HSE

Health and Safety Executive

High reliability organisations

A review of the literature

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HSE

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High reliability organisations

A review of the literature

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A number of major hazard organisations have been attempting to influence the organisational and safety culture at their sites to transform them into a high reliability organisation (ie organisations that are able to manage and sustain almost error-free performance despite operating in hazardous conditions where the consequences of errors could be catastrophic) with a positive safety culture. In recent years there has been a huge increase in the literature talking about the control of major hazard risks, in particular the philosophies of high reliability organisations, resilience management and safety culture. These works identify key features and characteristics that need to be adopted by organisations to achieve ongoing high reliability and safety objectives.

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HSE Books

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EXECUTIVE SUMMARY

Background

A number of major hazard organisations have been attempting to influence the organisational and safety culture at their sites to transform them into a high reliability organisation (i.e. organisations that are able to manage and sustain almost error-free performance despite operating in hazardous conditions where the consequences of errors could be catastrophic) with a positive safety culture. In recent years there has been a huge increase in the literature talking about the control of major hazard risks, in particular the philosophies of high reliability organisations, resilience management and safety culture. These works identify key features and characteristics that need to be adopted by organisations to achieve ongoing high reliability and safety objectives.

Objectives

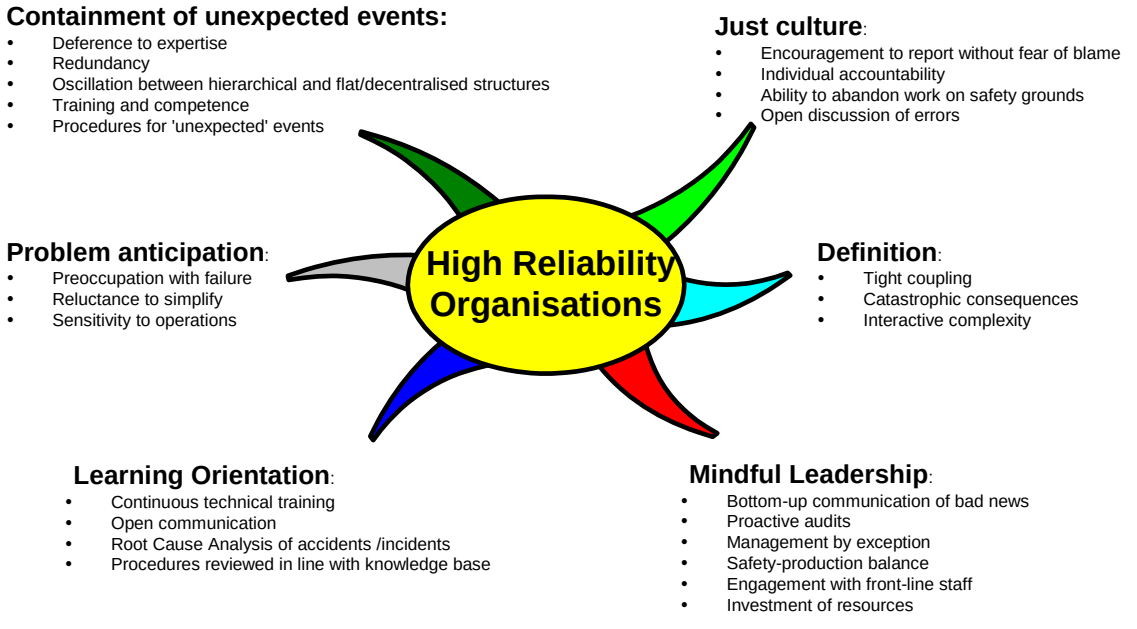
The overall aim of this work is to carry out a review of the literature on high reliability organisations in order to identify the characteristics and processes that account for these organisations' high safety and reliability levels.

The objectives of the work are as follows:

- Review documents to identify the key characteristics of high reliability organisations for the management of major accident risks,
- From these high level documents develop descriptions of the key facets, and
- Critically evaluate research findings on high reliability organisations.

Main Findings

Key peer-reviewed papers were identified that discussed the processes and practices that are in place in high reliability organisations. The majority of empirical papers on high reliability organisations (HROs) employ a qualitative, case-study approach offering rich descriptions of the types of processes that are in place in these organisations. The many descriptions regarding HROs and their associated processes and characteristics, were summarised in a mind map in order to capture the common issues that emerged in the literature.



The mind map used Weick and Sutcliffe's (2007) work on HROs as an overarching, organising framework.

In particular, the following facets and processes were characteristic of high reliability organisations:

- Description of HROs as organisations where failure may have far-reaching, potentially catastrophic consequences. Such organisations will be typically characterised by:
    - Interactive complexity i.e. interaction among system components is unpredictable and/or invisible, and
    - Tight coupling (i.e. high degree of interdependence among a system's components including people, equipment and procedures).

- **Successful containment of unexpected events** by:
    - Having in place back-up systems in the event of failures and cross-checking of important decisions *(redundancy)*,
    - Allowing people with expertise, irrespective of rank, to make important safety-related decisions in emergencies, whilst during routine operations there is a clear hierarchical structure and an understanding of who is responsible for what *(deference to expertise in emergencies; oscillation between hierarchical and flat organisational structures)*, investment in training and technical competence, and
    - Well-defined procedures for all possible unexpected events.

- **Effective anticipation of potential failures** through:
    - Engagement with front line staff in order to obtain 'the bigger picture' of operations *(sensitivity to operations)*,
    - Attentiveness to minor or what may appear as trivial signals that may indicate potential problem areas within the organisation and use incidents and near misses as indicators of a system's 'health' *(preoccupation with failure)*,
    - Systematic collection and analysis of all warning signals, no matter how trivial they may appear to be, and avoid making assumptions regarding the nature of failures. Explanations regarding the causes of incidents tend to be systemic rather than focusing on individual, 'blame the operator' justifications *(reluctance to simplify)*.

- **Just culture** characterised by:
    - Open reporting systems for near misses and accidents without fear of punishment,
    - Follow-up of accident investigation outcomes by implementing corrective actions,
    - Empowering staff to abandon work on safety grounds, and
    - Fostering a sense of personal accountability for safety.

- **Learning orientation** characterised by:
    - Continuous technical training,
    - Systematic analysis of incidents to identify their root causes and accident types or trends within the organisation,
    - Open communication of accident investigation outcomes, and
    - Updating procedures in line with the organisational knowledge base.

- **Mindful leadership** characterised by:
    - Proactive commissions of audits to identify problems in the system (often in response to incidents that occur in other similar industries),
    - 'Bottom-up' communication of 'bad news',
    - Engagement with front line staff through site visits,
    - Investment of resources in safety management and the ability to balance profits with safety.

In addition to peer-reviewed papers, regulatory documents were included in the review either because they specifically referred to HROs or because their recommendations overlapped with processes that are considered to contribute to high levels of reliability. Although recommendations in these documents appeared to be informed by relevant literature, some important key HRO features were omitted, such as those capturing HROs' resilience and ability to cope effectively with errors.

Finally, the findings were presented in the context of some limitations of HRO research. These limitations centre on the following issues:

- Limited empirical knowledge regarding the extent to which HRO processes can be meaningfully applied to more mainstream organisations and contexts,
- Lack of a comprehensive theoretical framework that would help explain why HROs succeed where other organisations fail with a particular focus on understanding the factors that facilitate the successful development of HRO processes,
- Limited understanding of the effects of HRO work environments on individuals and the implications of such potential effects for more 'traditional', mainstream organisations,
- Limited evidence regarding the predictive validity of HRO-based quantitative measures in terms of safety performance or other relevant indicators.

Conclusion

Overall, the review has shown that although there are rich descriptions and understandings of HRO processes, these tend to be confined to very specific contexts and, consequently, knowledge of their applicability and/or feasibility in more mainstream organisational contexts is limited. As it has been argued, it is unlikely that HRO processes can simply be 'lifted off' from one context and be applied into another without consideration of broader issues pertaining to, but not limited to, the nature of work and working conditions. Equally important, however, is the extent to which the implementation of HRO processes makes financial sense for mainstream organisations whereby the consequences of error will typically not be as far-reaching (in terms of damage to the environment and/or potentially fatal injuries to people, although losses in terms of an organisation's reputation or credibility may be substantial). Further, empirical findings on HROs tend to be largely descriptive in so far as they do not appear to be organised within a broader theoretical framework. Such a framework could facilitate the applicability of these processes in other organisational contexts. In a sense, HROs may be regarded as 'ideal' organisations whereby they manage to develop and maintain certain features, such as fair and equitable cultures, that are challenging for most organisations. A theoretical framework would help explain the factors that facilitate the development of these processes, which could subsequently be considered in other contexts. Finally, a better understanding is needed on the psychological effects of HRO work environments on individuals as well as the links between HRO processes and safety performance so that the benefits of implementing HRO processes in mainstream organisations can be more comprehensively considered.

1 INTRODUCTION

1.1 BACKGROUND

A number of major hazard organisations have been attempting to influence the organisational and safety culture at their sites to transform them into a high reliability organisation (i.e. organisations that are able to manage and sustain almost error-free performance despite operating in hazardous conditions where the consequences of errors could be catastrophic), with a positive safety culture. In recent years there has been a huge increase in the literature talking about the control of major hazard risks, in particular the philosophies of high reliability organisations, resilience management and safety culture. These works identify key features and characteristics that need to be adopted by organisations to achieve ongoing high reliability and safety objectives.

1.2 AIMS

The overall aim of this work is to carry out a review of the literature on high reliability organisations in order to identify the characteristics and processes that account for these organisations' high safety and reliability levels.

The objectives of the work are as follows:

- Review documents to identify the key characteristics of high reliability organisations for the management of major accident risks,
- From these high level documents develop descriptions of the key facets, and
- Critically evaluate research findings on high reliability organisations.

2 METHOD

The scope of this narrative literature review was to identify key peer-reviewed papers in the area of high reliability organisations (HROs) by focusing on seminal as well as most recent research papers in the area, with the aim of providing a synthesis and a critique of the literature (Cronin, Ryan and Coughlan, 2008).

2.1 IDENTIFICATION OF PAPERS

A search of online databases was carried out in order to identify peer-reviewed journal papers of relevance for inclusion. Four electronic databases were: PsycInfo, Web of Science, Science Direct and Google Scholar. Search terms that were used included high reliability, high reliability organisations, resilient performance, resilience engineering and error-free performance. Broad search terms were used in order to ensure that relevant material was not excluded. The search was limited to papers published in English from 1990 to 2010. More specific searches were also carried out in order to identify articles by leading authors in the area. Searches were also carried out within specific academic journals (e.g. Safety Science, Organization Science) in order to identify any relevant papers in press or recently available. Finally, another search strategy that was used involved checking the reference lists of relevant papers in order to identify further key materials.

2.2 SELECTION CRITERIA

Papers were deemed appropriate for inclusion if they focused primarily on the topic of HROs and were published in peer-reviewed journals. Both theoretical/discussion and empirical papers were included as well as book chapters that explicitly focused on HROs. In addition, a small number of regulatory documents that made references to HROs or related concepts were also included.

A total of 37 relevant papers and book chapters were included in the literature review.

3 FINDINGS

The review of the literature on high reliability organisations (HROs) is split into six sections. The first section discusses the two prominent approaches to understanding accidents in complex systems, namely Normal Accident Theory (NAT) and High Reliability Organisation Theory (HROT), followed by a discussion of the difficulty in defining and identifying a HRO. The third section provides an overview of key articles that have explored the characteristics and practices of HROs followed by a discussion of quantitative attempts to capture and measure HRO characteristics. The review then discusses research that has applied or 'exported' HRO principles in other contexts and most prominently in healthcare, and summarises regulatory recommendations to enable organisations to work towards becoming a HRO.

The final sections of this report summarise and organise the plethora of HRO characteristics and processes into a mind map, followed by some critical reflections and concluding remarks on the evidence and research on HROs.

It should be mentioned that references to 'safety' and/or 'safety performance' throughout this report refer to process safety rather than to occupational health and safety. Process safety can be defined as a blend of engineering and management skills focused on preventing catastrophic accidents, particularly explosions, fires and toxic releases associated with the use of chemicals and petroleum products (Centre for Chemical Process Safety, 2010).

3.1 ACCIDENTS IN COMPLEX SYSTEMS

There are two prominent schools of thought that seek to explain accidents in complex, high hazard organisations: Normal Accident Theory (NAT) and High Reliability Organisation Theory (HROT).

Normal accident theory was developed by Charles Perrow (1984) and its main premise is that accidents are inevitable in complex organisations that operate high-risk technologies. In particular, Perrow (1984) argued that there are certain defining characteristics, which make the occurrence of accidents in complex, high hazard organisations inevitable. These features were defined as tight coupling and interactive complexity. Coupling refers to the degree of interdependence among a system's components (e.g. people, equipment, procedures), whilst interactive complexity refers to the extent to which the interactions among the system's components are unpredictable and/or invisible (Perrow, 1984). For instance, tightly coupled systems are often highly automated ones whereby the timing of tasks is such that does not allow for human intervention (Hopkins, 1999). Perrow (1984) identifies as high-risk those organisations that operate systems, which are very complex and can interact in unexpected ways. Further, because tasks or processes are often interdependent, a failure that occurs in one part of the system can quickly spread to other parts of the system. The presence of these characteristics means that there is insufficient knowledge (due to the system's complexity) and time (due to the tight coupling of tasks) to fully understand, intervene and contain potential failures (Perrow, 1984). Drawing on the characteristics of tight coupling and interactive complexity, Perrow (1984) further classified systems such as nuclear weapons, aircrafts and military systems as 'high risk' whereas manufacturing plants, including oil refineries and chemical plants, were classified in the 'lower risk' categories.

Although NAT has advanced our understanding of organisational or system characteristics that increase the likelihood of catastrophic errors, it has also received several criticisms. For instance, Leveson, Dulac, Marais, and Caroll (2009) argued that Perrow's classification of industries in 'high risk' and 'low risk' groups does not accurately reflect the accident rates

experienced in these industries. Specifically, nuclear weapons (which are classified as a 'high risk' system) have lower accident rates compared to manufacturing plants (which are classified as a 'low risk' system), which is contrary to NAT's predictions (Leveson et al., 2009). Possible explanations offered for these inconsistent predictions is that Perrow's classification system fails to accurately capture and differentiate between the design features of systems in these industries (Leveson et al., 2009) and that it ignores the conditions whereby complex systems do not fail (Weick et al., 1999). Further, Hopkins (1999) argues that the central concepts of NAT, namely coupling and complexity, are poorly defined and the theory itself can only explain a small number of accidents because it applies to very specific types of organisations (i.e. those that are tightly coupled and interactively complex). In addition, the theory provides a pessimistic view regarding accidents in complex systems and fails to offer suggestions as to how the risk of accidents may be reduced (Hopkins, 1999).

This latter criticism is addressed by HROT, which focuses on understanding the conditions whereby complex systems do not fail and is informed by research in technologically complex organisations that are able to sustain high levels of safety performance. HRO researchers argue that accidents in complex systems are not inevitable because there are processes in place that enable high hazard organisations to effectively prevent and contain catastrophic errors helping them to achieve a consistent record of safety over long time periods (e.g. Roberts, 1990; LaPorte and Consolini, 1998). In such organisations the potential of failure has catastrophic consequences, yet these organisations *'are so effective that the probability of serious error is very low'* (LaPorte and Consolini, 1998, p. 848). HRO researchers maintain a positive view regarding the nature of accidents in complex systems by arguing that organisations can become more reliable by creating or 'engineering' a positive safety culture and reinforcing safety-related behaviours and attitudes (e.g. Weick and Roberts, 1993). This line of research has examined the characteristics of such organisations and the practices and processes that they adopt which enable them to both achieve and maintain their excellent safety performance record (these are discussed in detail in section 3.3). HRO researchers do not maintain that such organisations are error-free; rather that they are constantly preoccupied with failure such that they can anticipate areas of potential failure and can cope and bounce back from errors when they occur. Characteristics such as a strong learning orientation, prioritisation of safety over other goals, continuous training and an emphasis on checks and procedures contribute to these organisations' impeccable safety records (e.g. LaPorte and Consolini, 1998; Roberts and Bea, 2001).

The HRO perspective shares much in common with resilience engineering, which has been applied in several high-risk systems including the aviation, petrochemical and nuclear industries. Resilience is defined as *'the ability of systems to survive and return to normal operation despite challenges'* (Nemeth and Cook, 2007, p. 623). Similarly, Wreathall (2006) defined resilience as an organisation's ability to both maintain a safe mode of operation and be able to resume its operations after a mishap. The resilience engineering approach aims to promote safety in environments that are susceptible to faults, hazards and face multiple, and often competing objectives by enabling organisations to effectively prevent and recover from unexpected events (e.g. Wreathall, 2006; Nemeth and Cook, 2007; Costella, Saurin, and Guimaraes, 2009). The resilience engineering perspective offers several principles that organisations could follow to 'engineer' a safety culture and enhance their reliability. These principles are discussed in section 3.3.1 and greatly overlap with the processes that are characteristic of HROs.

Finally, HROT is not without its critics. In particular, the theory has been criticised for ignoring the broader social and environmental contexts in which HROs operate and which may limit the potential of these organisations to learn from errors. For instance, it has been argued that the political implications of errors may impact on the extent to which errors can be openly reported

and consequently affect the learning opportunities for HROs (Sagan, 1994; cited in Weick, Sutcliffe and Obstfeld, 1999).

3.2 DEFINING HIGH RELIABILITY ORGANISATIONS

There has been much debate in the literature regarding how to best identify and define a HRO. Early research on HROs, carried out by researchers at the University of California, Berkeley, defined HROs in terms of an organisation's ability to sustain almost error-free performance over long time periods (e.g. Roberts, 1990, 1993):

> *'[…] One can identify this subset* [of organisations that have high safety records] *by answering the question, "how many times could this organisation have failed resulting in catastrophic consequences that it did not?" If the answer is on the order of tens of thousands of times the organisation is "high reliability"'* (Roberts, 1990, p. 160)

This definition, however, has been criticised as being too all encompassing and unhelpful in terms of identifying a HRO. For instance, Hopkins (2007) noted that several organisations could fail catastrophically every minute of every day and would still be identified as 'high reliability' because they still manage to succeed much more often than they fail. Marais, Dulac and Leveson (2004) similarly argued that organisations that did not have the level of safety record described in Roberts' (1990) definition *'would be shut down immediately'* (p.3).

Traditionally, HRO researchers have relied on accident statistics as evidence that an organisation meets the 'high reliability' criterion of almost error-free performance. However, these statistics have been criticised as lacking objectivity and confounding reliability with safety. In particular, Hopkins (2007) noted that reliability is not tantamount to safety as the two can often pull in opposite directions. For instance, Hopkins (2007) cited as an example an electricity company, which was identified as an HRO on the basis of its 99.95% record of continuous energy supply, and argued that reliable energy supply could take place at the expense of safety (e.g. by cutting corners for example), whilst in other cases maintaining a safe operation may involve switching off the energy supply thus compromising reliability (Hopkins, 2007). In order to resolve the issue regarding the adequacy of accident statistics in identifying HROs, Rochlin (1993) argued that HROs are distinguished by the way in which they manage their innately risky and complex technologies:

> *'What distinguishes reliability-enhancing organizations, is not their absolute error or accident rate, but their effective management of innately risky technologies through organisational control of both hazard and probability […]'* (Rochlin, 1993, p. 17)

Thus, the above definition suggests that a HRO may be more meaningfully defined by focusing on the processes that it uses to successfully manage its risks rather than on its accident statistics.

In addition to using accident statistics to identify an organisation as a HRO, other researchers have focused on the types of technological characteristics that make organisations 'high risk' consistent with Perrow's (1984) concepts of 'tight coupling' and 'interactive complexity'. In other words, the focus here is on the type of organisations that could or could not qualify as HROs. For instance, Roberts and Rousseau (1989) identified several characteristics that, they argued, distinguish HROs from other kinds of organisations including:

- Hyper complexity and tight coupling: the organisation is characterised by a variety of components and systems, which are interdependent and its processes are unpredictable (due to their complexity) and difficult to interrupt (Perrow, 1984).

- Existence of extremely hierarchical structures with clear roles and responsibilities.
- Redundancy whereby several individuals make decisions and oversee important operations.
- High levels of accountability with expectations regarding strict adherence to procedures and 'getting it right first time' and substandard performance is not tolerated.
- Compressed time factors whereby major activities need to take place in seconds (e.g. naval flight operations).

Roberts and Rousseau (1989) argue that although some organisations have some of these characteristics, HROs will typically have *all* of them. The use of such criteria as those proposed by Roberts and Rousseau (1989) implies that only certain types of organisations can be HROs (Hopkins, 2007). Hopkins (2007) notes that recently, researchers have moved away from attempting to identify criteria to enable the classification as to whether an organisation is an HRO, and instead have focused on the types of processes and practices that enable certain organisations to achieve and sustain high levels of reliability. It is further argued that this shift in focus *'moves away from questions of just how safe does an organisation have to be before it can be considered an HRO, and it highlights instead what an organisation needs to do in order to reach the required end state'* (Hopkins, 2007, p. 6).

This shift is consistent with the assertions of many HRO theorists regarding the didactic principles that HRO research has to offer to 'traditional organisations'. Although HRO research has been criticised for its focus on contexts and operations that are not equivalent and to a certain extent removed from the types of operations that are found in traditional organisations, Waller and Roberts (2003) argue that there is much to be learnt from the core principles that are incorporated in HRO processes. However, they warn that these principles cannot be simply transferred from one context to the other. Consistent with Waller and Roberts' (2003) arguments, Weick and Sutcliffe (2007) argue that HROs and non-HROs are more similar than they appear to be. They argue that failure, if not managed properly, can be disastrous for all types of organisations although the consequences of failure will vary depending on the context (e.g. for HROs failure may lead to fatalities whereas in other types of organisations it may lead to loss of reputation or credibility) (Weick and Sutcliffe, 2007). Weick and Sutcliffe (2007) further argue that much like HROs, non-HROs are also faced with having to make complex decisions in climates of uncertainty, often in the face of incomplete knowledge of the 'bigger picture'. In other words, they argue that HROs and non-HROs have many commonalities and there is much to be learnt from HRO practices and principles.

In summary, attempts to identify and define HROs in the literature have focused on one hand, on organisations with good safety records and on the other, on the types of organisations that are eligible to be HROs. This differential focus has created much debate in the literature regarding how best to identify and define HROs. An alternative approach focuses instead on the types of processes and characteristics that are 'reliability-enhancing' in order to help organisations improve and sustain their safety performance. This approach, therefore, recognises that all types of organisations can work towards achieving HRO status.

3.3 CHARACTERISTICS OF HIGH RELIABILITY ORGANISATIONS

Research on HROs was initiated by a team based at the University of California, Berkeley approximately 20 years ago who studied three 'error free' organisations the Federal Aviation Administration's air traffic control, Pacific Gas and Electric Company's operation of its nuclear power plant and the US Navy's nuclear powered aircraft carriers (Roberts, 1993). The researchers used a multi-method approach to study these three organisations, which included facilitated workshops with high level operators and managers, interviews, observations and

surveys (e.g. Roberts and Rousseau, 1989; Roberts, 1990, 1993; Mannarelli, Roberts, and Bea, 1996).

All three organisations were technologically complex requiring high levels of operational expertise in light of the potentially catastrophic consequences (for the organisation and the public alike) that failures could have in these contexts (Rochlin, 1993). This line of research identified several characteristics and processes that enabled these three organisations to achieve and maintain their excellent safety records (e.g. Roberts and Rousseau, 1989; Roberts, 1990, 1993; La Porte and Consolini, 1998; Roberts and Bea, 2001). These included:

- *Deference to expertise during emergencies:* Decision-making is hierarchical during routine, periods accompanied by a clear differentiation of responsibilities as to who is responsible for what. However, in emergencies, decision-making migrates to individuals with expertise irrespective of their hierarchical position within the organisation.

- *Management by exception:* Managers monitor decisions but do not intervene unless required, usually when there is an unplanned deviation in a course of action (Roberts, 1993). This management style is often referred to as '*management by exception'* whereby managers focus on strategic, tactical decisions and only get involved with operational decisions as and when required (e.g. Bass, 1999).

- *Climate of continuous training* in order to enhance and maintain operators' knowledge of the complex operations within the organisation, improve their technical competence and enable them to recognise hazards and respond to 'unexpected' problems appropriately. Training is also seen as a means of building interpersonal trust and credibility among co-workers (i.e. belief that colleagues are well-equipped to do their jobs).

- *Several channels are used to communicate safety critical information* and to ensure that expertise can be accessed in a timely manner especially in emergencies. For instance, nuclear powered aircraft carriers use twenty different communication devices ranging from radios to sound powered phones (Roberts, 1990).

- *In-built redundancy* including the provision of back-up systems in case of a failure, internal cross-checks of safety-critical decisions and continuous monitoring of safety critical activities (e.g. Roberts, 1990; Hofmann, Jacobs and Landy, 1995). For instance, nuclear powered aircraft carriers operate a 'buddy system' whereby activities carried out by one individual are observed by a second member of staff (Roberts, 1990).

The importance of these processes in the development of high reliability performance has been corroborated by research into the culture of nuclear submarines. More specifically, Bierly and Spender (1995) examined the culture and practices of a Los Angeles nuclear submarine with an impeccable accident record. They identified a number of characteristics that contributed to the nuclear submarine's good safety performance. In particular, the nuclear submarine culture was characterised by:

- Continuous technical learning through extensive training and exercises that captured all potential 'failure scenarios';

- Good incident reporting culture and analysis of accidents and near misses to gain a realistic picture of the organisation's state of operations;

- Good two-way communications between operators and management; and

- A combination of centralised and de-centralised decision-making.

Drawing on HRO research, Weick et al. (1999) and Weick and Sutcliffe (2007) identified five characteristics that they defined as 'reliability-enhancing'. The first is defined as *preoccupation with failure* and refers to HROs' constant preoccupation with potential errors and failures. Incidents and near misses are seen as indicators of a system's *'health and reliability'*. For this reason, HROs value and reward the reporting of near misses and errors because they are viewed as learning opportunities and a means of obtaining a realistic picture of operations. Further, near misses are thoroughly analysed because they are seen as opportunities to improve (operational) processes. As Rochlin (1993) argues (cited in Weick et al. 1999, p. 40):

> *"[…] the value* [of errors] *to the organisation of remaining fully informed and aware of the potentiality for the modality of error far outweighs whatever internal or external satisfaction that might be gained from identifying and punishing an individual and/or manufacturing a scapegoat to deflect internal or external criticism."*

The second reliability-enhancing characteristic is defined as *reluctance to simplify* and focuses on HROs' ability to collect, analyse and prioritise all warning signs that something may be wrong and avoid making any assumptions regarding the causes of failure (Weick and Sutcliffe, 2007). For instance, HROs assume that failures are systemic, rather than localised in nature, and could potentially lead to a broader causal chain of events with potential catastrophic consequences (Weick et al., 1999). Similarly, HROs take steps to create nuanced understandings regarding the causes of incidents that go beyond simplistic 'blame the operator' interpretations. Reluctance to simplify captures HROs' scepticism and constant doubt about all aspects of their operations (Weick and Sutcliffe, 2007).

Further, HROs are characterised by a heightened *sensitivity to operations*, which refers to their ability to obtain and maintain the bigger picture of operations that enables them to anticipate effectively potential future failures. In line with this, HROs seek the views of front line staff in order to get a realistic picture of the status of operations and safety concerns within the organisation (Weick and Sutcliffe, 2007).

Commitment to resilience is the fourth reliability-enhancing characteristic and is concerned with the ability of HROs to not only effectively anticipate errors but also to cope with and bounce back from errors and 'unexpected events' (Weick et al., 1999; Weick and Sutcliffe, 2007). According to Weick and Sutcliffe, this characteristic exemplifies HROs' commitment to learning from past experience and errors both from within the organisation and from other industries.

Deference to expertise is the final HRO characteristic proposed by Weick et al. (1999) and Weick and Sutcliffe (2007). During normal operations, HROs are characterised by a hierarchical structure with clearly defined roles and responsibilities and lines of reporting so that everyone knows who is responsible for what. However, in emergencies, this structure ceases to exist and decision-making is deferred to individuals with the expert knowledge to deal with a specific problem, irrespective of their status within the organisational hierarchy. As Weick et al. (1999, p. 49) argue:

> *"[…] What is distinctive about effective HROs is that they loosen the designation of who is the "important" decision maker in order to allow decision making to migrate along with problems […] hierarchical rank is subordinated to expertise and experience."*

Weick and Sutcliffe (2007) argue that the characteristics of preoccupation with failure, reluctance to simplify and sensitivity to operations capture the ability of HROs to anticipate problems and unexpected events, whereas through their commitment to resilience and deference to expertise HROs can successfully contain problems should they occur. The abovementioned

characteristics afford HROs a quality that is referred to as *'collective mindfulness'* (Weick and Sutcliffe, 2007).

Finally, drawing on lessons learnt from HRO research, Roberts and Bea (2001) identified three characteristics that organisations can implement to enhance their reliability:

1. *HROs aggressively seek to know what they do not know*: investment of resources to train and re-train staff to enhance technical competence and enable them to anticipate and respond appropriately to unexpected events. They also analyse accidents and near misses to identify the types of accidents that happen in the organisation and target the aspects of the system that require redundancies.

2. *HROs balance efficiency with reliability*: HROs use incentive schemes to balance safety with profits and enable employees to make decisions that are safe in the short-run and profitable in the long-term.

3. *HROs communicate the big picture to everyone*: HROs have effective communication channels so that they can access quickly expertise in emergencies and communicate the 'big picture' to everyone. They also have well-defined procedures for both normal and emergency situations with well-known decision rules as to when they should be used.

It can be seen that HRO researchers have described several characteristics and processes that enable HROs to achieve their good safety record and sustain a reliable performance over long time periods. It should be mentioned that researchers have often used different terms to capture essentially the same HRO processes or practices. For instance, Roberts and Bea's (2001) aforementioned description of HROs' inclination to 'aggressively seek to know what they do not know' overlaps with Weick and Sutcliffe's (2007) concepts of 'preoccupation with failure' and 'reluctance to simplify'. In other words, all three descriptions capture HROs' ability to collect, analyse and synthesise information about the 'bigger picture' of current operations in such a way that enables them to effectively contain and prevent potential future failures.

3.3.1 HROs and resilience engineering

The HRO perspective overlaps with the resilience engineering approach to accidents in complex systems because both approaches argue that an organisation can develop or *'engineer'* a safety culture (Costella et al., 2009). In other words, both approaches identify principles to enable organisations to be both more reliable and to be better able to bounce back for errors and return to normal modes of operation.

Resilience engineering has been applied in several high-risk environments, such as in aviation, petrochemical and nuclear power industries and involves helping organisations to both avoid failures and be able to recover quickly once these have occurred. Researchers have proposed several characteristics that can enable organisations to develop 'resilience', that is, the ability to *'cope with unanticipated dangers after they have become manifest, learning to bounce back'* (Wildavsky, 1991; cited in Weick et al., 1999 p. 46). In particular, Reason (2000, 2005), Wreathall (2006) and Costella et al. (2009) have proposed that resilience may be 'engineered' by incorporating the following characteristics and processes:

- *Just culture:* There is an open accident and near miss reporting system within the organisation, and individuals are supported and able to suspend work on safety grounds without fear of being penalised for their decisions. The notion of a just culture often encompasses a 'no blame' approach to mistakes. However, in developing a just culture a distinction must be made between unacceptable or blameworthy behaviour that requires disciplinary action and other types of behaviour (such as necessary violations arising from

inadequacies in the equipment or workplace which make compliance with procedures unfeasible) (Reason, 2000, 2005). The development of a just culture requires a balance between supporting the reporting of incidents and near misses on one hand and not tolerating unacceptable behaviours on the other (e.g. Wreathall, 2006).

- *Management commitment:* Management balances the pressures of production with safety and management behaviour (including allocation of resources) sends the message that safety is as or more important than other business objectives.

- *Increased flexibility:* systems should be designed in a way that support, rather than constrain, individuals in carrying out their jobs; in addition, individuals have the discretion to make decisions when necessary without having to await for management instructions.

- *Learning culture:* The organisation learns from experience by systematically gathering and analysing near misses and incidents and encouraging the reporting of incidents; in addition, Costella et al. (2009) argue that organisations can also learn from normal working practices and disseminating and sharing best practice. For instance, focusing on how procedures are implemented during normal working practices can help identify any gaps between how managers think that procedures should be used and how they are actually applied by front line staff (Costella et al., 2009).

- *Preparedness:* The organisation is proactive in its safety management and is able to anticipate problems, changes and hazards. Preparedness captures the ability to anticipate all potential threats eventualities.

- *Opacity/Awareness:* The organisation collects and analyses information that enables the identification of weaknesses in its defences. Awareness overlaps with Reason's (2005) concept of an informed culture whereby the organisation has an understanding of both the hazards that it faces and the adequacy (or lack thereof) of its defences to control them.

- *Resources:* Resources, which may take the form of either additional staff or time to respond to emergencies for example, are crucial to enabling organisations to respond to unexpected events.

More recently, Provera, Montefusco and Canato (2008) argued that a 'just culture' is essential in promoting both organisational learning and highly reliable operations. They carried out a series of semi-structured interviews in order to identify and compare the attitudes towards blame in HROs (such as commercial airlines) and non-HROs (such as retail banks). The authors found that a just culture, which was prominent in HROs, was characterised by 1) rewards for the reporting of near misses and accidents, 2) an absence of blame and fear of punishment, 3) debriefing processes whereby individuals involved in incidents actively participated in the investigation process, and 4) outcomes of the investigation process were followed up through the development of corrective actions that were communicated to all staff. On the other hand, interviews conducted at an intensive care unit showed that errors were not openly discussed within the organisation but rather were contained and dealt only within individual teams. Provera et al. (2008) argue that a just culture encourages a systemic view of errors and failures rather than 'blame the operator' explanations that are typical in traditional organisations. Reason (2000) further argues that a just culture partly depends on a collective understanding of what types of actions are blameworthy and which are not. In other words, fear of blame is heightened in organisations where there is a fragmented understanding of the types of mistakes that are blameworthy, and will impact negatively upon individuals' willingness to report incidents and near misses. Provera et al. (2008) identified several barriers to the development of a 'just culture' in traditional organisations, which included:

- Costly and time consuming – implementing a just culture requires organisations to invest time and resources in order to re-visit their operational and communication procedures; given that the consequences of errors in traditional organisations are not as far-reaching as in HROs, management is often reluctant to make that investment.

- Cultural constraints – individuals tend to resolve problems with their supervisors or colleagues rather than report them, which limits open communication and learning from mistakes.

Cooke and Rohlender (2006) have put similar arguments forward regarding the importance of having an effective incident reporting system and learning from previous incidents in becoming a HRO.

Recent accounts of the causal factors contributing to major accidents have drawn upon HRO research findings to exemplify the types of characteristics that can help prevent failure in high-risk systems. As mentioned, HROs have a proactive approach to safety and a strong learning orientation, which is exemplified by the fact that they analyse, synthesize and communicate all incidents and near misses in order to prevent failures (e.g. Roberts and Bea, 2001; Weick and Sutcliffe, 2007). It has been argued that one thing that many of the major accidents that have occurred share in common is that fact that organisations often fail to systematically analyse precursor events and communicate these to relevant people within the organisation, usually management, so that appropriate control measures can be taken (e.g. Cooke and Rohleder, 2006; Hopkins, 2009).

Although this may be obvious in hindsight, several major industrial accidents suggest that organisations may be failing to systematically collect and communicate effectively information that may help prevent future incidents. For instance, Hopkins (2009) discussed the factors that contributed to the BP Texas City refinery disaster that resulted in 15 deaths and 180 injuries. In his analysis, Hopkins (2009) showed that contributory factors to the accident included an ineffective auditing system that failed to pick up problems in the safety management system, a reluctance to communicate to senior management 'bad news', ignoring warning signs of impeding disaster, ineffective incident reporting and investigation systems and cost-cutting on safety-critical activities such as maintenance. Hopkins (2009) argued that the disaster would have been averted if the organisation, and particular its senior management, had exhibited 'mindful' qualities or '*mindful leadership*'. Drawing on HRO research findings, Hopkins (2009) argued that a mindful leadership style comprises the following qualities:

- Seeking the views of frontline staff in order to gain a realistic and 'bigger' picture of operations within the organisation;
- Providing the necessary resources to ensure operational safety;
- Encouraging 'bottom-up' communications;
- Using accidents that happen in other organisations as opportunities to check whether similar problems exist in their organisation, and
- Proactively commission audits to diagnose any weaknesses in the organisation's defences and question audit findings that only deliver 'good news'.

In summary, the resilience engineering perspective shares much in common with the HRO approach and offers principles that can be implemented by organisations to improve their reliability and safety performance. Propositions regarding the importance of fostering a just culture, management commitment to safety and allowing individuals the latitude of making important safety-related decisions are consistent with HRO principles and processes.

3.4 ASSESSMENT OF HIGH RELIABILITY

It will have become evident from the aforementioned discussion that HRO research has identified processes and characteristics that organisations could aspire to develop in seeking to achieve HRO status. As Hopkins (2007) argues, HROs represent an 'ideal' organisation and organisations can exhibit varying degrees of reliability-enhancing characteristics. HRO research has resulted in an increased interest in the development of measures that would enable organisations to assess the extent to which they possess 'reliability-seeking' characteristics.

Koch (1993) argued that HROs reinforce a distinct set of expectations and behavioural norms that are not commonly found in other organisations. In line with this, Koch (1993) developed a measure in order to capture the reliability-seeking nature of organisations and particular facets of their culture. The aim was to develop a measure that could be generalised to different industries and would capture individuals' attitudes toward their job and key factors that are important in assuring safety (Koch, 1993). Koch (1993) developed two measures: the first was a longer 37-item scale which tapped into culture of reliability-seeking organisations, and a second, shorter scale consisting of 25 items which aimed at distinguishing reliability-seeking organisations from other organisations. Key factors that were captured by the scales included:

- Accountability/responsibility (i.e. HROs make each person responsible for decisions in preventing accidents to ensure operational safety)
- Interaction/Communication (i.e. the extent to which knowledge of events 'flow upward' in the organisational hierarchy)
- Adaptiveness/responsiveness assessed two elements: first, the extent to which organisations are able to adapt or recover from unexpected events, and second the ability to change from 'low to high-tempo operations' (i.e. quick decision-making in emergencies);
- Hazard Awareness (i.e. the extent to which organisations are aware and can anticipate dangerous situations and take appropriate action);
- Inquisitiveness/search for detail taps into individuals' abilities to ask questions and be attentive to detail in safety-critical situations.
- Role clarity assesses the individuals' understanding of both their own as well as colleagues' responsibilities in assuring safe performance.
- Maturity, which assesses the extent to which organisations tolerate self-centred, risky behaviour.
- Training/socialisation, which captures organisations' training procedures and practices and the extent to which they instil safety-related values and behaviours among organisational members.

More recently, Weick and Sutcliffe (2007) developed a set of measures to enable organisations to assess their tendencies toward mindfulness or lack thereof (see section 3.3). In addition, the measures also capture the five core characteristics of HROs that include preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience and deference to expertise. Weick and Sutcliffe (2007) argue that these audits enable organisations to assess their practices and use the findings to diagnose potential areas that require improvement. In line with this, Vogus and Sutcliffe (2007) developed and validated the Mindfulness Organising Scale in hospital nursing units, which captures the extent to which an organisation demonstrates the abovementioned HRO principles.

The abovementioned research represents important first steps towards the development of quantitative measures to enable organisations to assess the extent to which they possess reliability-seeking characteristics and what is required to come closer to achieving HRO status. The merits of this work notwithstanding, more research is required to ascertain the predictive validity of such and other similar HRO measures. In particular, evidence is lacking as to the extent to which organisations that exhibit 'collective mindfulness' or reliability-seeking characteristics also tend to hold better safety records in comparison to those organisations that have tendencies towards 'mindlessness' (e.g. Weick and Sutcliffe, 2007). Therefore, more research is required to provide evidence of links between such measures and safety performance indicators in different organisational contexts. Finally, although quantitative measures may enable organisations to assess their progress towards developing more reliable or 'mindful' properties, little is known regarding the factors or underlying mechanisms that foster the development of HRO characteristics. These issues are discussed further in section 4.2.

3.5 APPLICATIONS OF HIGH RELIABILITY ORGANISATION PRINCIPLES

There have been several attempts to apply HRO principles in other contexts, and most prominently in healthcare (e.g. Roberts, Desai and Madsen, 2005; Baker, Day and Salas, 2006; Madsen Desai, Roberts and Wong, 2006; Stralen, Calderon, Clements, Daniel, Rao, Padgett, Kausen and Roberts, 2006), in order to identify the types of reliability enhancing practices that may be meaningfully transferred and generalised to other organisational contexts.

Tamuz and Harrison (2006) argue that the HRO processes relating to redundancy, incident reporting and accident analysis in order to identify root causes may be usefully transferred to healthcare contexts. In a recent study, Roberts et al. (2005) introduced HRO processes in a children's medical centre which included, 1) having several clinical staff check on a patient's health (redundancy), 2) provision of training for clinical staff to increase their awareness of how things could go wrong (culture of continuous learning), 3) enabling the best qualified staff to make decisions in a given situation, particularly in emergencies and encouraging staff and in particular nurses to be involved in patient care plans (deference to expertise).

Another study examined the implementation of HRO processes in a paediatric intensive care unit in order to enable it to become more reliable. In particular, Madsen et al. (2006) introduced decentralised decision-making by enabling nurses to carry out tasks traditionally done by doctors (accompanied by relevant training and decision-aids/protocols) and open communication by setting up frequent debriefings for all staff following abnormal events. It was shown that the implementation of these HRO processes improved response times and quality of care and reduced mortality rates (Madsen et al., 2006). Frankel, Leonard, and Denham (2006) also discussed the importance of open communication in helping healthcare organisations become more reliable. In particular, they argued that the dominant ethos/mentality in hospital operating theatres is one where the underlying expectation is that staff are 'experts' and infallible. Unlike the HRO environment, such expectations do not foster an environment where staff can openly raise concerns regarding a patient's care (Frankel et al., 2006). Frankel et al. (2006) discuss a number of initiatives taken by several healthcare organisations, mainly in the US, to enhance their reliability including the introduction of 'red rules', which, if not followed, can result in potential dismissal. An example of a 'red rule' is the compulsory participation of relevant clinical staff in briefings before invasive procedures.

The research by Madsen et al. (2006) also highlighted the importance of leadership in implementing and sustaining HRO processes. Specifically, it was shown that in the absence of individuals that will promote and champion high reliability processes, these will tend to disappear and the organisation returns to its 'normal' way of operation (Madsen et al., 2006). In particular, once the initial champions of the HRO practices left the intensive care unit, practices

that were in place to support decentralised decision-making and hold regular debriefings were discontinued (Madsen et al., 2006). The importance of effective leadership is also acknowledged by Frankel et al. (2006) who argued that leaders drive the values, behaviours and culture within an organisation and that leadership engagement in safety is one of the key components for enhancing reliability and safety in healthcare.

In another study, Xiao and Moss (2001) explored the practices adopted by teams working in trauma resuscitation. Using observations and interviews, the authors found that the practices that enabled the teams to perform reliably incorporated several HRO principles including clear role differentiation among team members, checking on the tasks carried out by each team member, and ensuring that the team is aware of both the status of tasks carried out by each member as well as of the patient's condition.

However, Tamuz and Harrison (2006) also highlighted some of the challenges in applying HRO principles in practice. It particular, they argued that some HRO principles can be ineffective or counter-productive in certain contexts. The authors provide as an example the double-checking of hazardous medication, which is a form of redundancy that is widely used in nursing. It is argued that excessive reliance on double-checking may undermine safety critical tasks by breeding a culture of complacency or a sense of diffusion of responsibility; that is, people may neglect important safety checks because they rely on others to duplicate their efforts (Tamuz and Harrison, 2006). The authors caution that the principles and practices that emerged from high reliability theory and normal accident theory should be used as *'[…] frames and not as blueprints'* and *'need to be tested empirically – both through research and through action […]'* (Tamuz and Harrison, 2006, pp. 1670-71). This echoes Waller and Roberts' (2003) arguments that more research is required to ascertain the appropriateness and suitability of HRO processes, as this is likely to be context-dependent.

3.6 REGULATORY PERSPECTIVES ON HIGH RELIABILITY

As was mentioned earlier, HRO characteristics are often discussed in the context of major incidents and are used to highlight the operational safety standards that organisations should try to emulate. The need for high hazard industries to incorporate HRO principles has become even more apparent since the Buncefield accident in December 2005. For instance, one of the recommendations put forward by the Buncefield Major Incident Investigation Board (MIIB) in its final report into the incident, which was published in 2008, was that the sector should prepare guidance and standards on how to achieve a high reliability industry. The final report of the MIIB defined HROs in terms of two key attributes; first, their sense of chronic unease and almost obsessive fear of complacency despite their good safety records; and second, their attentiveness to weak signals as potential precursors of future systemic failures so that operations will cease to allow investigation of an incident, no matter how insignificant that incident may appear to be. This definition provides a somewhat narrow view of HROs and ignores key HRO attributes and processes identified in the literature as will be discussed in more detail below.

Further, the MIIB report (2008) highlighted a number of high reliability organisational factors that were crucial in the context of the Buncefield investigation. Consistent with the final report, it was recommended that the following factors should be addressed to achieve a high reliability organisation:

- A clear definition and understanding of roles and responsibilities and assuring competence in these roles;

- Enabling front line staff, and in particular control room operators, to diagnose and respond to incidents through effective control room design and alarm systems;

- Provide appropriate staffing and shift work arrangements to control major accident hazards;
- Provide appropriate training, experience and competence assurance systems for staff engaging in safety-critical activities;
- Auditing and operational monitoring of contractors' abilities to supply and maintain high integrity equipment;
- Providing appropriate arrangements for the effective supervision of control room staff;
- Setting and implementing appropriate standards for safe and effective communication at shifts and handovers;
- Provision of effective standardised procedures for key maintenance, testing and operational activities;
- Ensuring that management of change is addressed effectively and includes organisational, procedural and equipment changes.

Defining HROs in terms of their 'chronic unease' and 'attentiveness to weak signals' does not do justice to the complexity and richness of descriptions that exist in the literature about how these organisations manage to maintain safe and reliable operations. For instance, the MIIB (2008) report fails to mention another key attribute of HROs, which refers to their ability to not only anticipate potential failures but also effectively cope with them should these occur. This attribute captures HROs' resilience and ability to contain and bounce back from errors; key mechanisms that account for HROs' resilience include redundancy (e.g. provision of back-up systems and continuous checking of safety critical activities), drawing on experts within the organisation to make important safety-critical decisions irrespective of their rank (i.e. 'deference to expertise'), and continuous technical training for staff in dealing with all potential failure scenarios (e.g. Roberts and Rousseau, 1988; Bierly and Spender, 1995; Weick and Sutcliffe, 2007).

In addition, the report's recommendations on how the industry can work towards high levels of reliability have some obvious omissions. In particular, other processes that have been identified as contributing to high reliability operations include:

- Encouraging an honest and open reporting of errors (without fear of punishment and promoting a collective understanding of which actions are blameworthy),
- Ensuring that accident investigations aim to identify the deeper, systemic causes of errors, identification of potential failure scenarios and provision of staff training to respond to such emergencies, and
- Management commitment to safety (or 'mindful leadership') characterised by a proactive commission of audits (often in response to incidents that occur in other similar industries), engagement with front life staff to obtain a realistic picture of operations 'on the ground' and investment of the necessary resources in safety management (see sections 3.3 and 4.1 for a detailed discussion and summary of HRO characteristics).

Another regulatory document published by the Norwegian Petroleum Safety Authority (PSA, 2004), the independent regulatory body under the Ministry of Labour and Government Administration, underlines the importance for organisations to have a positive health, safety and environment culture. The aim of this document is to outline key characteristics in order to assist the industry in improving its health, safety and environment culture. Although HROs are not

explicitly addressed, the characteristics discussed as important for achieving a positive health, safety and environment culture overlap with HRO principles. In particular, the Norwegian PSA (2004) recommends that organisations should work towards developing and implementing the following characteristics:

- A *reporting* culture characterised by good reporting systems and a climate of trust within the organisation; the aim should be to learn from previous incidents and not to attribute blame.

- A *just* culture whereby reactions to mistakes should be proportionate to the nature and consequences of mistakes and there is a system of rewards and sanctions in place that is perceived as fair and constructive.

- A *learning* culture whereby information is communicated and shared effectively both horizontally- across different departments or shifts – and vertically – across hierarchical levels within the organisation but also with customers and sub-contractors.

- A *flexible* culture that adapts successfully to external demands without compromising safety.

It is further recommended that a combination of qualitative (participant observation, use of documents such as reports, workshops) and quantitative methods (questionnaire-based surveys, structured interviews, injury statistics) should be used to identify and diagnose an organisation's existing health, safety and environment culture (PSA, 2004).

In a more recent report titled *Safety – Status and Signals 2009-2010*, the PSA summarises its priorities during the previous year (i.e. 2009) and the key safety challenges for the industry during 2010. The importance of management in reducing major accident risks and knowledge from prior incidents is cited as one of the top priorities. In particular, the report emphasises the important role that leaders play in keeping track of the weaknesses in organisational operations, integrating information across different parts of the business, as well as learning from previous errors and applying that knowledge to improve risk management. Thus, leaders are seen as playing a key role in the management of major accident hazards (PSA, 2010). These principles are in line with the practices and features that are characteristic of HROs including their high levels of learning orientation, management commitment to safety and their ability to foster an open and fair culture whereby errors are openly discussed, analysed and used as learning opportunities (e.g. Weick and Sutcliffe, 2007).

4 DISCUSSION AND CONCLUSIONS

4.1 SUMMARY OF RELIABILITY-ENHANCING CHARACTERISTICS

It will be evident from this review that research has identified several reliability-enhancing characteristics that are common in organisations that are able to maintain impeccable safety records despite the fact that potential failures can be catastrophic (e.g. Roberts and Rousseau, 1989; Roberts, 1990, 1993; Roberts and Bea, 2001; Weick and Sutcliffe, 2007). Given the plethora of descriptions regarding HROs and their associated processes and characteristics, a mind map was developed in order to capture the common issues that emerged in the literature (see Figure 1). Mind maps are a useful way of organising and presenting concepts in a pictorial manner. The development of a mind map involves starting off at the centre with a key topic or concept and then branching out to themes that are related to and help define the main topic. A mind map helps define a topic by gradually moving from abstract to more concrete, specific descriptions (Brinkmann, 2003).

The mind map that follows drew upon Weick and Sutcliffe's (2007) HRO characteristics as an overarching organising framework complemented by resilience engineering principles and Perrow's (1984) definitions of high-risk systems (see section 3.3 for a detailed discussion of HRO characteristics). It captures six HRO-related concepts, which include the following:

- Description of HROs as organisations operating in hazardous conditions where potential failures may have far-reaching, potentially catastrophic consequences. Such organisations will be typically characterised by *interactive complexity* (i.e. interaction among system components is unpredictable and/or invisible) and *tight coupling* (i.e. high degree of interdependence among a system's components including people, equipment and procedures).

- Containment of unexpected events by: having in place back-up systems in the event of failures and cross-checking of important decisions *(redundancy)*, allowing people with expertise, irrespective of rank, to make safety-critical decisions in emergencies, whilst during routine operations there is a clear hierarchical structure and an understanding of who is responsible for what *(deference to expertise in emergencies, oscillation between hierarchical and flat organisational structures)*, investment in training and technical competence and use of well-defined procedures to cover all possible unexpected events.

- Effective problem anticipation by: engaging with front line staff in order to obtain 'the bigger picture' of operations (sensitivity to operations*)*, being attentive to even seemingly minor or trivial signals that may indicate potential problem areas within the organisation and using near misses and incidents as indicators of a system's health *(preoccupation with failure)*, systematically collecting and analysing all warning signals and avoid making assumptions regarding the causes of failures; and using accident investigations to identify the potential systemic factors contributing to incidents *(reluctance to simplify)*.

- Just culture characterised by open reporting systems for near misses and accidents without fear of punishment, follow-up of accident investigation outcomes by implementing corrective actions, empowering staff to abandon work on safety grounds and fostering a sense of personal accountability for safety.

- Learning orientation through continuous technical training, systematic analysis of incidents to identify their root causes and accident types within the organisation, open communication of accident investigation outcomes, and updating procedures in line with the organisational knowledge base.

- Mindful leadership characterised by proactive commissions of audits to identify problems in the system (often in response to incidents that occur in other similar industries), 'bottom-up' communication of bad news, engagement with front line staff through site visits, investment of resources in safety management and the ability to balance profits with safety.

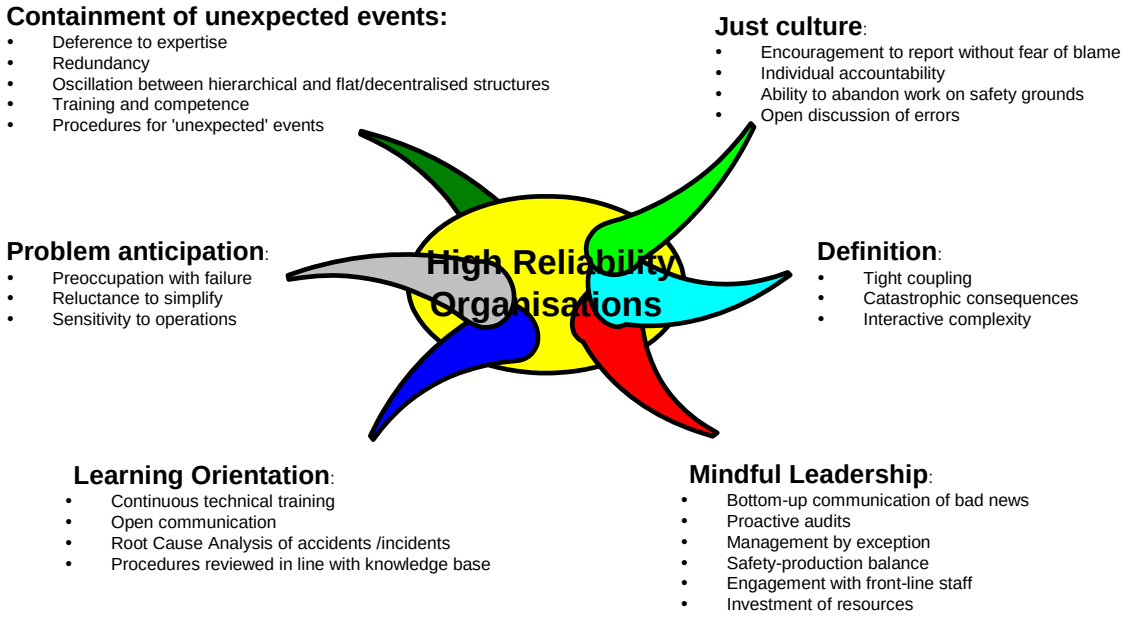


Figure 1. Mind map of High Reliability Organisation processes and characteristics

4.2 LIMITATIONS OF HRO RESEARCH

Research on HROs to date has illustrated a number of processes that are in place in organisations with good safety records. However, HRO theory and research has several limitations that need to be mentioned.

First, one common criticism of HRO research is that it has been carried out in a small range of organisations, which have been referred to as 'exotic' (e.g. Waller and Roberts, 2003) in so far as they tend to be either military organisations (i.e. naval carriers) or organisations with distinct service-oriented cultures (i.e. air traffic controllers). Consequently, although there have been efforts to apply HRO principles in other contexts, such as healthcare (e.g. Roberts et al., 2005; Baker et al., 2006; Stralen et al., 2006; Madsen et al., 2006) or software companies (Vogus and Welbourne, 2003), we know very little regarding whether or which HRO processes can be meaningfully applied to other types of organisations. For instance, it has been argued that HROs tend to be non-profit organisations where safety is a primary objective, whereas HRO processes may be less easily implemented in organisations that face constant market pressures and conflicting goals (e.g. Marais et al., 2004; Tamuz and Harrison, 2006). In these contexts, it may be difficult to successfully balance safety objectives with production demands (e.g. Hopkins, 2000; Boin and Schulman, 2008). Waller and Roberts (2003) argue that HROs '*may hold critical answers for 'normal' organisational adaptability, growth and survival'* (p. 184), however more research is required to distil the HRO processes that may be meaningfully applied to other organisational contexts.

Second, HRO research lacks a comprehensive theoretical framework that would help explain why HROs are able to operate and sustain these levels of performance where others would fail and how the HRO processes identified account for HROs operational efficiency and reliability. For instance, it has been hypothesized that redundancy and continuous training are crucial HRO processes (e.g. Roberts, 1990). However, to date, HRO research tends to be descriptive and lacks evidence of cause-effect relationships between specific HRO processes and safety performance (Boin and Schulman, 2008). Understanding the factors that facilitate the development of HRO processes, as well as the links between specific HRO processes and safety performance would help inform a more comprehensive approach as to how organisations can become more reliable or 'mindful'.

Thirdly, and related to the abovementioned issue, HROs appear to combine two unique qualities that enable them to sustain almost error-free performance; these qualities relate to HROs' ability to both anticipate and cope with unexpected events should they occur (Weick et al., 1999). The underlying assumption underpinning these qualities is that first, it is possible to identify and anticipate potential failure scenarios, and second, it is possible to spot errors when they occur and identify a timely and appropriate course of action in real time to avert catastrophic consequences (e.g. Weick et al., 1999; Blatt, Christianson, Sutcliffe and Rosenthal, 2006). However, research carried out in 'unpredictable' organisational contexts, such as healthcare, shows that effective anticipation and prevention of errors in real time is not always possible. For instance, Blatt et al. (2006) argue that certain work environments can be 'messy' such that it may not be possible to anticipate potential failure scenarios or errors without the benefit of hindsight. Further, resilience and the ability to intervene and rectify errors once these have been detected may be determined by relational factors, such as leadership style. For instance, it has been shown that doctors are more likely to raise safety concerns and act upon errors when they perceive their line managers as receptive to concerns/suggestions (Blatt et al., 2006).

This raises the question as to whether there is something fundamental about the HRO environments and how they are regulated that enable them to marry anticipation and resilience (e.g. Boin and Schulman, 2008) or whether there is something about the underlying mechanisms by which HROs work and operate (e.g. their culture, leadership styles, or socialisation of new recruits) that enable them to successfully both anticipate and cope with the unexpected.

Finally, although there has been extensive research into the characteristics and processes that are in place in HROs, we know very little about the impact of HRO work environments on individuals. Empirical research suggests that individuals are more likely to flourish and be more satisfied in environments that offer them opportunities for autonomy, participation, personal development and creativity (e.g. Rousseau, 1989; Tesluk, Vance and Mathieu, 1999; Sparks, Faragher and Cooper, 2001). HRO environments tend to be characterised by an absence of such characteristics; experimentation and innovation are discouraged as they can be costly, their hierarchical structures (in normal operations) provide few opportunities for participative decision-making and job demands are high given the grave consequences of error (Rousseau, 1989). Research on the impact of HROs' work environments on individuals suggests that these environments tend to be experienced as stressful often because individuals are expected to behave in ways that are very different to how they would behave outside of work (Rousseau, 1989). For instance, Rousseau (1989) found that operators perceived HRO-cultures as 'security-oriented' whereby the emphasis is on adherence to rules and procedures, hierarchical, non-participative decision-making, attention to detail and perfectionism (Rousseau, 1989). Interestingly, empirical findings also suggest that perceptions of culture in HROs are not uniform; rather they tend to vary according to an individual's hierarchical level whereby management is more like to perceive HRO cultures as supportive and participative than front line staff (Rousseau, 1989). However, work in this area tends to be scant and more research is required to understand the psychological effects of HROs' distinct work environments on

individuals. This will have important implications in considering the benefits of implementing HRO principles in 'traditional', mainstream organisations.

4.3 CONCLUDING REMARKS

The scope of this review was to identify published, peer-reviewed research on HROs, distil and summarise their key features and evaluate the research findings, especially in the context of mainstream organisations. In doing so, the review was comprehensive rather than exhaustive in nature whereby only key papers in the area were reviewed. A number of papers were found that examined in depth HRO processes and practices. The majority were qualitative typically employing a case study-based approach. This approach accounts for the rich description of the contexts and processes of HROs that are evident in these papers.

Overall, the review has shown that there are rich descriptions and understandings of HRO processes in very specific contexts; however, little is known about the extent to which these processes are transferable to mainstream organisational contexts (Leveson et al., 2006; Waller and Roberts, 2003). For instance, it has been hypothesised that redundancy, an element of HRO resilience, could potentially be counter- productive in other contexts as it may breed a sense of complacency and diffusion of responsibility (Tamuz and Harrison, 2006). It is thus possible that HRO processes that are effective in some contexts may be ineffective or even detrimental in others.

In addition to the issue of transferability, several other important questions are raised. One issue that remains unclear is the precise mechanisms whereby the HRO features relate to safety performance (Boin and Schulman, 2008). For instance, are there some HRO features more important than others? The implicit assumption appears to be that the presence of certain HRO processes accounts for these organisations' good safety records, however, this needs to be tested empirically. Another question that arises is how are HRO principles implemented in practice? HROs manage to succeed where other organisations fail; for instance, they manage to balance effectively competing priorities (such as safety vs. productivity) and foster an open, free of blame culture; these are issues that are challenging for most mainstream organisations (e.g. Reason, 2000). Yet we know very little about the underlying mechanisms through which these 'mindful' states are achieved. For instance, is there something about their socialisation processes and/or the nature of their reward and communication systems that promote a just, equitable culture? HRO research offers a predominantly descriptive rather than explanatory framework that limits the answers to questions regarding the potential underlying mechanisms that enable HROs to successfully maintain high levels of safety performance.

Finally, the review findings suggest that there have been some important steps towards the development of quantitative measures to enable organisations to assess the extent to which they possess reliability-seeking characteristics. However, evidence of the predictive validity of such measures and their links with safety performance is limited (e.g. Boin and Schulman, 2008). Establishment of such links are particularly pertinent in light of the fact that the development of HRO practices and processes is both labour and resource intensive and consequently their implementation may be 'resisted' in contexts where errors have minor consequences (e.g. Weick et al., 1999).

In summary, research in HROs has revealed a number of important processes that play an undoubtedly important role in the safety performance of these organisations. Equally however, this line of research has also raised a number of important questions predominantly regarding the transferability and underlying mechanisms of HRO processes, as well as their financial 'sense' especially in the context of lower risk, mainstream organisations.

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High reliability organisations

A review of the literature

A number of major hazard organisations have been attempting to influence the organisational and safety culture at their sites to transform them into a high reliability organisation (ie organisations that are able to manage and sustain almost error-free performance despite operating in hazardous conditions where the consequences of errors could be catastrophic) with a positive safety culture. In recent years there has been a huge increase in the literature talking about the control of major hazard risks, in particular the philosophies of high reliability organisations, resilience management and safety culture. These works identify key features and characteristics that need to be adopted by organisations to achieve ongoing high reliability and safety objectives.

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