this element of the process is a violation in itself that would inevitability lead to and deviations of product quality. In spite of the teams' concerns the management had still scheduled for its removal, which heightened the likelihood of defects/ failure as a system defence was removed (exposing more latent failure opportunities). In parallel with increased take-off and landings conducted by the airlines customers would inevitably expose the system to more quality control issues.

Bristol Management Response

There have been activities e.g. zero basing whereby NDT operations have been removed where duplication is evident in the repair strategy. All NDT changes to routing documents require authorisation by the controlling Level 3 engineers, who must be authorised by the OEM. This response was completely overlooked by the management team who failed to acknowledge the concerns of the teams who were genuinely alarmed by intentions of local management proposals.

<u>Planning Problems 23: Commercial Pressures and individual accountability</u>

Bristol Works & Staff Concern

Planning for the human factors requirements to take into account the circadian rhythm and performance influencing factors raised concern of how this would impact on turn round times. The issue highlighted the need for management to define what is meant by a critical task where fatigue is thought to be of concern during the early hours of night shift working.

Bristol Management Response

When confronted with this question there was clearly a very poor level of consideration for how to plan against such risks as outlined by EASA part – 145. *The formal management response was that teams should refer to regulations and the definition this holds in terms of accepting or rejecting what constitutes a safety critical process.*

Planning Problems 24: Communication and Leadership

Bristol Works & Staff Concern

There was a concern about the amount of time it took for information to cascade to the shop floor and it was pointed out that rumours seemed to propagate much faster. There was a general feeling that more thought should be put into the planning of the communication strategy and that it was vastly in need of improvement.

Bristol Management Response

There is a communications policy in operation on the Bristol site, which has been adopted by the management team. The researcher therefore argues that such a cursory response implies little or no evidence exists for policy deployment where the execution of a planning strategy is dependant of a two way communications process that provides pace and timing for effective organisation change.

Planning Problems 25: Leadership and Commercial Pressure

Bristol Works & Staff Concern

Staff were concerned that time allocated for tasks was continually being reduced and they felt under pressure to complete their work in what they describe as 'unrealistic' timescales, which could increase the likelihood of error

Bristol Management Response

This is an extremely competitive business with more capacity worldwide than is required. In this climate of competitiveness and an increasingly intelligent customer, the drive for cost reduction is paramount. We must continue to review the process and *implement improvements whilst maintaining the highest levels of quality and reliability.* The response given by management clearly highlights a situation where a lack of understanding for the principles of Lean planning is at stake. There is much written about how to plan for improved flow that Suri (1998) specifically relates to in terms of planning for both push & pull techniques within the context to quick response manufacturing.

Equipment Problems 26: Commercial Pressures, Poor Leadership and Poor Individual Accountability

Bristol Works & Staff Concern

Individuals highlighted the fact that specialist tooling is regularly damaged and upon reporting the situation several times, nothing has happened. Concerns were raised that continued working with damaged tools would lead to maintenance error.

Bristol Management Response

Guidelines on the process of dealing with tooling issues have been cascaded to the production managers who should be consulted initially. When damaged tooling is reported as requiring rectification then it is the responsibility of the manager to ensure that procedures are followed to repair the tool. Whilst there is acknowledgement by the management team of their responsibility, there is no mention of the process (if any) by which the teams can facilitate accountability for ownership of tooling and specialist equipment being used.

Equipment Problems 27: Blame, Poor Decision-Making and Leadership

Bristol Works & Staff Concern

The shop floor teams repeatedly voiced their concern that manuals are not being updated and after numerous reported occurrences to the management team the issue of no feedback has become the norm.

Bristol Management Response

The manager's response to this situation was such that a process exists whereby situations such as these can be alerted through a MEMS report that can be raised by anyone within the organisation. The researcher, in view of this situation, saw little evidence of any form of reactivity and considered the use of the MEMS process more suitable as a procedure for dealing with events, hazards etc., rather than the suggested use.

Training Problems 28: Poor Communication and Leadership

Bristol Works & Staff Concern

There were a number of comments regarding poor communication between Management and the shop/office floor. This was a highly emotive area of debate and extracted a number of deep-rooted issues surrounding weak leadership where interdepartmental differences had impacted on the quality of training through poor communication.

Bristol Management Response

During 2001 the Bristol site introduced a communications policy that aims to ensure each person in the business understands how they are performing in relation to issues affecting their business area. Where the policy is not being adhered to, employees should firstly consult their local management and if, after consulting with their local management, the policy is still not being adhered to then employees should contact their local HR representative. From the researcher's point of view, this indicates a management attitude that makes no reference to sub cultural differences within and between teams that West (2004) argued should always be understood and removed.

Training Problems 29: Communication and Leadership

Bristol Works & Staff Concern

It was highlighted that before effective training could take place communication on behalf of the '1st line' management team should be improved because training by specialists from other business areas required good communication with key individuals, this should take the form of regular briefings, which the team thought would improve the situation and assist in the deployment of more cooperative training.

Bristol Management Response

The Bristol business has a published a communications policy, which is intended to be reviewed in the near future. The recent employee engagement survey highlighted similar issues, which are currently being addressed. This approach however, does little for those individuals who still feel unsupported by a system, which appears to be technical, rather that social.

<u>Training Problems 30 Leadership and lack of Individual Accountability</u>

Bristol Works & Staff Concern

Concerns rose over the level of management commitment given to past 'initiatives' and individuals requested assurances that management are committed to supporting the human factors issues.

Bristol Management Response

It is the responsibility of every individual to drive initiatives such as human factors and not just the management team. There is no doubt that this initiative is supported throughout the leadership team, but no amount of willingness by the teams themselves can sustain the type of changes required to properly manage a human factor programme, which according to Kurogane. (1993) begins and end with leadership.

<u>Training Problems 31: Commercial Pressure, Peer Pressure and Role Ambiguity</u>

Bristol Works & Staff Concern

Concerns were raised that upon being asked to carry out new tasks training was not given and it was felt that people were expected to be 'up to speed' without support.

Bristol Management Response

The management response to this concern reflects the position that a successful training policy is in place and meets with the requirements of the competency structure and a review of on the job training showed that management support this requirement by allowing time for individuals to learn new tasks. This was a view that did demonstrate a degree of understanding, but the management response did little to convince the teams that any real-time level of support was adequate to satisfy their concerns.

<u>Training Problems 32: Knowledge Errors and Leadership</u>

Bristol Works & Staff Concern

There was concern shown on the level of computer literacy at shop floor level, in the general use of the company software system, and about the general level of SAP knowledge required to comply with inspection procedures.

Bristol Management Response

The response given by the management team was that training co-ordinators are in place to ensure individuals receive appropriate training. In their view this level of education provides over and above standard training requirements and as a result of this an introduction of a new process system is soon expected to be in place. The training department are aware of the situation and plans are in place to ensure individuals receive appropriate training and refresher training.

5.13 Derby Focus Group Transcripts

During the following summary of transcripts the researcher reminds the reader of the need to consider the geographical location of the Derby site, which unlike the previous two case studies has unique type of organisation where the shop floor teams consist of a wide and diverse range of sub contract labour. The results of the following transcripts are based on a very different type of organisational culture that Johnson (1993) claimed is linked to social conditioning that ultimately defines the quality of organisational and 'team situational awareness'.

<u>Planning Problems 34: Leadership and Communication</u>

Derby Works & Staff Concern

In view of the wide use and mix of sub contract labour the shop floor teams presented a very negative opinion of the current situation surrounding the quality of management planning where a clear lack of understanding exists of who will perform the shift-handover-process. Because of the differences in organisational sub cultures the teams are not mature in their ability to identify a nominated person to perform this task.

Derby Management Response

Whilst the cohesiveness nature of the shop floor teams can be described as loose by comparison to that of Ansty and Bristol the fact remains that the management culture is not. For example the response put forward reflects a common approach whereby the attitudes of management is wholly dismissive of the complexities of social factors and as shown below reflects a highly individualistic position claiming that: *"A good practice guide has been produced detailing how these handovers should be carried out and a trial to assess its effectiveness is currently underway."*

Planning Problems 35: Commercial Pressure, Peer Pressure and lack of Team responsibility

Derby Works & Staff Concern

The issue of daily organisation of workflow was discussed within the context of planning. Concerns were raised that some managers were undermining the role of self-management where teams are being told which jobs to work on from a 'work to list'

Derby Management Response

The response from management was that it recognised this was the case, but would continue to operate in this way until the lead-time performance had improved. In response to this situation the researcher contends that teams will always be in a constant state of change and failure to permit the complex interplay between culture, structure and processes will ultimately deny the principles of autonomy and responsibility for change as a necessary process in achieving the end goal of TQM.

Planning Problems 36: Commercial Pressures leading to Boredom, Knlwledge Errors, Poor Decision Making and Poor Leadership

Derby Works & Staff Concern

According to EASA Part-145 the repair & overhaul business is committed to plan safety critical tasks when individuals are likely to be most alert, including plans to work around human performance limitations of the circadian rhythm. A request was made on the basis of what defines a 'safety critical task' and this was further expressed by the need to recognise night shift working as an error prone period.

Derby Management Response

The response by the management team is that this issue that will be considered as part of the long-term strategy to remove night shift working. However in the mean time the fact remains that individuals within teams are subjected to risk factors. The researcher therefore refers back to the human factors authors such as Stout (1994) who referred to this type of situation as 'internal' factors where these considerations would typically include influencing conditions such as fatigue and noise distraction. The effects of ignoring this situation (even on a temporary basis) have not only resulted in decreased human performance, but can also be seen as the underlying cause of many workplace mistakes that often, as early illustrated in the iceberg model, result in catastrophic accidents.

Equipment Problems 37: Commercial Pressure and time lagged decision making

Derby Works & Staff Concern

Several team members report queuing for PC access on work related tasks, this created a tendency towards getting on with the job from memory where the wait is long. While this does suggest a desire and willingness to 'get the job done' a bias towards productivity without proper regards for safety is therefore apparent.

Derby Management Response

The management response to this situation was such that while PC access from time to time may cause frustration, in general the distribution of PC's appears to be consistent with team requirements. However, a review is underway as part of the Technical Data Integration programme and the opportunity will exist to redress these concerns in the near future.

A response such as this is according to Helmreich & Wilhelm (1997) a perceived measure by which the majority employees gauge their employer's commitment to safety.

Equipment Problems 38: Commercial Pressure and Blame

Derby Works & Staff Concern

When the group expressed concern over insufficient investment in tooling the standard answer was said to be *"there is no money available"*

Derby Management Response

The management team responded by saying there is an established tooling budget, which is available to address in particular the refurbishment of tooling. Guidelines on the process of dealing with tooling issues have been cascaded to the production managers who should be consulted initially with tooling concerns. They go on to argue that it is not sensible to try to claim there is no money available, since tooling budgets are incorporated as part of most major build activities such as fitting of fuel & oil pipes along with turbines and fan blades.

<u>Equipment Problems 39: Commercial Pressure and Rue Breaking</u>

Derby Works & Staff Concern

During discussions regarding the reasons why people do not follow or use procedures, it was discussed that accessing some maintenance data was becoming more difficult as increasing reliance is placed upon electronic formats, with people reporting having to 'click on dozens of links' to find a procedure or information. Additionally, the number of computers and screens, in particular printers, is thought to put people in compromising situations where it is easier to 'work around' the need to refer to official documents.

Derby Management Response

The situation is known to be problematic and a full assessment should be carried out on all new equipment. However, considering this situation in terms of a temporary fix, individuals are still carrying out carrying out their work without an important human factors feature referred to as 'declarative knowledge, which according to Stout (1994) often denies the importance of 'procedural knowledge' where information about the steps required to accomplish various activities can induce a work around that results in rule-based errors.

<u>Equipment Problems 40: Communication, Commercial Pressure and Poor leadership</u>

Derby Works & Staff Concern

With the move to the new building being planned, concerns were raised that the 'same old equipment' would simply be moved across to the new site. In terms of human factors, there is an issue of whether obviously poor standards of machinery and equipment will be fit for [67h purpose. It seems there is a clear case for communication and debate of this issue, with key individuals who may disagree.

Derby Management Response

All equipment transferred to the new facility has been fully assessed to ensure it is fit for function and complies with the latest legal requirements. As a result of this review a significant amount of equipment requires refurbishment or replacement, within a capital budget of £4 million. While there was an acceptance that financial investment is required for equipment refurbishments there is a noticeable reluctance by the management team to engage directly in face-to-face discussion as requested above according to the works & staff concerns.

Training Problems 41: Knowledge Errors, Communication and Leadership

Derby Works & Staff Concern

Several issues were raised concerning the issue of MEMS that highlighted the fact that not everyone is computer literate based on the format of the MEMS system, which does not lend itself to be people friendly. A paper version of the MEMS report form was thought to be needed to compliment the electronic version with people being able to fill out and post a MEMS report at well publicised points throughout the facility. Conversely, it was also thought that a facility for uploading copies of bad data, i.e. photographs or other data might be beneficial to those who are computer literate. Concern was raised as to the competency of the MEMS investigators, since they were trained a while ago. The opinion being that they should have refresher training and ongoing recurrent training to ensure confidence that the error management process is carried out. A suggestion was put forward that there should be some type of MEMS 'Champions' in the facility where people can go and talk through the system and get advice or up to date information. It was strongly felt that future additional investigators should be sourced from the shop floor in addition to the existing staff investigators. Whilst these people may not be ideal for investigating local shop floor maintenance errors due to bias and norms, it would increase the confidence and trust of the MEMS system.

Derby Management Response

A paper version of the MEMS form will be provided; this will identify the problem and the person who is reporting it. To keep the system simple there are no links available when reporting a problem. This information can be shown in the text or supplied later. All AR&O UK MEMS investigators have recently attended an all-day meeting in Bristol to discuss an investigation and share thoughts. While further events are expected to happen in due course, most human factors authors refer to this type of situation as barriers to effective teamwork. These are known to take place frequently and can lead to a person making errors or mistakes, which are also described in terms of violations.

Training Problems 42 Errors, Communication and Leadership

Derby Works & Staff Concern

During the discussion of the MEMS system and the submission of the MEMS report form an interesting point was made that not everyone has a LAN Username and password, which is currently required to submit a report. Additionally, not every body is computer literate and as such will obviously require some IT training to resolve this problem.

Derby Management Response

IT training is available to all employees, however in the mean time it will also be acceptable for paper copies of the form to be used instead.

Training Problems 43: Knowledge Errors and Leadership

Derby Works & Staff Concern

Shift and task handover documentation was discussed, with reference to best practice of EASA Part -145 and CAP 716. While AR&O within its AROP system of F2.2/2 has a flow chart to guide the user through the intent of the process it is not clear of how this process should be carried out, with differing standards and methods of practice around each of the UK sites.

Derby Management Response

In respect to this situation there is a pilot scheme envisaged for the near future that aims to standardise this process across and within different sites. Also there is a shift

& task handover working party on the Derby site with representatives of each production area. Staff areas will also be involved as appropriate. Good progress has been made with pilot methods of shift handover. However it is not expected that all areas would use the same system, which is why the procedure does not specify this more closely. In view of this response the apparent lack of consistency would appear to suggest that managers are inadvertently contradicting the safest and most effect method of human factors control where standardisation is the most effective method to be deployed.

Training Problems 44: Rule Breaking, Leadership and Responsiveness to Change

Derby Works & Staff Concern

During discussion the question was asked 'why don't we follow procedures?' with reference to the SAP system as this was cited as being hard to use. Individuals also commented that the language used is difficult to understand. Some also described how they have written their own version of instructions so they could fit with the intent of the procedures. Also mentioned was a request to have the procedures amended to a simpler version, which was previously denied

Derby Management Response

Standard processes have been written to ensure that all work is recorded on SAP, which can be understood by other people later in the process without question or need for correction. These processes have been documented in procedures of SAP scripts that are available to help all users of the system. If users can see ways of improving these documents they should suggest this by using the feedback methods in the AROP section of the intranet for procedures or the MEMS system. Both these links were referenced in the recent QMS training. If there is difficulty in getting a desirable change made, the Quality Assurance department should be asked to help. While the management team accepted that personal procedures and scripts can be very helpful they may not be kept up to date when changes are made to the system and so should not be used at all times. This response was considered by the researcher as wholly appropriate owing to the fact that once a paper document has been printed it immediately becomes an out of date and illegal method to use.

5.14 East Kilbride Focus Group Transcripts

Following on from the Derby transcripts the researcher next focused the review on the East Kilbride site, which is situated within the city of Glasgow. It encompasses a very strong and different kind of work ethic, which unlike the Derby site, is united in its view about the problems surrounding human error concerns. The rationale behind these differences will be expanded upon during the next chapter, which is illustrated in statistical terms from a hypothesis driven point of view.

<u>Planning Problems 45: Commercial Pressure and Poor Leadership leading to a Blame Culture</u>

East Kilbride Works & Staff Concern

The manner in which time pressure is applied was reported to be autocratic and authoritarian and in some cases this was perceived by the team as being threatening. Instances were cited of individuals being taken into offices and told to 'pull their finger out'. In view of this situation time limits were being prescribed for task and job performance, this included those activities associated with the collection of spares parts, which are not value adding, but are necessary and therefore recorded under what the business refers to as diversions.

As a result of these circumstances the teams reported a condition whereby it is becoming impossible to perform the job in the allocated time. The popular perception was that this situation is getting much worse and fears are wide spread that the it would never change.

East Kilbride Management Response

There will always be an element of time pressure involved in a manufacturing businesses because of it is a customer-facing unit. As customers are becoming more demanding and their expectations increase, we must be able to match these expectations by responding appropriately to customer needs. However, this should still be possible to achieve without creating an environment where individuals experience a level of pressure that should not be allowed to prevail and in view of this complaint anyone who does feel this way should register their issue or concerns under the MEMS system, which will be properly logged and investigated accordingly.

The reporting manager who accounted for this situation presents a really bad example of where the senior leadership has allowed a climate of fear and intimidation to take place. This type of practice contradicts the guidelines stipulated by EASA under CAP 716 that no organisation should allow this type of situation to exist.

<u>Planning Problems 46: Commercial Pressures and Poor Team Responisbility</u>

East Kilbride Works & Staff Concern

Planned time for some work tasks is often insufficient, especially on older engines, which require extra work, thereby causing excessive time pressures.

East Kilbride Management Response

Management are keen to engage team members in understanding planned times. An improvement team has been brought together to review current planned v actual times which, we trust, will be fully supported by the teams. In light of this problem the management team reported significant difficulties in convincing individuals to work overtime especially at weekends due the high levels of interest in watching and play football. While this example did underline a lack of commercial responsibility on behalf of the teams, the question ultimately rests with management planning for failing to consider social and cultural factors in contingency planning.

<u>Planning Problems 47: Commercial Pressure and Leadership</u>

East Kilbride Works & Staff Concern

There were concerns raised about the priority of work raised as persons who inputted data were often unaware of operations at the shop floor. It was felt that this caused time pressure, which could lead to an increase in maintenance errors.

East Kilbride Management Response

Planning and scheduling process priorities do exist as standard practice and in the case of priority 1 situations all requests are routed via the SAP system and discussed with the appropriate manager prior to a decision being made. When orders are rescheduled or raised, SAP calculates a new schedule date for each activity and this includes queue time, which acts as a buffer to protect against rushing.

The researcher's view on this situation is such that one must refer to the concept of Lean load & capacity planning. He argues that SAP planning has shown to inadvertently create system waste through the concept of 'overproduction' that disrupts flow and results in excessive lead-time performance. According to Kaplan

(1990) this type of approach to production planning not only limits the ability to process efficiency, but also affects quality through the creation of an environment where products are hidden through mass storage, which increases the risk to quality through damage. In other words SAP has inadvertently created a 'push' situation where unnecessary products down-stream have queued owing to the practice of short-term gain.

<u>Planning Problems 48: Commercial Pressure and Communication</u>

East Kilbride Works & Staff Concern

The rotation of the 3-shift system was discussed with regard to the optimal phasing of the shifts. There was a general agreement that a review of the shift rotation of would be worthwhile in light of this experience.

East Kilbride Management Response

As customers become more demanding and the business comes under more pressure to reduce turnaround times, an element of shift working including nights and weekends will become inevitable. In light of this situation it will become necessary to maintain an appropriate level of customer responsiveness. The important task is to identify the most appropriate and safe pattern for each set of circumstances. Part of the Paragon New Facility Project is looking at shift pattern options with the trade unions.

<u>Planning Problems 49: Commercial Pressure and Poor Leadership</u>

East Kilbride Works & Staff Concern

There was concern that the practice of 'shipping dirty' as required by the customer was an unacceptable lowering of repair engineering standards. This was not a unanimous opinion but it underlined an example of commercial pressure driving the overhaul process. It was accepted that an inspector could send a component back to the clean line process if he or she felt that the dirt impaired the inspection process

East Kilbride Management Response

The last sentence of the comment addresses this issue.

From the researchers perspective it is evident that problems associated with planning are highly affected by the quality of leadership. In respect to this example Helmreich

& Merritt (1995) claimed that a team's performance is very closely associated with the effects of motivation and based on the cursory comments from the response it is clear to see why. The level of concern therefore presents a very real problem that explains the extent to which the managers have demonstrated a clear lack of understanding of how to control commercial pressure, which in turn has affected the limitations of team situational control.

Equipment Problems 50: Leadership, communication and commercial Pressure

East Kilbride Works & Staff Concern

The subject of inadequate tooling arose and the fact that people have tried to report this to managers in the past, but still the problem goes unnoticed. The opinion was that there is generally little or no response to the concerns being raised. Thus an improvement in communication of these issues in terms of response action needs to be seen from the team's perspective

East Kilbride Management Response

This is one of the key areas that the MEMS system is being established to address, however the researcher reminds the reader that a lack of equipment according to Hobbs (2000) is an important local factor in influencing the quality of work especially in relation to damaged tooling which Hobb's research cited as a major cause of damage if allowed to prevail.

Equipment Problems 51: Leadership and Poor Responsiveness to Change leading to Low Morale

East Kilbride Works & Staff Concern

There was a concern that machines were only repaired when they broke down as opposed to being maintained in line with a planned schedule.

East Kilbride Management Response

The response given by the manager claimed that an internal maintaince group is operating a planned maintenance system, which has already addressed various problems of this type with machines throughout the facility. However, it is the intension of the business to introduce a TPM (Total Productive Maintenance) program.

In understanding the complexity of this situation it is important to consider the implications of the management response above in terms of the correct choice of communication strategy when facilitating system change as radical as the introduction of TPM. This is a concept that Burnes (2000) highlighted in terms of 3 different approaches affecting the individual, group and system as whole. The correct choice of model options was discussed earlier in the literature review as illustrated in figure 5.11 shown below.

Figure 5.11.

Change Management Model

	Incremental	**Punctuated**	**Continuous**
Individuals	Learning	Promotion	Career development
Groups	Kaizen	Team building	Changes in composition and task
Systems	Fine Tuning	BPR	Culture

Source: Taken From Burnes (2000) pp-304

<u>Equipment Problems 52: Task Uncertainty and Role Ambiguity</u>

East Kilbride Works & Staff Concern

There was an issue about the quantities and availability of measuring equipment as well as its correct storage.

East Kilbride Management Response

It is the responsibility of each individual team to define the required quantities of measuring equipment. Where an additional requirement is found then advice must be sought from the Metrology Manager in conjunction with GQP C.4.63 as to the most appropriate use and availability of measuring equipment. The satisfactory storage and retrieval of equipment is the responsibility of each individual team in their respective area. Any anomalies or problems should in the first instance be reported to local management.

<u>Equipment Problems 53: Rule Breaking and Poor Leadership & Responsiveness to Change</u>

East Kilbride Works & Staff Concern

Personal tooling is still being used rather than dedicated and controlled tool kits. This is particularly true in the component repair area where the concept of tool control was considered to be lacking.

East Kilbride Management Response

Where standardised tool kits are deemed necessary local management should have implementation plans in place. This explanation by the manager in question provides only a cursory overview of the situation and underlines poor or inadequate levels of leadership, which is not responding to the team's need for change.

<u>Training Problems 54: Rule Breaking due to Poor Responsiveness to Change</u>

East Kilbride Works & Staff Concern

The subject of procedural compliance was raised and it was agreed generally that the instance of 'black books' representing unofficial data was fairly widespread. It was discussed that better availability, in terms of numbers of manuals etc were needed for review and communication. It was also thought that the future introduction of a new electronic system of access to data management might alleviate the situations currently faced, thereby providing sufficient computer terminals for easier methods of working.

East Kilbride Management Response

Under no circumstances should the unofficial use of documents be present within the repair process. From the researcher's perspective the position of working to 'black books' is endemic within the organisation and requires a far deeper response to this situation in terms of management reviewing the real extent to which procedural non-compliance has been allowed to exist.

Training Problems 55: Poor Communication and Slow Responsiveness to Change

East Kilbride Works & Staff Concern

Clarification is needed with regard to how the MEMS system is intended to interface with current business tools such as customer complaints, major quality investigations, safety alerts and accidents. The period of time for feedback to the originators of MEMS reports needs to be defined further so that people feel they will be able to have some visual progress with regard to their submissions. This will obviously encourage confidence and future use of the system if training is available to support this change.

East Kilbride Management Response

The intention is that the MEMS database will record all of the items highlighted. The question, however from the researcher's perspective, should warrant a more thorough explanation. The above response is very shallow, and could be construed as patronising to many of the teams who voiced this type of concern. With a more carefully worded response the teams may have felt more confident in how the MEMS process was expected to work as a whole, this could have improved relationships in what is already being described as a 'them & us' culture.

5.15 Summary of Quantitative Results Phase 2

The following table summary (in accordance with the works of Miles and Huberman, 1994) is presented as a holistic overview of the socio-technical systems at each case study site. The summary table which has exposed major issues with the design of each socio-technical system where the researcher found evidence of significant gaps that was openly found to exist. By simplifying the content of events from each case study location the researcher was able to condense a large array of error provoking factors into 9 generic measures, whereby a methodology can then be established in terms of linking both data sets into one cross-case design. In acknowledgement of the complexity surrounding this requirement, the researcher designed a method whereby a set of codes are used to assign units of meaning which relate to key words, sentences or paragraphs as a whole. The assumption being that the researcher will be able to examine, identify and highlight similarities of findings, within the context of different error trends through a linking methodology of questionnaire results and focus group concerns. In principle this approach was taken from Ragin (1987) who argued in favour of a method that would enable the development of *"Dialogue between ideas and evidence"* The researcher has therefore structured, in fig 5.12, below the following model that summarises the entire range of error provoking factors by patterns of reoccurring themes.

Figure 5.12

All Sites Qualitative Summary Model

Evaluation Themes	Field Specialists	Questionnaire Dominant Themes	Focus Group Dominant Themes	Planning Scores	Equipment Scores	Training Scores
Commercial Pressure	Reason (1995)	Commercial Pressure	Commercial Pressure	70%	70%	80%
Task Uncertainty	Scholtes (1998)	Leadership	Leadership	70%	60%	80%
Low Morale	Jonassen (1997)	Communication	Communication	60%	70%	80%
Boredom	Broadbent (1989)	Individual Accountability	Individual Accountability	60%	70%	60%
Knowledge Errors	Helmreich et al(1995)	Attitude Differences	Attitude Differences	80%	90%	60%
Blame	Stout et al (1996)	Role Ambiguity	Role Ambiguity	70%	80%	70%
Lack of Empowerment	Rasmussen (1998)	Peer Pressure	Peer Pressure	70%	70%	80%
Poor Decision Making	Dawson (1994)	Responsiveness To Change	Responsiveness To Change	50%	70%	80%
Specialist Knowledge	West (2004)	Team Responsibility	Team Responsibility	20%	20%	10%
Rule Breaking	Banbury (1998)	Problem Solving	Problem Solving	20%	20%	20%

Source: Researcher

During the qualitative phase of the research, many reflective sessions were conducted during which the researcher compared the findings with the survey and also against the literature base. The most striking outcomes of the second phase were the validation of the survey findings (planning, equipment and training). Also it must be noted that there is a new importance of commercial pressure as a catalyst for issues within the socio-technical system design (exposing rule breaking and many other forms of confusion or system violation).

Secondly there also appeared a consistent trend whereby staff and shop floor personnel were asking for more autonomy or leadership clarification to operating issues but this was not forthcoming from management. In the most part the local management defended a 'rule book' approach to leadership or 'blame' culture and greater issues concerning a rift between 'them and us' (management and other teams).

There are also other emerging themes from the qualitative research and many other violations to the system have become evident. These issues and latent errors concern equipment availability, documentation availability, broken or inappropriate tooling as well as transport issues, supplier management issues and the accountability for quality control (NDT testing as well as removal of quality control personnel).

5.16 Phase Three: Implemented changes at the Sites

At the close of the qualitative stage, the research findings were drawn together and communicated to the host company and its four case sites. This took the form of a power-point presentation to the senior management teams at each site (a presentation at each site) and a presentation to the corporate executives (led by the Director for Quality at the main board level).

At each presentation, feedback to the study was received from the teams and there was no public disagreement with the findings. By far the largest subject for discussion at each site were the process and practices of planning and a belief that the cases were conforming to good planning procedures but, given this study, the problems associated with planning when compounded by commercial pressures to repair and return engines to customers were recognized.

It was well reported that one of the most significant reasons for mistakes was due to the influence of failing to manage time pressures, which in turn had exerted undue stress on teams who admitted to 'corner-cutting'. For this reason, senior managers at the cases and corporately began to plan how best to change and improve the socio-technical systems as a working party. At this point the researcher disengaged with the case study businesses and instead waited for 6 months before revisiting the sites to see what systems and safety defences had been introduced as a reaction to the study findings. The next section will present the main changes to the systems that were studied at each site. The main recommendations of this study to the case businesses were that management should be aware of their responsibilities, which include the setting of deadlines and allocating tasks that minimize mistakes based on

1. Prioritization of work
2. Control of the actual time available to carry out work
3. Management of contingencies against illness and holidays
4. Management of engineering specialization of tasks
5. Monitoring and controlling of the availability of parts and spares.

With these legal requirements in mind the researcher claims that failure to understand and adequately manage applied human factors thinking is the major reason why engineers are central to the problem of human error. The resultant factor being that each case study site was shown to experience similar problems both statistically and experientially in terms of rule-based risks through which a mistake or event could take place. In order to address this situation a number of changes are recommended, these should begin and end with leadership at the most the senior level, which underlines the importance of maintaining human factors awareness to the already existing standards of the quality management system that states: "*Leaders should develop the mission, vision, values and ethics and are role models of a culture of excellence*"
In respect of this position, it must also be noted that repeating an initiative that was unsuccessful in the past may have different results when applied to other areas of the business in the future. While it may not always be possible to foresee and plan for every maintenance need, the necessary improvements in the area of planning are considered to be the most important step in preventing the practice of unintentional corner cutting. The consequences of which, at worst will lead to mistakes and best create ineffective communications that undermine the process of cross-functional team working. To resolve this problem the researcher has designed and implemented a working model as shown below, which is based on three key stages of working development. The model is referred to as socio-technical, which is aimed at improving the performance of self-managed teams in terms of helping the business to improve both efficiency and effectiveness in respect of the continuous cycle of business improvement out-put.

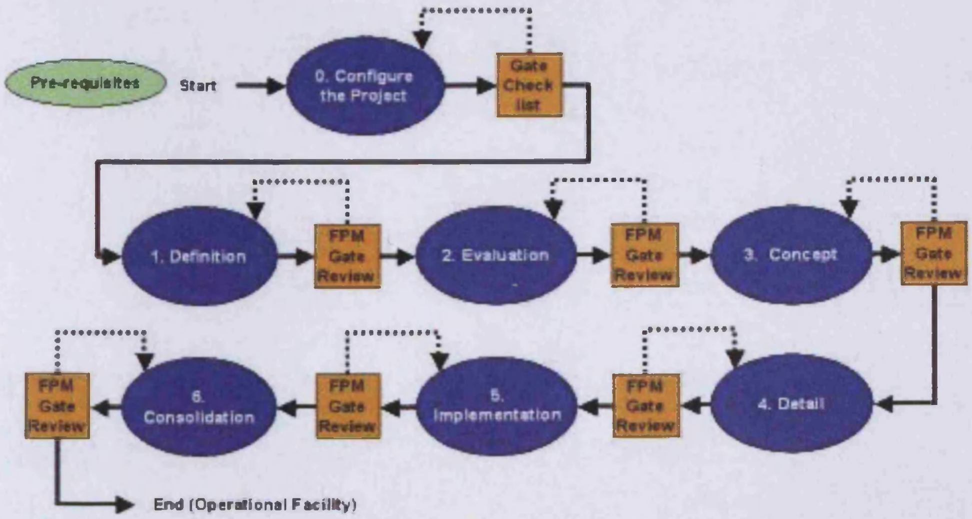
The case study businesses, armed with the aforementioned problems and the results of the study, began to enact changes to the systems they managed. Whilst this is beyond the official research design of this study (this study is not a longitudinal case study) the opportunity was presented to study the outcomes of the research. This is a rarity and not many doctoral researchers get to see what happens as a result of a problem-driven project. It was considered appropriate for the student to continue to monitor these changes and to report upon what practices had evolved.

5.17 Summary of Phase Three Site Changes

For the sake of completeness, the process of deploying TQM at the case study sites has continued and the next few pages will present an epilogue to this study. In 2002, the business began a process of change and had, in 2006, successfully deployed three very large transformation projects across both the Ansty and Bristol sites. It was previously noted that these two sites had the most socio-technical features and commercial pressures in common. The projects were entitled 'Journey to Process Excellence' and were a deployment of a total quality management strategy centrally as a corporate initiative. The major elements of change included the re-design & re-layout of the facilities. These redesign activities included two at the Ansty site (namely 'Fast Jet' and 'HERC' projects), followed by a combustor repair centre project located within the Bristol site. The new projects involved a fundamental review of the material flow processes at each site and moved from the chaotic nature of a job shop environment to a more flow oriented design (RRPS Factory Design & Layout FDL model) as shown below.

Figure 5.13

Factory Design & Layout Model

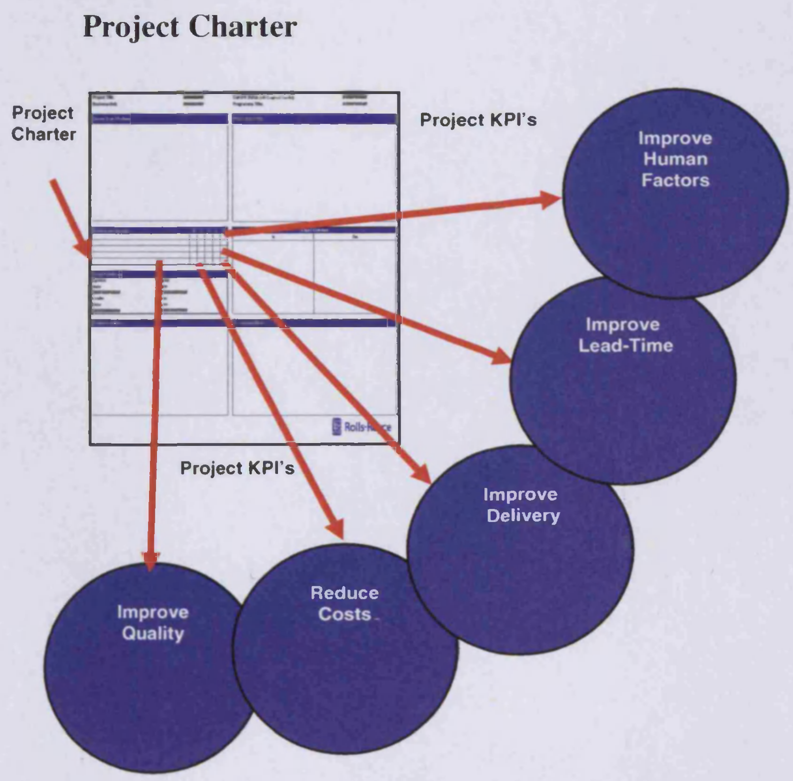


Source: Figure Taken From The Case Study Production System

To operate the new system, there have been many improvements and changes to the leadership, planning and management commitment/engagement with the new material flow system. The new approach to management has been changed as a result of new processes for material movement, less quantity and variety of materials are issued to the production units and the improvement methodology of DMAIC (Six Sigma) has been deployed to the sites via a central corporate strategy (part of the Journey to Excellence programme). The design & layout of the new facilities project model conforms to Lean ways of working and has integrated human factors management practices. The DMAIC process also covers the project-by-project approach and has formalised change controls through the introduction of a charter to establish an agreed business case with the key stakeholders as illustrated in the model shown below (Figure 5.14).

Figure 5.14

The New Project Charter



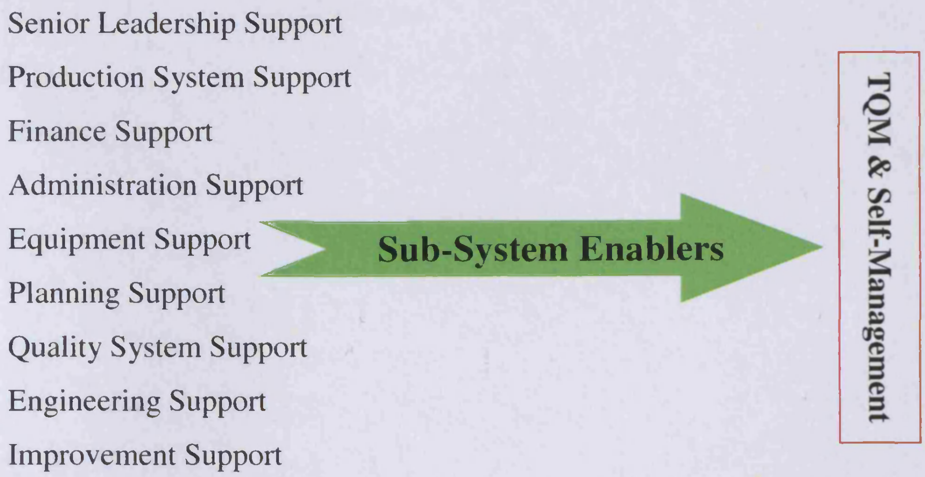
Source: Model Taken From the Case Study Production System

Under the new project charter to control change, a business case is needed to begin the process to nominate a change. The management at the sites now raise and review (with the Finance Management Team and others) the projects and implement the change using cross-functional management groups following a standard process with 5 gateway reviews to ensure the project is deployed in a controlled and sustainable way. As such any change to the socio-technical system is controlled to a standard and reviewed by experts.

The new approach was accepted as a means to sustain what is now regarded as a deployment model for process excellence to take place. The approach also promotes self-management as a major feature of organisational change through changed business structures and deployment of responsibilities to the teams. As such, an equal amount of effort is channelled into the soft elements of social system changes as much as the harder technical changes. The model below is taken from the case study business and shows the new direction of change based on engendering a self-management capability for engine overhaul teams.

Figure 5.15:

The New Direction of Change



Source: Researcher

The new redesign of the business structure has also brought with it formal allocations of roles and responsibilities to the team level as well as the management/specialist roles. These two activities are joined under a general approach to the site employees being a team and that specialists support engine repair personnel in a proactive and system-wide approach. Socio-technical systems thinking is directly embraced by the corporate and site quality management model (see figure 5.16). As such most of the research outcomes have become embedded in the new model. As an extension to the research, the company has detailed a journey and sequence to the socio-technical systems evolution. The starting point is a new 'process basics' approach (as outlined in the case study chapter) as a foundation to later improvement capabilities found in new Lean and new Six Sigma skills for autonomous teams.

Figure 5.16:

The New Quality management Model

Source: Taken From The Case Study Production System.

The new system also pays much greater attention to uninterrupted material flow and planning. These new activities include formal processes to:

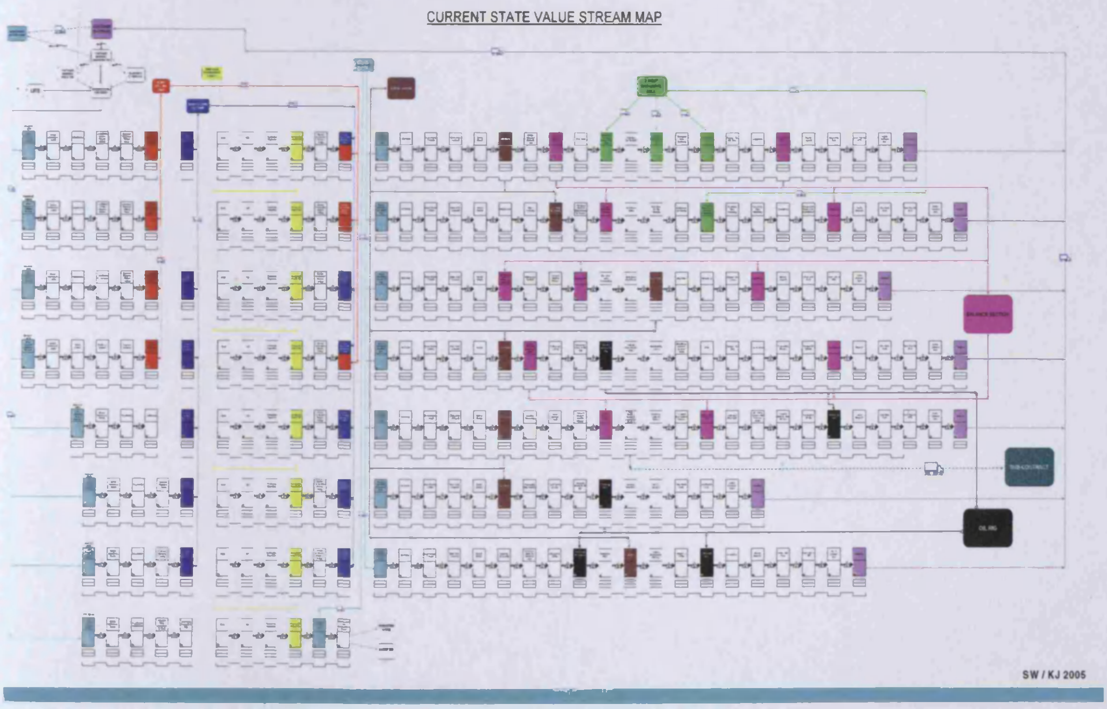
1. Measure & understand load & capacity planning over a ten year forecast
2. Ensure adequate labour is available allowing for surge capability at 20%
3. Only strip & build engines at the rate of customer demand.
4. Measure & understand product quantity through a P&Q analysis
5. Identify the opportunity to create value stream through value stream mapping

6. Design the system to be visual and error proof against overproduction.
7. Manage human resources in a cross-functional way facilitated by management.
8. Resolve team situational awareness issues in a systematic and continuous way.

It should be noted that these activities are all basic requirements for effective and good quality planning. They also reinforce teamwork and safe management at the team level. Another dimension to the new design, at the highest level and beyond process basics, is that of value stream management (figure 5.17) and the highly reliable flow of materials. This new addition to the model connects different teams (and has a distinct tool box of techniques) to create greater dependency between individuals and teams. A new environment emerges whereby employees are more willing and empowered to work together to ensure materials flow through the facility and are optimised (at the quickest possible turnaround time to reduce the significance of commercial pressures). Thus team working is enhanced and the human factors features needed for effective team situational awareness is able to develop.

Figure 5.17

Fast Jet Traditional Value Stream Map Ansty

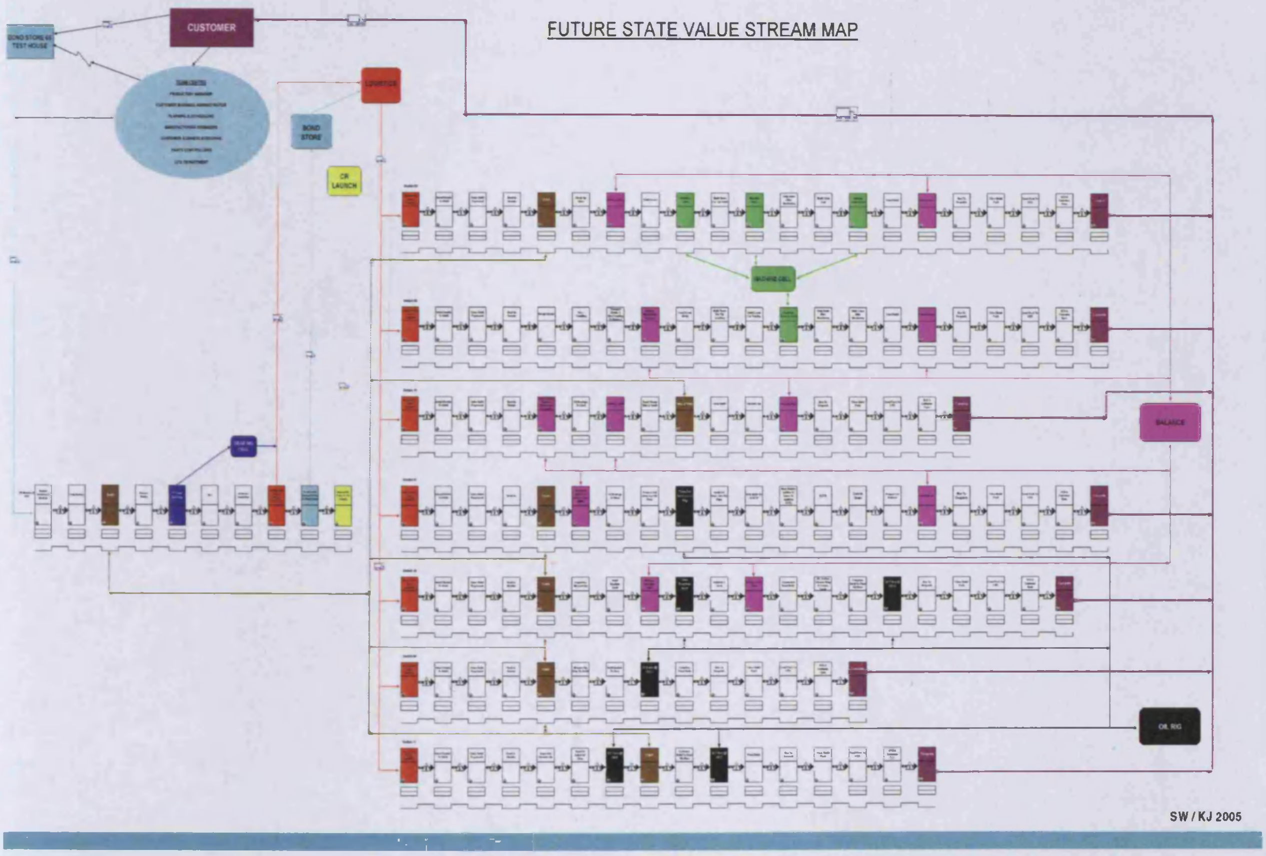


Source: Case Study Ansty Site Concept Design and Layout Business Plan

The value stream management process shows diagrammatically on one sheet of paper the total engine strip & build activities and how they are coordinated. Each of the process steps have data recorded relevant to the individual step in order to establish the true lead time through the system and the amount of time that value is actually added to each module build (enhancing planning capabilities at the sites). The value stream management reviews demonstrated that there was 99% waste activity at the sites that were studied, this waste has now been reduced allowing materials to flow and teams to better organise the documentation, tools, equipment, transit boxes and other supporting features including better visual management in the factories (Figure 5.18).

Figure 5.18

Fast Jet Future State Value Stream Map Ansty

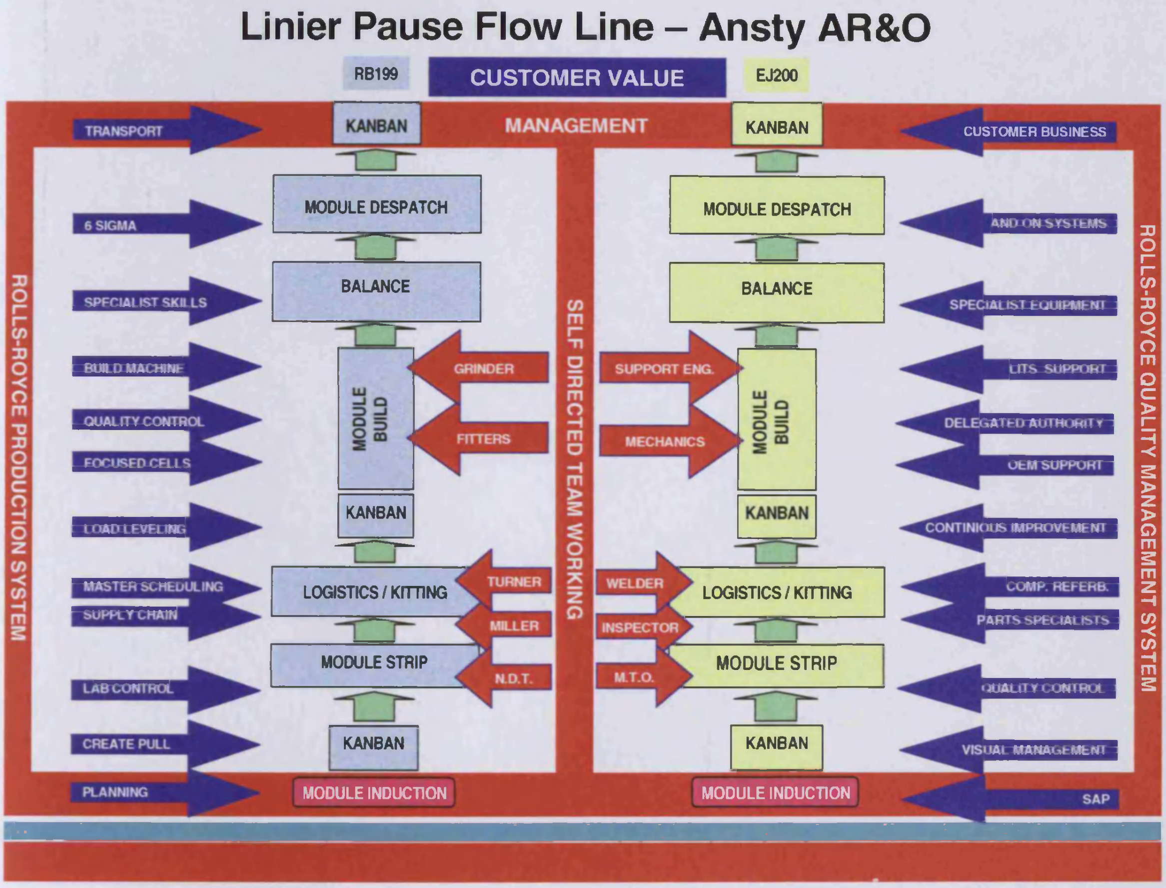


Source: Case Study Ansty Site Concept Design and Layout Business Plan

The new controlled material flow processes and team based working within the value stream is further defined in the schematic plan shown below (figure 5.19). The diagram shows clearly how materials are deliberately stocked using Lean Kanbans and how the process path has been simplified (allowing pull production and full availability of parts to meet customer demand).

Figure 5.19

Fast Jet Design & Layout Plan



Source: Taken From the Researcher's Presentation To The Ministry of Defence (2006) Case Study Ansty Site Concept Design and Layout Business Plan

A determining factor in the success of this approach is based on understanding the importance of load & capacity balancing, which the researcher accepted on the basis of Theory of Constraints (TOC) thinking within the concept of "Little's Law"[57] as

[57]Little's Law is a Lean manufacturing calculation that focuses on the amount of WIP released into a system, which is consistent with the required cycle time and output capability.

illustrated in the example shown below. These new additions have added a greater stability to the flow of work whilst reducing the amount of work in 'half finished' or temporarily halted form. The new levels of control provide a stable platform for teams and individuals to engage with self-management of flow.

Work In Progress Calculations

$$\frac{\text{Demand x TRT}}{\text{Time}} = \text{WIP}$$

$$\frac{\text{D x T}}{\text{T}} = \text{WIP}$$

Example
D = 84 outputs per year
TRT = 100 days based on future state VSM predictions
Time = 249 available business days per year

$$\frac{84 \times 100}{249}$$

$$\frac{8400}{249}$$

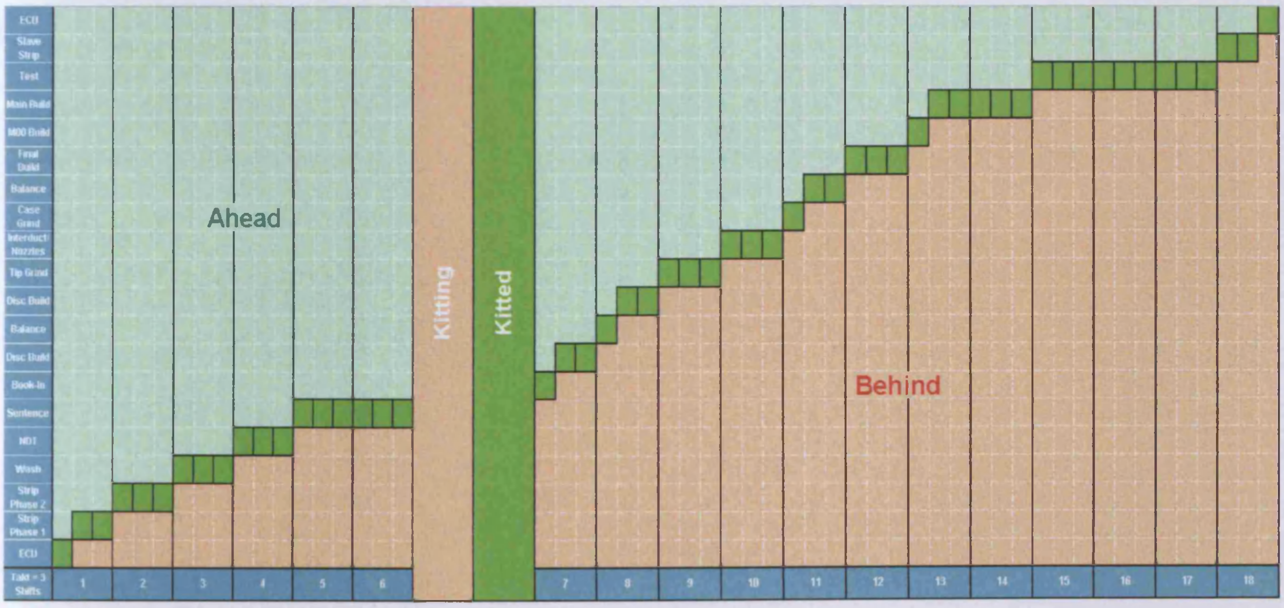
Future state WIP = 34

The introduction of load levelling at the sites has served to further steady the flow of materials in the repair system and to set a basic rhythm to the operations, which from a human factors perspective reduces the impact of commercial pressures on production loading. The new design has also included the introduction of a planning & scheduling model to enable control and effective use of a FIFO system through the concept of a visual control. The waterfall design is a generic tool that can track or map a component through a process in relation to variables such as surges in labour and unscheduled delays. This problem was only highlighted when constructing the planning & capacity model as a means to check current 'load' in order to establish the root causes for cell bottlenecks and greater engagement with the local teams. From the research phases, the rift between management and the working teams was aggravated by: a lack of transparency as well as commercial pressures that had led to friction, a management defence of the rule book and working to the SAP computer system schedules. The new model has a much greater level of transparency and the plan is promoted in a visual format to all areas of the facility (Figure 5.20).

The visual planning model is regarded as 'best practice' amongst many repair & overhaul lines at both the Ansty and Bristol sites and beyond the case study company. The model is characterised by issuing materials for one repair unit at a time (Lean single piece flow – see Ohno, 1985). The new visual control of repair operation shows WIP days plotted along the horizontal axis, set against a chronological sequence of operations shown on the vertical axis of the chart. The critical path is stepped in green and components are represented by magnetic counters, controlled or moved by different team members at the start and end of each day to show their progress. The importance being that each counter must always move to the right and if behind in its due date will drop away from the critical path and fall into the red, thereby providing a dynamic monitor or early indicator of a process, which is starting to fail. This provides a visual trigger for management intervention to correct the slow movement of work around the team or for the team to seek management assistance – thereby reducing the 'them and us' rift of blame that existed during the formal study.

Figure 5.20

Visual Management System



Source: Case Study Ansty Site Concept Design and Layout Business Plan

The time between concluding the formal study and the presentation of the results to the local and corporate management has witnessed a great amount of change and movement from the existing conditions during the research to the new repair processes that are evident at the sites. The new system has addressed the past dysfunctions of leadership that were created by commercial pressures. The changes have impacted on the transparency of the system, it has increased the effectiveness of communication and the attention pacing production has allowed a greater flow of materials and equipment etc.

In parallel the teams are more focussed on the customer due to the hard changes to the technical system and its material flow. The issues of morale, boredom and a perceived lack of empowerment have been addressed and greater communication has been used to enhance team situational awareness.

The divide between specialist knowledge, role ambiguity and rule breaking to get around the old way of working has also changed such that, by design, the new work environment has influenced a level of behavioural change and employee engagement that is more conducive to effective human factors management. These activities have increased levels of empowerment whilst encouraging a greater responsiveness to change and a new relationship with holders of specialist knowledge as well as managers.

Teamwork and problem-solving have also benefited from the greater transparency of operation and devices for production control. In term the general decision making (at the many levels of staff and personnel) has improved.

Overall, the new changes to the system have created a new way of working that is 180 degrees away from the case study businesses that started this research in 2002. The epilogue shows that despite the view of the literature that culture takes a long time to change, these businesses have shown major socio-technical systems redesigns without a compromise in terms of output or the human factors defences needed to ensure compliance within a regulated environment. This is contradictory to the gurus of human factors that stimulated this study and shows a major gap in the work of Reason (1995) who has long dominated thinking in this area of management.

5.18 Chapter Summary

This chapter has reviewed the main results of the study. It has presented a review of the quantitative phase of questionnaire results and shown the existence of common error themes from the perspective of gaps in the socio-technical system. The results showed a significant range of gaps where the qualitative reviews of system performance were reviewed using a panel group of experts in terms of providing a number of resolves from representatives of the teams and managers who the researcher drew together to discuss issues with the existing safety management system design.

The evidence suggests that while over 50% of all case study results are measured in terms of a satisfactory condition, the fact remains that numerous barriers are breeched and offer the potential for latent errors and risks to turn into major catastrophic failures within the facility.

The highest occurrence of problem failure causes originate from the technical system, where a general lack of planning and the use of inappropriate equipment was widely believed to exist. The results also show that the flaws in system design are further compounded by a series of gaps in the social system where human resource training in particular is not currently supporting the basic requirements of self-management for TQM.

It was also evident from the qualitative phase of research results that differences exist between the management and staff /shop floor teams in many of the major areas of safety system design. This phase of the research showed major failings in the control systems and barrier defences of the case study sites. Many of the problems cited by the operational teams were defended by management using traditional scientific management reactions. These included the deference of the issue to a functional support specialism (which reflected a silo mentality) and a reference to existing rules and policies rather than using team concerns to engage with problem-solving activities to make robust the production system. The findings suggest that those involved in the case studies, at the forefront of autonomous team working, had paid insufficient attention to the system design and had significant levels of role ambiguity – a latent error factor. The study results show that the case studies are not compliant to the principles of TQM and that whilst the structural arrangement of work is autonomous – the system design is incompatible with high performance, organisational learning, process improvement and system resilience. With regards to Reason's 'Swiss Cheese' model many of the case study defences have significant holes. These holes include leadership, planning, documented work standards, inter-team communication, training and role ambiguity. The incompatibility of these two systems has therefore resulted in significant levels of error related risk that could, if left unchallenged, penetrate any one of the following defence mechanisms as listed below.

1. Regulatory compliance to include legal benefits through avoiding enforcement action, which may extend to loss of license to operate.

2. Product escapes that relate to errors that could have a direct impact on product and passenger safety.

In light of this and other such discoveries the results from both hard & soft data sets will be analysed in more detail during the next chapter through a single cross-case design. The purpose of which will provide a greater depth of understanding where a series of cause and effect relationships can be established against the prescribed literature review. While error reduction is seen as a desirable end in itself, the fact remains that maintenance organisations such as the one found in this study, react favourably to change when improved human factors engineering can be measured against the cost of non-quality in terms of a profit and loss. The researcher will build a model that, it is hoped, will help managers, EASA and academics alike, in terms of understanding how to reduce variation, within the complexity of high product mix and low volume demand.

Chapter 6 Research Analysis

6.0 Chapter Introduction

The previous chapter has outlined the major findings of this study and begun the process of answering the guiding research questions that support closing the gap in the body of knowledge. It has also identified major gaps in the defences of the safety systems that support autonomous team working. The previous chapters have shown that merely changing elements of the socio-technical system without a holistic approach to designing structures that support robust and resilient processes simply exposes businesses to risk – risk that is greatly heightened when commercial pressures to satisfy customers in a timely manner is introduced.

This chapter will focus on the analysis of research results and draw comparisons with the main body of literature in order to conceptualize the study and present a model with which to inform professional practice and the improvement of the understanding of operations management in high variety and low volume regulated industries. This chapter will refine the data presented in the previous two chapters in order to make sense of the research and build the model of human factors management, which contributes to the understanding of operations management in the safety critical aerospace repair sector.

At the outset of this study, the early implications of the literature suggested that self-management was the most evolved form of high performance management with great potential from the perspective of organizational behaviour. From the operations management perspective, this structural form runs contrary to the needs of a robust and resilient safety system within which it is acceptable to have redundancy built into processes to allow them to recover from failures. The appeal of the self-management of highly skilled teams was therefore counterbalanced with the limitations created by poor control of human factors in the designed production system. The study has, to-date, identified three significant barriers that limit the opportunity for self-managed teams to facilitate the principles of TQM, namely; planning and control, equipment and training. The evidence to support this claim has been researched using two fundamentally different and yet complementary methodologies of quantitative and qualitative research perspectives.

6.1 The Quality of Results

The quantitative research provided a deep insight into the views of employees and using statistical analysis as evidence, a series of hypotheses and predictions were either accepted or rejected. To provide robustness to the study, three different types of test were conducted. These tests included:

1. Mann-Whitney Test (Non-parametric)
2. Two Sample-T Tests (Parametric)
3. Chi Squared Test (Non-parametric)

The researcher also used a probability value where statistical differences of 'error provoking risk' were found to exist. The population sample within each case study was drawn from 'works' and 'staff' groups, a common one-directional hypothesis test for attitude differences between groups and across sites was used.

6.2 The Findings

From the charts that follow, the researcher is able to state that no significant differences in attitudes exist between the 2 main groups, based on the probability value of $p = <0.86$. In other words, both the 'staff' & 'works' groups who took part in the questionnaire are of the same opinion as to 'how much and in which areas the problems of human error risk lies'. The results show that the original literature-derived hypotheses prediction was incorrect. Instead the researcher accepts the position of a common held belief system that barriers to TQM are both real and statistically proven to exist.

Whilst the quantitative results provided a framework of understanding, the severity of risk could only be accepted in part, based on the assumption that human factors research requires a more meaningful explanation in terms of the contributions of both the written and spoken word. Such research is best conducted using qualitative methods in an environment that stimulates debate and interaction between stakeholders, and where anecdote opens up new insights.

6.3 Mann-Whitney Analysis

To satisfy the demands of cluster grouping of responses, the next section will explain the issues that relate directly to the original research question by demonstrating a number of significant relationships between case study groupings. The research at this stage is regarded as the most important because of the statistical relevance in either accepting or rejecting the null hypothesis.

A series of 36 Mann-Whitney tests (summarised below) in Fig 6.0 were based on the assumption that all data entries were non-parametric in nature and taken from random samples of two populations within the same site locations. Each of the Mann-Whitney test results are based on a mean rank score approach that highlights which group submitted the highest or lower scores, with a social science cut off point of p = <0.05. For the purpose of this study the table of results shown below provides a range of values at construct level by way of highlighting areas of cultural differences within each of the 4 Aero Repair & Overhaul case study sites.

Figure 6.0

Mann-Whitney Analysis Table

	Planning	Equipment	Training	Communication	Procedures	Quality Management	Fatigue	Safety Culture	Management Attitudes
Bristol Staff v Works	0.00	0.16	0.04	0.88	0.87	0.08	0.09	0.29	0.58
Ansty Staff v Works	0.97	0.55	0.12	0.01	0.27	0.32	0.77	0.11	0.21
Derby Staff v Works	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
East Kilbride Staff v Works	0.33	0.46	0.83	0.00	0.66	0.62	0.08	0.25	0.01

Source: The Researcher

6.4 Two Sample T Test Analysis

Two sample T tests were used to analyse the study problem areas (shown in fig 6.1). The 3 highest problem areas of concern across each site location were considered in terms of their statistical level of variance between the staff and works case study grouping. The chart depicts each of the case study scores against the statistical level of variance and compares the differences between mean scores. A series of one tailed hypothesis predictions were either accepted or rejected on the basis of a social cut off point of p = >0.05.

Figure 6.1

Two Sample T Test Analysis Table

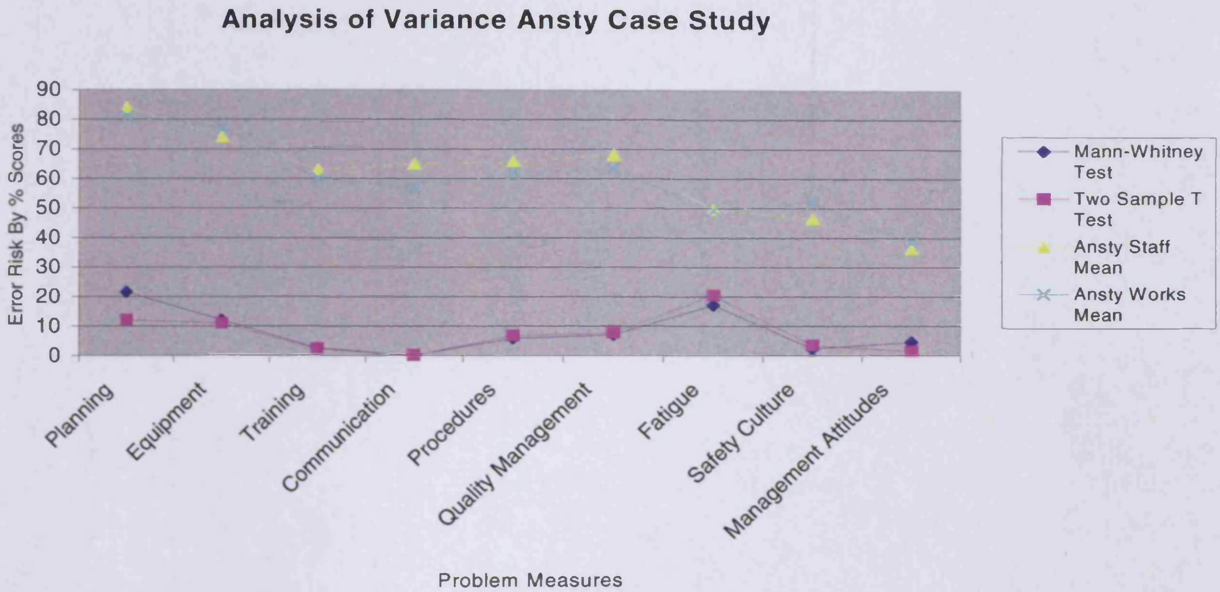
	Planning	Equipment	Training	Communication	Procedures	Quality Management	Fatigue	Safety Culture	Management Attitudes
Bristol Staff v Works	0.01	0.18	0.08	0.79	0.29	0.14	0.03	0.32	0.76
Antsy Staff v Works	0.55	0.50	0.11	0.01	0.31	0.35	0.92	0.16	0.07
Derby Staff v Works	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
East Kilbride Staff v Works	0.39	0.45	0.88	0.00	0.66	0.57	0.20	0.30	0.00

Source: Researcher

6.5 Analysis of Hypothesis (The Case Study of Ansty)

The Ansty case study provided a closely aligned set of results with only one negative correlation, which was in relation to training. This particular case study chart shown below in Fig 6.2 provides strong evidence of an organisation, which is closely aligned with high levels of correlation in attitudes relating to human factors engineering.

Figure 6.2



Source: The Researcher

The Mann-Whitney & Two Sample T test results are based on a 95% confidence interval displaying data taken from the highest problem areas of concern namely:

Mean planning for staff = 84%
Mean planning for works = 81%
<u>The null hypothesis for planning problems was accepted based on the test being significant at p 0.97.</u>

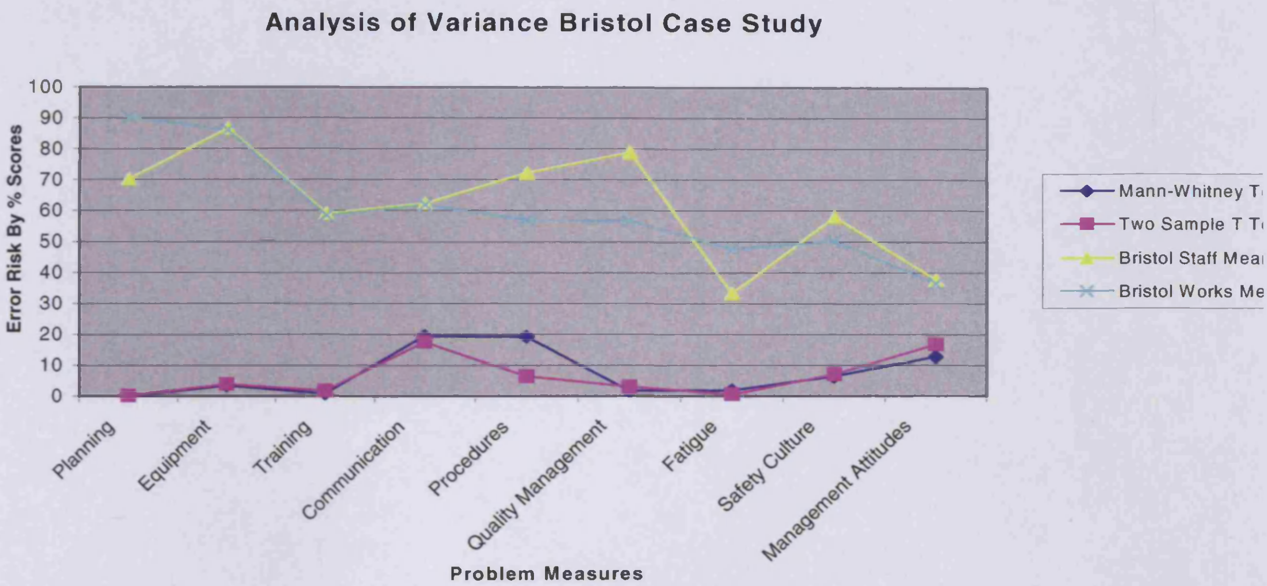
Mean equipment for staff = 82%
Mean equipment for works = 86%
<u>The null hypothesis for tooling problems was accepted based on the test being significant at p 0.55</u>

Mean training for staff = 63%
Mean training for works = 60%
<u>The null hypothesis for training problems was accepted based on the test being significant at p 0.11.</u>

6.6 Analysis of Hypothesis (Bristol Case Study)

With the exceptions of planning, both groups within the Bristol site were found to experience similar levels of difficulty, which is indicated in Fig 6.3 based on the majority of cases showing the existence of a shared understanding of human factor concerns.

Figure 6.3



Source: The Researcher

The Mann-Whitney & Two Sample T test results are based on a 95% confidence interval displaying data taken from the highest problem areas of concern namely:

Mean planning for staff = 70%
Mean planning for works = 90%
The null hypothesis for planning problems was rejected based on the test being significant at p 0.01.

Mean equipment for staff = 87%
Mean equipment for works = 86%
The null hypothesis for tooling problems was accepted based on the test being significant at p 0.18

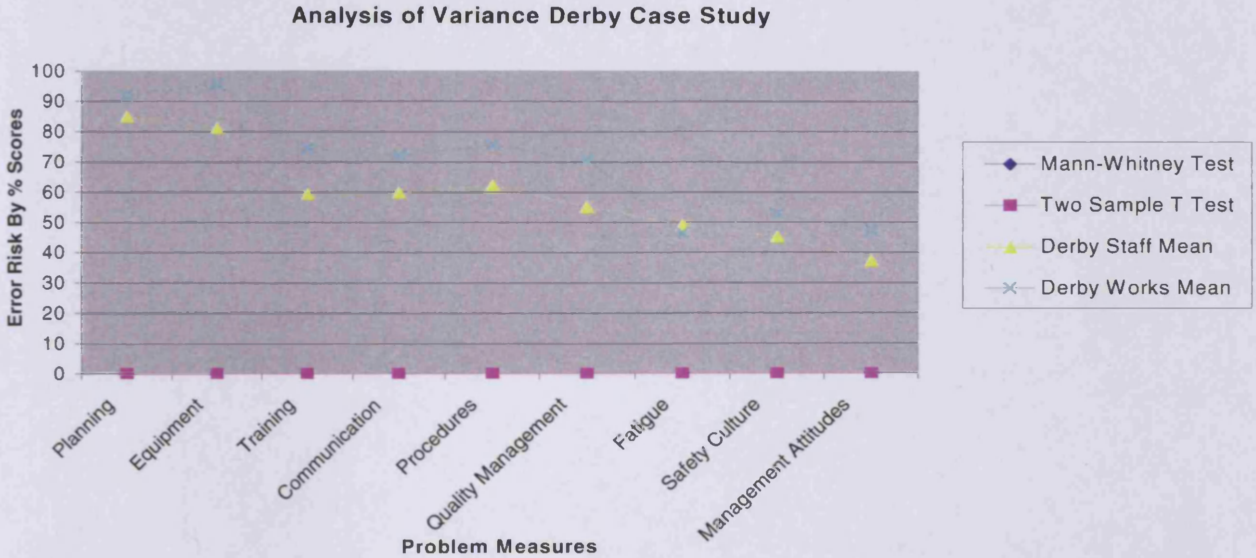
Mean training for staff = 59%

Mean training for works = 58%
The null hypothesis for planning problems was accepted based on the test being significant at p 0.08.

6.7 Analysis of Hypothesis (Derby Case Study)

The Derby site case study is an outlier and a total of 8 negative correlations were found with p-values that failed to correlate < 0.00 between staff and works population. Thereby indicating, in Fig 6.4 below, an organisation, which is not closely aligned with only 1 positive correlation of fatigue between the two case study groupings.

Figure 6.4



Source: The Researcher

The Mann-Whitney & Two Sample T test results are based on a 95% confidence interval displaying data taken from the highest problem areas of concern namely:

Mean planning for staff = 85%
Mean planning for works = 92%
<u>The null hypothesis for planning problems was rejected based on the test being significant at p 0.00.</u>

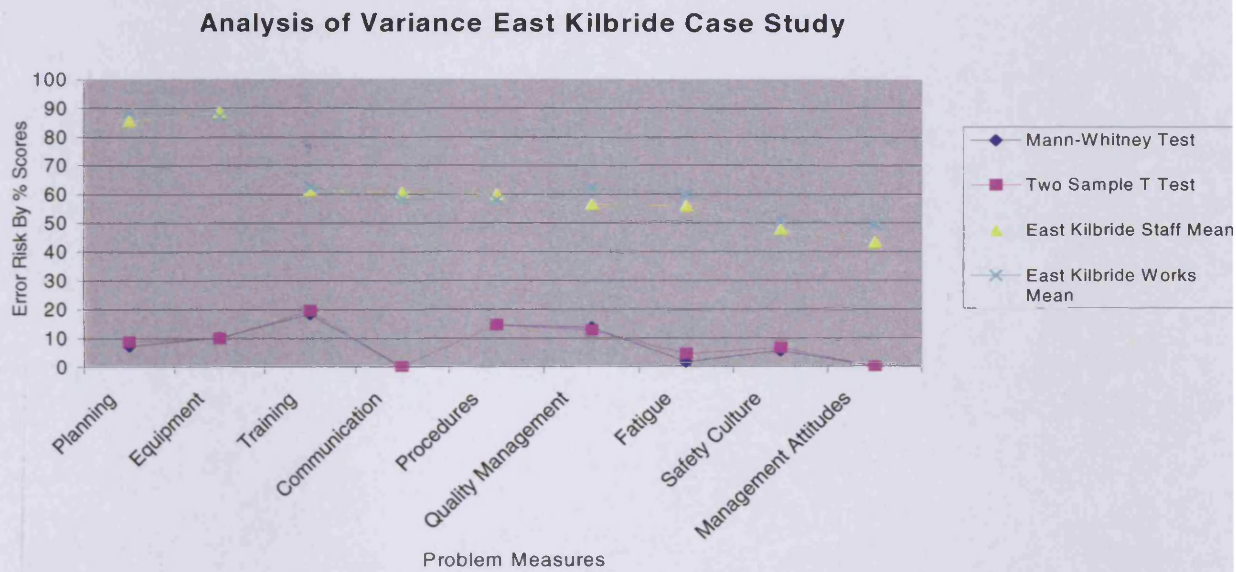
Mean equipment for staff = 81%
Median equipment for works = 96%
<u>The null hypothesis for tooling problems was rejected based on the test being significant at p 0.00</u>

Mean training for staff = 59%
Mean training for works = 74%
<u>The null hypothesis for training problems was rejected based on the test being significant at p 0.00.</u>

6.8 Analysis of Hypothesis (East Kilbride Case Study)

For East Kilbride, the main cause for concern is centred on the construct measure of planning, which demonstrates a positive correlation based on the highest problem rating scores as shown in Fig 6.5 in the chart below: With the exception of design & maintenance interface this organisation is able to demonstrate that its organisational culture is closely aligned.

Figure 6.5



Source: The Researcher

The Mann-Whitney & Two Sample T test results are based on a 95% confidence interval displaying data taken from the highest problem areas of concern namely:

Mean planning for staff = 86%
Mean planning for works = 88%
The null hypothesis for planning problems was accepted based on the test being significant at p 0.33.

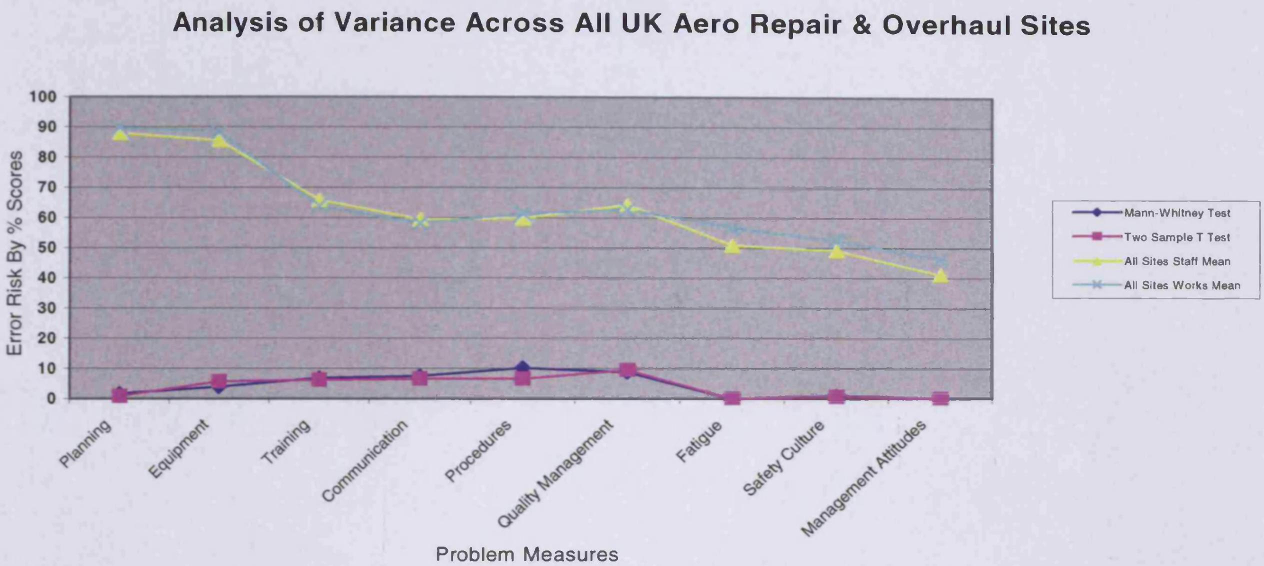
Mean equipment for staff = 89%
Mean equipment for works = 87%
The null hypothesis for planning problems was accepted based on the test being significant at p 0.45

Mean training for staff = 61%
Mean training for works = 62%
The null hypothesis for planning problems was accepted based on the test being significant at p 0.83.

6.9 Analysis of Variance All Case Study Groups

This particular test provided a closely aligned set of results, which shows, in Fig 6.5 below, an entire organisation, which is closely aligned to the same set of concerns surrounding human error risk.

Figure 6.5



Source: The Researcher

The variance of test results are based on 95% confidence intervals that display data taken from the highest levels of human factor concerns:

Mean planning for staff = 88%%

Mean planning for works = 85%

The null hypothesis for planning problems was accepted based on the test being significant at p 0.49.

Mean equipment for staff = 85%

Mean equipment for works = 87%

The null hypothesis for planning problems was accepted based on the test being significant at p 0.26

Mean training for staff = 65%

Mean training for works = 63%

The null hypothesis for planning problems was accepted based on the test being significant at p 0.31

Against the highest 3 categories of human error provoking themes, the analysis from each of the quantitative tests, concluded that no case study organisation was achieving the goal of TQM. The type of data used to support this claim was identified as being of non-parametric origin because it failed to meet the normal distribution criteria of the 'Anderson Darling' test. In other words the test demonstrated that in the majority of cases the questionnaire data fell below the threshold value of p> 0.05 thereby confirming the direction of all hypotheses testing in terms of analysing data about the medium and not the mean. The relevance of which, provided the researcher with a degree of certainty that his original hypothesis was in fact wrong. For example all questionnaire results were based on the medium rank score, which provided evidence that each case study group is of the same statistical opinion, based on the social science cut off point of p = <0.05.

In acceptance of this position, the researcher draws on earlier data presented from the raw scores of results and provides a series of test measures based on statistical differences of error provoking risk. The population sample was identified on the basis of 'works' and 'staff' groups using a common one-directional hypothesis test that provided data based on the relationships of attitudes between groups and across sites. The analysis of results chart shows no significant relationship between scores from each of the 2 main groups existed, based on the probability value of p = 0.86. The level of which is regarded as significant in terms of 'staff' & 'works' populations who are of the same opinion as to which areas of error risk exists. The null hypothesis was therefore rejected on the basis of a 2-sample T Test correlation for the staff group against the score of 2.71 based on a standard deviation of 1.18. The works group by comparison showed a survey mean of 2.73 with a standard deviation of 1.23 based on a median test score set at 2.00 respectively. The general consensus for all error related concerns is based on a 2 sample T Test at p = 0.70 and Mann-Whitney at p = 0.67 and further supported by the Chi-Squared test at p = 0.90.The analysis of results therefore provided a trend both consistent and reliable enough to satisfy the researcher that attitudes towards human factors, present a significant risk in terms of the highest order as shown below:

1. Planning 80% risk
2. Equipment 78% risk
3. Training 58% risk

Whilst the above test results provide wide spread evidence of opinions between and across groups, the researcher still required a more in-depth understanding of the levels of variance between sites and across groups measured in terms of the data mean.

For this purpose the Chi squared test was used as a means of comparing observed values against expected values by way of determining the statistical difference between sets of case study results. The null hypothesis was again rejected based on the statistical probability value of p = 0.90 where no difference in collective opinions was shown to exist. The statistical evidence taken from the Chi Squared test was based on 3 different categories of measurement highlighted by the criteria shown below in Fig 6.6

1. Observed value (Percentage problem score)
2. Expected value (Scores based on all cases experiencing the same problems)
3. Chi-Squared value (The difference between observed and expected values)

Figure 6.6

Chi Squared Analysis of Variance

	Planning	Equipment	Training	Communication	Procedures	Quality Management	Fatigue	Safety Culture	Management Attitudes	Total Scores By Group
Bristol Staff Observed Value	63%	78%	53%	56%	65%	71%	30%	52%	34%	502%
Expected Value	77%	77%	56%	55%	57%	57%	43%	45%	34%	501%
Chi-Squared Value	2.49	0.02	0.21	0.02	1.25	3.67	4.09	1.20	0.12	
Bristol Works Observed Value	81%	78%	53%	56%	51%	51%	43%	45%	33%	491%
Expected Value	75%	75%	55%	54%	55%	55%	42%	44%	35%	490%
Chi-Squared Value	0.45	0.12	0.08	0.10	0.34	0.34	0.00	0.39	0.14	
Ansty Staff Observed Value	84%	74%	63%	58%	59%	61%	45%	42%	33%	519%
Expected Value	79%	79%	58%	57%	59%	59%	48%	46%	37%	522%
Chi-Squared Value	0.26	0.33	0.36	0.02	0.00	0.01	0.00	0.38	0.49	
Ansty Works Observed Value	81%	77%	60%	51%	56%	57%	44%	47%	35%	508%
Expected Value	78%	78%	57%	56%	57%	57%	44%	45%	37%	509%
Chi-Squared Value	0.13	0.00	0.14	0.36	0.28	0.00	0.00	0.07	0.06	
Derby Staff Observed Value	76%	73%	53%	54%	56%	50%	44%	41%	34%	481%
Expected Value	74%	73%	54%	53%	54%	54%	42%	43%	35%	482%

Chi-Squared Value	0.07	0.00	0.02	0.03	0.05	0.32	0.14	0.07	0.01	
Derby Works Observed Value	83%	86%	67%	65%	68%	64%	42%	48%	42%	565%
Expected Value	86%	86%	64%	62%	64%	64%	49%	50%	41%	566%
Chi-Squared Value	0.14	0.00	0.18	0.29	0.00	0.00	0.93	0.10	0.14	
East Kilbride Staff Observed Value	78%	80%	55%	55%	54%	51%	51%	43%	39%	506%
Expected Value	77%	77%	57%	55%	57%	57%	44%	45%	36%	505%
Chi-Squared Value	0.00	0.10	0.06	0.00	0.16	0.63	1.23	0.09	0.19	
East Kilbride Works Observed Value	80%	78%	56%	52%	52%	56%	54%	46%	44%	518%
Expected Value	79%	79%	56%	57%	58%	58%	45%	46%	37%	515%
Chi-Squared Value	0.00	0.01	0.08	0.37	0.69	0.97	1.93	0.00	1.22	
Aggregate Construct Scores	626%	624%	460%	447%	461%	461%	353%	364%	294%	

Source: Researcher

The reliability of the questionnaire was therefore considered as extremely high confirming the existence of common problems between and across all of the case study groups. Within the Chi-Squared analysis itself a number of anomalies were found to exist, which are highlighted in red, as failed values that did not meet their expected scores against the specific case study correlation. The null hypothesis was subsequently accepted confirming an organisation, which is cohesive of attitudinal measures in terms of the type of quality related problems that were found to exist.

The areas highlighted in bold confirm unusual differences 'between groups' as shown in the table of analysis below.

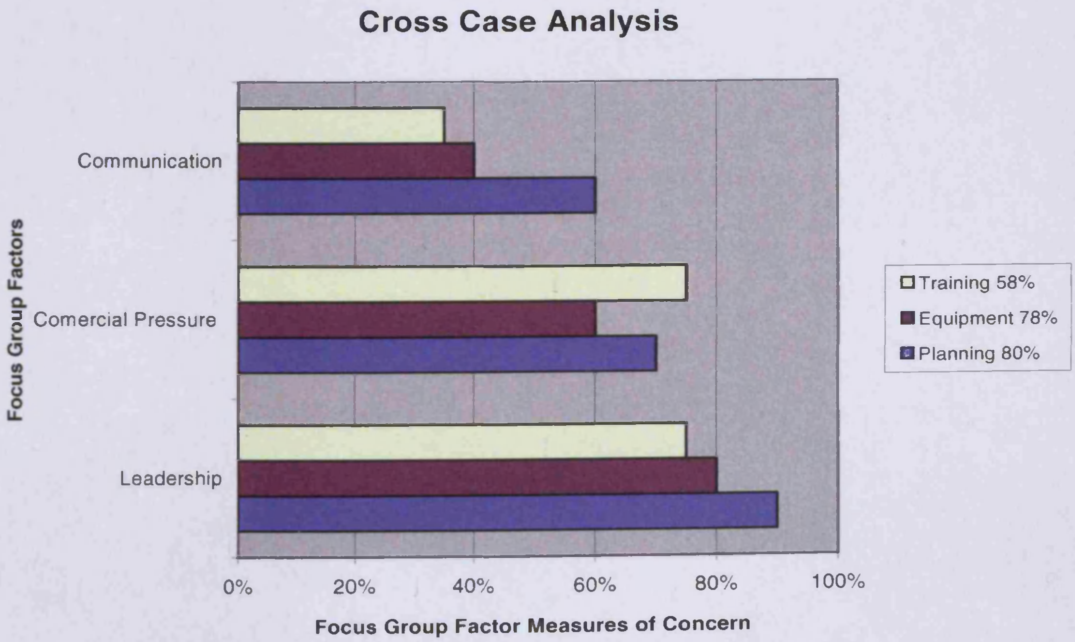
6.10 Cross Case Analysis

Whilst providing a reliable and statistically significant trend the quantitative approach could only be accepted in part as the study required a more holistic form of analysis, which the researcher accepted on the basis of Miles and Huberman (1994) recommendation in terms of incorporating different types of data into one cross-case design (qualitative cross case comparisons). In light of this a number of factors were found to be widely apparent in terms of their influences to both motivation and cognitive thinking. This was found to be evident across all case studies especially in those areas, which the researcher claimed could impact greatly on the quality of decision-making in critical situations. The importance of this finding therefore legitimised the use of a broad based methodology that Ragin (1987) advocated as a single cross-case model, which considers the analysis of all results in terms of the study as a whole. The explanations that follow are based on utilising this approach where configurations and associations of results were accounted for within a historical framework that formed grounded patterns of information by using data from both sets of results. The chart shown below, which is presented in terms of a pareto of contributing factors against the three highest questionnaire themes, provides a summary of this position. Analysing the results based on this approach therefore differs considerably from the majority of other human factors research, where experimental studies have, in many ways, excluded the value of empirical evidence, although there are a common range of problems beginning with measures of local reality which link back to the business strategy as a whole. In order to expand on this position a matrix analysis was created, as shown in fig 6.7, which enabled the researcher to extrapolate common error provoking trends based on the following list.

1. Leadership
2. Commercial Pressure
3. Communication

The qualitative themes are displayed in the left side of the chart presenting a mean score rating that was taken from semi structured interviews and focus group research. The chart shown below in Fig 6.7 also provides a link to the main questionnaire results by the bar colour coding illustrated within the chart key as 'survey results'.

Figure 6.7



Source: Researcher

The evidence suggests that many of the underlying causes of human error risk are not always committed by careless individuals, but instead the chart reflects a wide range of contributing factors that fall in line with evidence taken from the literature review. To support this argument the researcher extracted information from each of the focus group workshops and discussed the most prominent issue, namely leadership in relationship to planning which represented the highest problem area within the entire range of questionnaire themes. It is also evident that problems associated with planning were highly affected by the quality of leadership at each case study site. For this reason the researcher accepted the view put forward by Helmreich & Merritt (1995) who claimed in their research that performance related factors associated with effective socio-technical systems are heavily dependent on the positive effect of motivation. For the most part evidence supporting this view was confirmed in many areas of this study where a strong 'them & us' type of culture existed this could be explained as a determining factor in understanding the limitations surrounding autonomy for team situational control. Supporting evidence of this claim can be found in the analysis that follows which is based on three key themes from all areas of the study.

6.11 Planning Problems

Beginning with the analysis of case study planning the researcher refers back to the hypothesis analysis illustrated on diagram 6.7 that statistically demonstrates levels of human factors concern set against the probability value of the null hypothesis being true. In other words the measure of planning was analysed as the most problematic area of all human factors risk that was accepted by all cases and by all groups concerned. In conjunction with the qualitative analysis the researcher will also discuss the findings summarised in the qualitative overview against the background literature as detailed in chapter two. For example problems associated with planning were found to be closely associated with a lack of management planning this highlighted an underlying issue with leadership that was found to unacceptable, based on the extract quotation from the teams point of view. *"Planned time for some work tasks is often insufficient, especially on older engines which require extra work, thereby causing excessive time pressures" The* management response in relation to this issue was explained in terms of a lack of training whereby individual competency levels were questioned on the basis and need to be managing themselves more efficiently.

This particular example is consistent with the existence of a 'claim' & 'blame' type culture, where training and retraining according to EASA is systematic of the continued reason for why human error is allowed to exist.

In other examples of problems relating to planning the researcher draws on the issue of overproduction, which was raised during discussions with reference to managers overloading the shop floor at Bristol, with too much work. The resultant factor being that bottleneck situations became the norm based on the transcript taken from text number 21 claiming that: *"Choke points were creating extended lead-times by local custom and practice to satisfy the accountants need to sell hours"*. The practice of which has not only created one big push system, but also has undermined the basic principles of TQM where Lean has not been utilised to meet the efficiency aspects of lead-time reduction. In essence the existing leadership has, on the one hand, promoted the corporate improvement strategy and, on the other, systematically undermined this approach in terms of practicing scientific management from the perspective of batch & queue. The response offered by the Bristol management team in relation to this problem was based on satisfying the accountants need to meet targeted demands of 'good hours sold' against monthly key performance indicators. This is yet another example of where the practices within industry, such those in this study in particular, have contradicted the popular held belief put forward by Seddon (2000) who argued that TQM and scientific management are diametrically opposed and will always fail to co-exist. This was also seen as an issue at the Derby site based on complaints about the organisation of day-to-day workflow.

For example the teams raised concerns, in text box 35, about their role within the framework of self-management. Individuals were being told which jobs to work on in the form a 'work to list' The response from the management team showed that it had recognised that this position was less than satisfactory, but insisted on a continuation of this approach until the current lead-time performance had improved. Based on the approach put forward by Suri (1998) this is a classic example of where managers should not assume that lead-time reduction can be achieved based on the principles of using SAP. In other words Suri is claiming that lead-time improvements cannot be used as a tactic and thereby emphasises the importance of changing the management psychology as the first step in moving towards the goal of TQM. For example 'work to' systems such as SAP are 'push' based and inadvertently create 'overproduction' which according to Ohno (1985) is one of the seven wastes that needs to be eliminated, which in turn

"Improves performance and leads to leaner operations, which in turn highlights poor quality and the need for change"

Finally the issues of leadership and it effect on planning was also prevalent at the East Kilbride site where one focus group in particular blamed the causes of ineffective planning on leadership, see transcript taken from text number 47.

Concerns were raised about the prioritisation of work by staff positions who were often unaware of the complexity of operations on the shop floor. It was argued that management created this type of system, which invariably caused time pressures, which could lead to an increase in maintenance error. As a response to this one manager had commented that planning and scheduling priorities do exist as standard practice. In the case of priority 1 all requests are discussed with the appropriate manager prior to a decision being made. When orders are rescheduled or raised in priority, SAP calculates new schedule dates for each activity and this includes queue time, which acts as a buffer to protect against rushing. This represents a different type of example where teams felt powerless to manage and organise their own time. Again senior leadership, as Reason (1995) describes, is often the most transparent and remote from the system itself.

Accepting this position the situation regularly occurs where individuals are required to rush work due to planning input changes. The response below underlines this position where information about time management was extracted from the questionnaire results as an obvious area for concern. *"We often have to rush jobs due to unrealistic deadlines"*

Bristol Staff Response	60% Strongly Agree
Bristol Works Response	77% Strongly Agree
Ansty Staff Response	82% Strongly Agree
Ansty Works Response	81% Strongly Agree
Derby Staff Response	76% Strongly Agree
Derby Works Response	84% Strongly Agree
East Kilbride Staff Response	78% Strongly Agree
East Kilbride Works Response	81% Strongly Agree

Whilst discussing the issue of commercial pressure, some individuals identified instances where undue stress was being brought to bear in order to complete work within an unrealistic time frame to satisfy customer demand. The opinions surrounding this problem highlighted an important example of where commercial pressure is driving the repair and overhaul process towards what human factors engineers refer to as the 'error zone' The following points provided examples of the intended strategic plan, based on the organisations quality procedures namely AROP F2.2/2 that was thought to be achievable through the implementation self-managed teams:

1. Improved performance through increased employee involvement
2. Customer focused objectives owned by the team
3. Team alignment to business performance measures
4. Teams planning and carrying out their assigned work task
5. Increased flexibility through multi-tasking of team members
6. Greater involvement in problem solving and decision-making
7. Team members developing their personal skills portfolio
8. Leadership and coaching style of management

However, the main barrier to achieving this aim was highlighted by problems within the supply chain that exposed each of the case studies to the risk associated with inappropriate levels of stocked inventory. The assumption being that due to obsolescence and depletion of working capital an insufficient number of engine components are failing to buffer against system variation and changes in customer demand. The consequences of not buffering against an under performing supply chain in many cases has resulted in team working becoming over dependent on its manager and support network for decisions that generally exist outside of the team's control. The symptoms of which are illustrated below in terms of failure to protect customer expectation based on sporadic material supply and parts control.

"Jobs are often delayed due to a shortage of spare parts"

Bristol Staff Response	80% Strongly Agree
Bristol Works Response	81% Strongly Agree
Ansty Staff Response	84% Strongly Agree
Ansty Works Response	89% Strongly Agree
Derby Staff Response	76% Strongly Agree
Derby Works Response	91% Strongly Agree

East Kilbride Staff Response	82% Strongly Agree
East Kilbride Works Response	83% Strongly Agree

The resultant factor being that, where communication creates a weakness within the social system, managers fail to find adequate time to support the requirements of daily workplace control:

"I am always properly briefed by those giving me a job"

Bristol Staff Response	56% Disagree
Bristol Works Response	53% Disagree
Ansty Staff Response	62% Disagree
Ansty Works Response	52% Disagree
Derby Staff Response	52% Disagree
Derby Works Response	68% Disagree
East Kilbride Staff Response	53% Disagree
East Kilbride Works Response	53% Disagree

The social system was designed to empower teams to plan, schedule and manage its own workflow. But in reality the barriers to achieving this aim have inadvertently created a level of interdepartmental confusion, which renders the socio-technical system as dysfunctional both within and across departments. The point in question being that team-based working was designed to form cohesive patterns of behavior within departments that in turn limits the extent to which teams are able to develop their wider responsibilities between one department and the next. West (2004) highlights this problem in terms of the team design, by underlining the importance of communication as to how cross-functional goals should be achieved.

In recognition of this requirement it becomes apparent that in each of the case studies a difference in attitude exists between the main groups namely works and staff, where many departments are consistently functioning in isolation to the next. One of many different causes to this problem dates back to 1998 when the creation of the team-based working process excluded the white-collar population within Aero Repair & Overhaul UK. After numerous interviews with the staff population, evidence of this problem became apparent when individuals expressed feelings of isolation and exclusion from the entire self-management process. Divisions were created because of the monetary reward system where shop floor teams were paid an extra 10% of their annual salary to accept a range of additional roles and responsibilities that encroached onto white-collar jobs. According to the staff perceptions many of these new roles included responsibilities such as technical documentation and control, which served to erode white-collar status and sub cultural identity. The analysis therefore highlights a major weakness within the social and technical system underlining a strategic leadership issue that has limited the ability of self-management to perform properly.

6.12 Equipment Problems Analysis

With each of the businesses experiencing some form of modernisation or relocation a number of concerns were raised that the 'same old equipment' would simply be moved as well. In many cases individuals voiced serious concerns claiming that they were very dissatisfied with the suitability and issue of existing equipment, which was not fit for purpose. This was reinforced by a number of groups who expressed concern about insufficient investment in tooling. Equipment problems were exposed as the second and most serious cause for concern. For example when requesting refurbishment or replacement tools the standard answer was said to be 'there is no money available' The summary of responses taken from the questionnaire underline this position in terms of the question that asked if: *"Some tools could be better designed"*

Bristol Staff Response	78% Strongly Agree
Bristol Works Response	78% Strongly Agree
Ansty Staff Response	74% Strongly Agree
Ansty Works Response	77% Strongly Agree
Derby Staff Response	73% Strongly Agree
Derby Works Response	86% Strongly Agree
East Kilbride Staff Response	80% Strongly Agree
East Kilbride Works Response	78% Strongly Agree

According to Hobbs (2000) problems with tools and equipment are cited as the most important local factor in influencing the quality of work. The results of this case study support the findings from Hobbs Australian research programme. Hobbs claimed that equipment deficiencies presented the second highest problem in his research programme, which resulted in system violations based on improvisation of rules. He claimed that problems associated with inadequate tooling provide a breeding ground for system violations, which encourage a silo mentality where designers work in isolation to engineers. With the introduction of condition-based refurbishment programmes engines are now being overhauled in less time than it takes to manufacture new replacements. In this sense the business has identified with the customer through partnership programmes where 'overhaul' is the least expensive option as opposed to buy. In order to extend engine life efficiency, designers have developed new ways of exploiting technology where design changes through 'single crystal technology' means that turbine blades are becoming stronger, lighter and last longer. Changes of this kind have also demanded a different approach for the maintainer in terms of tooling challenges that no longer fit their intended form or function. The resultant factor being that minor changes to engine specification coupled with a fragmented social system has resulted in a 'can do' attitude whereby tooling is sometimes adapted without proper or full regard for its function and purpose.

Other cases were highlighted in relation to specialist tooling, which is often partially damaged or broken and was found to be still in use, where risk to compliance could lead to maintenance error. It was claimed that the problem of inappropriate use of tooling is regularly reported to management and often goes un-noticed to the extent that it has now become accepted as the working 'norm'. When damaged tooling is reported for rectification it is the responsibility of the manager to ensure that quality procedures are followed to enable its correct repair. The general opinion surrounding this issue was reflected by the wider problem that little or no change would become apparent, until radical improvements were made to improve communication within the social system. The researcher is therefore suggesting that the system weaknesses is strongly associated with 'lack of management' often caused by time constraints from commercial pressure that has led to an unacceptable level of illegal tooling use. In light of this claim Karasek & Theorell (1996) argue, " *The responsibility and workplace control is often overlooked, in relation to job demand and individual autonomy"* For example evidence of bad behaviours by management have 'encouraged individuals to take rational risks when using some equipment that was inappropriate and not designed for its subsequent use. The word 'risk' was not perceived as being compatible with the message promoted by the European Aviation

Agency, in respect to 'always follow the procedure'. The type of problems discussed by the focus groups are also conducive with the questionnaire survey that highlighted concern across all case studies with reference to procedural. *"The procedures I use always adopt best practice"*

Bristol Staff Response	80% Strongly Disagree
Bristol Works Response	40% Agree
Ansty Staff Response	57% Disagree
Ansty Works Response	57% Disagree
Derby Staff Response	57% Disagree
Derby Works Response	59% Disagree
East Kilbride Staff Response	58% Disagree
East Kilbride Works Response	48% Agree

With the exception of Bristol & East Kilbride works all other case studies admitted to breaking procedures. This was confirmed during the focus group workshops, based on the practice and use of engineering 'black books' When interviewed, some engineers described how they have written their own version of procedures with the aim of carrying out their work more effectively, thus entering into the area as previously referred to as the 'error zone'

6.13 Training Problems Analysis

According to Hobbs (2000) errors become incorporated at the person level of analysis in terms of the misapplication of rules that arise because of problems with information, which is one of the most difficult factors to control. In view of this dilemma West (2004) stressed the importance of communication and underlined the critical nature of training to enhance team performance, which Pasmore (1988) also cited as an important area of concern. Training should also incorporate a wide range of other responsibilities, such as 'flow' based on planning within the context of Lean. From a practical standpoint the analysis of results has also supported the work of Hobbs (2000) thus demonstrating that engineers often struggle to follow procedures because of an inappropriate design. In understanding the complexity of this problem the qualitative analysis provided explanations that cited problems within training, within the context of 'systems application processing' (SAP) For example a reiteration of numerous procedures was found to be apparent which required a more human friendly approach in areas where data access was both difficult to understand and obtain. This led to the focus group workshop asking 'why don't we follow procedures' with reference to the SAP. The commenting response was that *"SAP language is difficult to understand"*. The resultant factor being that some team members described how they have written their own version of instructions so they could fit with the intent of the procedures.

Also mentioned was a request to carry out a training amendment so that scripts could be made simpler, a request that was subsequently denied. In respect of this example the general view held was that training in the use of SAP was still patchy at best, with people feeling under confident in using the system. This situation, brought about by lack of understanding in the use of computers, was thought to be very likely to increase the opportunity for error because people were still being shown, unofficially, how to get around the system. The use of written procedures provides the necessary information for tasks to be completed based on the use of a standardised approach that maintains the most effective and safe method of working. This became apparent in chapter 4 when three off combustion chambers were fitted with the wrong parts, because of non-compliance to SAP. Failure to follow what is described as the application of good rules will, according to Reason (1995), inevitably result in shortcuts that lead to mistakes. This type of situation is indicative of knowledge-based situations where the selection of an incorrect of thinking program is directly linked to the system's failure at the organisational level of control.

During the explanation of the MEMS system and the submission of the MEMS report forms the point was made that not everyone has a LAN username and password. In addition, it was also voiced that not everyone is computer literate and required computer training in order to use the MEMS reporting system, which does not lend itself to be people friendly. A paper version of the MEMS report form was thought to be needed to compliment the electronic version, with people being able to fill out and post a MEMS report at well publicised points throughout the facilities. In light of this problem Wellins (1992) claimed that organisational training should represent 20% of each employee's time, further claiming that companies who invest in depth and breadth of training broaden their range of activities for teams to perform satisfactorily.

Concern was also raised as to the competency of the MEMS investigators, based on divided opinion that investigators only represented the staff population. The popular belief held that refresher training and ongoing recurrent training was necessary to ensure a renewed level of confidence in the shop floor that investigates were carrying out there work correctly. Whilst these people may not be ideal for investigating local shop floor maintenance errors, it would on the other hand increase the confidence and trust of the MEMS system if they were still being used.

It light of this position West (2004) explained this type of problem in terms of 'intergroup relationships' and argued that differences should always be exposed to encourage one cross functionally represented system. West is critical of organisations that introduce team working without addressing the issues of intergroup relations. He also argued that unless differences between teams are fully understood, intergroup difference would erode the stability and potential for teams to perform properly. This was an issue that was highlighted during the study in response to the measurement of cross-functional management, which is a fundamental requirement of TQM as highlighted by the responses listed below. *"Management, works and staff communicate well with each other"*

Bristol Staff Response	90% Strongly Disagree
Bristol Works Response	72% Disagree
Ansty Staff Response	62% Disagree
Ansty Works Response	58% Disagree
Derby Staff Response	52% Disagree
Derby Works Response	64% Disagree
East Kilbride Staff Response	57% Disagree
East Kilbride Works Response	58% Disagree

It is not surprising therefore that a lack of training of communication was measured as a contributing factor that perpetuated the problem of cultural diversity, where some departments are perceived to be working in isolation to next.

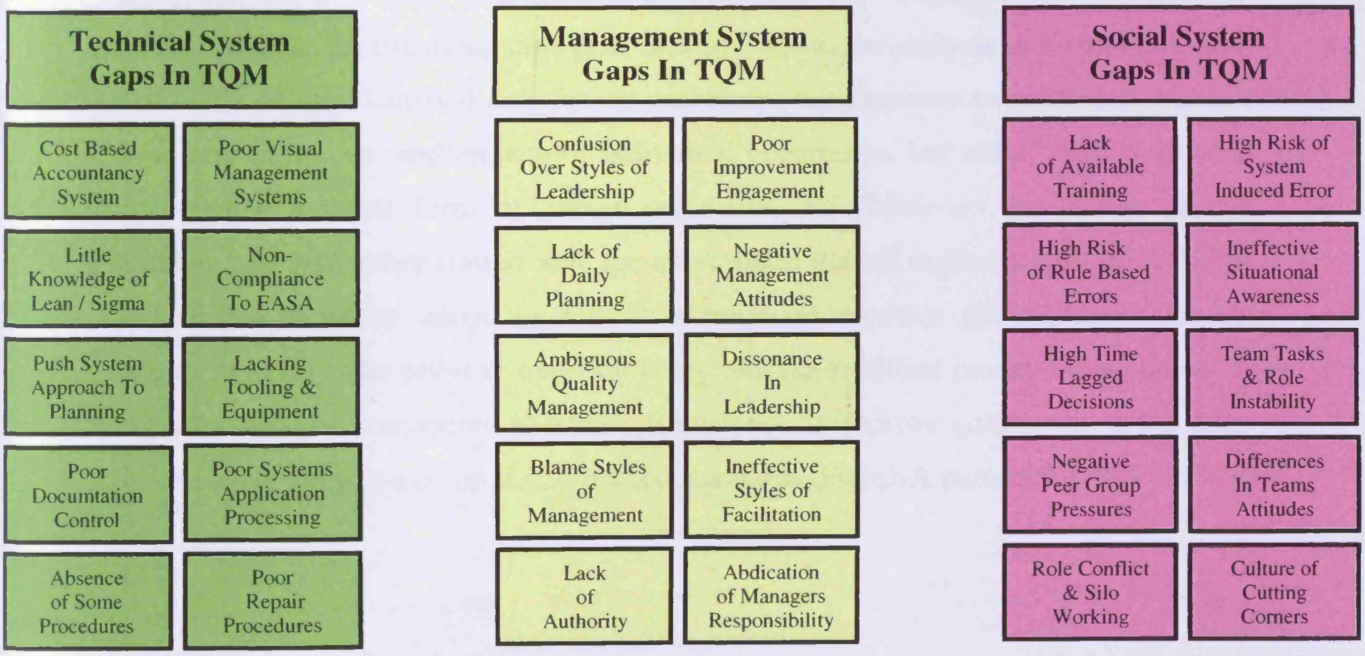
In light of this situation West (2004) claims that a key aspect of team structure should include cross-functional representation of departmental types, where targets and goals should be made clear with feedback of performance.

6.14 Analysis of Gaps in Critical To Quality Characteristics

The critical success factors identified from the analysis of this chapter have been characterised into three distinct areas. Based this position the summary model shown below in figure 6.8 illustrates that most, if not all, of the issues found in this study could be considered as a consequence of misdirected leadership, where problems with planning, equipment and training originated from the same area as previously highlighted in figure 6.7. The significance of this position is based on the evaluation of the cross-case analysis that confirmed the existence of risk factors associated with human error that can be described as, a general 'lack of management' owing to gaps in the wider socio-technical system as illustrated in figure 6.8 below. In other words, different error types as suggested by Hobbs (2000) are not always committed by careless engineers, but instead can be induced through a system weakness at the at the rule-based level of human factors control.

Figure 6.8

Analysis of CTQC Across All Case Study Sites



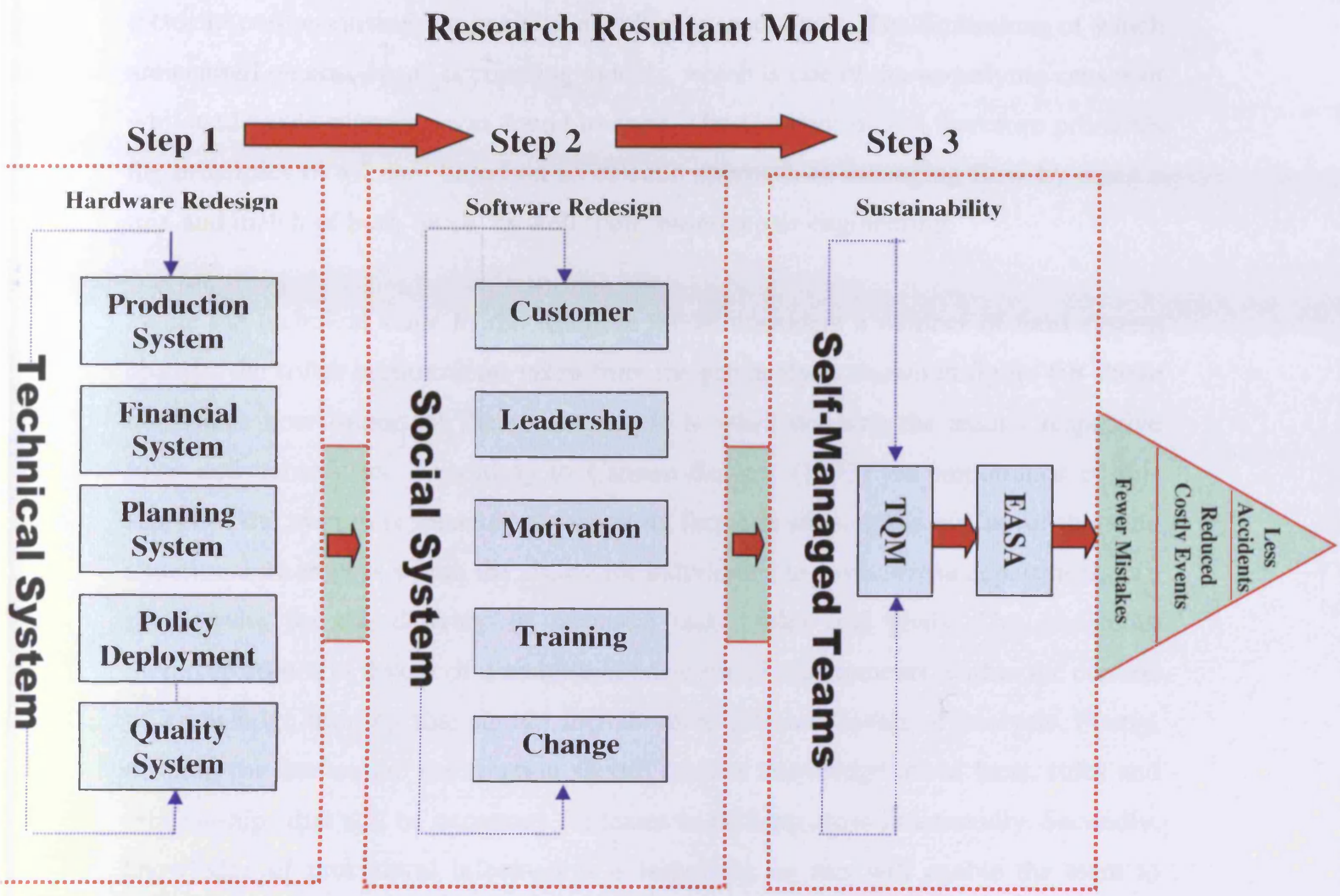
Source: Researcher

In respect to this situation the researcher confirms for the position of realism was the correct approach taken for this study where a middle ground is recommended in terms of how best to regain control of human error risk. This opportunity will next be discussed, based on the introduction of resultant model as an enabler for the organisation to achieve both efficiency (speed of delivery) & effectiveness (reduced human error) as shown below in figure 6.9. The resultant model also provides a valuable framework for those case study managers who are trying to develop a positive culture as the first step in preventing 'corner cutting' where individuals for the most part in this study were found to be at significant risk of making errors because of breaking rules. According to Hobbs (2000) this is occurs because of the: *"Misapplication of rules that arise because of problems with information, which is one of the most difficult factors to control"*.

6.15 Resultant Model

The discussion throughout this chapter has underlined a general trend where self-management within the context of TQM is at significant risk of procedural non-compliance. The model shown below in recognising this position was designed to bridge a number of gaps in support of EASA where self-managed team working can safely facilitate the organisational goal of TQM. From the analysis of results it is clear that many of the identified risk factors associated with barriers to achieving this aim were not limited to random acts of individual occurrence, but rather system induced that created a latent form of human error risk. To counteract the effects of this problem, the researcher started with the assumption that all organisations are different and should therefore adopt an eclectic strategy to improve the quality of human factors thinking. The point in question being that the resultant model shown below in Fig 6.9 should be considered as a basic framework to improve quality and at the same time is designed to meet the safety related standards of EASA part-145.

Figure 6.9



Source: Researcher

6.16 Chapter Summary

In deploying the resultant model it is highly recommended that each of the cases concerned cascade within their business plan a guiding framework for change so that everyone is communicated to and understands. This is a powerful approach that should be used to facilitate strategic change based on agreed milestones where pace and timing is seen as an important feature to create a cohesive structure so that teams are adequately empowered to deliver the system goals. The application of policy deployment is therefore seen as a powerful tool that will engender a more committed and focused approach by senior leadership, based on the principles of joint decision-making through the concept of Hoshin[58] Kanri. In light of this consideration the chapter has also shown that commercial pressures are seen as a major contributing factor in compromising the position of self-managed teams. The limitations of which are centred on cost-based accounting models, which is one of the underlying causes of why inadequate planning was found to exist. The resultant model therefore promotes the principles of a Lean; based on an eclectic approach to managing flow by using a mix and match of both 'push' as well 'pull' based repair engineering.

While the technical stage of the resultant model considers a number of hard system changes the softer requirements taken from the gap analysis shown in figure 6.8 above underlines how important the social system is when defining the team's respective roles and behaviours. According to Cannon-Bowers (1993) the importance of this aspect of the system is seen as a determining factor in shaping the quality of the team situational awareness where the ability for individuals to work across departments is a prerequisite for the delivery of technical tasks, roles and goals. The researcher therefore argues in favour of a number of basic social requirements, within the context of knowledge training that should include three different levels of analysis. Firstly, training for declarative information should contain knowledge about facts, rules and relationships that will be necessary for teams to perform cross-functionally. Secondly, knowledge of procedural information is important, as this will enable the team to understand how to self-manage goal relationships with other team members, so as to avoid knowledge-based errors. Thirdly, training for strategic knowledge should focus on relevant information about the system as a whole, which will help in areas such as problem solving, where information can be communicated efficiently between one department and the next. Learning about systems however, is not a naturally evolving phenomenon and as such the researcher argues that successful development of effective and efficient social systems requires a more gradualist approach, which is critical to the safe practice and performance of self-managed teams. In respect to this situation the researcher was able to demonstrate sufficient examples of where managers assumed compatibility with Leaner ways of working, but at the same time failed to understand the complexity of how to apply the correct mix and balance of autonomous team working within the context of TQM.

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[58]The term hoshin is a concept that ensures focus is not blurred and the deployment of policy can be engaged by all.

It was for this reason that either too much, or too little responsibility exists within teams, which in turn has created a level of system induced error risk where low levels of team situational awareness has resulted in a culture of corner cutting at the rule based level, as illustrated in figure 7.0 below

Figure 7.0

Analysis of Different Error Types

	Planning&Leadership	Equipment & Leadership	Training & Leadership
Rule-Based Errors	H	H	M
Knowledge-Based Errors	H	M	M
Skill-Based Errors	L	L	L

Source: Researcher

In summary this chapter has demonstrated that problems facing teams and their limited ability to resolve such situations cannot be understated and what may require the application of a particular type of problem analysis for one case study could be completely different when compared to another area of the business. Therefore aknowledging this position the researcher's contribution to the main frame of applied human factors research contradict a significant number of other studies, which tend to be highly indualistic and often miss the importance of the socio-technical system as a valid contribution to the application of safer human factors management thinking.

Chapter 7 Conclusion

7.0 Chapter Introduction

The initial interest of the researcher in Human Factor engineering was stimulated by dissatisfaction with the existing body of knowledge for operations management (that is focussed exclusively on high variety, low volume and skills routines) and has ignored the importance of low volume and high variety industrial settings. This dissatisfaction and motivation to learn more, whilst closing a gap in the body of knowledge, set in process a long journey of research, covering many years and countless miles. This chapter marks the conclusion of this journey and thesis. The chapter will build from the analysis of the results and mark out what learning has happened and the next generation of research questions this work has uncovered. In so doing, it will spend some time in discussing the implications of the findings for the design of effective operations management systems and how best to teach these concepts to university students and practicing managers. The original research question as declared in chapter 1, set out to understand the extent to which, self-managed teams across each of the Aero Repair & Overhaul UK sites is currently able to facilitate TQM. The results of the study with respect to this question have exposed a number of key factors affecting this position, based on a general lack of knowledge of how to manage Lean production tools and techniques in what was described as non-linear environments. This position was similar to other literature examples and seen as common to other human factors studies.

What makes this condition unique for Aero Repair & Overhaul is the outcome of where non-compliance to procedures in a safety critical environment will as the background literature has shown place at risk passenger safety, which is of paramount concern. Therefore it is claimed that effective human factors management must be seen as an essential feature of operations management and cannot be carried out without due consideration for the deployment and control of socio-technical system design. In light of this position, the researcher rejects the value of individualistic research when attempting to solve complex problems of a socio-technical nature; this approach fails to account for the complexity of knowledge-based systems. Individualistic research is, more often than not, better aligned to mechanistic environments of new production such as those found in traditional Lean organisations.

7.1 Changes to Self-Managed Teams

In order to resolve the issue of team empowerment versus 'control', the important yet absent 'linking pin' phenomena (Lewin, 1958) could not be ignored. In other words the recommendations are that a 'team leader' should be introduced which according to Storey (1994) is associated with the high performance of TQM designs While the main framework of STS literature was fully endorsed, the most appropriate structure for improved human factors performance was therefore concerned with the current issue of the safety critical processes where effective team working is dependent on the vital linking pin of the team leader. The rationale being that, the current disadvantage of just relying on the group responsibility without leadership, which is more often referred to as the 'diffusion of responsibility', is at the detriment of a human factors performance. While the researcher draws upon many aspects of socio-technical research he also extends his advice beyond the industrial sector of operations management to the immediate resolution of the system where front line engineers experienced exposure to commercial pressures, which manifested in terms of corner cutting and rule-based mistakes. This type of phenomena may not always be associated with 'intergroup conflict' but it is a subject unique to situations involving small groups who often act cohesively, but are pressurized to cut corners because of conflicts that arise between engineers and managers both between teams and across sites. The implications show a close resemblance to the findings of Reason (2003), where teams often failed to share responsibility for ownership of shift task handovers. In other words in the absence of a direct or immediate line of accountability the concept of 'social loafing' was often seen as apparent, it also reflected a tendency for some individuals to work less hard on a task when they believe others are working on it as well. The belief being that in absence of task ownership some individuals assumed that their own efforts would be pooled with that of other group members and would not be seen in isolation. It is for these reasons the researcher points out the importance and application of the role of the team leader, who can provide the important 'linking pin' between shifts, a role which the teams themselves have not been adequately able to demonstrate. The point in question being that individual responsibility is an organizational and legal requirement by the licensing regulations that should include adequate education and training as a means of engendering a culture of shared but not 'diffused responsibility'.

7.2 Reflections on Methods Used

No research initiative is complete without a reflection upon what has worked well and what would be done differently if it were possible to start the research process again. The next section will provide an account of this reflection.

The questionnaire used by the study was drawn from human factors knowledge, which is limited in its treatment of management attitudes and vague in what this term means. In hindsight, the addition of a section on the attitudes of management to certain practices such as information sharing, cross functional working, and the extent to which the manager sees criticism as a positive dimension of change processes rather than a threat, would have been appropriate. These facets could have been examined in more detail but, given the time and word count of this thesis and its realist, rather than ethnographic, nature these interactions could not be investigated fully. These issues were detected in the other phases of the research.

A repeat of the study would benefit from such a section added to the questionnaire but this is a proposed improvement to the next generation of research questions. To date, none of the major human factors authors have considered these features when building their models (Reason, 2003). These activities and behaviours were found, by this study, to significantly influence the performance of the socio-technical system in terms of enabling self-management by teams to facilitate high performance via TQM.

Upon reflection, the questionnaire was the correct method for the primary stage of this investigation, on the grounds that the research has identified many vague areas that were previously ignored by operations and human factors specialists. One of the implications of the questionnaire was the major amount of time spent processing the outcomes/returns (approximately a year of manipulation to the standards expected in the Research Design stage).

The administration of the questionnaire was greatly assisted by the engagement of an HR specialist at each site and this was considered to have been of help in the achievement of such a high return rate.

The researcher also under-estimated the amount of time spent feeding back to site management following the questionnaire and focus group stages. Many sites began to enact changes based upon their learning from the early stages of this study but at a site level rather than a corporate change to the implementation of TQM and the corporate model that underpinned this approach to self managed teams, Lean processes and continuous improvement.

The researcher's day book was a very effective method which allowed the collection of qualitative observations about feelings, emotions and attitudes, which surrounded the research process. These were important during the group panel interviews where simple transcription would have missed innuendo and sarcasm etc. The day book also allowed the researcher to collect data whist walking the facilities and make observations about Human Factors within the workplace. As an expert in Human Factors investigation, a lot of data was collected in this manner.

The use of secondary data and access to company archives, including statutory records of risk registers and the MEM's database was a major advantage and strength of this study. The addition, this aspect of research allowed the findings of this study to be compared with another source of system and human factor assessment. Whilst the MEMS and MEDA methods are standard software that does not have the true level of depth and meaning of this study, it did offer a second perspective on the socio-technical system as a secondary check to ensure reliability and validity of the research results. The researcher benefited from many informal interviews that supported the formal process of interviewing. Whilst at the sites many managers, who were concerned about their role, had questions following the questionnaire and panel group stages and these interviews offered new insights into the culture, diversity and collective mental model of managers and the stresses they were experiencing within the organisation.

The selection of four sites also proved to be an advantage in meeting the needs of a robust case-based study in that it fitted the design criteria of Eisenhardt (1989, 1991) and Leonard-Barton (1992). The amount of data that the four sites generated was, it has to be acknowledged, enormous and required extensive treatment with qualitative methods of data analysis (Miles and Huberman, 1994).

The researcher benefited greatly from interaction, via structured interviews with industry experts at the beginning of this study. These experts included nuclear safety investigators, aviation expert assessors (CAP regulation 716 assessors), rail industry accident experts and 'world leading' academics in the fields of human psychology and operations management (Dr. Simon Banbury, Lean Enterprise Research Centre Staff, Cardiff Business School).

In any type of research design a trade-off will always exist between theory and practical considerations, this has been accepted in terms of limiting conditions. However, from a theoretical perspective the researcher claims that given a greater amount of time and access to the organisation he would have made the research more robust by increasing the actual numbers of focus group sessions as a means of testing the questionnaire model derived from the quantitative phase of the research design with more rigour. In addition, a different selection of the exact type of case study strategy to be deployed could have provided alternative courses of action as a means of including, amongst others, grounded theory. At the time of writing this approach was deemed as inappropriate because of ethical issues when aligning ethnographic research with certain questions and outcomes that relate to the uniqueness of this study in particular. In other words the researcher considered such issues impractical to manage owing to the economic and political tensions, which exist between the trade union and local management teams.

Given the opportunity to repeat the study in the future, funding permitting, it could have included an additional choice of global case studies such as other repair facilities of Canada, Singapore and the United States of America. Therefore from a latent error perspective, no reference to the quality of design processes was made, which, on reflection, could have impacted on several latent error conditions referred to earlier as slips, lapses and mistakes. This area of research often referred to as 'concurrent engineering' was not of interest to this study as the older engine designs of more than 15 years would not have benefited from such cross-functional approaches. Although this is not to suggest that this approach could not have been considered based on the Trent family of engines, which, since the start of this study, have already been, in some cases, on their second cycle of repair. The researcher therefore proposes that there are few differences between old and new designs and that a second study could focus on concurrent engineering practice and not the design effectiveness of what the industry refer to as 'legacy' types of aero engine repair. Further more the supplier network was not examined, which again is thought be of an influencing factor, but was considered à process that was outside the scope of case study and therefore did not form part of the socio-technical system design.

Finally the researcher could not ignore important constraints imposed on to this study in the form of the official secrets act 1971 and the restrictions imposed as a direct result of the terrorist attacks 9/11 in the USA. In other words the practice of knowledge sharing across global sectors is often limited by non-disclosure agreements, which are typically enforced by United States Government in terms of export and control of information from one country to the next. This has impacted to a large extent on the transfer of knowledge that has typically affected the way that training across repair and maintenance operations can be carried out. For example in the UK those organisations wishing to trade with the United States of America, and in some circumstances any person anywhere in the world, are now required to register their activities with the DTI export control authorities. This includes restriction of knowledge transfer relating to any one or the following shown in the listed below.

1. Marketing and sales
2. Basic operations, maintenance and training
3. Repair procedures
4. Design, manufacture and production
5. Software
6. Any service that could be considered in the possible use of defence.

Overall, the research strategy and design proved to be very robust in a field of study where positivistic methods had dominated what little studies existed. The methods mark a contribution. They go well beyond the Microsystems view of human factors authors since 1990 and obscure definitions of TQM authors, to engage with case study informants that blended qualitative and quantitative methods as well as limited ethnographic dimensions of the operations management and socio-technical systems designs at the case study companies. Such an approach is unique to this type of human factors study and represents a small closing of a gap where new structures of investigation are needed to really identify the key factors that influence teams in aero repair settings. In this way the methods defended here form a solid, legitimate and valid source of robust data and a strong theoretical foundation when generalising between systems.

7.3 Generalisation of the Study Findings and Model

The benefit of a doctoral research programme of this nature, one that deals with a real problem-driven management issue and seeks as an outcome to inform better management practice, is to speculate beyond the cases involved with this study and to generalise the findings. Generalising from case based research is difficult yet the design of this research has involved the countermeasures suggested by Silverman (2000) and Miles and Huberman (1994) to allow such generalisations to be undertaken.

Generalising beyond these cases, it is possible to propose that businesses engaged in the same technical operating system, that of complex and low volume repair, with team structures and deployed responsibility for self-management, would conform to the same issues and management problems as detected by this study.

Miles and Huberman (1994 p 277) contend that every research investigation should be reviewed against a series of measures designed to test the 'goodness' of the research. These measures enhance the external reliability and 'replicability' of the research. The researcher has taken due care to make explicit the methods used for this investigation, to assure an objective approach, and has provided data displays to assist the reader. There has also been an attempt to provide clarity in the approach and description of the investigation in order to improve the 'reliability' and 'auditability' of the work whilst presenting the data collected in a manner that provides as much contextual sensitivity and 'authenticity' as possible.

Silverman (2000) notes that providing generalisations from case based research requires that the researcher has qualitative and quantitative research methods and employed a purposive or theoretical sampling framework to the selection of case study firms. The selection of the aero repair cases were purposive due to the likelihood that new theory would emerge following a robust study. The selection of informants was purposive only in terms of engaging with a representative number of staff grades (as stated in the research design chapter).

Miles and Huberman, citing Firestone (1993), contend that there are three forms of generalisation. These include generalisations between the sample and the population, analytical generalisations based upon a connected theory and case-to-case generalisations.

This research generalises to the full population of the corporate aero repair group and can be generalised to the entire population of military and civilian repair businesses in the UK that share a common national culture (Hofstede, 2001). The generalisation being that managers will face very similar social and technical processes in maintaining aero engines. The degree to which self-managed teams are engaged will differ but the main issues discovered by this research will hold true. Analytical generalisations are founded upon this similarity of operations management system; the sectors that could be the targets of generalisation include repairs of marine engines (civilian and military), energy generation, and nuclear submarines. Going further, other high variety, low volume and highly skilled operations settings (with large consequences for poor human factor management) could include any safety critical operation system that faces commercial pressure and is reliant upon human intervention to ensure material flow. These settings could include the healthcare management system and patient flow where expert knowledge is used in a decentralised form to supply a patient journey. Many recent authors in the field of Healthcare have identified rifts between managers, clinicians and the safe flow of patients suggesting synergy between this study and that of healthcare socio technical systems (Powell et al, 2009).

7.4 Implications for Professional Practice of Management

As far as generalisations from case studies permit (Silvermann 2000) there are a number of implications for professional managers and these will now be explored.

It is at this point in the research process that numerous gaps in the system, which are responsible for the failure of self-management, in terms of inappropriate system designs, have been identified. The researcher therefore argues that a culture of excellence thinking, within the context of TQM, is not an all-encompassing approach for self-management to take place. Moreover he draws attention to the limitations of the 'one size fits all' and considers the writings of Hofestede (2001) who argued that theoretical transportation of social systems cannot be easily applied from one industry setting to the next.

For this reason attention is drawn to the dangers of theoretical transportation, which, in the case of this study, resulted in the unknowing introduction of a number of underlying problems, this occurred as early as 1998. For example it was the executives' belief, during this period, that self-managed teams could readily support changes in customer demand, based on the corporate statement, which claimed: *"There are sufficient examples of successful team based working both within the USA and Japan to confirm that it contributes in a very meaningful way to business improvement"*. Emulation of innovations that have come from different cultures appear to be simple modifications to the existing socio-technical system, but the researcher argues this 'theoretical transplantation' approach is an unsubstantiated claim.

At this point in time it was discovered that in fact no prior research was used to substantiate this claim and that the above statement was based entirely on assumption, with no supporting evidence. In addition the researcher also draws attention to a major theoretical contradiction that exists between the philosophy of self-management and Lean operations management models claiming they are not naturally aligned and moreover, one is actually in contradiction with the other. For example the more prescriptive Lean becomes the less choice an individual has over his or her autonomy at work and unless these differences, at the very least, are understood self-managed teams can easily become a major source of non-quality. In other words business environments such as the one found in this study, which are high in product variation can opt for the model of self-management, but should be aware of their unique entities that cannot be managed in the same way as new production thinking.

The researcher cautions against transportation and accepts the advice given by West (2004) who argued that prior to any form of system redesign a measure and assessment of the existing organisational culture should always take place. In light of

this consideration the fact is underlined that Aero Repair & Overhaul did not carry out any form of cultural assessment and instead adopted a 'big bang' approach to change described by Peters (1993) in terms of: *"Change radically and do it quickly"*
The lessons learnt position therefore implies that big bang models are often too simplistic when organisational change is both complex and part of a continuous and open-ended process. It unsettles the socio-technical system and its complex interaction/relationship and the roles of the stakeholders (staff, shop floor and management), thereby creating role ambiguity and confusion which results in poor material flow and an unstable working environment – these contribute to the breeches of human factors and system defences.

By radically transforming a system, variation in processes is increased, roles become unclear and system/material flow co-ordination becomes more difficult. Therefore the response is to clarify roles and demarcate between employees. If left to evolve, this situation will manifest itself in mechanistic and dysfunctional ways of working. This confirms the work of Reason and summarises the state of the case businesses at the beginning of this study. The implications for the practice of management is to understand the complex weave of relationships that are being manipulated when redesigning the socio-technical system for autonomous working and to allow this deployment of responsibility to self managed teams to evolve in a paced and controlled manner – an anti 'big bang' theory. Such an approach is rarely taught at business schools and neither are the contingencies of each workplace. Again – as stated on the very first page of this thesis – the teaching of how best to design low volume and high variety workplaces is not taught. Indeed authors such as Hill (1987) have retreated from this area and have not explored, in detail, the contingencies of designing structures for such low volume/high variety workplaces. As such they have ignored the human factors that underpin the performance of any system especially repair and overhaul (Slack et al, 2008).

From a practical provision of advice it is important for professional managers to understand the limitations of human factors which are defined by the quality and design of material flow systems (and the capability of processes/people requirements). Managers need to understand the real demand affecting any system because if they do not understand and control demand then erratic demand will induce system variation as teams and material flows will become confused. Such confusion leads to error and is a design and latent error as defined by Reason – a management failing.

Managers, facing the variety of aero repair services with many shared resources and complex irregular flows of work, must understand the structures and methods (as well as technology) in order to be successful. This is a contingent approach to the design of a facility and its social engagement. Here the researcher argues that scientific methods are not all bad although the negative image is portrayed in operations management and TQM literatures and for safety critical processes, it is believed that it is necessary to add duplication of tasks, functional specialisms and to divorce production from inspection. This line of thinking supports Reason's human factor view of preventing risks of human error and poor operations designs with latent risks beyond the control of the autonomous team.

This study indicates that there are many psychological design issues available to support the visual management of the workplace in such a way that colours and simple indicators show when a process or material flow performance is performing to a predefined and acceptable standard. These methods also trigger reaction when the visual indicator shows that abnormal conditions are encountered. It is important that managers understand these mechanisms and design dynamic control measures that allow the team to react to indicators that show (as a warning) system variation and a tendency to the important loss of material flow control. Managers cannot abdicate this design responsibility and must ensure that robust processes are monitored using policing mechanisms to ensure that the variation does not destabilise the operations system. They must concentrate on stabilising material flow.

Managers should also be aware of the constraints of any business and how change impacts on the business over time. It should not be seen as a management weakness to move from a mechanistic structure to an organic one and back again as the wider environment and commercial pressures dictate. The answer to optimal material flow is less to do with the tools of TQM and more to do with the balance and equilibrium of the socio-technical system in delivering materials in a stable manner.

7.15 Implications for Teaching

The contribution of this study to the teaching of operations management at universities is another important area. It shows that, in the field of human factors, the dynamics of workplaces and science of human factors must be understood by students. The subject is not a unified discipline and therefore it is important for students to understand the different approaches. Teaching should reinforce the contingencies needed to make effective socio-technical systems and therefore the researcher argues that such teaching should be conducted by case study. Students should be able to appreciate the differences in work context (especially low volume and high variety) where operations management designs are critically important. This approach to teaching could involve work placement, visits or traditional study of cases in classrooms. The scope and importance of this subject is not easily transferred to students in the form a lecture.

The teaching of Lean ways of working, from a variety of perspectives, from human resources to operations management, should promote the concepts of people integration and processes of system-induced error (regardless of the process). According to the researcher, it is important that the soft elements of a production system design are balanced and integrated with harder technology. Much of the HR literature favors the self-managed team but stops far short of the practicalities of managing such a structure. Lectures fail to express the complexity of team design and choices for managers in optimizing their work flow. For high variety and highly skilled operations, it is important to teach the problems for individuals and for businesses when the values of a profession (such as engineering) are compromised or changed by de-skilling or deployment to teams. Also multi-skilling and the effects of going the other way to de-skilling also has implications for the individual and the time they need to get back to effective ways of working. In the experience of the researcher this is rarely covered at an undergraduate or masters level- to the detriment of students striving towards becoming better systems thinkers.

A final implication of this study is the 'positive spin' promoted by lecturers as they teach TQM in a biased way. Much teaching is positive and ignores the impact on the individual even though the most frequent source of human error is from employees failing to sustain the system. TQM can be as demotivational through use of routines/standards and de-skilling of knowledge and reduction in creative skills. Up-skilling of the workforce by de-skilling the qualified can be as concerning to those gaining the skills as much as those who are losing them. This aspect of knowledge transfer is poorly explained in the textbooks and lectures for management students. This study shows that these issues are at the very heart of what makes a successful and sustainable system of TQM, i.e. continuous improvement and a learning environment. Failure to appreciate the design of a system therefore aggravates employees and creates latent system failures, which further thwarts material flow. A balanced approach to TQM teaching is therefore recommended.

7.6 Future Research Directions

With these restrictions in mind it has not been difficult to understand the complexity of implementing 'open systems thinking' when numerous assumptions and attempts to manage change have all been carried out in isolation from the manner in which engineers are legally permitted to work. These disadvantages have therefore reflected a general lack of individual accountability where entire teams of engineers no longer carry out single tasks, but are expected to be multi skilled conforming to the 'group think'. The responsibility has therefore shifted from the individual, to that of the 'team' this, in part, has created role confusion surrounding 'who does what' within the less defined responsibility of the entire team. In acceptance of this position the researcher has therefore presented a problem driven solution to address this gap, but has not been able to provide definitive answers to specific human factors solutions. The implications of which suggest a greater need for more detailed and localised research that will help provide a series of platforms whereby the greater understanding of human factors programmes can be more efficiently and effectively applied. So when examining other and more similar types of industry as to the effects of those conditions found in this study it will be necessary to proceed with caution as to who and what information can be involved. In light of the known limitations surrounding disclosure 'by any means' the researcher has therefore included the possibility of knowledge sharing to include the need for more research studies that extend beyond the scope of this project to include:

1 Case study research across other UK or US aero repair & overhaul sites that include a larger sample size. This study would therefore address the issue of national and company cultural bias towards human factor management. These businesses operate under the same regulations with similar technology and therefore differences in the two populations would be culturally embedded. This study may also detect differences in the understanding of what is TQM (an extension of Hofstede's 2001 seminal study).
2 Carry out comparative studies across other plc business sites to include the resultant model against established error provoking trends to-date. Such a study would detect, under the same company policies and conditions, differences in market groups within the same company. These other groups would allow the researcher to test for contingencies that are product and customer specific and to find patterns that match with this study.
3 Compare established trends with other case studies using the resultant model against other similar repair engineering business. This study would include businesses that make other repairable structures such as fuel tanks for planes, helicopter rotor boxes, field guns, ships, tanks etc and the intention is to identify the common issues from a socio-technical system design. The researcher would also expand the enabler and inhibitor analysis to see if differences in management perception or business structure (not team working) generates better performance than that found in this study.

Based on the need to satisfy objective number three, the researcher is already able to satisfy the question put forward by Kearney (2002) who claimed that 80% of all total quality programmes had not been able to demonstrate any form of statistical assessment. The findings from this study can therefore be used to address this position in terms of bridging the gap between theory and practice, within this under researched and yet critical area of human factors engineering. This is not to suggest self-managed team working has reached its natural level of maturity, or that supervised team working lacks the ability to become self-managing, but moreover it is the current lack of focus for what is meant by self-management, within the context of any given socio-technical system. For example the corporate strategy for the implementation of TQM is based on the principles of new manufacturing where most, if not all, variation can be removed through the application of Six Sigma and Lean. Whilst the researcher promotes the same tools and techniques of new production, the fact remains that human error will always emerge and therefore in practice must require a more pragmatic approach in how best to manage the middle ground in terms of open as well as closed-loop systems. This was a dichotomy that Seddon (2000) argued against in terms of their diametrically opposed position, which he claimed would always fail to co-exist.

As a result of the findings from this study in which the 'middle ground' is favoured, some obvious contradictions, which have led to some undesirable actions cannot be ignored, thereby confirming the need for wider schools of human factors research, based on the following list of topics shown below.

1. Studies that measure leadership commitment to self-management for TQM
2. Studies that measure the financial benefits of self-management & TQM
3. Studies that measure organisational cultures for their compatibility with TQM.

By researching these types of questions, programmes such as the one presented in this study can be used to reinforce a number of legally required benefits that should also encourage good practices in relation to application of EASA part -145. These actions are mutually supportive, for example more information on financial benefits should increase leadership commitment to review industry experience in all aspects of maintenance, with a view to encouraging or mandating the same type of scientific research. The results could then be extended throughout the entire plc organisation to include, Defence, Energy, Marine and Nuclear business groups. In the short term it will be necessary for industry to decide how best to standardise, as far as possible, this approach, which the researcher has already started to simplify in terms of both macro and micro models alike. The presentation of which included the resultant model from a macro perspective followed by a micro visual control system. The combination and application of these two systems will help to reduce the problems of overproduction associated with rule-based errors, which are highly important to control and yet reasonably easy to resolve.

Following the completion of this thesis, a number of conferences and publications have been targeted for the dissemination of this work and its findings/new models. These include the IOSH Annual Conference (specialist branch and area branch) for aviation related safety/quality. The work will also be submitted to conferences in the patient safety arena where common management models (Lean and TQM) are being implemented. The work will also be submitted for publication in the form of peer-reviewed papers at the International Institute of Risk and Safety Management Journal (HSW) and practical journals IOSH (SHP) Safety and Health Practitioner Journal. It is also the intention of the researcher to publish a book that promotes the model that has resulted from this research.

7.7 Chapter Summary

The findings taken from this study were found to be broadly in line with other similar forms of research carried out in the field of front line operations. While it has demonstrated a number of unique areas of research criteria the root cause of many chronic and long-term quality issues were similar to those outside of the aviation industry where commercial pressure is seen as the main limitations in terms of the ability of self-managed teams to facilitate the principles of TQM. During the creation of the earlier chapters the researcher has drawn attention to the importance of identifying with the correct selection of methodological approach that would be best placed to measure specific types of quality / safety related problems. In other words this study has provided a different level of understanding based on inputs (before the event) as oposed to outputs driven research namley (after the event) as an early indicator in terms of how people and technology have limited their opportunities to co-exist. This was a position that Adam (1993) described as the primary objective of human factors in terms of; *"knowing what is going on so you can figure out what to do"*. In light of this statement, there is an overriding legal requirement now in place whereby organisations in Europe and the USA must commit to gaining a wider understanding of human factors risk, which, prior to the introduction of EASA in July 2004, many businesses chose to ignore.

However, this was not the case for this organisation that, in spite of its many imperfections, opted for a more pro-active approach, based on guidance taken from this study some two years before, during 2002. In many respects this study has already benefited from the resultant findings, which has already impacted on large-scale change before its completion date. These benefits have arisen in several ways and in particular the issue of team control has been addressed at both micro and macro levels of change. Firstly recognising that in order to protect the customer it was necessary to assist the existing model of self-management with the reintroduction of team leaders whose role and function is to provide the missing link in terms of support to teams at Bristol. In addition, the earlier model highlighting a need to control variation was also introduced at three different site locations, system redesigns have already been completed based on improving information and physical product flow in terms of managing a three tier system namely; strip, kit. & build. In other words major change and investment to the existing design & layout of engine overhaul locations has started to take place, they have seen a transformation to what the researcher refers to as the 'middle ground'. These changes have demonstrated deliverable benefits in the form of dramatically reduced lead-times within the Fast Jet centre at Ansty where order and conformity has also resulted in less system variation, this is now considered the norm in terms of a repair & overhaul. Following on from this model, other fast Jet support contracts are being won, this includes partnership agreements between Defence Aerospace at Bristol and the RAF, also the Royal Navy, to repair and overhaul Harrier jump-jet engines. The finicial benefits of which form a new £198m contract to support the aircraft's Pegasus engine over the next ten years. According to Group Captain Andy Ebdon;

"This contract to Rolls-Royce for complete through-life support of Pegasus is a very significant achievement. It not only assures affordable engine availability, but also incentivises both industry and the MOD to actively work together to improve efficiency. The end effect is better value for money and improved support performance for the front line"

Finally the researcher contends that, for those organisations in which human factors programmes are not yet discovered it is important to state that good operational performance management is wholly dependant on the quality of socio-technical system designs. Only when each business group has engaged with the critical mass of the entire organisation can the real benefits of TQM begin. The journey is open-ended and begins with education as a means of engendering sustainable change to working, both differently and in a more effective way. The consequence of ignoring this position will ultimately lead to an environment of human fallibility, where imperfect conditions, without proper regard for systemic issues, as history has shown, will lead to poor customer satisfaction, lack of human factors awareness and ultimately the loss of human life.

This concludes the final chapter of this very long and arduous journey from a motivated ambition to learn more about human factors engineering to the resultant contribution and model that has been generated by this study. It is hoped that this doctoral study will be of use to future researchers who seek to make a difference to the professional management of 'non traditional' operations management businesses. The significance of these contributions cannot ever be underestimated in terms of the quality of working life and the protection of human life.

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Appendices

Appendix 1

National Transportation Safety Board Accident Summaries.

Boeing 737-200, en route from Hilo, to Honolulu, Hawaii, 28 April 1988.
Explosive decompression, loss of cabin crown, due to undetected cracking.
Aloha Aircraft Accident Report 89/03

Boeing 747-122, en route Los Angeles to Sydney, Australia, 24 February 1989.
Loss of cargo door.
Aircraft Accident Report 90/01

DC-9-33F, Carswell Air Force Base (AFB), Fort Worth, Texas, 18 March 1989.
Loss of control after cargo door opened in flight.
Aircraft Accident Report 90/02

DC-10-10, Sioux Gateway Airport, Iowa, 19 July 1989.
Crash landing after engine burst and loss of all hydraulics. Undetected rotor crack.
Aircraft Accident Report 90/06

Embraer 120, near Eagle Lake, Texas, 11 September 1991.
Aircraft broke up after stabiliser leading edge separated in flight.
Aircraft Accident Report 92/04

B747, Narita, Japan, 1 March 1994.
No. 1 pylon failed on landing. Improper maintenance.
Aircraft Accident Report 94/02

Learjet 35A, Fresno, California, 14 December 1994.
In flight fire due to improper electrical installation.
Aircraft Accident Report 95/04

Douglas DC-9-32, Atlanta International Airport, Atlanta, Georgia, 8 June 1995.
Engine burst due to undetected cracks.
Aircraft Accident Report 96/03

Embraer EMB-120RT, near Carrollton, Georgia, 21 August 1995.
Propeller blade separation due to inadequate maintenance.
Aircraft Accident Report 96/0

Appendix 2

Questionnaire & Administration

Dear Colleague,

This questionnaire has been designed for use within AR&O to measure the 'safety health' of our businesses and to highlight potential problem areas within the organisation. The AR&O executive team have commissioned this survey as part of our human factors safety campaign, and we are very keen to hear your views. Your input will provide useful feedback as to where the problems (if any) lie. The results will analysed and the findings will be shared, so that we can start to develop joint solutions.
This questionnaire is anonymous so please answer the following questions as honestly as you can.
To help us gain the most from the results please also complete the following page, which provides information on the nature of your job and your experience. If you are in a job where you think you can be identified from this data, then just fill in those parts that you are happy with.
Please complete the questionnaires on your own, without discussing your answers with colleagues. It is your view and experience, which are important. Please return the completed questionnaire to the nominated person within one week of issue.
The questionnaires will take about 20 minutes to complete.
The results will all be analysed and you will be given feedback on the outcomes.

Thank you for your assistance.

David Price

Job details

Date

Location:

Your Job: Tick all those which apply

Description of Job

The number of years you have worked in aviation maintenance engineering

The number of years with Rolls-Royce

The number of years in your current job/position, or with current responsibilities

The shifts you work:

- Permanent days
- Permanent nights
- Rotating shifts

Approx number of hours you work in typical week

- <40
- 40-50
- 50-60
- 60-70

Please indicate in the appropriate box the extent to which you agree or disagree with the following statements	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Management, works and staff communicate well with each other					
Managers always let us know of important safety findings					
I am always properly briefed by those giving me a job					
Before I start a job I'm always given the necessary information					
I am fully aware of the contents of the Company's safety policy					
I know exactly what I am expected to do and my responsibilities					
I know those parts of my job where I can be held accountable					
I sometimes think my colleagues are confused over their exact roles and responsibilities					
There is often confusion between departments over exact roles and responsibilities					
The procedures we use are accurate & complete					
The company provides us with all the information to work effectively					
The procedures we use are clear and easy to understand					
We can easily identify where procedures have been revised					
The procedures we use are practical and easy to understand					
The procedures we use always adopt 'best practice'					
We have a good system for reporting problems with SAP maintenance data and documentation					
We have a good system for fixing problems with SAP maintenance data and documentation					
We have systems in place to ensure that all the resources specified in the procedures are readily available					
We often have to rush jobs due to staff shortages					
Jobs are often delayed due to vital equipment being missing or in the wrong place					
I am often not given enough time to do the job					
We usually manage to complete a job despite the non-availability of the specified equipment/tools					
Jobs are often delayed due to a shortage of spares					
Engines/modules/components are sometimes released even if some work can't be done due to parts shortages					
Some deadlines are unrealistic					
We often have to rush jobs due to unrealistic deadlines					
There was pressure placed upon me to work additional hours when I felt that I was not at my best					
There were conflicting commercial & safety demands					
People who are prepared to cut corners seem to always get promoted					
I accept that changes to my job are necessary from time to time					
I am always willing to change the way I work to fit in with the Company requirements					
The training I receive is appropriate for the job I do					
Appropriate refresher, or continuation, training is regularly provided					
I am confident that I have the necessary experience/qualifications					

Please indicate in the appropriate box the extent to which you agree or disagree with the following statements	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
I am confident that all my colleagues understand the hazards & risks associated with maintaining engines/modules/components					
I have a good knowledge of maintenance rules & procedures					
I would be confident flying in an aircraft fitted with engines on which my colleagues had worked on after engine/component overhaul					
I am confident our managers have the necessary experience/qualifications for the work they do					
I sometimes go to work when I am ill or feel less than 100%					
During the last month I have made an error in my work due to tiredness					
During the last month some of my colleagues have made errors in their work due to tiredness					
I often have to work long hours or a large amount of overtime					
My job can sometimes be physically tiring					
My working conditions often make it difficult for me to do my work properly					
Some tools could be better designed					
The engines/modules/components could be better designed to allow for easier repair and overhaul					
Anyone who makes an error deserves to be disciplined					
My colleagues fully understand the implications of their actions on airworthiness and aviation safety					
All the people I work with are very safety conscious					
People don't care about the job anymore - they just do it for the money					
It is the responsibility of the inspector to check that no one has made any errors - that's what he's paid for					
I find my work boring and unsatisfying					
It doesn't really matter if I make the odd mistake as my work is always checked					
Some procedures are often not fully followed by some people					
Some procedures are only there to protect management's back					
The real risks from us making mistakes are quite small					
My colleagues often do not follow some procedures					
I experience some pressure from my workmates to do things differently to the procedures					
Management regularly demonstrate their strong commitment to safety					
All my colleagues think management are strongly committed to safety					
We never see anyone in management where I work					
The management have no idea of what really goes on					
Management are happy to discuss any of our concerns					
My immediate boss sometimes pressures me not to follow maintenance procedures					
My immediate boss would approve of my actions if I did not follow procedures in order to get an engine/module/component away					