Preface

This thesis would not exist had it not been for three key people in my life this past year. I would like to thank Martin Rasmussen for being an endless source of support in relation to writing this thesis, and Ida Brevik and Lars-Erik Halvorsen for giving me a chance at succeeding in life.

I would also like to thank Karin Laumann for letting me aboard the Petro-HRA project, and friends and family for supporting me through it all.

A special thanks goes to Ralph Hagen, for allowing me to use one of his spot-on and wonderful cartoons for my front cover. Faith in humanity restored.

Veronica Rønneberg Reitan
Trondheim, 29.04.2015

Abstract

This master thesis examines management support and safety culture in order to create a suggestion for a new PSF in Petro-HRA. Building on SPAR-H, the work processes PSF is examined and two select factors, management support and safety culture, are chosen for review. A literature review uncovers five factors for management support and six factors for safety culture. The findings of the review are discussed in addition to the discussion and selection of four factors that will come to make up the new work processes PSF. A suggested definition for the PSF, along with appropriate PSF levels and applicable questions for use in analysis are provided.

Keywords: Management support, safety culture, safety climate, HRA, SPAR-H, petroleum, Petro-HRA

Introduction

Throughout the past 30 years accidents like Chernobyl (1986) and the near accident of Three Mile Island (1979), both in the nuclear industry, have together with accidents such as Deepwater Horizon (2010) and Piper Alpha (1988) in the offshore industry, contributed to an increased focus on human reliability (Cullen, 1991; Meshkati, 1990; Water, 2011). The Norwegian Petroleum Safety Authority has even stated that focusing on the improvements of technical solutions alone is not enough, and that human and organizational factors must be taken into account (Jærnes et al., 2005). In the petroleum industry, mapping accidents scenarios and evaluating safety has usually been done with a Quantitative Reliability Analysis (QRA), an analysis that evaluate technical systems and capabilities, traditionally without focusing on the role of the humans in the system and their capabilities (Kim & Jung, 2003; Skogdalen & Vinnem, 2011). Human errors and capabilities are however not as straight forward as technical errors and technical capabilities. Compared to machines, humans can learn from their mistakes. This means that a person never will encounter the same problem twice with the same amount of experience, and neither would two people face the same problem with the same amount of experience (Bedford & Cooke, 2001). Secondly, how we process information affects us when we work – contrary to machines, the human working memory can only process so much until we overload, and start filtering information based on past experiences. We might lose valuable information in the process and start to make mistakes (Reason, 1990). There are many definitions of what a mistake, a human error, is, and the term is used differently across different industries. Reason (2013) has suggested the following definition of human error; "occasions in which a planned sequence of mental or physical activities fail to achieve its desired goal without the intervention of some change agency" (Reason, 2013, p. 10).

Human error has a long and unfortunate history of being attributed to people's lack of competence, skill, care, memory or attention. People at the sharp end are being blamed, shamed, and threatened with various punishments as a means of reducing unwanted behavior. This is popularly called the person approach (Reason, 2000). An alternative way of looking at human error is called the system approach, where errors are considered consequences, and not causes. Errors are viewed as inevitable, even in the best organizations, and the best way of dealing with the human element is to control the environment, i.e. the conditions under which humans work (Reason, 2000). For organizations working in a high-risk industry, such as nuclear, aviation or petroleum, this becomes particularly important, as accidents in these organizations have the potential to be catastrophic.

One way to attempt to predict human error is by using human reliability analysis (HRA). In the general sciences objects are measured by for example weight, length, and mass; and predicted outcomes are based on these numerical values. In psychology, we use error estimations, based on factors contributing to an event (Boring, Gertman, Joe & Marble, 2005). The most frequently used method for doing so is SPAR-H (Standardized Plant Analysis Risk Human Reliability Analysis). SPAR-H uses eight performance shaping factors (PSFs) to calculate the probability of human error. The PSFs represent human attributes, environment and tasks that can have an effect on human performance, positively or negatively. There are three general PSFs, available time, stress, and complexity, and five that are personnel specific, experience/training, procedures, ergonomics, fitness for duty, and work processes (Gertman, Blackman, Marble, Byers & Smith, 2005).

The Petro-HRA project (Laumann, Øien, Taylor, Boring, & Rasmussen, 2014) now aims to convert the SPAR-H method to fit the petroleum industry. This project is a collaboration between Statoil, DNV GL, SINTEF, Institute for Energy Technology (IFE), the Norwegian University of Science and Technology (NTNU), and Idaho National Laboratory. The project is funded by The Research Council of Norway, and the Institute for Energy Technology is the project owner. SPAR-H is chosen because it in addition to not being very resource demanding and that it promotes inter-analyst consistency, also provides guidance to assigning the different PSFs (Gould, Ringstad & van de Merwe, 2012). The work of deciding and choosing which PSFs that are going to be a part of Petro-HRA has already started, and factors Complexity and Ergonomics have already been reviewed (Rasmussen & Laumann, 2014; Rasmussen, Standal, & Laumann, 2015).

This thesis will focus on the PSF work processes, which is considered a "catch all" PSF, representing six different sub-factors; inter organizational, safety culture, work planning, communication, management support and policies (Whaley, Kelly, Boring, & Galyean, 2011). Reviewing the whole PSF is considered to be too far-reaching for the limits of a master thesis, hence this thesis will focus on two of the factors, namely safety culture and management support. The review will be attempting to identify elements that can clarify what it is in management support and safety culture that has an effect on safety, in addition to presenting a suggestion for work processes as a PSF for Petro-HRA.

This thesis will be exploring the following objectives:

1) The current status of the factors management support and safety culture in SPAR-H.

2) Difficulties with defining and measuring management support and safety culture
3) What is highlighted in research that contributes to the factor’s effect on performance, and is applicable to post-initiating events.
4) Discussion and suggestions for the future of both concepts in work processes as a PSF for Petro-HRA.

Theory

Human reliability analysis

Within the Norwegian and UK oil and gas industry, QRA has been the main tool for risk management (Skogdalen & Vinnem, 2011). QRA, also called Probabilistic risk analysis (PRA), originated in the American nuclear sector in the late 1970s, and gained considerable attention after the Three Mile Island accident in 1979 (Bedford & Cooke, 2001). Focusing mainly on technical systems and capabilities, it has been criticized for not including human and organizational factors. In order to incorporate the human element, HRA is now being used together with QRA to try to estimate human failure events (Skogdalen & Vinnem, 2011; Kim & Jung, 2003). HRA methods can be either holistic or atomistic, where holistic methods take into account the overall event, and atomistic methods look at contributing factors that make up a human error probability (HEP) (Boring et al., 2005). HRA methods are concerned with three main goals; identifying "a set of factors believed to be related to performance, focus on classes of human error or behavior, and then manipulate those factors to arrive at a failure rate estimate" (Blackman, Gertman & Boring, 2008, p. 1733).

Critique of HRA

An interesting point made recently by French, Bedford, Pollard, and Soane (2011) claims the problem with HRA is that their foundation is built on engineering approaches, reducing hazards to something designed out of a system. They do this because high risk industries need to learn from limited experience, simulation, stories, and symbolic representations, as they cannot afford to learn from mistakes (Weick, 1987). This makes current HRA methods best suited for the known and knowable spaces. The problem is that many accident scenarios involving human behavior lie in the complex space. While organizational behavior studies are important in identifying individual, organizational and cultural factors, there is a lack of validated models to make quantification straightforward, if even possible (French et al., 2011).

As an example we need to look no further than the Three Mile Island accident (Commission on the Three Mile Island Accident, 1979, as cited by French et.al, 2011, p. 758). The operators were completely unprepared for the incident leading up to the accident, as it was not something that was anticipated by the reactor's design or safety studies. French et al. (2011) points out that because the operators behaved according to their mental models of what they believed was happening, and that the situation was more or less unimaginable, they made no mistakes in the sense of human error within HRA theory.

SPAR-H

SPAR-H, originally developed for the nuclear industry, appeared in response for a need of an easy to use HRA method (Gertman et al., 2005). THERP, Technique for Human Error Rate Prediction, had been the leading analysis tool of its kind, but proved to be both time consuming and demanding a lot from its conductors (Blackman et al., 2008; Boring & Blackman, 2007; Whaley et al., 2011). A simplified version of THERP was made, called Accident Sequence Evaluation Program Human Reliability Analysis Procedure (ASEP), but the results deviated too much from the original analysis. It became a screening method, used only for rough estimates. SPAR-H was then created with THERP and ASEP as a foundation. SPAR-H has since its birth gone through three main revisions, the most recent one in 2005. There has also been released a step-by-step guidance to aid in using SPAR-H (Boring & Blackman, 2007, Gertman et al., 2005; Whaley et al., 2011).

SPAR-H is concerned with the last of the three goals in HRA mentioned earlier, namely failure rate estimates, or quantification of human error probabilities (HEPs). Prior to this, the risk analyst has already collected data about the situation or task that is being examined, by using task analysis and human error identification. Human error identification means describing possible causes and types of errors in the situation, while task analysis is describing tasks performed by the operator and the operators general role in the system (Kirwan, 1994).

In an accident scenario, many causes can potentially lead up to an initiating event (e.g. gas leak), which in turn will have consequences. SPAR-H is concerned with post-initiating events, which means it is concerned with where the probabilities for human error are greatest after an initiating event has occurred, but before there is a major accident. These are scenarios where the human operator plays a critical role, and failure here is called a human failure event (HFE). In SPAR-H HFE are categorized into two task types - diagnosis and action. Diagnosis means processing information, getting ready to perform an action (carrying out an activity, like operating equipment). When personnel diagnose an event they interpret and decide what to do next, relying on knowledge and experience (Gertman et al., 2005). By calculating a human error probability (HEP), SPAR-H can quantify the probabilities for human failure using performance shaping factors (PSFs) (Whaley et al., 2011).

The PSFs are – available time, stress, complexity, experience and training, procedures, ergonomics/HMI, fitness-for-duty and work processes. "These PSFs were derived from reviews of psychological research on human error" (Boring et al., 2005, p. 1818). The HEP is calculated by multiplying the eight PSFs, according to their impact on the HEP. Each PSF has a nominal baseline of 1.0, meaning it has no influence on the HEP, or there is insufficient information to rate it. A PSF can affect the HEP both positive (by a decrease in error probability), or negative (by an increase in error probability). A decrease in error probability would mean the PSF is rated with a nominal value lower than 1.0, while an increase would set it higher than 1.0 (Lois et al. 2009). HEPs for both diagnosis and action are made and summed up to a combined HEP. The multipliers for diagnosis and action are for some PSFs different (Whaley et al., 2011), like are shown in figure 1.

Figure 1. Examples from the SPAR-H worksheets for assigning PSFs (Gertman et al.,2005)

A. Evaluate PSFs for the Diagnosis Portion of the Task, If Any.

PSFs	PSF Levels	Multiplier for Diagnosis	Please note specific reasons for PSF level selection in this column.
Work Processes	Poor	2 ☐	
	Nominal	1 ☐	
	Good	0.8 ☐	
	Insufficient Information	1 ☐	

A. Evaluate PSFs for the Action Portion of the Task, If Any.

PSFs	PSF Levels	Multiplier for Action	Please note specific reasons for PSF level selection in this column.
Work Processes	Poor	5 ☐	
	Nominal	1 ☐	
	Good	0.5 ☐	
	Insufficient Information	1 ☐	

Work processes in SPAR-H

The work processes PSF was originally called Crew Dynamics, and focused on communication and team interaction in command and control situations. Poor Crew Dynamics would be linked to situations where there was a lack of training or procedures, implying poor communication. In the 1999 revision the PSF was relabeled Work Processes, now also including elements like plant culture and management involvement (Boring & Blackman, 2007).

Work processes today consists of six different factors, namely; inter organizational, safety culture, work planning, communication, management support and policies (Gertman et al., 2005). A potential problem when including this many factors is that it may give the user problems in assigning the appropriate level. Because though one of the factors may be sufficiently good, it is not enough to be assigned "*good*" unless it contributed specifically to diagnose an event. Also, should there be conflicting factors, meaning that one could be assigned "*good*" and another "*poor*", the dominant factor is to be chosen (Whaley et al., 2011). Choosing a dominant factor is subjective and left to expert opinion.

A description of work processes is provided in SPAR-H (Gertman et al., 2005). The first paragraph of this description is given here:

"Work processes refer to aspects of doing work, including inter-organizational, safety culture, work planning, communication, and management support and policies. How work is planned, communicated, and executed can affect individual and crew performance. If planning and communication are poor, then individuals may not fully understand the work requirements. Work processes also include any management, organizational, or supervisory factors that may affect performance" (Gertman et al., 2005, p. 26).

Defining management support and safety culture

Management support. SPAR-H does not offer a specific definition of what management support is. What is clear from SPAR-H and the guidance provided is that management support tells us something about how supervisors and managers relate to employees in order to provide support for performance on daily work tasks, as well as support during an event.

"Work processes include consideration of coordination, command, and control. Work processes also include any management, organizational, or supervisory factors that may affect performance". "The shift supervisor also plays a major role in work processes. Instances where the shift supervisor gets too involved in the specifics of the event – in contrast to maintaining a position of leadership in the control room – would indicate a breakdown in Work Processes" (Gertman et al., 2005, p. 26).

Managers and supervisors influence employees in different ways. Supervisors differ from site managers by having an impact on immediate and behavioral aspects of daily activities. They affect employees more directly by providing feedback and monitoring compliance with higher level management direction. Site managers appear to be more influential on the more ambiguous work constructs such as workforce attitudes and motivation. They also establish priorities through procedures and policies, giving them an indirect effect on the workforce (O'Dea & Flin, 2000; Thompson, Hilton & Witt, 1998). In addition to this, managers and supervisors both influence workers' behaviors directly and indirectly. "The direct effects relate to the managers' and supervisors' modeling of safe and unsafe behaviors and to their reinforcement of subordinates' behavior through monitoring and control" (Flin & Yule, 2004, p. 46). They also affect employees indirectly by creating a distinct safety culture by setting practices and procedures (Flin & Yule, 2004).

Management support is part of a supportive environment, together with social support and workplace climate (Nahrang, Hofman & Morgeson, 2011). In the context of safety, management is supportive through leadership by being concerned about employee safety, convey a message of safe work practices to employees, and aid employees in developing a higher standard of safety (Nahrang, Hofman & Morgeson, 2011; Zacharatos, Barling & Iverson, 2005).

Gertman et al. (2002) proposes three ways in which management can negatively influence safety - inadequate supervision, inadequate knowledge of systems and plant operations, and organizational structure. In their study, reviewing operating events at U.S. commercial power plants, 30 percent of the 37 operating events investigated had management and supervision as a present error. Of the 270 errors identified, 11 were related to management and supervision.

Measuring. Management is supportive through leadership, which means we can measure leadership to make assumptions about management support. Transformational leadership is a leadership style that has recently been found by many authors to have an effect on safety performance (Flin & Yule, 2004; Zacharatos et al., 2005). Self-report surveys or questionnaires are widely used to gather information about leadership style. The results of these surveys are then compared to safety performance measures so that conclusions on effect can be made (Hunter, Bedell-Avers & Mumford, 2007).

Transformational leaders are supportive through inspiring safe working practices by setting a leading example, encouraging employees to speak up about occupational safety issues, and opt for the importance of sharing information about safety and risk (Barling, Loughlin & Kelloway, 2002). This is particularly true for middle managers, which have proven to be most effective when they are involved in safety and promote open communication (Flin & Yule, 2004).

The four I's that comprise transformational leadership are idealized influence, inspirational motivation, intellectual stimulation and individualized consideration (Bass & Avolio, 1994). Barling et al. (2002) conceptualize the importance of safety through transformational leadership like this:

1) Idealized influence means leaders promote and model safety through their personal behaviors.
2) Inspirational motivation convinces employees to believe they can attain higher levels of safety.
3) Intellectually stimulating leaders help employees focus on safety and develop new ways to attain higher safety levels.
4) Individualized consideration is shown by leaders who are genuinely concerned for their employees well being and safety (Barling et al., 2002).

Transformational leadership also gives clues to other ways of measuring management support for safety. Looking at the four I's we can see that safety-oriented interactions are important, as well as a managers personal behavior, which is a shared view of many authors (Zohar, 2002a). In addition to this, elements of transactional styles of leadership have been found to have an effect at the supervisory level through monitoring and reinforcing employees' safety behavior (Flin & Yule, 2004).

Issues with measuring. It has recently been suggested that safety-specific transformational leadership differ from regular transformational leadership (Kelloway, Mullen & Francis, 2006). A safety-specific transformational leader is one that possesses the qualities of transformational leadership, but focuses explicitly on inspiring and promoting practices related to positive safety. The difference is highlighted because transformational leaders not necessarily are safety leaders (Mullen & Kelloway, 2009).

Safety culture

Guldenmund (2010, p.1466) once suggested that; "Safety culture has become a term used by people all around the globe to explain everything relating to safety failures that cannot be explained in any other way". The SPAR-H guidance document does not explicitly mention any characteristics of safety culture, however there are two references that are relatable to culture. One is the line referring to schisms; "schisms between operators and management are also considered work process problems" (Gertman et al., 2005, p. 26). Different safety cultures can cause schisms by that schisms are "a split or division between strongly opposed sections or parties, caused by differences in opinion or belief" (Schism, 2010, p. 7167). The second line stating, "Conditions with effects adverse to quality are also included in the work processes category, as are problems associated with a safety-conscious work environment" (Gertman et al., 2005, p. 26), where a safety-conscious work environment is to be considered as a part of safety culture. Safety consciousness is employees' safety knowledge and safety behaviors (Kelloway et al., 2006).

There is no universal agreement on the definition of safety culture, despite it being listed as a contributing factor to several industrial accidents. Amongst those are the nuclear accident at Chernobyl (1986), and the Piper Alpha oil platform explosion (1988) (Clarke 2000; Cox & Flin, 1998; Wiegmann, Zhang, Von Thaden, Sharma, & Gibbons, 2004). Earlier attempts at defining safety culture has ended up in a few broad categories of general interests, with uncertain hints of linking them together into a model (Guldenmund, 2000), and the studies generally lack in theoretical underpinning (Clarke, 2000). There is also an ongoing debate on the differences between safety culture and safety climate, and the terms are often used interchangeably (Clarke, 2000; Mearns & Flin, 1999).

The Advisory Committee on the Safety of Nuclear Installations (ACSNI) proposed the following definition of safety culture; "the safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies and patterns of behavior that determine the commitment to and the style and proficiency of an organization's health and safety management" (ACSNI, 1993, p.23, as referred to in Lee & Harrison, 2000, p.62).

Safety culture is also considered to be stable over time, resistant to change (Wiegmann et al., 2004). Safety climate has been suggested to be a 'snap shot' of safety culture (Mearns, Flin, Gordon, & Fleming, 1998; Wiegmann et al., 2004), and the difference between the two is proposed as the difference between mood and personality. Safety culture then, is the enduring characteristics of an organization's way of dealing with safety issues, while safety climate will differ depending on the situation and operational circumstances (Wiegmann et al., 2004). Others have claimed that climate is the espoused values of an organization, identified as attitudes, with culture being the cause of these attitudes (Guldenmund, 2000; Schein, 1992). This means that safety climate reflect employees' perceptions of the organizations' policies, the practices concerning safety at work, and procedures. This informs employees of the priority given to safety at work in their organization (Barling et al., 2002).

Regardless of this, most researchers have tried to identify some common key indicators of safety culture (Wiegmann et al., 2004), because attitudes are always attitudes about something (Guldenmund, 2000). There are as many elements of safety culture and climate as there are authors, but as an example of content categories Wiegmann and colleagues (2004) have identified five global factors of safety culture: organizational commitment, employee empowerment, management involvement, reward systems, and reporting systems. Where management involvement refers to safety specific interaction between managers and employees. In safety climate most studies seem to highlight some form of management support, either through commitment or concern for employee's safety (Griffin & Neal, 2000). No matter what you include in the culture concept, it is important to remember that; "a culture is much more than the sum of its parts" (Lee & Harrison, 2000, p. 62).

Measuring. There are three approaches to assessing safety culture. The academic approach uses interviews and observations to make thick descriptions about the culture. The analytic approach mainly uses self-administered questionnaires to develop factors, dimensions or scales on which the organization can be assessed or compared on. Finally, the pragmatic approach relies on expert opinion in order to develop an organization's safety culture, and is primarily concerned with the future (Guldenmund, 2010). Most research on safety culture imply that the concept is measured on a continuum, from poor to good, but some also claim safety culture in an organization to be either present or absent (Wiegmann et al., 2004).

Interestingly, safety climate questionnaires have been the predominant way to measure safety culture (Guldenmund, 2007: Guldenmund, 2010). "Most studies seem to have focused on climate measurement issues, including factorial structure of measurement scales and its predictive validity with regard to a variety of safety outcomes" (Zohar, 2010, s.1517). Climate, as mentioned previously, is closely linked to attitudes, and safety climate research has been said to basically be attitude research (Guldenmund, 2007). Clarke (2006) has elaborated this by pointing out that boiling down the safety culture and safety climate research we are left with 'perceptions' and 'attitudes' - attitudes towards safety practices, and perceptions of risk. Attitudes in turn inform the importance of acting safely, meaning it influences people's behavior (Zohar, 2002b) and behavior is measurable, which makes climate semi-quantitative. Culture, on the other hand, remains a challenge to quantify, because it relies heavily on qualitative data, like interviews, observations and mutual comparisons (Guldenmund, 2000).

Issues with measuring. Comparing HRA in the offshore environment to the nuclear industry, which is the birthplace of SPAR-H, there are two things that become apparent. First, that there is a higher variation in operational concept in the offshore oil installations than for nuclear plants, which amongst others affect available personnel and regulatory requirements, and second, that there is in general less time available to analysis (Gould et al., 2012; Ringstad & Szameitat, 2000). This brings two challenges to measuring safety culture – a vast number of suppliers and sub-contractors will create a variety of subcultures, not only on different levels, but also within crew teams. Which in turn will give test conductors an even greater challenge given the time they have to complete the test, as interviewing and working with the interviews afterwards is time consuming.

Subcultures are problematic in a number of ways. For one, interviews with different groups of people (crew, teams etc.) might deliver very different results in terms of measured safety culture. For example, in an earlier study by Rundmo (1994), it was found that personnel in the “sharp end”, who were the ones most prone to accidents, had a higher perception of risk than others. It is also difficult to decide the limits of a group, and one person can belong to several subcultures by being a member of multiple groups (Guldenmund, 2010).

Subcultures also have cross-level challenges. Illustrating this, Mearns et al. (1998) found that senior management were more positive to safety than the middle management. They attribute this to that the senior management is mostly set onshore, and are not in any direct risk of injury. They hold the ‘safety culture’ of the organization, with general values and beliefs, whereas the middle managers are set to enforce this culture, through setting a ‘climate’. Hence the work force might be experiencing contradictory information from the safety culture and the safety climate.

Method

The literature search was made primarily through an electronic search of relevant data bases connected to all major publishing journals, primarily PsycNET (psycnet.apa.org) and Google Scholar (scholar.google.com). Search words include: safety climate, safety culture, safety leadership, transformational leadership and offshore safety. In addition to the electronic search, a manual search was conducted using reference lists of key theoretical and empirical articles.

In this review articles concerning research from high risk industries were primarily favored. Some articles were included from the manufacturing industry because of particularly good measures of either safety culture/climate or management support. Because safety climate has been a popular measure for safety culture, and there is confusion between the terms, both articles on safety culture and safety climate have been included. For the rest of this thesis, when referring to both terms the word 'safety culture/climate' will be used, and if one of the concepts are mentioned specifically it will be denoted 'safety culture' and 'safety climate' respectively.

For being included in the review the criteria was that the article must 1) measure safety culture/climate or aspects of management support mentioned earlier, 2) be within a high risk organization and 3) have a measure of performance. Safety related performance, in this review, is any behavior that leads to greater safety and the avoidance of accidents, for example compliance and participation. "Safety compliance means following set policies and procedures, while safety participations mean behaviors that indirectly leads to a safer environment "(Cree & Kelloway, 1997), like raising safety issues with managers (Mullen, 2005). Accident and injury data were also a source of performance measure.

The search was completed when searching did not result in new relevant data. A total of 25 pieces of literature were found to be relevant. 14 pieces were found for management support, and 11 were found for safety culture/climate. A complete list with the literature used for the review can be found in Tables 1 and 2. The literature was continuously reviewed through thematic analysis (Howitt, 2010). Similar emergent themes, or elements, were grouped together into factors for management support and safety culture/climate respectively.

None of the articles for safety culture display a direct relationship between the factors identified and performance. Within management support a couple of the articles did (Zacharatos et al., 2005). The factors that have been identified have been done so based on their frequently mentioning in the research, being highlighted as being important, and because they were part of a research piece saying that safety culture/climate or management support had an effect on safety performance. Some of the factors that came up were found to already be covered by other PSFs, and were disregarded in this review. Those include factors that fit under training, experience and procedures. An example of this is Vredenburgh’s article (2002) that found that front-end hiring and training of new personnel was the most effective step in reducing injury rates.

Table 1. Research and literature reviewed for management support

Author and year	Title
Barling, Kelloway & Loughlin (2002)	Development and Test of a Model Linking Safety-Specific Transformational Leadership and Occupational Safety
Hofmann & Morgeson (1999)	Safety-Related Behavior as a Social Exchange: The Role of Perceived Organizational Support and Leader-Member Exchange.
Kelloway, Mullen & Francis (2006)	Divergent Effects of Transformational and Passive Leadership on Employee Safety
Mearns, Withaker & Flin (2003)	Safety Climate, safety management practice and safety performance in offshore environments
Mullen & Kelloway (2009)	Safety leadership: A longitudinal study of the effects of transformational leadership on safety outcomes
O'Dea & Flin (2000)	Safety Leadership in the Offshore and Gas Industry
O'Dea & Flin (2001)	Site managers and safety leadership in the offshore oil and gas industry
Thompsen, Hilton & Witt (1998)	Where the Safety Rubber Meets the Shop Floor: A Confirmatory Model of Management Influence on Workplace Safety
Vredenburgh (2002)	Organizational Safety: Which management practices are most effective in reducing employee injury rates?
Zacharatos, Barling & Iverson (2005)	High-performance work systems and occupational safety
Zohar (2002a)	Modifying Supervisory Practices to Improve Subunit Safety: A Leadership-Based Intervention Model
Zohar (2002b)	The effects of leadership dimensions, safety climate, and assigned priorities on minor injuries in work groups
Zohar & Luria (2003)	The use of supervisory practices as leverage to improve safety behavior: A cross-level intervention model
Zohar & Luria (2004)	Climate as a Social-Cognitive Construction of Supervisory Safety Practices: Scripts as Proxy of Behavior Patterns

Table 2. Research and literature reviewed for safety culture/climate

Author and year	Title
Griffin & Neal (2006)	A Study of the Lagged Relationships Among Safety Climate, Safety motivation, Safety behavior, and Accidents at the Individual and Group Levels
Griffin & Neal (2000)	Perceptions of safety at work: A framework for linking safety climate to safety performance, knowledge, and motivation
Lee (1998)	Assessment of safety culture at a nuclear reprocessing plant
Lee & Harrison (2000)	Assessing safety culture in nuclear power plants
Mearns, K., Flin, R., Gordon, R. and Fleming, M. (1998)	Measuring safety climate on offshore installations
Mearns, K., Withaker, S.M., Flin, R. (2003)	Safety climate, safety management practice and safety performance in offshore environments.
Neal, Griffin & Hart (2000)	The impact of organizational climate on safety climate and individual behavior
Thompsen, Hilton & Witt (1998)	Where the Safety Rubber Meets the Shop Floor: A Conformatory Model of Management Influence on Workplace Safety
Zacharatos, Barling & Iverson (2005)	High-performance work systems and occupational safety
Zohar (2000)	A group-level model of safety climate: testing the effect of group climate on microaccidents in manufacturing jobs
Zohar & Luria (2004)	Climate as a social-cognitive construction of supervisory safety practices: Scripts as proxy of behavior patterns

Results

The literature review identified many elements that together make up management support and safety culture/climate respectively. Many more elements were also found, but disregarded for either being covered in another PSF, or only mentioned once by one author in addition to not relating to other elements. This was done because the focus of this review is not to examine the composition of management support and safety culture/climate, but to review which factors stood out from the literature as having an effect on safety performance. The review resulted in five factors for management support and six factors of safety culture/climate. The factors and their contributing elements can be seen in Tables 3 and 4, and a description of the factors follow each table.

Problems with data collection include issues with a lack of relevant research articles, and conflicting results. The main problem considering the literature on this field, are the problems related to inconsistencies in what the concepts are defined to be. Authors not only give different definitions, but also relate the concept to different things. Safety culture is, in addition, a more ambiguous concept than management support because of its undefined nature. The factors presented here are not a suggestion for an absolute list of management support or safety culture/climate factors; they are simply the factors most commonly mentioned and highlighted as being important for safety outcomes in the research pieces reviewed. It is unlikely that the list is exhaustive.

Management support and safety culture/climate have overlapping themes, which will be covered in the discussion section. Because of this, some articles about safety culture/climate are relevant for management support, and vice versa. This complicates the review, as there are unclear boundaries as to where one concept ends and another begins. This might be less of an issue in use of the current SPAR-H method, as both are contained within the same PSF, which is scored as a whole.

Table 3. Management support

Factor	Elements	Source
Commitment	Management commitment to safety Management commitment to employees/concern for employees	O'Dea & Flin (2000) Vredenburgh (2002) Mullen & Kelloway (2009) Mearns et al. (2003) Barling et al. (2002) Hofmann & Morgeson (1999) Mullen & Kelloway (2009) Kelloway et al. (2006) Zohar (2002b) Zohar & Luria (2004)
Communication	Safety communication/interaction Open communication Feedback	Hofmann & Morgeson (1999) Zohar & Luria (2003) Mullen & Kelloway (2009) Barling et al. (2002) Zohar (2002a) Vredenburgh (2002) Mearns et al. (2003) Zohar (2002b) Zohar (2002a) Zohar & Luria (2003) Thompson et al. (1998) Vredenburgh (2002) Zohar & Luria (2004)
Trust	Relationship building Trust in management	Hofmann & Morgeson (1999) Zohar (2002b) O'Dea & Flin (2001) Zohar & Luria (2004) Zacharatos et al. (2005) Barling et al. (2002) Hofmann & Morgeson (1999)
Involvement	Actively tending to safety issues	Kelloway et al. (2006) Mearns et al. (2003) O'Dea & Flin (2001)
Supervision	Monitoring compliance with managements' direction Visibility	Thompson et al. (1998) Zohar (2002b) Zohar (2002a) O'Dea & Flin (2001)

Commitment. Accidents have been negatively associated with management commitment (Mearns et al., 2003). Commitment can be said to illustrate how management expresses safety values. Although being an ill defined concept, commitment is seen by most to be related to leaders modeling behavior and talking positively about safety, and by showing a sincere concern for employee safety, by for example clearly prioritizing safety over production (O'Dea & Flin, 2000). When management expresses their values through commitment, employees are informed of the importance of safety. O'Dea and Flin (2000) supports this by finding that team leader commitment to safety was a predictor of workforce compliance to rules. Managers' and supervisors' personal commitment also facilitates trust and organizational loyalty (Barling et al., 2002). Management commitment to employees demonstrates that the organization values each worker, which leads to more open communication and trust (Hofmann & Morgeson, 1999). Commitment is somewhat overlapping with involvement, although constantly separated in the literature. Commitment in some instances, resemble an attitude, where involvement is the action taken on the basis of that attitude.

Communication. Communication with management is important in predicting safety outcomes, in a number of ways. Safety-oriented interactions between managers/supervisors and employees have increased the use of protective gear, and lowered minor-injury rates (Zohar, 2002a). Feedback is supporting this by increasing safety-oriented interactions. Feedback is given by one-to-one interactions, addressing specific safety related actions and events, and talking more about safety with employees in general (Vredenburgh, 2002; Zohar & Luria, 2003). Feedback can also be linked to relationship building through communication, which has previously been found to have a positive effect on accident rates (Smith et al., 1978, as referred to in Flin & Yule, 2004). Open communication about accidents, general safety concerns and accidents is also found to be important. This is important, amongst others, to reduce the risk of under-reporting of near-misses (Kelloway et al., 2006; Vredenburgh, 2002; Zohar, 2002a).

Trust. Trust in management has been found to have an effect on safety incidents (Zacharatos, Barling, & Iverson, 2005). Trust is built through good relations between managers/supervisors and employees. Trust fosters open communication. Employees who found their management to be supportive, and had a good relationship with their supervisor, were more likely to raise concerns regarding safety. Safety related interactions like these could ultimately be linked to commitment and frequency of accidents (Hofmann & Morgeson, 1999). O'Dea and Flin (2001) emphasize the importance of an "open door" policy, where trusting relationships set the foundation for communication, where employees openly can come with suggestions and be heard.

Involvement. Managers can be involved in safety through multiple levels, from work planning to safety management programs. Individually, managers and supervisors can involve themselves in safety through decision-making and personal responsibility (Mearns et al., 2003). Involvement is also related to being proactive about safety, by tending to safety related matters and following up on incidents and accidents, and by doing so being a support for employees (O'Dea & Flin, 2001). Leaders uninvolved, or passive to safety, can affect safety performance negatively (Kelloway et al., 2006). When the leader is more involved in subordinate's safety this has an effect on the safety climate, which in turn affects the group's safety behavior (Zohar, 2002b).

Involvement is highlighted as an important part of transformational leadership. Transformational leadership in turn affects safety consciousness, which is employees' knowledge of safety and safety behaviors, this is turn predicts safety outcomes (Barling et al., 2002; Kelloway et al., 2006).

Supervision. Supervisor actions can be related to safety outcomes through supervision. Ineffective supervision has been associated with poor safety records (Zohar, 2002b). Supervisor support (monitoring) has been shown to have a direct effect on compliance to rules (Thompsen et al., 1998), and an increase in supervisory practices resulted in a significant decrease of minor injuries in one study (Zohar, 2002a). Supervision is also closely related to feedback and safety specific interactions (Zohar, 2002b). Supervision can also mean being visible at the worksite, by participating in the work tasks and thereby being a role model for safety (O'Dea & Flin, 2001). Visibility is added under supervision in this review because it refers to an overseeing activity, but it could also have been placed elsewhere, like under involvement.

Safety culture

Table 4. Safety culture

Factor	Element	Source
Regulatory	Rules and regulations Policies Procedures	Mearns et al. (1998) Zohar (2000) Lee (1998) Lee & Harisson (2000) Zohar & Luria (2004) Mearns et al. (1998) Zohar & Luria (2004) Zohar (2000) Zacharatos et al. (2005) Lee (1998)
Practices	Practices Managerial patterns	Zohar (2000) Griffin & Neal (2000) Zohar & Luria (2004)
Management	Goal congruence Politics Management safety values Management/supervisor commitment to safety Management style Concern for employees	Thompsen et al. (1998) Thompsen et al. (1998) Neal & Griffin (2006) Zacharatos et al. (2005) Zohar & Luria, 2004 Mearns et al. (1998) Mearns et al. (2003) Lee & Harisson (2000) Mearns et al. (2000) Neal et al. (2000) Griffin & Neal (2000)
Autonomy	Trust (supervisor competence) Fairness Perceived empowerment	Thompsen et al. (1998) Mearns et al. (2003) Thompsen et al. (1998) Lee & Harisson (2000) Lee (1998)

Communication	Open communication Safety communication	Neal et al. (2000) Mearns et al. (1998) Zacharatos et al. (2005) Mearns et al. (2003) Griffin & Neal (2000) Lee & Harrison (2000)
Safety environment	Safety systems Safety equipment	Neal et al. (2000) Mearns et al. (1998) Zacharatos et al. (2005) Mearns et al. (1998) Griffin & Neal (2000)

Regulatory. "Procedures, rules, and regulations" was found by Clarke and Flitcroft (2006, as referred to in Clarke, 2006, p. 324) to be the second most frequently occurring theme in safety climate research. Policies, together with rules and regulations, form the strategic safety culture (strategic goals etc.), in which procedures are established to facilitate these policies and regulations (Wiegmann et al., 2004; Zohar, 2000). Middle management and supervisors are then set to enforce the procedures, interpreting them by setting practices (Mearns et al., 1998; Zohar, 2000). This means that there are two levels on which culture/climate forms, one related to organization level and the other to supervisory practices and employees (Zohar, 2000).

Practices. Practices are the actual implementations of the procedures set by management. Practices can differ from procedures by that procedures rarely cover *every* situation, which gives supervisors a certain amount of freedom in deciding how things should be done. This will in turn result in differences in practice between companies and teams, which means there will be different cultures/climates (Zohar, 2000). Zohar and Luria (2004) also focus on the predictability of practices, managerial patterns, and how this affects climate. An example here is that the supervisor consistently ignores certain safety procedures in favor of production speed.

Management. Management is the most noted factor that is said to affect safety culture, and it overlaps somewhat with both regulatory and practices. The factor incorporates everything management (including supervisors) does to set the stage for safety. Management prioritizing safety and visits by senior onshore personnel were related to management commitment to safety (Mearns et al., 2003). Managers and supervisors can display political behavior when they avoid elevating unpleasant and controversial matters, which can result in employees hesitating to raise safety concerns (Thompsen et al., 1998). Managers' safety values and concern for safety inform employees on the importance of safety. Zohar and Luria (2004) have, among others, emphasized managers' priority of safety relative to competing goals, like production speed. Management style has also been shown to affect employees' safety perceptions (Lee & Harrison, 2000).

Management can also be said to hold all the concepts found for management support, as most researchers emphasize the close connection between management and culture. Managers are said to affect safety climate, which in turn affect safety outcomes, like compliance with rules (Kelloway et al., 2006; Thompson et al., 1998). When SPAR-H separates the two concepts, it could be based on that management support is referring to supervisory practices, while safety culture is the employee's perception of those practices.

Autonomy. Autonomy refers to employees' feelings of trust, being treated fairly, and empowerment. An aspect of good safety culture is to empower employees into taking responsibility for safety (Wiegmann et al., 2004) Trusting management decision and experiencing your supervisor as competent, is another important aspect of autonomy. Raising safety concerns is easier if employees experience that their supervisor will take them seriously and address the issue (Mearns et al., 2003). Also being treated fairly is highlighted as important. Employees who feel they are being treated fairly will more often raise safety concerns, and are more likely to report near-misses (Lee & Harrison, 2000; Thompsen et al., 1998).

Communication. Communication was found to be an important part of safety culture/climate, and two types of communication stood out: open communication and safety specific communication. Safety specific communication refers to the exchange of information that concerns safety, like technical aspects (Griffin & Neal, 2000). Open communication is important in that everyone feels free to talk about safety concerns and near misses without fear of being reprimanded (Mearns et al., 1998; Neal et al., 2000). This in turn affects trust in management, overlapping the communication factor with autonomy, and also management support. Open communication is also beneficial in that when employees are comfortable with talking about safety related issues with their supervisor they become more committed to following safety procedures and practices (Hofmann & Morgeson, 1999).

Safety environment. Safety environment is the physical safety environment and the safety systems provided. This means everything from the actual existence of, to adequacy of safety equipment, to the safety systems provided (Griffin & Neal, 2000). A safety system has been identified to be different aspects of the organization's safety management system, including safety officials, safety committees and permit to work systems (Flin, Mearns, O'Connor, & Bryden, 2000). Though it is not so much about the actual environment as it is about employee perceptions of that environment. For example, the availability of safety equipment can impact employees' attitudes to using them. If safety equipment is not readily available, this can be taken as a sign from management that it is not important. These safety behaviors (or lack of them) inform the culture. "Culture involves beliefs about how to behave within an organizational unit" (Mearns et al., 1998, p.239).

Discussion and implications for future improvement of the PSF

This review has focused on literature linking safety culture/climate and management support to safety performance within high risk industries, with the intention of making a contribution to the Petro-HRA project. Reviewing relevant literature has resulted in two systematic frameworks with factors that are within the boundaries of the PSF work processes. Factors have emerged through thematic analysis. Six factors were found for safety culture (management, regulatory, communication, safety environment, motivation, perceived safety and practices), and five factors were found for management support (trust, communication, commitment, supervision, and involvement).

In management support the factors can be grouped based on how they affect employees. Two of the factors are considered to have a direct effect, communication and supervision, while the other four affect indirectly. In safety culture factors can be divided in terms of levels, where management and regulatory are on a management/supervisor level of influence, while safety environment, autonomy and practices are considered employee level. Communication in safety culture/climate is a multi-level construct affecting safety through both the management/supervisor level and the employee level. Because the factors found in this review refer to employees' attitudes and perceptions of these factors, another way to group them is by using Guldenmund's (2000) suggested four categories of safety attitude objects; hardware/physical environment, software, people, and behavior. Although slightly differently grouped, this review produced examples for all of Guldenmund's categories. Hardware/physical environment in this case would be safety environment, with things like protective gear and safety systems. Safety procedures could be considered software, as it is often a part of the safety management system. Because procedures are formed by the rules and regulations, all things regulatory could also be placed within software. People, in this review, will be related to supervisors and managers. Behavior is any act related to safety, which in this review would be found in several of the factors. Management (concern for employees), communication, and practices can all be related to behavior.

Reviewing the literature

One of the major challenges with reviewing the literature was the notable difference in measured concepts. Few articles presented a complete list of concepts for what safety culture and management support entailed, and the number of items varied from three (Thompsen et al., 1998) to 19 (Lee, 1998). Some explained every item in detail, while others only listed the names of the items. There was also a degree of overlap between items for safety culture/climate and management support, in addition to inconsistencies in the general definitions. This is not a new finding, as several authors have already noted the issues within his field (Clarke, 2006; Guldenmund, 2000; Guldenmund, 2010). For one, there is a wide disagreement on the use of safety culture and safety climate. The terms are used interchangeably and only a few do separate them. One of the earliest articles did not separate safety climate from organizational climate, but claimed the concept of safety culture was really organizational climate looking at safety (Thompsen et al., 1998). There is also confusion on which underlying factors safety culture/climate consist of. For example, while some authors considered trust in management to be an integral part of safety climate (Thompsen et al., 1998), others have measured it separately as a mediator (Zacharatos et al., 2005). This was also true for other factors in safety culture/climate, like safety behaviors (e.g. wearing protective gear) and trust in management.

The management support material had fewer of these issues, but inconsistencies were also found here. Overlapping factors was the most common one. For example, where concern for employees was related to relationship-building in one article (Zohar, 2002b), it was related to work commitment in another (Hofmann & Morgeson, 1999). This overlapping of themes comes primarily from that reasearchers each make up the contents for the concepts they use, making them very subjective. It is also common for researchers to change contents of a concept for a follow-up study, making it difficult to pinpoint consistencies. The lack of agreement on definitions result in a pool of concepts, where everything is related to everything. This makes arguing about the importance of some concepts over others difficult, as there are no clear boundaries, and no clear relationship between cause and effect.

The close connection between safety culture/climate and management support was also made clear several places in the literature (Mearns et al., 2003; Zohar, 2002b). O'Dea and Flin (2001) claims that when management is proactive and actively tending to safety issues they can challenge poor safety practices. Safety practices was found, in this review, to be a factor within safety cuture/climate.

An interesting conflicting finding was found between the reviewed literature and the guidance provided for *work processes* in SPAR-H. Involvement, in this review, was considered a positive thing managers and supervisors can do to enhance safety performance, however in SPAR-H, involvement is specifically listed as something potentially negative, by managers becoming "too involved" (Gertman et al., 2005).

Policies was one of the sub-factors identified within *regulatory* for safety culture, but *policies* is also a separate concept within *work processes* (Whaley et al., 2011). Many authors mention ‘policies’ as the company’s ideal culture, created by high-level managers as company goals and strategy (Clarke, 2000; Wiegman et al., 2004). It is then the middle-managers who need to convey these believes and attitudes from the higher levels to the work force, but because of differences in risk perception (amongst other things), the ideal culture is translated into something more meaningful to employees, and thus creates a sub-culture, or a safety climate. Policies then, have an indirect effect on safety culture/climate.

Improving work processes

The factors that emerge from this review are all very general in that they give us some information on how safety culture and management support function, generally, in high risk industries. The work processes PSF in SPAR-H is also very general in its’ listing of contributing factors and description of these. Looking at work processes as a whole, the way it is presented today, a suggestion as to how the different factors relate to each other can be illustrated like this:

Safety culture in this model is the binding and mediating factor. Management support and policies are regarded as management level activities, while communication, inter-organizational and work planning are primarily employee level activities. Management support and policies give input to the safety culture, which in turn affect communication, inter-organizational and work planning.

In the way that HRAs are intended, with their focus on PSFs and the isolation of these, culture becomes a tricky concept to split because it is a concept that makes its impact over time. Looking specifically at safety culture in a post-initiating event is then difficult, because culture, unlike an accident scenario, does not have a start, middle and an ending - culture is continuous through time. This does not mean that safety culture does not impact accident scenarios, it does, but pinpointing specific parts of a culture to a certain point in time is a challenge, not only to SPAR-H, but also to HRA in general. Discarding safety culture as a concept within HRA would be a cheap fix to a complicated problem, and would result in overlooking, or turning a blind eye, to important safety issues. The only applicable solution, as of yet, is to make the concept more usable by extracting factors that are precise enough to inform us about someone's performance at a certain point in time.

Of the factors found in this review, a few can be said to fit this criteria and be carried on into a new PSF specifically designed for Petro-HRA. To recap, the factors need to be usable in a post-initiating event, meaning an initiating event has already occurred and the performance of the crew now determine the outcome of the scenario. Factors such as commitment, management and regulatory all have elements that mostly relate to pre-initating events, meaning everything happening up until an initiating event (e.g. gas leak). Elements such as management safety values and relationship building are important to safety, but they do not carry the urgency in them that makes them applicable to post-initiating events.

After excluding the factors that are covered by other PSFs, like regulatory and safety environment, we are left with four factors. The two factors from safety culture/climate are autonomy and practices, and the two factors from management support are supervision and involvement. Management can have an effect on the overall performance of the crew by being involved in the situation, supporting employees by supervision. It is highlighted throughout the literature that active and engaged leaders have the best effect on employee performance. Involvement here means actively tending to the situation, without losing footing or becoming passive. While supervision is supervising the actions taken to avoid an accident, thereby being an active support, and not leaving employees to fend for themselves. The engagement from management will in turn make employees feel safer, evoking feelings of trust and empowerment, which are important in engaging employees in the situation, making them take action, follow procedure etc. When employees have trust in management, and feel empowered (autonomy), they work more safely by being able to make safety related decisions. This is supported by Cohen and Cleveland (1983), who found that employees who were involved in decision making, had specific responsibilities and got immediate feedback about their work, had safer work habits. Autonomy is also closely related to practices, which reflects how things are done in a particular organization or team. 'Managerial patterns' is one part of practices that can affect employee performance by informing employees on how situations should be handled. In example, a supervisor who consistently violates certain rules will affect employee decisions on following similar rules. Practices relate closely to involvement but are separated by that involvement refer to management actions, while practices refer to both management and employee actions.

Looking at the work processes PSF as a whole, the remaining factors not covered by this review are communication, policies, inter-organizational and work planning. Inter-organizational and work planning have not been reviewed, and it is therefore difficult to give recommendations for their use, but as they share similarities of those of regulatory elements, which were found not suitable for assessing post-initiating events, they will not be included in the new PSF. Communication was a factor identified within both management support and safety culture/climate, and policies was found to be an element in the factor regulatory within safety culture/climate. This review has found that while policies are important to safety culture/climate, they do not have an explicit direct effect on situations that can be tied to post-initiating events, which excludes this element from the new PSF. Communication is a challenging factor as communication undoubtedly is important to safety, even in post-initiating events. However, the types of communication uncovered in this review, safety related interactions and open communication, are more likely related to pre-initiating events. Because communication already is covered by its own factor, it will be disregarded as a factor in this review and also not included in the new PSF. Future work on this PSF should look into whether communication can be re-added as a factor.

Keeping the name *work processes*, the new PSF for Petro-HRA will entail two concepts, management support and safety culture. Each of the concepts has two factors; supervision and involvement for management support, and autonomy and practice for safety culture. The name safety culture is preferred over safety climate because culture implies something more stabile than climate (Lee & Harrison, 2000). A suggestion for definition and practical applicable questions, as well as appropriate guidance for PSF levels, are provided below. The PSF levels are taken from SPAR-H (Gertman et al., 2005) and adapted to fit the new factors. Having established a definition for the concepts, the future work for this PSF is deciding what the multipliers for the PSF levels should be.

Work processes

Definition: work processes refer to managerial and cultural factors that influence crew performance. Managers and supervisors have an effect on employees' behavior (Flin & Yule, 2004) Management support for safety is therefore an important part of engaging employees in taking ownership to safety (Mearns et al., 2003). Proactive managerial practices include supervision, where supervisors monitor compliance with management direction (Zohar, 2002b), and being seen to support and model the correct safety behaviors (O'Dea & Flin, 2001). Management and supervisors are also proactive through actively tending to safety issues, involving themselves in safety related matters (Kelloway et al., 2006). Managerial practices are closely tied to cultural factors (Flin & Yule, 2004), which include employees' feelings of empowerment, trust and fair treatment. Viewing your supervisor as competent, trusting their decisions and believing you are being treated fairly all add up to an environment in which employees take responsibility for safety (Mearns et al., 2003; Thompson et al., 1998). Empowered employees speak up about safety and show good judgment in safety related matters (Lee & Harrison, 2000).

Practical questions:

- Does your supervisor actively tend to safety related matters?
- Are supervisors visible and present in events, supporting safe behaviors?
- Do you feel you can put safety first in an uncertain event without the fear of being reprimanded for consequences such as production downtime or other economic loss?
- Do you trust your management and/or supervisor to be competent and to make good decisions?

Poor- performance is negatively affected by the work processes at the rig (e.g., poor command and control by supervisor(s) and management; Supervisor(s) and management are not consistent in practices; performance expectations are not made clear; employees are not encouraged to raise safety concerns).

Nominal- performance is not significantly affected by work processes at the rig, or work processes do not appear to play an important role (e.g., crew and management practices are adequate; supervisor is available but not proactively engaging in events).

Good- work processes employed at the rig enhance performance and lead to a more successful outcome than would be the case if work processes were not well implemented and supportive (e.g., cohesive crew; empowered employees; proficient supervision by supervisor(s) and management; supervisor(s) actively tend to safety related events).

Challenges for work processes

Cultural elements carry with them a few challenges that one should be aware of when trying to assess them. Because culture forms differently for different groups of people, it be teams, crews or even whole organizations (Guldenmund, 2010), the results obtained from one group might not be fitting for another. The undefined nature of safety culture might bring the analyst into situations where things relevant to the PSF appear that are not taken into account in the definition. This is what French et al. (2011) would denote an "unknowable space", and the analyst is encouraged to provide such information in the worksheet, should the analyst feel it would significantly impact the choice of PSF level.

Strengths and limitations

The strengths of this review revolve mainly around the now more specific definition of the PSF, which will help increase inter-rater reliability. The factors that have been chosen for the new PSF have in addition been chosen specifically with the intention of being applicable to post-initating event scenarios, as opposed to the previous definition, which entailed many concepts better suited for pre-initiating scenarios.

Limitations include lack of relevant literature, and that the literature had little consistency in the factors measured, which makes it difficult to choose some factors over others when deciding which factors affect safety performance the most.

Conclusion

This thesis has attempted to identify factors within management support and safety culture/climate that are applicable to form a new work processes PSF for Petro-HRA. A review of the relevant literature has uncovered four main factors that are suited for post-initiating event scenarios. The factors found for management support are involvement and supervision, while the factors found for safety culture/climate are practices and autonomy.

It is important to mention that the factors found in this review are those who stood out in the literature reviewed, and that they not necessarily make up a comprehensive list of possible factors for management support and safety culture/climate. The communication factor should also be reviewed to assess its possible place in the work processes PSF. Summing up the research in this review, it is obvious that work processes as a PSF for Petro-HRA is as of yet - a work in process. Regardless of this, the review has made some progress in establishing a new framework for the work processes PSF in Petro-HRA.

References

Barling, J., Loughlin, C., & Kelloway, E. K. (2002). Development and test of a model linking safety-specific transformational leadership and occupational safety. *Journal of Applied Psychology*, *87*(3), 488. Doi: 10.1037/0021-9010.87.3.488

Bass, B. M. & Avolio, B. J. (1994) *Improving organizational effectiveness through transformational leadership.* California: Sage Publications.

Bedford, T. & Cooke, R. (2001) *Probabilistic risk analysis: foundations and methods*. Cambridge: Cambridge University Press.

Boring, R. L., & Blackman, H. S. (2007). The origins of the SPAR-H method's performance shaping factor multipliers. *Human Factors and Power Plants and HPRCT 13th Annual Meeting,* 177-184. Doi: 10.1109/HFPP.2007.4413202

Blackman, H. S., Gertman, D. I., & Boring, R. L. (2008). Human error quantification using performance shaping factors in the SPAR-H method. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 52(21), 1733-1737. Doi: 10.1177/154193120805202109

Boring, R. L., Gertman, D. I., Joe, J. C., & Marble, J. L. (2005) Human reliability analysis in the U.S. nuclear power industry: A comparison of atomistic and holistic methods. *Proceedings of the Human Factors and Ergonomics Society 49th annual meeting, 49(19) 1815-1819.* Doi: 10.1177/154193120504901913

Clarke, S. (2000). Safety culture: under-specified and overrated?. *International Journal of Management Reviews*, *2*(1), 65-90. Doi: 10.1111/1468-2370.00031

Clarke, S. (2006). The relationship between safety climate and safety performance: a meta-analytic review. *Journal of occupational health psychology*, *11*(4), 315. Doi: 10.1037/1076-8998.11.4.315

Cohen, H. H., & Cleveland, R. J. (1983). Safety program practices in record-holding plants. *Professional Safety*, *28*(3), 26-33.

Cox, S., & Flin, R. (1998). Safety culture: philosopher's stone or man of straw?. *Work & Stress*, *12*(3), 189-201. Doi: 10.1080/02678379808256861

Cree, T., & Kelloway, E. K. (1997). Responses to occupational hazards: Exit and participation. *Journal of Occupational Health Psychology*, *2*(4), 304. Doi: 10.1037/1076-8998.2.4.304

Cullen, W. D. (1990). *The Public Inquiry into the Piper Alpha Disaster*. London, UK: HMSO

Flin, R., Mearns, K., O'Connor, P., & Bryden, R. (2000). Measuring safety climate: identifying the common features. *Safety science*, *34*(1), 177-192. Doi: 10.1016/S0925-7535(00)00012-6

Flin, R., & Yule, S. (2004). Leadership for safety: industrial experience. *Quality and Safety in Health Care*, *13(2) 45-51.* Doi:10.1136/qshc.2003.009555

French, S., Bedford, T., Pollard, S. J., & Soane, E. (2011). Human reliability analysis: A critique and review for managers. *Safety science*, *49*(6), 753-763. Doi: http://dx.doi.org/10.1016/j.ssci.2011.02.008

Gertman, D., Blackman, H., Marble, J., Byers, J., & Smith, C. (2005) *The SPAR-H Human Reliability Analysis Method.* US Nuclear Regulatory Commission.

Gertman, D. I., Halbert, B. P., Parrish, M. W., Sattison, M. B., Brownson, D., & Tortorelli, J. P. (2002) *Review of findings for human error contribution to risk in operating events*. Office of Nuclear Regulatory Research, Division of Systems Analysis and Regulatory Effectiveness, US Nuclear Regulatory Commission

Griffin, M. A., & Neal, A. (2000). Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. *Journal of occupational health psychology*, *5*(3), 347. Doi: 10.1037/1076-8998.5.3.347

Gould, K. S., Ringstad, A. J., & Van de Merwe, K. (2012) Human Reliability Analysis in Major Accident Risk Analyses in the Norwegian Petroleum Industry. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting.* Doi: 10.1177/1071181312561421.

Guldenmund, F. W. (2007). The use of questionnaires in safety culture research–an evaluation. *Safety Science*, *45*(6), 723-743. Doi: 10.1016/j.ssci.2007.04.006.

Guldenmund, F. W. (2000). The nature of safety culture: a review of theory and research. *Safety science*, *34*(1), 215-257. Doi: 10.1016/S0925-7535(00)00014-X

Guldenmund, F. W. (2010). (Mis)understanding safety culture and its relationship to safety management. *Risk analysis*, *30*(10), 1466-1480. Doi: 10.1111/j.1539-6924.2010.01452.x

Hofmann, D. A., & Morgeson, F. P. (1999). Safety-related behavior as a social exchange: The role of perceived organizational support and leader–member exchange. *Journal of applied psychology*, *84*(2), 286. Doi: 10.1037/0021-9010.84.2.286

Howitt, D. (2010) *Introduction to Qualitative Methods in Psychology*. Pearson Education Ltd. Essex, UK

Hunter, S. T., Bedell-Avers, K. E., & Mumford, M. D. (2007). The typical leadership study: Assumptions, implications, and potential remedies. *The Leadership Quarterly*, *18*(5), 435-446. Doi: 10.1016/j.leaqua.2007.07.001

Jærnes, S., Åsland, J. E., Heber, H., Morvik, R., Leistad, G., Enoksen, A. M., & Ellingsen, A. (2005). Human factors I bore- og brønnoperasjoner. Utfordringer, prosjekter, og aktiviteter. *Petroleumstilsynet.* Report nr 2005-4029. Retrieved from Http://www.ptil.no/nyheter/ny-rapport-om-human-factors-i-bore-og-broennoperasjoner-article2296-24.html

Kelloway, E. K., Mullen, J., & Francis, L. (2006). Divergent effects of transformational and passive leadership on employee safety. *Journal of Occupational Health Psychology*, *11*(1), 76. Doi: 10.1037/1076-8998.11.1.76

Kim, J. W., & Jung, W. (2003). A taxonomy of performance influencing factors for human reliability analysis of emergency tasks. *Journal of Loss Prevention in the Process Industries*, *16*(6), 479-495. Doi: 10.1016/S0950-4230(03)00075-5

Kirwan, B. (1994). *A Guide to Practical Human Reliability Assessment*. Boca Raton, FL: CRC Press.

LaSala, K. P. (1998) Human Performance Reliability: A Historical Perspective. *IEEE Transactions on Reliability, 47(3), 365-371.* Doi: 10.1109/24.740553

Laumann, K., Øien, K., Taylor, C., Boring, R. L., & Rasmussen, M. (2014, June). Analysis of human actions as barriers in major accidents in the petroleum industry, applicability of human reliability analysis methods (Petro-HRA). In *Probabilistic Safety Assessment and Management Conference, Honolulu, Hawaii*. Retrieved from: http://psam12.org/proceedings/paper/paper_92_1.pdf

Lee, T. (1998). Assessment of safety culture at a nuclear reprocessing plant. *Work & Stress*, *12*(3), 217-237. Doi: 10.1080/02678379808256863

Lee, T., & Harrison, K. (2000). Assessing safety culture in nuclear power stations. *Safety science*, *34*(1), 61-97. Doi: 10.1016/S0925-7535(00)00007-2

Lois, E., Dang, V. N., Forester, J., Broberg, H., Massaiu, S., Hildebrandt, M., Braarud, P. Ø., Parry, G., Julius, J., Boring, R., Männistö, I., & Bye, A. (2009). International HRA empirical study—pilot phase report. Description of overall approach and first pilot results from comparing HRA methods to simulator data (HWR-844). *Halden, Norway: OECD Halden Reactor Project*

Mearns, K. J., & Flin, R. (1999). Assessing the state of organizational safety—culture or climate?. *Current Psychology*, *18*(1), 5-17. Doi: 10.1007/s12144-999-1013-3

Mearns, K., Flin, R., Gordon, R., & Fleming, M. (1998). Measuring safety climate on offshore installations. *Work & Stress*, *12*(3), 238-254. Doi: 10.1080/02678379808256864

Mearns, K., Whitaker, S. M., & Flin, R. (2003). Safety climate, safety management practice and safety performance in offshore environments. *Safety science*, *41*(8), 641-680. Doi: 10.1016/S0925-7535(02)00011-5

Meshkati, N. (1991) Human factors in large-scale technological systems' accidents: Three Mile Island, Bhopal, Chernobyl. *Organization & Environment*, 5, 133-154. Doi: 10.1177/108602669100500203

Mullen, J. (2004) Investigating factors that influence individual safety behavior at work. *Journal of Safety Research 35(3), 275-285. Doi:* 10.1016/j.jsr.2004.03.011

Mullen, J. (2005). Testing a model of employee willingness to raise safety issues. *Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement*, *37*(4), 273. Doi: 10.1037/h0087262

Mullen, J. E., & Kelloway, E. K. (2009). Safety leadership: A longitudinal study of the effects of transformational leadership on safety outcomes. *Journal of Occupational and Organizational Psychology*, *82*(2), 253-272. Doi: 10.1348/096317908X325313

Nahrgang, J. D., Morgeson, F. P., & Hofmann, D. A. (2011). Safety at work: a meta-analytic investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. *Journal of Applied Psychology*, *96*(1), 71. Doi: 10.1037/a0021484

Neal, A., Griffin, M. A., & Hart, P. M. (2000). The impact of organizational climate on safety climate and individual behavior. *Safety science*, *34*(1), 99-109. Doi: 10.1016/S0925-7535(00)00008-4

Neal, A., & Griffin, M. A. (2006). A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. *Journal of Applied Psychology*, *91*(4), 946. Doi: 10.1037/0021-9010.91.4.946

O'Dea, A., & Flin, R. (2001). Site managers and safety leadership in the offshore oil and gas industry. *Safety Science*, *37*(1), 39-57. Doi: 10.1016/S0925-7535(00)00049-7

O'Dea, A., & Flin, R. (2000) *Safety Leadership in the Offshore Oil and Gas Industry.* Paper presented at the SPE International Conference on Health, Safety, and the Environment in Oil and Gas Exploration and Production, Stavanger.

Rasmussen, M., & Laumman, K. (2014). The suitability of the SPAR-H "Ergonomics/HMI" PSF in a computerized control room in the petroleum industry. In *Proceedings of the*

Probabilistic Safety Assessment and Management (PSAM 12) Conference. Retrieved from: http://psam12.org/proceedings/paper/paper_175_1.pdf

Rasmussen, M., Standal, M. I., & Laumann, K. (2015) Task complexity as a performance shaping factor: A review and recommendations in SPAR-H adaption. *Safety Science, 76, 228-238*

Reason, J. (1990) *Human Error.* Cambridge: Cambridge University Press.

Reason, J. (2000) Human error: models and management. *BMJ*, 320-786. Doi: 10.1136/bmj.320.7237.768.

Reason, J. (2013). *A life in error: from little slips to big disasters*. Ashgate Publishing, Ltd..

Ringstad, A. J. & Szameitat, S. (2000) A Comparative Study of Accident and near Miss Reporting Systems in the German Nuclear Industry and the Norwegian Offshore Industry. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 44(27) 380-383.* Doi:10.1177/154193120004402726

Rundmo, T. (1994). Associations between safety and contingency measures and occupational accidents on offshore petroleum platforms. *Scandinavian journal of work, environment & health*, 128-131. Retrieved from http://psycnet.apa.org/doi/10.5271/sjweh.1421

Schein, E. H. (1992) *Organizational culture and leadership, 2nd edition*. Jossey-Bass: San Francisco

Schism (2010) In Stevenson, A., & Lindberg, C. A. (Ed.) *The New Oxford American Dictionary, third edition.* Oxford: University press.

Skogdalen, J. E., & Vinnem, J. E. (2011) Quantitative risk analysis offshore – Human and organizational factors. *Reliability Engineering and System Safety, 96, 468-479*. Doi: 10.1016/j.ress.2010.12.013

Thompson, R. C., Hilton, T. F., & Witt, L. A. (1998). Where the safety rubber meets the shop floor: A confirmatory model of management influence on workplace safety. *Journal of safety Research*, *29*(1), 15-24. Doi: 10.1016/S0022-4375(97)00025-X

Vredenburgh, A. G. (2002). Organizational safety: which management practices are most effective in reducing employee injury rates?. *Journal of safety Research*, *33*(2), 259-276. Doi: 10.1016/S0022-4375(02)00016-6

Water, D. (2011). The gulf oil disaster and the future of offshore drilling. *Report to the President [of the USA]*. Retrieved from http://www.eoearth.org/view/article/162358/

Weick, K. E. (1987). *Organizational culture as a source of high reliability*. National Emergency Training Center. California, California Management review

Wiegmann, D. A., Zhang, H., Von Thaden, T. L., Sharma, G., & Gibbons, A. M. (2004). Safety culture: An integrative review. *The International Journal of Aviation Psychology*, *14*(2), 117-134. Doi: 10.1207/s15327108ijap1402_1

Whaley, A. M., Kelly, D. L., Boring, R. L., & Galyean, W. J. (2011) *SPAR-H Step-by-Step Guidance.* INL/EXT-10-18533. Idaho Falls, ID: Idaho National Laboratory.

Zacharatos, A., Barling, J., & Iverson, R. D. (2005). High-performance work systems and occupational safety. *Journal of Applied Psychology*, *90*(1), 77. Doi: 10.1037/0021-9010.90.1.77

Zohar, D. (2000). A group-level model of safety climate: testing the effect of group climate on microaccidents in manufacturing jobs. *Journal of applied psychology*, *85*(4), 587. Doi: 10.1037/0021-9010.85.4.587

Zohar, D. (2002a). Modifying supervisory practices to improve subunit safety: a leadership-based intervention model. *Journal of Applied psychology*, *87*(1), 156. Doi: 10.1037/0021-9010.87.1.156

Zohar, D. (2002b). The effects of leadership dimensions, safety climate, and assigned priorities on minor injuries in work groups. *Journal of Organizational Behavior*, *23*(1), 75-92. Doi: 10.1002/job.130

Zohar, D. (2010). Thirty years of safety climate research: Reflections and future directions. *Accident Analysis & Prevention*, *42*(5), 1517-1522. Doi: 10.1016/j.aap.2009.12.019