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A Literature Review of Safety Culture

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A Literature Review of Safety Culture

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Abstract

Workplace safety has been historically neglected by organizations in order to enhance profitability. Over the past 30 years, safety concerns and attention to safety have increased due to a series of disastrous events occurring across many different industries (e.g., Chernobyl, Upper Big-Branch Mine, Davis-Besse etc.). Many organizations have focused on promoting a healthy safety culture as a way to understand past incidents, and to prevent future disasters. There is an extensive academic literature devoted to safety culture, and the Department of Energy has also published a significant number of documents related to safety culture. The purpose of the current endeavor was to conduct a review of the safety culture literature in order to understand definitions, methodologies, models, and successful interventions for improving safety culture. After reviewing the literature, we observed four emerging themes. First, it was apparent that although safety culture is a valuable construct, it has some inherent weaknesses. For example, there is no common definition of safety culture and no standard way for assessing the construct. Second, it is apparent that researchers know how to measure particular components of safety culture, with specific focus on individual and organizational factors. Such existing methodologies can be leveraged for future assessments. Third, based on the published literature, the relationship between safety culture and performance is tenuous at best. There are few empirical studies that examine the relationship between safety culture and safety performance metrics. Further, most of these studies do not include a description of the implementation of interventions to improve safety culture, or do not measure the effect of these interventions on safety culture or performance. Fourth, safety culture is best viewed as a dynamic, multi-faceted overall system composed of individual, engineered and organizational models. By addressing all three components of safety culture, organizations have a better chance of understanding, evaluating, and making positive changes towards safety within their own organization.

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NOMENCLATURE

BLS	Bureau of Labor Statistics
DOE	Department of Energy
EFCOG	Energy Facilitators Contract Group
HSS	Office of Health, Safety and Security
IAEA	International Atomic Energy Agency
INPO	Institute of Nuclear Power Operations
INSAG	International Safety Advisory Group
NNSA	National Nuclear Security Administration
NSC	National Safety Council
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety & Health Administration
SNL	Sandia National Laboratories
TRC	Total Recordable Cases

1. BACKGROUND

According to a 2012 report from the Bureau of Labor Statistics (BLS), nearly three million nonfatal workplace injuries and illness were reported by private industry employers in 2011; meaning an incident rate of 3.5 cases per 100 equivalent full-time workers (BLS, 2012). Further, the total recordable cases (TRC) injury and illness incident rate among government workers was higher, reaching 5.7 cases per 100 full-time workers, and approximately 1.1million employees sought medical consultation after being injured on the job. The National Safety Council (NSC) reported that organizations in the United States lost approximately $168.9 billion as a result of both injuries and injury deaths (Lin et al., 2011). Additionally, the NSC reported that each worker must increase his or her productivity on average $1200 in order to offset the costs of a single injured worker.

Given these costs, organizations are now investing more time and resources into the protection of their employees. This has not always been the case as workplace safety has been historically neglected by organizations to enhance profitability. Safety concerns, and attention to safety, have also increased after a series of disastrous events in the early 1900s through the present (e.g. Triangle Shirtwaist factory fire, 1911; Hawks Nest Tunnel 1930s; Three Mile Island, 1979; Challenger explosion, 1986; Chernobyl, 1986). Although the frequency of such large-scale acccidents has generally decreased over time, organizational disasters are still evident today. Safety culture has become a common construct in which to discuss these significant accidents and other industrial safety incidents.

The Nuclear Regulatory Commission (NRC) has been emphasizing the importance of having a strong safety culture for nuclear operations since 1989, in which they published a policy statement emphasizing the expectations for a strong safety culture. Since then, several incidents occurring at nuclear power plants generated a lot of additional discourse about safety culture. For example, in March of 2002, maintenance workers discovered that boric acid corrosion caused the development of a large hole in the reactor pressure vessel head in the Davis-Besse nuclear plant. The NRC investigation concluded that leadership was aware of the potentially damaging effects of boric acid corrosion because the same issue was identified at Turkey Point, another U.S. power plant, in 1987. However, inspectors failed to detect the progressing degradation even though the acid had actually corroded through over 6 inches of carbon steel over an area the size of a football. Future investigations cited congressional pressure as a factor which led to the NRC safety culture oversight in the Reactor Oversight Process. As a result of the 2002 event, the NRC fined the FirstEnergy Corporation, the operator of the Davis-Besse plant, over $5 million. The company paid an additional $28 million in fines under a settlement with the U.S. Department of Justice and the plant was shut down for a 2 year period.

Efforts to address safety culture within the nuclear power industry are also supported by other organizations, such as International Atomic Energy Agency (IAEA) and Institute of Nuclear Power Operations (INPO). INPO was established as a result of the accident at Three Mile Island, which occurred in March of 1979, and as a response to concerns posed by the Kemeny Commission, the group which was appointed to investigate the accident by President Carter. The objectives of INPO are to specify appropriate safety standards for management, quality assurance, operating procedures and practices and to conduct independent evaluations of nuclear power facilities. In addition, INPO systematically gathers, reviews, and analyzes incidents that occur industry-wide in an effort to relay information to potentially affected parties. As a result of the Davis-Besse event, INPO published the *Principles for a Strong Nuclear Safety Culture* in November 2004, and continues to assist nuclear power plants in assessing safety culture within their operations. Other INPO guidance specifies required safety culture self assessments for plants (INPO SOER 02-4). Safety culture remains a significant focus for INPO, and INPO published *Traits of a Healthy Nuclear Safety Culture* in December 2012, which defines three traits and ten attributes that comprise safety culture.

The NRC has continuously been strengthening their efforts in this area in response to events in the industry (such as Davis-Besse), and in 2009 began a three-year project to develop an updated safety culture policy statement. During this time, the power reactor sector sought to explicitly work to achieve a strong nuclear safety culture. They did this by establishing a repeatable, holistic approach for sites to use in assessing safety culture on a continuing basis. This guidance can be found in *Fostering a Strong Nuclear Safety Culture* (NEI 09-07, 2010) and specifies the process that plants can follow to assess their safety culture.

The updated NRC safety culture policy statement was published as Final in the Federal Register in 2011. This policy statement includes a definition of safety culture and the nine traits that characterize it, considers the interface of safety and security, recognizes diversity of regulated entities, applies to safety-related vendors and suppliers, considers negative factors (e.g., incentive goals) and does not address implementation directly. The statement of policy (NRC, 2011) is as follows:

> "The Commission's expectation that individuals and organizations performing regulated activities establish and maintain a positive safety culture commensurate with the safety and security significance of their actions and the nature and complexity of their organizations and functions."

Nuclear power is not the only industry that has been focused on safety culture. Almost every high consequence industry has been attempting to address concerns around safety culture in their particular domain. For example, there was a great deal of discourse around the concept of safety culture following a series of mining incidents in 2010. The Upper Big Branch Mine in West

Virginia had previously been cited for numerous safety violations (Maher, Powers, & Hughes, 2010). In April 2010, a methane buildup resulted in an explosion and the collapse of a mine. In the following days, there was speculation surrounding the safety culture of workers, as well as those who held leadership positions at this mine. Even when supervisors assured employees that working conditions were safe, the miners knew that their safety equipment (e.g., the methane detectors and ventilation systems) did not consistently operate (Berkes & Langfitt, 2010). Miners observed engineers rewiring methane detector equipment under management supervision so that employees could continue to work in these unsafe environments for the purpose of increasing productivity (Christopher, 2010). This eventually led to a destructive situation and resulted in injuries, deaths, and a large financial burden.

Safety Culture is also included in DOE's Integrated Safety Management System Guide (DOE G 450.4-1C), and Attachment 10 to the ISMS Guide defines three safety culture focus areas and associated attributes as guidance for achieving a strong safety culture. Further, the Energy Facility Contractors Group (EFCOG) has been focusing on safety culture for many years, and a Subgroup has been established under the Integrated Safety Management & Quality Assurance Working Group to focus on Safety Culture/High Reliability Organizations. Leveraging these efforts, efforts have also been established within both the Department of Energy's (DOE's) Office of Health, Safety and Security (HSS), and within the National Nuclear Security Administration (NNSA) to specifically focus on safety culture within DOE and NNSA facilities.

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2. PURPOSE: INTRODUCTION TO SAFETY CULTURE

Some safety culture researchers posit that allowing employees to work without following safety protocol creates a negative organizational safety culture (Agnew & Daniels, 2010; Arboleda, Morrow, Crum, & Shelley, 2003; Clarke, 1999; Harvey, Bolam, Gregrory, & Erdos, 2001). They maintain that if cultures such as the ones present in the Upper Big Branch Mine and Davis-Besse are sustained for an extended period, disasters are almost inevitable (Agnew & Daniels, 2010). On the other hand, these researchers maintain that a positive safety culture can help prevent work-related injuries, including major disasters similar to what occurred at the Upper Big Branch Mine (e.g., Bailey, 1997; Hayes, Perander, Smecko, & Trask, 1998; O'Toole, 2002).

We should expect that injuries and their associated costs will decrease over time when an organization views safety as an investment rather than an expense (OSHA, 2003). Similarly, there is widespread belief that a small near-term investment in safety programs could potentially prevent large, future costs due to a disaster. These costs could include workers compensation, lost-time work, or substantial legal costs. Additionally, public reputations could be damaged if the incident was significant, resulting in other financial losses for companies in the market (Myers, 2010). In an attempt to reduce injuries and costs, many organizations have developed efforts to assess and promote a positive safety culture (e.g., Arboleda et al., 2003; Haber, Shurberg, & Hofmann, 1994).

Most researchers would agree that safety culture is a valuable construct. In fact, there is a significant body of literature devoted to safety culture (for a review, see Guldenmund, 2000 and Zohar, 2010). However, a review of the safety culture literature suggests that the construct has some inherent weaknesses. First, despite the fact that the concept of safety culture was initially developed over 25 years ago, a common definition and assessment methodology has not been established. Second, the safety culture construct is further confounded by the research on safety climate, which in some cases is used interchangeably with safety culture and in other cases is thought to be a distinct construct. In many cases researchers are in fact measuring safety climate rather than safety culture. Third, the assessment techniques that do exist are diagnostic rather than predictive. In fact, the majority of work in this domain measures employee perceptions of safety related factors at a single point in time. These studies are successful at describing how employees perceive their work environment but are poor at predicting what this means for future organizational performance. Fourth, based on the literature, the association between safety performance and safety culture is tenuous at best. Few empirical studies examine the relationship between measures of safety performance (e.g., injury rates or other metrics) and safety culture. Finally, because most of the approaches to measuring safety culture result in assessments across a number of factors/dimensions, there is not yet a defined way to combine the results into a measure of safety culture (e.g., if scores on some dimensions are high while others are low, what can we conclude about the overall safety culture?).

The purpose of this paper is to review the literature on safety culture and to advocate a balanced view for managing safety in the workplace. Safety is best managed through the three different systems described by Reason (1997) including the person model, the engineering model, and the organization model. The following sections elucidate the literature on the origins, definitions, differences between safety climate and safety culture, models, case studies, other types of studies related to this construct, and a summary of Reason's balanced approach to preventing organizational safety incidents and its practical applications.

3. ORIGINS OF SAFETY CULTURE

3.1. Organizational Culture

One way to frame safety culture is to examine it within the broader context of organizational culture. Although these constructs were developed separately (i.e., safety culture was not originally a subculture of organizational culture), they are related concepts. Schein (1990) defines organizational culture as:

> "[A] pattern of basic assumptions, invented, discovered, or developed by a given group, as it learns to cope with its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore is to be taught to new members as the correct way to perceive, think, and feel in relation to those problems" (p. 111).

Schein states that an organization's culture manifests itself in three ways: 1) through observable artifacts, 2) values, and 3) basic underlying assumptions. Artifacts are those things that employees observe and feel when entering an organization. Schein describes these things as "palpable but hard to decipher accurately" (p.111). They include things such as the physical layout of the space, how employees address each other, and the organization's emotional intensity. Artifacts also include statements of philosophy, annual reports and company records. Although artifacts can be observed and felt, Schein posits that they are not reliable indicators of how members of an organization react. For example, we may observe that one organization is much more formal than another, but artifacts do not tell us why this is so.

Schein considers an organization's values as those things that espouse norms, ideologies, charters, and philosophies. These things can be investigated through questionnaires, survey instruments, interviews, and observations. The goal of investigating an organization's values is to understand why particular observed phenomena occur the way they do. An organization's values are typically the basis of an organization's mission. For example, the following is the current mission statement for the Massey Energy Company (http://www.masseyenergyco.com), which owned and operated the Upper Big Branch Mine:

> Customers: To supply our customers with the highest quality coals at reasonable and competitive prices.
> Shareholders: To earn optimal rates of return on the capital used in our business.
> Employees: To provide for the best possible well-being of members.
> Communities: To be responsible citizens and responsive to the needs of our environment.

The values of the organization are clearly stated in the preceding mission statement. However, preliminary evidence from the investigation of the mine disaster suggests that these principles

were not applied consistently at the Upper Big Branch Mine (Berkes & Langfitt, 2010; Christopher, 2010). The organization's basic assumptions may have influenced the inconsistent application of the mission statement. Schein describes an organization's assumptions as those that are underlying and usually unconscious and that determine perceptions, thought processes, feelings, and behavior (Schein, 1990). It is possible for an organization to have conflicting values but a general consensus about its assumptions. Alternatively, employees may agree about their organization's espoused values, but may disagree about the underlying organizational assumptions. These contradictories may manifest themselves as inconsistent behavior (1990).

Employee surveys are probably the most frequently used assessment method to examine organizational culture. In a recent review, Jung et al. (2009) identified 70 instruments for measuring this construct; these surveys measure employee attitudes and perceptions across different dimensions of an organization's culture. Twenty-six major dimensions (e.g., ethics, rewards, development, leadership, goals, etc.) were identified within those instruments. Organizations who monitor and effectively intervene upon their culture generally improve the work environment for their employees (2009). With regard to safety, the authors speculate that increasing employee perceptions of their safety culture may be associated with similar positive benefits in terms of reduced injuries and associated costs, although the authors did not directly investigate this association. Likewise, they suggest that there are negative consequences involved in a non-existent or poorly structured safety culture.

3.2. Safety Culture

The term safety culture can be traced back to the 1986 nuclear explosion at Chernobyl (Wiegmann et al., 2002). At Chernobyl, two explosions led to the release of molten core fragments of the Chernobyl-4 nuclear reactor and fission products into the atmosphere. It is noted as one of the worst commercial nuclear power accidents in history. The International Safety Advisory Group (INSAG), an advisory group to the International Atomic Energy Agency (IAEA) tasked with investigating the Chernoybl accident, used the term "poor safety culture" to identify factors contributing and leading up to the Chernobyl accident (Wiegmann et al., 2002).

Although INSAG borrowed the term 'culture' from anthropologists, there is no mention of any other bodies of literature in their report. Thus, it can be inferred that the safety culture literature did not originally develop theoretically from organizational culture. INSAG claimed that 'the phrase safety culture refers to a very general matter, the personal dedication and accountability of all individuals engaged in any activity which has a bearing on the safety of nuclear power plants'. However, the group left the meaning of the term open to interpretation and did not provide guidance as to how this construct could be assessed; a fact that still plagues this concept today.

INSAG defined safety culture as "that assembly of characteristics and attitudes in organizations and individuals, which establishes that, as an overriding priority, nuclear power plant safety

issues receive the attention warranted by their significance." This definition highlights two major points: First, while safety culture is about good safety attitudes, it is also about good safety management established by organizations and second, good safety culture means assigning the highest priority to safety. The INSAG report presented the concept of safety culture as it related to both organizations and individuals, but it did not provide a link between safety culture and measures of safety performance.

Since the initial use of the term, researchers have continued to develop definitions of safety culture. Table 1 summarizes some of these definitions found in the literature (see Guldenmund, 2000; Yule, 2003; and Choudry, Fand and Mohamed, 2007).

Table 1. Definitions of Safety Culture

Reference	Definition of Safety Culture
Cox and Cox (1991)	Safety culture reflects the attitudes, beliefs, perceptions, and values that employees share in relation to safety (safety culture)
International Safety Advisory Group (1991)	Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance (safety culture)
Pidgeon (1991)	The set of beliefs, norms, attitudes, roles, and social and technical practices that are concerned with minimizing the exposure of employees, managers, customers and members of the public to conditions considered dangerous or injurious (safety culture)
Ostrom et al. (1993)	The concept that the organization's beliefs and attitudes, manifested in actions, policies, and procedures, affect its safety performance (safety culture)
Geller (1994)	In a total safety culture (TSC), everyone feels responsible for safety and pursues it on a daily basis (safety culture)
Berends (1996)	The collective mental programming towards safety of a group of organization members (safety culture)
Lee (1996)	The safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies, and

Reference	Definition of Safety Culture
	patterns of behavior that determine the commitment to, and the style and proficiency of, and organization's health and safety management (safety culture)
Kennedy and Kirwan (1998)	An abstract concept, which is underpinned by the amalgamation of individual and group perceptions, thought processes, feelings, and behaviors, which in turn gives rise to the particular way of doing things in the organization. It is a sub-element of the overall organizational culture. (safety culture)
Hale (2000)	Refers to the attitudes, beliefs, and perceptions shared by natural groups as defining norms and values, which determine how they act and react in relation to risks and risk control systems. (safety culture)
Glendon and Stanton (2000)	Compromises attitudes, behaviors, norms and values, personal responsibilities as well as human resource features such as training and development. (safety culture)
Guldenmund (2000)	Those aspects of the organizational culture which will impact on attitudes and behavior related to increasing or decreasing risk. (safety culture)
Cooper (2000)	Culture is the product of multiple goal-directed interactions between people (psychological), jobs (behavioral), and the organizational (situational); while safety culture is that observable degree of effort by which all organizational members directs their attention and actions toward improving safety on a daily basis. (safety culture)
Mohamed (2003)	A sub-facet of organizational culture, which affects workers' attitudes and behavior in relation to an organization's on-going safety performance. (safety culture)
Richter and Koch (2004)	Shared and learned meanings, experiences, and interpretations of work and safety – expressed partially symbolically- which guide people's actions toward risk, accidents and prevention. (safety culture)

Reference	Definition of Safety Culture
Fang et al. (2006)	A set of prevailing indicators, beliefs, and values that the organization owns in safety. (safety culture)
Nuclear Regulatory Commission (2011)	Nuclear Safety Culture is the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment.

As this table shows, most definitions are relatively similar in the beliefs perspective, with each focusing on the way that people think or behave in relation to safety. These definitions tend to reflect the view that safety culture is something that an organization 'is' rather than something that an organization 'has'. The concept of safety culture is often presented separately from an organization's other characteristics, such as the work schedule, technology, business strategy and financial decision-making (Reiman & Oedewald, 2004).

In their 2002 review of safety culture and safety climate research, Wiegmann, et al. identified the following as being common attributes related to safety culture across the various definitions found in the literature:

- Refers to shared values among a group or organization.
- Is concerned with formal safety issues, and is closely related to, but not restricted to, management and supervisory systems.
- Emphasizes contribution of everyone, at all levels, in an organization
- Impacts how individual members of the organization behave at work.
- Is reflected in contingency between reward systems and safety performance.
- Is reflected in an organization's willingness to learn from errors, incidents and accidents
- Is relatively enduring, stable and resistant to change.

The literature reflects no consensus as to the number of factors that comprise an organization's safety culture – as few as 2 and as many as 19 have been reported (Wiegmann et al., 2002). Wiegmann, et al. (2002; 2004) identified five factors that are commonly agreed to reflect safety culture: organizational commitment, management involvement, employee empowerment, reward systems and reporting systems. Pidgeon (1998) argued that a "good" safety culture is related to four factors: senior management commitment to safety, realistic and flexible practices for handling both well-defined and ill-defined hazards, continuous organizational learning, and a care and concern for hazards shared across the workforce.

The history of the use of safety culture as a construct in which to understand organizational safety performance is rooted in large-scale industrial accidents (such as the Chernobyl accident in 1986 and the Challenger accident in 1986). In these instances, safety culture was the term used for an explanatory construct for the way that a combination of managerial, organizational and social factors resulted in an accident (Clarke, 2000). It is useful, however, to note that a researchers (Cox and Flin, 1998) have highlighted that the post-hoc analysis of safety culture that has occurred after major industrial accidents do not actually establish causality between safety culture and safety performance. Glendon and Litherland (2001) conclude that there has not yet been evidence of causal links between measures of safety culture and performance outcomes. Sorensen (2002) recognizes that while there have been some substantial efforts in the literature to establish a relationship between safety culture (or its associated attributes) and operational safety, performance indicators that can be used to detect changes in safety culture (and thus predict changes in safety performance) have not been defined. He further states that "no performance indictors to gauge safety culture and its impact on safety of operations have been identified and validated," and "statistical evidence that unambiguously links safety culture or specific attributes of safety culture with the safety or operations is surprisingly rare, especially within the nuclear industry."

Despite the cautions raised by researchers, including the lack of consensus on definitions and the lack of theoretical underpinnings for the construct (Pidgeon, 1998; Glendon & Litherland, 2001), there continues to be agreement that a positive safety culture is something to which every organization should aspire, and that a "negative" safety culture may be associated with undesirable outcomes. Sorensen (2002) notes that one of the omissions in the guides published by the nuclear power industry for establishing and evaluating safety culture is an explicit link between safety culture and safety operations, and that such a link is assumed (but not demonstrated) to be in place. Guldenmund (2010) identifies a number of reasons why safety culture remains a highly valued construct despite some of the deficiencies previously identified, including that if there is a perception that indicators of safety culture deterioration can be identified, these can be used as a leading indicator or a pending catastrophe, and that a healthy safety culture is viewed by many as a mediator for safe performance even in the absence of other aspects of a robust safety management program (instrumentation, procedures or supervision). Others caution against the overreliance on a robust safety culture to compensate for other safety deficiencies.

3.3. Safety Culture versus Safety Climate

Whereas safety culture represents long-term attitudes, beliefs and the stable ways in which people behave, safety climate represents a snapshot of the current state of these factors at any one time (Flin et al., 2000). Thus, safety climate is something that an organization 'has' at a particular time. Flin et al. (2000) identified emergent themes in their review of 18 published reports on safety climate. They report that the most commonly measured climate dimensions are

those related to management, risk, safety arrangements, procedures, training, and work pressure (in that order). It is noted that that the use of the term safety climate appeared prior to the use of the term safety culture in the literature.

Table 2 is a collection of definitions of safety climate as described by Guldenmund (2000), Yule (2003), and Choudry, Fand and Mohamed (2007).

Table 2. Definitions of Safety Climate

Reference	Definition of Safety Climate
Zohar (1980)	A summary of molar perceptions that employees share about their work environment.
Glennon (1982a, b)	Employees' perceptions of the many characteristics of their organization that have a direct impact upon their behavior to reduce or eliminate danger and, safety climate is a special kind of organizational climate.
Brown and Holmes (1986)	A set of perception of beliefs held by an individual and/or group about a particular entity.
Dedobbeleer and Beland (1991)	Molar perceptions people have of their work setting.
Cooper and Philips (1994)	Safety climate is concerned with the shared perceptions and beliefs that workers hold regarding safety in their work place.
Niskanen (1994)	Safety climate refers to a set of attributes that can be perceived about particular work organizations and which may be induced by the policies and practices that those organizations impose upon their workers and supervisors.
Coyle et al. (1995)	The objective measurement of attitudes and perceptions toward occupational health and safety issues.
Cabrera et al. (1997)	The shared perceptions of organizational members about their work environment and, more precisely, about their organizational safety policies.
Williamson et al. (1997)	Safety climate is a summary concept describing the safety ethic in an organization or workplace which is reflected in employees' beliefs about safety.

There is continued confusion in the literature regarding safety culture and safety climate. While some researchers have used the terms interchangeably, others argue that safety climate is distinct from safety culture in some essential dimensions. Some researchers (Wiegmann, et al, 2002; Cox and Flin, 1998) have described the distinction between safety culture and safety climate as analogous to the distinction between personality and mood in psychology. That is, personality (or culture) is an emergent property of a system that is relatively stable and difficult to change.

Mood (or climate) is then a transient property that is sensitive to external environments and situations. In this view, safety climate can be considered a snapshot of the underlying culture at a particular point in time. Safety climate measures tend to focus on employee's current perceptions and attitudes about safety and do not usually claim to assess the underlying values or management philosophies (Cox and Flin, 1998). Weigmann, et al. (2002) highlights that, as compared to safety culture, safety climate is a temporal phenomenon, relatively unstable and subject to change, more closely connected to situational and environmental factors, and more related to perceptions of the state of safety at a particular time.

As with safety culture, there is no consensus in the literature regarding the dimensions/factors that comprise safety climate. Clarke (2000) reviewed 16 empirical studies of safety climate and notes that the number of factors ranged from 1 to 16 in those studies. However, she identifies five common themes: work task/work environment, personal involvement and responsibility, management attitudes, safety management system, and management actions. Mearns, et al. (2003), citing Flin et al. (2000), identifies management commitment, supervisor competence, priority of safety over production and time pressure as the recurring themes across various safety climate dimensions.

However, while there is little empirical evidence relating measures of safety culture to safety outcomes, there does seem to be consensus that there is a link between safety climate and safety performance as demonstrated in a variety of studies across industries. For example, Zohar (2010) concludes that safety climate has been validated as a robust leading indicator of safety outcomes, Mearns, et al. (2003) notes that it is becoming accepted that a favorable safety climate is essential for safe operation based on a number of studies that demonstrate that elements of safety climate have been found to be predictors of unsafe behaviors or accidents, and a meta-analysis performed by Christian, et al. (2009) found a significant correlation between safety climate and safety outcomes. However, Gadd and Collins (2002) conclude that there has been little research that has attempted to validate safety climate assessment tools with actual safety performance, and that most research relies on self-reported measures of behavior rather than actual safety behaviors. Gadd and Collins (2002) suggest that such an approach might be subject to social desirability biases, where people respond as they feel they "should" rather than as they would actually behave. Thus, the survey results may not actually predict behavior in the organization.

Cox and Flin (1998) note that questionnaires that claim to measure safety culture or safety climate are very similar in terms of what dimensions they choose to focus on. Silbey (2009) notes that most of the assessment techniques used to measure safety culture rely on data collected from individuals through survey instruments, and thus may actually be measuring safety climate. Similarly, Guldenmund (2010) suggests that safety climate scales have been used extensively to (attempt to) measure safety culture.

3.4. Models of Safety Culture

Geller (1994) developed a model of safety culture that has three distinct, dynamic and interactive factors: person, behavior, and environment. He presented 10 principles that form the foundation for a total safety culture. These 10 principles for achieving a 'total safety culture' within the workplace include: 1) employee driven safety rules and procedures, 2) a behavior-based approach, 3) a focus on safety processes not outcomes, 4) a view of behavior being directed by activators and motivated by consequences, 5) focus on achieving success, not on avoiding failure, 6) observation and feedback on work practices, 7) effective feedback through behavior-based coaching, 8) observation and coaching as key activities, 9) the importance of self-esteem, belonging and empowerment and 10) safety as a priority rather than a value. Three years later, Geller (1997) proposed a 'Total Safety Culture' model that includes 'the safety triad' and recognizes the dynamic and interactive relationship between person, environment and behavior. Again, he advocates the 10 principles or values that form the basis of a total safety culture.

Cooper (2000) presents a model that recognizes the presence of an interactive or reciprocal relationship between psychological, situational and behavioral factors of safety culture. He claims that organizational culture is the product of multiple goal-directed interactions between people (psychological), jobs (behavioral), and the organization (situational). He suggests that people can neither be deterministically controlled through their environment nor entirely self-determining, but they and their environments influence one another in a perpetual dynamic interplay. In his reciprocal safety culture model, attitudes and perceptions can be assessed through safety climate questionnaires. Actual safety-related behaviors are assessed through checklists developed as part of behavioral safety initiatives. Further, situational features are assessed through safety management systems audits/inspections. This reciprocal framework has the potential to quantify the relevant components of safety culture and can be measured independently or in combination. Geller's (1997) model is similar to Cooper's reciprocal model, with the only difference being that the term *environment* is used rather than *situation*.

Another model of safety culture is safety citizenship behavior (SCB). Advocates of the SCB model of safety culture posit that safety initiatives based on mere compliance are not sufficient (Dilda, Mearns, & Flin, 2009; Hofmann, Morgeson, & Gerras, 2003). They claim that organizations need individuals who are proactive in participating and initiating improvements in safety. They refer to these behaviors as SCB. SCB is a higher order construct that consists of different types of behaviors such as stewardship, voicing one's opinion, helping co-workers, whistle-blowing, initiating workplace change, and civic virtue (Hofmann et al., 2003). SCB is a subcategory of organizational citizenship behavior (OCB). Like OCB, although these behaviors are not directly incentivized and are not part of a reward system, they serve to promote effective functioning of an organization. The concept of citizenship behavior is based on the principle of reciprocity. According to this principle, employees will have high-quality relationships with their

supervisor, which are based on trust and support, in so far as they engage in behaviors that are valuable to the organization (Dilda et al., 2009).

Past research has shown that employees exhibit higher degrees of safety compliance than SCB. Safety compliance behaviors are characterized by rule following, wearing protective clothing, avoiding risky practices, etc. Compared to SCB, safety compliance ensures control and rigid implementation of rules, while SCB allows employees to use their discretion with respect to the safety of their work (Dilda et al., 2009). Dilda et al. (2009) attempted to determine what motivates employees to engage in SCB. The authors interviewed and administered a survey that measured employee safety compliance and SCB to 24 supervisory-level employees at a UK based oil and gas company. The interviews questions were developed by Bolino and Turnley (2005) and followed a semi-structured pattern. The survey consisted of seven items from the Offshore Safety Questionnaire, which measured safety compliance and eight items from a survey developed by Hofman, Morgeson, and Gerras (2003), which measured SCB. Participants rated all items on Likert scale from 1 (strongly disagree) to 5 (strongly agree). The results indicated that participants reported engaging in high levels of both safety compliance and SCB. Participants also reported the following motivators for engaging in SCB: self-preservation (i.e., wanting to be safe), individual priority (i.e., care for others/personal enthusiasm, responsibility for one's own safety), team spirit and peer pressure, and culture (i.e., it is the way we do things here, everyone is safety conscious, we are told/expected to observe safety, we have safety programs).

3.5. Case Studies

There have been multitudes of case studies that have assessed safety culture in a specific company or industry. A review of these case studies was undertaken to identify any studies in which researchers specifically measured the effect of safety culture interventions – that is, where they measured safety culture, took specific actions to address shortcomings identified, and then re-measured safety culture to identify the effects of their interventions. Similarly, Hale et al (2010) conducted a literature review looking for studies that documented the effect of interventions on safety culture, and concluded that there are few methodologically sound studies that have been published. While no such studies were found, there were some studies that did attempt to look at changes in safety culture due to various factors. A few of these studies are summarized below.

Nielsen, Rasmussen, Glasscock and Spangenberg (2008) looked at two twin plants (owned by the same company) which manufacture wind turbines. Despite being owned by the same company and producing the same products, one plant (Plant B) had significantly more errors than the other (Plant A). Plant A, prior to the study, was involved in a comprehensive work environment project based on worker involvement and one focus was on safety related issues. Employees from both plants attended a one week introductory course on safety. Accident data (self-reported) was collected at both plants from one year prior to baseline and until six months after the study. Audits were conducted at T0 and T1 and questionnaire data was collected as

well. The researchers did not have a formal intervention but the intervention Plant A learned was transferred to Plant B over the course of the study. The researchers found that the self-reported accident data decreased in Plant B. Unfortunately, it is unclear what the work environment project entailed and exactly what knowledge was transferred from Plant A to Plant B. Thus, it is hard to interpret the researchers' results and make a definite statement about a change in safety culture.

Zhou, Fang and Mohamed (2011) examined the consistency of safety climate factor structure and safety climate questionnaires over a three year period at a Chinese construction company. Construction workers at the Chinese construction company were given a survey of safety climate in 2004 and again in 2007. The survey consisted of 87-items asking about key aspects of safety climate within the organization. The researchers performed a factor analysis on the items for both years and found that both years comprised the same four-factor structure of safety culture; 1) safety regulations, 2) safety supervision, safety training and workmates' support, 3) management commitment and 4) safety attitude. In addition, the confirmatory factor analysis established that the second-order factor of safety climate was unchanged. While this study found a change in perception over time, the study did not identify a particular safety issue and implement an intervention or training to address this issue. This study does not shed any light onto any quantitative behavioral safety change.

Cooper, Phillips, Sutherland and Makin (1994) performed a field study on a large multinational company in which the production workers were employed on a continuous, three-shift, seven-day week, 10-day cycle. The researchers analyzed the company's accident records and performed in-depth, semi-structured interviews with a random sample of 15% of the workforce. Based on this information, the researchers developed departmental checklists. Safety observers were recruited and undertook two days' training. Following a practice period, a copy of the checklist for each department was displayed in the respective department. The department was also asked to set safety 'goals' for critical behaviors in that department. The observations in each department took about 10 minutes to complete and were done on every shift by the observer touring the department. The results of the weekly observations were posted in each department to make explicit to the workforce where to focus their attention the following week. The researchers found a steady global improvement in safe behavior performance across the factory as a whole; however, these results were attributed to the goal-setting and awareness exercises (e.g., posting the results of the weekly observations). Further, there was no tie to safety performance explored. Once again, this study does not show any quantitative behavioral change.

Havold (2005) completed a case study looking at safety culture at a Norwegian shipping company. Seafaring has historically been one of the world's most dangerous occupations. A self-completion study was administered to 20 ships which included questions about the company's safety culture and the employees' perceptions of safety. The researchers performed a

factor analysis on the results and identified four factors: 1) Employee and management's attitude to safety and quality, 2) Knowledge, 3) Attitudes to safety rules/instructions and 4) Quality and safety experience. The researchers concluded that there was a high degree of consensus among respondents regarding safety culture regardless of nationality, vessel or occupation but did not implement any sort of intervention or training and did not show any quantitative change in safety behavior.

Naevestad (2010) interviewed three different groups working on or with a Norwegian offshore platform: onshore managers, crane operators and process operators. The company initiated a safety culture campaign and, a year later, the author interviewed people from all three groups and asked questions about the safety culture campaign, thoughts about safety culture, etc. The researcher concluded that a few lessons learned regarding how to implement safety culture campaigns can be learned from the study: meaningfulness is a prerequisite of successful culture change, safety cultures are created/recreated through group wise negotiation processes, safety culture campaigns should be tailored to specific groups, those wanting to shape safety culture should participate in the negotiation processes in which cultures are created/recreated and safety culture campaigns should be sensitive to shared patterns of meaning.

Fang, Chen and Wong (2006), interested in safety culture, conducted a safety climate questionnaire to all sites and all employees at a leading construction company and its subcontractors in Hong Kong. The questionnaire entailed 110 items. The researchers performed a factor analysis on the results and found 15 different factors, the first 10 being: (1) safety attitude and management commitment, (2) safety consultation and safety training, (3) supervisor's role and workmate's role, (4) risk taking behavior, (5) safety resources, (6) appraisal of safety procedure and work risk, (7) improper safety procedure, (8) worker's involvement, (9) workmate's influence and (10) competence. The researchers also performed a logistic regression and found significant relationships between safety climate and personal characteristics, including: (1) gender, (2) marital status, (3) education level, (4) number of family members to support, (5) safety knowledge, (6) drinking habits, (7) direct employer and (8) individual safety behavior.

Organizations may not be able to change their entire safety culture, but may be able to enhance some of the areas that need improvement (personal conversation with Sonja Haber, 2013). There are many studies that address specific interventions for specific organizational factors that comprise safety culture, such as communication, decision making, leadership, etc. Many of these studies can be found in journals for practitioners. Each of these interventions is described in terms of how practitioners can implement each one as a way to enhance one or more facets of safety culture, and tend to describe the practical ways in which practitioners may influence the different factors. However, most studies do not describe post-tests of the effectiveness of these interventions. Therefore, recommendations from these papers should be used with caution.

3.6. Other Safety Culture Examples

It is also interesting to look at historical examples of changes in societal safety culture, such as safety/seatbelt use, motorcycle helmet use, and the safety of athletes playing football. Each of these presents an opportunity to look at changes in behaviors that have resulted in changes in culture, though it is important to note that these behavioral changes have generally taken decades to come to fruition.

When safety/seat belts were introduced in the late 1960s/early 1970s, only 16% of people were using lap belts and only 7% were using both torso and lap belts (Roberson et al., 1972). Despite the number of people who were killed, injured or maimed in car accidents, the use of seatbelts was not considered essential. There were multiple methods employed attempting to change people's behavior regarding seat belt use; television advertisements, law enforcement, incentives and human factors (e.g., making seatbelts more comfortable to wear) were all implemented. A variety of approaches were taken for the television advertisements; social pressure, death/injury/deformation, ticketing ("Click it or ticket it" program). A 1974 study found that these television advertisements had no impact of seatbelt use after a few years of broadcasting the ads (Robertson et al., 1974). However, after 30 years, there has been a positive change in how seatbelt use is viewed. In 2010, the U.S. Department of Transportation, National Highway Traffic Safety Administration found that the average seatbelt use in the United States was 85%, with 15 states achieving rates of 90% or better. The rate of seatbelt use has increased significantly, but it should be noted that, 42 years later, the use of seatbelts is still not 100%.

The use of motorcycle helmets increased in 1967 when a federal standard was issued requiring states to have motorcycle helmet use laws in order to qualify for federal safety programs and highway funds (Watson, Zador & Wilks, 1980). This federal standard was repealed in 1976, and 26 states subsequently repealed their motorcycle helmet laws. As a result, the motorcycle mortality rate increased by about 30% (Watson et al., 1980). In the intervening years, helmet laws have been re-enacted in many states, and by 2011, 47 of the 50 states had some sort of requirement for helmet use (universal, age-specific or experience-specific; National Highway Traffic Safety Administration).. The National Highway Traffic Safety Administration found that motorcycle helmet use increased from 48% in 2005 to 67% in 2009, which is an improvement but still far from ideal. Despite the fact that helmet use has been shown to decrease the mean cost of hospitalization (Brandt, Ahms, Corpron, et al., 2002) and decrease the rate of death, approximately 30% of motorcycle riders are not wearing helmets.

In both of these cases it is clear that changes in individual behaviors have taken a long time, despite significant evidence about the risks of behaviors involved (e.g., not wearing a seatbelt or a helmet), and have still not yet achieved 100% adherence to safe behaviors.

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4. SAFETY CULTURE AND SAFETY CONSCIOUS WORK ENVIRONMENT WITHIN THE DOE COMPLEX

Recent efforts to measure safety culture at DOE facilities have resulted from recent events at DOE sites, and have been codified in Secretary Chu's December 2011 commitment to assess safety culture within DOE (DOE, 2011).. Further, the NNSA has also committed to addressing safety culture, through the recent establishment of an NNSA Safety Culture Working Group (Memo from Mr. D'Agostino, 2012). In response, DOE's HSS has established a methodological approach to assessing safety culture, leveraging the work of Sonja Haber, currently an independent consultant from Human Performance Analysis. Haber derived her safety culture philosophy from research in the organizational culture domain, specifically from Mintzberg's 1979 model. Thus, she views safety culture as one facet of organizational culture rather than as a separate construct. Haber posits that human performance in high risk systems is related to three main areas: organizational and management factors, human-system integration, and human reliability. The former is characterized as the impact of organizational and management factors such as the programs, processes and structures that facilitate or inhibit a positive safety culture. Human-system integration can be described as "the integration of human capabilities/intelligence into the design of complex systems to support safe and efficient operations" (Haber & Shurberg, 1998). Lastly, the human reliability area involves the evaluation of the reliability of human performance during the operation, maintenance, and testing or a system or facility to promote safe operations (Haber & Shurberg, 1998).

Haber and her colleagues have used a number of different methods to assess safety culture including structured interview protocols, behavioral checklists, behavioral anchored rating scales (BARS), the Organizational Culture Index (OCI), a validated questionnaire developed by Human Synergistics in the late 1980s, and the Attention to Safety Scale, a measure developed by Haber's colleagues at the University of California Los Angeles. These methodologies were developed as part of a project on safety culture, which was funded by the NRC during the late 1980's. During this time, Haber and her colleagues at the University of California Berkeley and Pennsylvania State University investigated the probability of low and high consequence events in high risk environments such as nuclear power plants. They were interested in examining not only individual safety performance but also organizational and management performance relative to safety.

The term Safety Conscious Work Environment (SCWE) originates from the Nuclear Regulatory Commission (NRC), and was described in a May 14, 1996 policy statement "Freedom of Employees in the Nuclear Industry to Raise Safety Concerns without Fear of Retaliation." In that policy, SCWE was defined as "a work environment where employees are encouraged to raise safety concerns and where concerns are promptly reviewed, given the proper priority based on their potential safety significance, and appropriately resolved with timely feedback to the

originator of the concerns and to other employees." The NRC further defined SCWE in later documents, and in 2004 described SCWE as an attribute of safety culture. In 2005, the NRC published a Guidance Document "NRC Regulatory Issue Summary 2005-18: Guidance for Establishing and Maintaining a Safety Conscious Work Environment." This Guidance specifically states that SCWE and safety culture are distinct concepts (RIS 2005-18, p.2), and that SCWE (employees' willingness to identify safety concerns) is one important attribute of a strong safety culture.

Within the NRC Guidance document, the following tools are identified to assess the SCWE of an organization: lessons learned evaluations, benchmarking, performance indicators, survey and interview tools, direct observations, exit interviews and surveys, and 360-degree appraisals.

The DOE has also committed to the importance of ensuring a strong SCWE within its operations. The DOE defines SCWE as "a work environment in which employees feel free to raise safety concerns to management without fear of retaliation." The DOE has published a SCWE Self-Assessment Guidance document (July, 2012), and has developed a training course (SAF-200) for senior managers across DOE that was rolled out in 2012, with courses continuing through 2013. In this training, SCWE is also considered a subset of an organizations' safety culture, as represented in Figure 1.

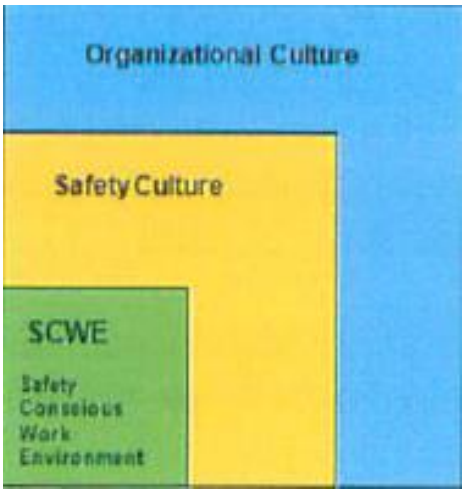

Figure 1. Notional Notional Representation of SCWE, Safety Culture and Organizational Culture

In December 2011, the DOE developed an Implementation Plan (IP) to address DNFSB Recommendation 2011-1, Safety Culture at the Waste Treatment and Immobilization Plant. As part of this IP, there was a commitment for the Secretary of Energy to set "clear and specific DOE-wide expectations for safety culture, including safety culture training." Further, there was a commitment to "conduct an Extent of Condition Review to find out whether similar safety culture weaknesses exist at other sites in addition to the WTP and whether there are barriers to strong safety culture at Headquarters and the Department as a whole (e.g., policies or

implementation issues)." This commitment further explained that the review will focus on the SCWE at each site examined, and broke down the action into five parts:

- Part 1, Issue the Secretary's Expectations for Nuclear Safety to the Department.
- Part 2, Defense Nuclear Facility-related SCWE Self-assessments
- Part 3, Independent HSS Reviews
- Part 4, Consolidated DOE Report on SCWE
- Part 5, Sustainment of a Robust Safety culture

The IP (Section 5.2.2) further defined the sites that were required to perform SCWE Self-Assessments, and included Sandia National Laboratories and Sandia Site Office. The IP further committed to developing SCWE Self-Assessment Guidance and training to prepare sites for the Self-Assessments that are required. Further, the IP defined which sites were required to have Independent Health, Safety and Security (HSS) Reviews, and defined the methodological approach for these independent reviews as using multiple assessment methodologies including: functional analysis, semi-structured interviews and focus groups, observations, Behavior Anchored Rating Scales, and safety culture surveys.

The SCWE Self-Assessment Guidance (Revision G) identifies the "ISMS safety culture attributes that offer the greatest potential for achieving SCWE excellence," and was developed by comparing the NRC guidance on SCWE against the attributes of safety culture described by DOE in Attachment 10 to the ISMS Guide. The italicized attributes are the ones that were identified as most clearly supporting SCWE.

Leadership Focus Area

a. ***Demonstrated safety leadership***
b. Risk-informed, conservative decision-making
c. ***Management engagement and time in the field***
d. Staff recruitment, selection, training, and development
e. ***Open communication and fostering an environment free from retribution***
f. ***Clear expectations and accountability***

Employee Engagement Focus Area

a. Personal commitment to everyone's safety
b. ***Teamwork and mutual respect***
c. Participation in work planning and improvement
d. Mindful of hazards and controls

Organizational Learning Focus Area

a. ***Credibility, trust and reporting errors and problems***
b. ***Effective resolution of reported problems***
c. ***Performance monitoring through multiple means***
d. Use of operational experience
e. ***Questioning attitude***

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5. EXISTING METHODOLOGIES TO ASSESS SAFETY CULTURE

There are many published studies have attempted to assess the safety culture of an organization and/or to evaluate whether the measures of safety culture have changed over time. Generally, the most frequently used methodologies in assessing safety culture have been observations, surveys, or interviews. Such approaches are typically focused on obtaining employees' perceptions (and changes in perception) of the company's safety culture.

The literature recognizes the need to use multiple data collection approaches (Gadd and Collins, 2002), since there is no single approach that can measure all of the factors related to safety culture simultaneously (e.g., norms, values, beliefs, attitudes, and behaviors). However, the literature also suggests that while most of those studying safety culture are using similar methodological approaches (e.g., interviews, surveys, observations), they are no standardized tools that can used across domains, e.g., not the same survey instrument (Weigmann, et al, 2002). This makes it difficult in some cases to compare results across studies (Gadd and Collins, 2002), and raises questions regarding the validation of the instruments that are being used. Clearly, both construct validity (the extent to which an assessment instrument actually measures what it is intended to measure) and discriminate validity (the power of an assessment instrument to differentiate between groups that have different levels of safety) are important, and thus is desired to use instruments that have been validated (Weigmann, et al, 2002) in future assessment activities.

As previously stated, the literature does not support the use of one specific methodological approach, or specific set of tools. However, DOE (through EFCOG) has developed their own methodological guidance for the assessment of both SCWE and safety culture. The DOE's SCWE Self-Assessment guidance (2012) provides lines of inquiry for each attribute of SCWE, written as expectations of excellence for each attribute, and provides recommendations for how to conduct these assessments. It recommends using a combination of several tools/techniques to evaluate lines of inquiry associated with SCWE: direct observations, surveys, interviews, documentation review (related to key SCWE related processes), performance indicators and VPP assessments. The methodology is similar to that advocated in other Safety Culture assessment approaches (including EFCOG/DOE Safety Culture Task Team's "Assessing Safety Culture in DOE Facilities" and IAEA-TECDOC-1321), and relies on convergent validity from multiple data collection approaches (e.g., looking for where the data collected from multiple approaches agrees).

The DOE HSS is currently performing (or plans to perform) independent assessments of safety culture at a number of DOE and NNSA sites (DOE IP, 2011). HSS is using an established methodology (see Haber and Barriere, 1998) for their assessments, which generally includes five distinct approaches to collecting information about organizational behaviors associated with safety culture traits. These methods include: functional analysis, structured interviews and focus

groups, Behavioral Anchored Rating Scales, behavioral observations, and the administration of an Organizational and Safety Culture survey (as an example, see *Independent Oversight Assessment of the Nuclear Safety Culture at the Salt Waste Processing Facility Project, 2013)*This approach has focused on the following organizational behaviors: Attention to Safety, Communication, Coordination of Work, Formalization, Organizational Learning, Performance Quality, Problem Identification and Resolution, Resource Allocation, Roles and Responsibilities, and Time Urgency.

Given the existence of such approaches, it seems logical to use these approaches rather than continue to develop unique approaches each time there is a need to assess safety culture. Continuing to use the same approach also allows for easier comparisons over time, and the ability to evaluate the effectiveness of interventions that are put in place.

6. THE NEED FOR A BALANCED APPROACH: BEYOND SAFETY CULTURE

There are a number of researchers who argue that the lack of consensus in defining safety culture has reduced the utility of the construct. Cox and Cox (1996), as cited in Cox and Flin (1998), are concerned that the concept of safety culture has become a "catch-all for social psychological and human factor issues." Pidgeon (1998) highlights four theoretical issues based on his review of safety culture research and suggests that, without understanding these issues, safety culture may be seen as a construct that provides cover for talking about safety without actually requiring the actions that are needed to address issues within the organization. Clarke (2000) further argues that safety culture as a concept "remains vague, lacks empirical validation and is used as an 'umbrella term' for all the social and organizational factors that affect accident rate."

Rollenhagen (2010) concludes that the concepts of safety culture and safety climate "are more and more applied as holistic terms subsuming various human and organizational factors." Silbey (2009), citing O'Reilly and Chatman (1996), states that culture names "what is left over after you forgot what it was you were originally trying to learn", and advocates that safety culture research suggests that "responsibility for consequences of complex technologies resides in an cultural ether, everywhere or nowhere" and that focus on culture has been a supplement for addressing the structural and historical conditions that affect safe organizational performance. Further, Guldenmund (2010) highlights that safety culture has become a term used to "explain everything relating to safety failures that cannot be explained in another way."

Reason (1997) advocates that organizational accidents can be mitigated only if organizations attend to three different safety systems: the person model, the organization model, and the engineering model. These are similar to the three areas (organizational and management factors, human-system integration, and human reliability) discussed by Haber and Shurber (1998). In Reason's approach, Reason claims that each one of these systems is dynamic and has reciprocal influences on each of the other systems. For example, changes to the technology system may result in changes in the person and/or organization system.

The person model of an organization represents individual safety performance and perceptions. The focus in this model is on individual unsafe acts and personal injury accidents. Errors are perceived as being shaped predominantly by psychological factors including inattention, forgetfulness, poor motivation, etc. Reason claims that this is the most widely adapted model of safety management; often because these individual factors are relatively easy to identify.

The organization model of safety management represents factors such as management structure and other organizational factors. This model views error as a consequence rather than as a cause. Reason advocates that in this model, errors occur as the result of latent conditions inherent to the system. These latent conditions produce weaknesses in the defenses of systems. Organizational

factors are shaped by societal, regulatory, and cultural influences. There has been increased focus on organizational factors in safety management in recent years.

The engineering model of safety management represents the different components of a system in addition to the human. These could be processes, procedures, equipment and tools, and other machine interfaces. This model views human error as a phenomenon that occurs as a result of mismatches between the system and the human rather than as a result of purely psychological factors. Organizations that advocate this model are likely to fix the system components before focusing on human behaviors. This model is probably the most difficult to implement because the identification of system factors that result in error is difficult. However, once those system deficiencies are identified, they may be easy to fix – or at least the fixes may be highly effective once implemented. Although these engineering fixes may cost more initially than other efforts, there is potential to save money in the long term by avoiding possible safety issues that may arise from poorly designed systems.

Guldenmund (2010b) similarly describes a model in which three features of an organization – culture, structure, and processes, dynamically interact to generate safety performance. In this model, structure is the formal framework of an organization; culture is the underlying assumptions of an organization, and processes are the patterns of activity throughout an organization. Guldenmund (2010b) further argues that culture cannot be isolated from structure or processes; and that in fact safety management is a process but is also represented in the structure of an organization. He suggests that focus on both the culture and safety management are needed, and that the notion of safety culture maturity might eventually be replaced with measures of how effectively an organization is able to implement their structures and processes.

6.1. Safety Culture Assessment as Part of the Balanced Approach

Researchers have suggested that while focusing on safety culture improvements may be beneficial, there is also a continuing need to address weaknesses in safety management programs simultaneously. As defined by Kirwan (1998; as cited in Mearns, Whitaker and Flin (2003)), safety management is the actual practices, roles and functions associated with remaining safe. Four key functions for safety management include: policy and planning, organization and communication, hazard management, and monitoring and review (Booth and Lee, 1995). Cooper (2000; as cited in Choudhry, et al 2007) suggests that measuring safety culture purely through employee perception instruments (e.g., surveys) may result in increased focus on employee perceptions rather than allowing a more holistic look at other factors, such as behaviors (performance), site situation (environment) or safety environment (processes, equipment, technology). Glendon (2008), citing Hofmann and Mark (2006), suggests that improving safety climate should be "one among several mutually reinforcing approaches to improving operational safety, which should also include system design and HR policies." Rollenhagen (2010) further cautions that the focus on safety culture within an operating

organization may result in a bias on safety related interventions and programs that are "overly" weighted to addressing beliefs, morals, values, attitudes and behaviors of the workforce; potentially at the risk of not focusing attention on the design basis for the systems in which the workforce must operate. Guldenmund (2010) proposes a three pronged approach for considering safety, and highlights the relationship between safety culture and safety management, as represented by the structure and processes of an organization. He argues that the establishment of an effective safety management system is what is critical, and that focusing on organizational processes and/or structure will eventually influence the culture within the organization. This is similar to the argument by Rollenhagen (2010) that changes in any aspect of an organization (e.g., people, technology, organization) are likely to result in changes in the others, and thus a balanced analytical approach is needed to understand and address safety. He highlights that cultural factor (such as norms, values, attitudes and behaviors) are often shaped by technological context, so that addressing technological issues in the system should be addressed when they exist. Choudry et al (2007) also suggest that it is important to study the reciprocal interactions between psychological, behavioral and environmental/situational variables in relation to safety culture, and that it is important to understand the degree to which safety management systems influence employee behaviors, and how behaviors also influence safety management systems. Dejoy et al (2004) also conclude that organizations can benefit from a balanced approach that includes both traditional safety management approaches and actions directed at fostering a healthy safety climate.

Clarke (2006) further suggests that interventions should focus on how individuals perceive their work environment as well as improving safety policy and procedures, and concludes that organizational variables unrelated to safety attitudes influence safety performance outcomes more than the safety climate. Similarly, Booth and Lee (1995) argues that safety culture reflects the issues that affect whether safety policies and procedures established as part of a safety management program are implemented and embraced by the workforce. This would imply that addressing these issues that affect implementation of safety policies and procedures would have a positive impact on safety culture. Olive, et al (2006) also identify that before improving the safety culture of an organization, there needs to be programs in place to ensure that safety precautions and procedures can actually be carried out, including programs to minimize or eliminate hazards from the environment, designs focused on minimizing hazards in the design of systems and processes, maintenance programs for systems and equipment, and effective training programs for normal and off-normal events.

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7. CONCLUSION

In conclusion, safety culture is a valuable construct, but has some inherent weaknesses. One such weakness is that there are multiple definitions of safety culture and multiple methods exist for evaluating this construct. Many definitions that we examined included similar, but not identical factors that comprise safety culture. This makes it difficult to know specifically which factors are included in different studies and also makes the results of studies difficult to generalize to different domains. Furthermore, although the literature includes unique definitions for safety culture and safety climate, these terms are often used interchangeably. This is problematic because in some studies, it is difficult to know whether safety culture or safety climate was measured. Many researchers theorize that safety culture is an emergent property of a system that is relatively stable and difficult to change. Alternatively, safety climate is seen as a transient property that is sensitive to external environments and situations (Gadd & Collins, 2002; Guldenmund, 2010; Guldenmund, 2010b; Rollenhagen, 2010; Yule, 2003; Zohar, 2010). Thus, by using these terms interchangeably, researchers confound whether they are measuring long-term or short-term safety changes. It may be necessary to apply different interventions to address safety climate as compared to safety culture.

Another weakness of the safety culture domain is that most studies focus on the individual and organizational components of safety culture but generally do not address the engineering model. This means that organizations are relying on individual employees to change their behavior in order to change the overall safety culture, which is difficult to achieve. Further, a focus on the organizational components such as management oversight and chain of command are only a part of the safety culture system. Thus, changes in overall safety culture may not be fully realized until changes across all three components are addressed.

Although the safety culture construct has some weaknesses, it is apparent that both academic and DOE researchers know how to measure safety culture, as demonstrated through published case studies. For example, researchers have successfully shown that they can assess how employees perceive their work environment and have done so in numerous published case studies. These studies demonstrated that measuring employee perceptions of safety culture is valuable and can help elucidate what is happening within an organization. However, these results should be used with caution because as mentioned previously, a standard definition of safety culture and the factors that comprise it is still lacking and there is not yet a set of standardized tools/methods that are used to measure safety culture. Additionally, the methodologies for assessing safety culture typically focus in the individual and the organization. The potential limitations of such a focus may include sample bias, ability to generalize the results to other populations, relevance of factors studied, the potential that safety climate is actually being measured as opposed to safety culture, and an under-reliance on the engineering component of safety culture and its implications for the overall safety system.

Safety culture and SCWE are prominent topics in both the academic literature and within the DOE complex; recent events within the DOE complex have driven senior administrators to commit to efforts to focus on safety culture and SCWE across facilities. DOE (through EFCOG) have developed and published a number of documents that outline approaches for evaluating safety culture, most of which are similar to those advocated in the academic literature. These established methodologies for evaluating both safety culture and SCWE can be, and should be, leveraged for future assessments rather than spending resources developing yet another customized approach.

Although researchers know how to measure safety culture, based on the published literature, the relationship between safety culture and performance is tenuous, at best. Few empirical studies examine the relationship between safety culture and safety performance metrics (although there is an acknowledged relationship between safety climate and safety performance). Additionally, most empirical studies examine employee perceptions of safety culture but either do not include (or do not document) the implementation of interventions in safety culture and/or performance areas that need improvement or do not measure the effect of interventions on safety culture on safety performance (e.g., pre and post-tests for interventions are lacking).

Lastly, the relationship between safety culture and safety performance may be affected by other factors that researchers have not yet fully explored, namely, those that comprise the engineering component of safety culture. A number of researchers have concluded that it is necessary to take a balanced approach to evaluating safety within an organization. Many argue that safety culture is best viewed as a dynamic, multifaceted overall system composed of individual, engineered, and organizational models. Most conclude that focusing on individuals through enforcing compliance is not enough to change culture; Employees must buy-in to safety efforts in order to improve safety culture. Further, it is extremely difficult to affect lasting behavior (individual) changes, so it is necessary to address the engineered and organizational models of safety culture to affect effective changes. Changes in individual behaviors may follow after implementation or organizational and engineering interventions. Therefore, assessment of safety culture should be done in the context of a balanced approach that addresses individual, organizational as well as engineered aspects of the system. Focusing on other aspects of the system (such as changes to hardware, procedures and processes) may also have the benefit of improving safety culture due to the interrelated nature of the system.

8. REFERENCES

1. Agnew, J. & Daniels, A. C. (2010). *Safe By Accident: Take the Luck Out of Safety: Leadership Practices that Build a Sustainable Safety Culture.* Atlanta, GA: Performance Management.
2. Arboleda, A., Morrow, P.C., Crum, M.R., & Shelley, M.C. (2003). Management practices as antecedents of safety culture within the trucking industry: similarities and differences by hierarchical level. *Journal of Safety Research, 34,* 189-197.
3. Bailey, C. (1997). Managerial factors related to safety program effectiveness: an update on the Minnesota perception study. *Professional Safety, 8,* 33-35.
4. Berends, J.J. (1996). On the measurement of safety culture (unpublished graduation report). Eindhoven University of technology, Eidhoven.
5. Berkes,H. & Langfitt, F. (2010, May 17). Mine probe examines airflow, possible tampering. National Public Radio. Retrieved from http://www.npr.org.
6. Bolino, M.C., & Turnley, W.H. (2005). The personal costs of citizenship behavior: The relationship between individual initiative and role overload, job stress, and work-family conflict. *Journal of Applied Psychology, 90,* 740-748.
7. Booth, R.T. and Lee, T.R. (1995). The Role of Human Factors and Safety Culture in Safety Management. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture,* 209, 393-400.
8. Brandt, M.M., Ahms, K. S., Corpron, C. A., Franklin, G. A. & Wahl, W. L. (2002). Hospital cost is reduced by motorcycle helmet use. *Journal of Trauma and Acute Care Surgery, 53(3),* 469-471.
9. Brown, R.L. & Holmes, H. (1986). The use of a factor-analytic procedure for assessing the validity of an employee safety climate model. *Accident Analysis and Prevention, 18,* 455-470.
10. Bureau of Labor Statistics. (2012). News release (USDL-12-2121). US Department of Labor.
11. Cabrera, D.D., Isla, R., & Vilela, L.D. (1997). An evaluation of safety climate in ground handling activities. In Soekkha, H.M. (Ed.), *Aviation Safety, Proceedings of the IASC-97 International Aviation Safety Conference,* Netherlands, 27-29 August, 255-268.
12. Choudry, R.M., Fang, D., & Mohamed, S. (2007). The nature of safety culture: A survey of the state-of-the-art. *Safety Science, 45,* 993-1012.
13. Christian, M.S., Bradley, J.C., Wallace, J.C., & Burke, M.J. (2009). Workplace safety: a meta-analysis of the roles of person and situation factors. *Journal of Applied Psychology, 94*, 1103-1127.
14. Christopher, A. (2010, July 14). Upper Big Branch workers deliberately disabled methane monitor months before fatal explosion, miners exclusively tell NPR News. National Public Radio. Retrieved from http://www.npr.org.
15. Clarke, S. (1999). Perceptions of organizational safety: implications for the development of safety culture. *Journal of Organizational Behavior, 20,* 185-198.

16. Clarke, S. (2000). Safety culture: under-specified and overrated? *International Journal of Management Review*, *2*, 65-90.
17. Clarke, S. (2006). Safety climate in an automobile manufacturing plant: The effects of work environment, job communication and safety attitudes on accidents and unsafe behavior. *Personnel Review,* 35:4, 413-430.
18. Cooper, M.D. (2000). Towards a model of safety culture. *Safety Science, 36,* 111-136.
19. Cooper, M.D., & Phillips, R.A. (1994). Validation of a Safety Climate Measure. Paper presented at the *British Psychological Society, Annual Occupational Psychology Conference*, Birmingham, January 3-5.
20. Cooper, M. D., Phillips, R. A., Sutherland, V. J. & Makin, P. J. (1994). Reducing accidents using goal setting and feedback: A field study. *Journal of Occupational and Organizational Psychology, 67,* 219-240.
21. Cox, S & Cox, T. (1991). The structure of employee attitudes to safety: an European example. *Work and Stress, 5,* 93-106.
22. Cox, S. & Flin, R. (1998). Safety culture: Philosopher's stone or man of straw? *Work & Stress, 12,* 189-201.
23. Coyle, I.R., Sleeman, S.D., Adams, N. (1995). Safety climate. *Journal of Safety Research, 26*, 247-254.
24. D'Agostino, Thomas. "Subject: National Nuclear Administration Safety Culture Working Group" Memorandum to James J. McConnell, Deputy Associate Administrator for Infrastructure and Operations. December 3, 2012.
25. DeDobbeleer, N. & Beland, F. (1991). A safety climate measure for construction sites. *Journal of safety Research, 22,* 97-103.
26. DeJoy, D., Schaffer, B., Wilson, M., Vandenberg, R., and Butts, M. (2004). Creating safer workplaces: assessing the determinants and role of safety climate. *Journal of Safety Research,* 35, 81-90.
27. Department of Energy (2011) DOE G 450.4-1C: Integrated Safety Management System Guide.
28. Department of Energy (2011) Memorandum from Secretary Chu to the Honorable Peter S. Winokur "The Department of Energy's (DOE's) Implementation Plan (IP) for Defense Nuclear Safety Board Recommendation 2011-1, Safety Culture at the Waste Treatment Stabilization Plant (WTP)," December 27, 2011.
29. Department of Energy (2012) *Safety Conscious Work Environment Self-Assessment Guidance*, Revision G.
30. Department of Energy (2012) *Health, SSAF-200: Safety Conscious Work Environment training materials*.
31. Department of Energy (2013) *Independent Oversight Assessment of the Nuclear Safety Culture at the Salt Waste Processing Facility Project.*
32. Dilda, A., Mearns, K., & Flin, R. (2009). Safety citizenship behavior: a proactive approach to risk management. *Journal of Risk Research, 12,* 475-483.

33. *EFCOG (January 23, 2009). EFCOG Meeting Handout: Assessing safety culture in DOE facilities.* EFCOG/DOE Safety Culture Task Team.
34. Fang, D., Chen, Y. & Wong, L. (2006). Safety climate in construction industry: A case study in Hong Kong. *Journal of Construction Engineering and Management, 132*, 573-584.
35. Flin, R., Mearns, K., O'Connor, P., & Bryden, R. (2000). Measuring safety climate: identifying the common features. *Safety Science, 34*, 177-192.
36. Gadd, S. & Collins, A.M. (2002). Safety culture: a review of the literature. Health & safety Laboratory. HSL/2002/25.
37. Geller, E.S. (1994). Ten principles for achieving a Total Safety Culture. Professional Safety September, 18-24.
38. Geller, S. (1997). *The Psychology of Safety: How to improve behaviors and attitudes on the job*. CRC Press LLC, Florida.
39. Glendon, I. (2008). Safety culture and safety climate how far have we come and where could we be heading? *Journal of Occupational Health and Safety: Australia and New Zealand*, 24: 249-271.
40. Glendon, A.I. & Litherland, D.K. (2001). Safety climate factors, group differences and safety behavior in road construction. *Safety Science*, *39*, 157-188.
41. Glendon, A.I. & Stanton, N.A. (2000). Perspectives on safety culture. *Safety Science*, *34*, 193-214.
42. Glennon, D.P. (1982a). Measuring organizational safety climate. *Australian Safety News January/February*, 23-28.
43. Glennon, D.P. (1982b). Safety climate in organisations. *Proceedings of the 19th Annual Conference of the Ergonomics Society of Australia and New Zealand*, 17-31.
44. Guldenmund, F.W. (2000). The nature of safety culture: A review of theory and research. *Safety Science*, *34*, 215-257.
45. Guldenmund, F.W. (2010). (Mis)understanding Safety Culture and Its Relationship to Safety Management. *Risk Analysis, 30*, 1466-1480.
46. Guldenmund, F.W. (2010b). Understanding and Exploring Safety Culture. Doctoral Dissertation, Delft University of Technology.
47. Haber, S.B. and Barriere, M.T. (1998). Development of a regulatory organizational and management review method. *Research Report RSP-0060*, Canadian Nuclear Safety Commission, Ottawa, Canada.
48. Haber, S.B. and Shurberg, D.A. (1998). Safety culture in the nuclear versus non-nuclear organization. U.S. Department of Energy (Contract No. DE-AC02-76CH00016).
49. Haber, S.B., Shurberg, D.A., & Hofmann, D. (1994). Safety culture management: the importance of organizational factors. U.S. Nuclear Regulatory Commission (BNL-NUREG-60966).
50. Hale, A.R. (2000). Editorial: culture's confusions. *Safety Science*, *34*, 1-14.

51. Hale, A.R., Guldenmund, F.W., van Loenhout, P.L.C.H., and Oh, J.I.H. (2010) Evaluating safety management and culture interventions to improve safety: Effective intervention strategies. *Safety Science,* 48, 1026-1035.
52. Harvey, J., Bolam, H., Gregory, D., & Erdos, G. (2001). The effectiveness of training to change safety culture and attitudes within a highly regulated environment. *Personnel Review, 30,* 615-636.
53. Havold, J. I. (2005). Safety-culture in a Norwegian shipping company. *Journal of Safety Research, 36,* 441-458.
54. Hayes, B.E., Perander, J., Smecko, T., & Trask, J. (1998). Measuring perceptions of workplace safety: development and validation of the work safety scale. *Journal of Safety Research, 29,* 145-161.
55. Heese, M. (2012). Got the Results, Now What Do You Do? Safety Culture Transformation from Theory into Practice. *Aviation Psychology and Applied Human Factors*, 2(1), 25-33.
56. Hofmann, D.A., Morgeson, F.P., & Gerras, S. (2003). Climate as a moderator of the relationship between LMX and content specific citizenship: Safety climate as an exemplar. *Journal of Applied Psychology, 88,* 170-178.
57. Hofmann, D. and Mark, B. (2006) An investigation of the relationship between safety climate and medication errors as well as other nurse and patient outcomes. *Personnel Psychology,* 59:4, 847-869.
58. Houghton, T. (2011). NRC's nuclear safety policy statement. Nuclear Engineering Institute: Washington, D.C.
59. Institute of Nuclear Power Operations. (2004). Principles for a strong nuclear safety culture. Atlanta, GA.
60. Institute of Nuclear Power Operations. (2012). INPO 12-012: Traits of a Healthy Nuclear Safety Culture. Atlanta, GA.
61. International Atomic Energy Agency (2002). IAEA-TECDOC-1321: *Self-assessment of safety culture in nuclear installations; Highlights and good practices. IAEA: Vienna.*
62. International Safety Advisory Group. (1991). Safety Culture (Safety Series No. 75-INSAG-4). International Atomic Energy Agency, Vienna.
63. Jung, T., Scott, T., Davies, H. T. O., Bower, P., Whalley, D., McNally, R., & Mannion, R. (2009). Instruments for exploring organizational culture: A review of the literature. *Public Administration Review, 6,* 1087-1088.
64. Kennedy, R. & Kirwan, B. (1998). Development of a hazard and operability-based method for indentifying safety management vulnerabilities in high risk systems. *Safety Science, 30,* 249-274.
65. Kirwan, B., 1998. Safety management assessment and task analysis—a missing link? In: Hale, A., Baram, M. (Eds.), *Safety Management: The Challenge of Change*. Elsevier, Oxford, pp. 67–92.
66. Lee, T.R. (1996). Perceptions, attitudes, and behavior: the vital elements of a safety culture. *Health and Safety, October,* 1-15.

67. Levy, M. L., Ozgur, B. M., Berry, C., Aryan, H. E. & Apuzzo, M. L. J. (2004). Birth and evolution of the football helmet. *Neurosurgery, 55(3)*, 656-662.
68. Lin, M., Kolosh, K.P., Fearn, K.T., Yario, J., Palmer, I., & Haas, T. (2011). Injury facts, the Council's annual statistical report on unintentional injuries and their characteristics and costs. Itasca, IL: NSC Press.
69. Myers, J. (2010, May 20). A tale of two CEOs: BP vs. Massey, Part II, Don Blankenship of Massey [Web log post]. Retrieved from http://topics.nytimes.com/top/reference/timestopics/subjects/m/mines_and_mining/mining_disasters/index.html.
70. Maher, K., Powers, S., & Hughes, S. (2010, April 13). Mine disaster inquiry to focus on blasting. Wall Street Journal. Retrieved from http://www.wsj.com.
71. Mearns, K., Whitaker, S.M., & Flin, R. (2003). Safety climate, safety management practice and safety performance in offshore environments. *Safety Science, 41*, 641-680.
72. Mintzberg, H. (1979). The structuring of organizations: A synthesis of the research. Prentice-Hall: New Jersey.
73. Mohamed, S. (2003). Scorecard approach to benchmarking organizational safety culture in construction. *Journal of Construction and Engineering Management, 128*, 375-384.
74. Naevestad, T-O. (2010). Evaluating a safety culture campaign: Some lessons from a Norwegian case. *Safety Science, 48*, 651-659.
75. Nielsen, K. J., Rasmussen, K., Glasscock, D. & Spangenberg, S. (2008). Changes in safety climate and accidents at two identical manufacturing plants. *Safety Science, 46*, 440-449.
76. Niskanen, T. (1994). Safety climate in the road administration. *Safety Science, 17*, 237-255.
77. Nuclear Energy Institute. (2010). Fostering a strong nuclear safety culture. (NEI 09-07, OEDO-2011-0022). Washington, D.C.
78. Nuclear Regulatory Commission (May 14, 1996) Policy Statement "Freedom of Employees in the Nuclear Industry to Raise Safety Concerns Without Fear of Retaliation."
79. Nuclear Regulatory Commission (August 25, 2005) NRC Regulatory Issue Summary 2005-18: Guidance for Establishing and Maintaining a Safety Conscious Work Environment.
80. Nuclear Regulatory Commission. (2011). Final Safety Culture Policy Statement. (NRC-2010-0282). Federal Register, 76, 34773-34778.
81. Occupational Safety and Health Administration. (2003). *Safety and Health Add Value.* OSHA 3180. Retrieved from http://www.osha.gov/Publications/safety-health addvalue.pdf.
82. Olive, C., O'Connor, M., and Mannan, M.S. (2006). Relationship of safety culture and process safety. *Journal of Hazardous Materials,* 130, 133-140.
83. Ostrum, L., Wilhelmsen, C., & Kaplan, B. (1993). Assessing safety culture. *Nuclear Safety, 34*, 163-172.

84. O'Toole, M.F. (2002). The relationship between employees' perceptions of safety and organizational culture. *Journal of Safety Research, 33,* 231-243.
85. Pidgeon, N.F. (1991). Safety culture and risk management in organizations. *Journal of Cross-Cultural Psychology, 22,* 129-140.
86. Pidgeon, N.F. (1998). Safety Culture: Key theoretical issues. *Work & Stress, 12,* 202-216.
87. Reason., J. (1997). *Managing the risks of organizational accidents*. Burlington, VT: Ashgate Publishing Company.
88. Reason, J. (1998). Achieving a safe culture: Theory and Practice. *Work & Stress: An International Journal of Work, Health & Organizations,* 12:3, 293-306.
89. Reiman, T. & Oedewald, P. (2004). Measuring maintenance culture and maintenance core task with CULTURE-questionnaire – a case study in the power industry. *Safety Science, 42,* 859-889.
90. Richter, A. & Koch, C. (2004). Integration, differentiation, and ambiguity in safety cultures. *Safety Science, 42,* 703-722.
91. Robertson, L. S., O'Neill, B. & Wixom, C. W. (1972). Factors associated with observed safety belt use. *Journal of Health and Social Behavior, 13,* 18-24.
92. Robertson, L. S., Kelley, A. B., O'Neill, B., Wixom, C. W., Eiswirth, R. S. & Haddon, W. (1974). A controlled study of the effect of television messages on safety belt use. *American Journal of Public Health, 64 (11),* 1071-1080.
93. Rollenhagen, C. (2010). Can focus on safety culture become an excuse for not rethinking design of technology? *Safety Science, 48,* 268-278.
94. Schein, E.H. (1990). Organizational Culture. *American Psychologist, 45,* 109-119.
95. Silbey, S.S. (2009). Taming Prometheus: Talk About Safety and Culture. *Annual Review of Sociology, 35,* 341-369.
96. Sorenson, J.N. (2002). Safety culture: a survey of the state-of-the-art. *Reliability Engineering and System Safety, 76,* 189-204.
97. Watson, G. S., Zador, P. L. & Wilks, A. (1980). The repeal of helmet use laws and increased motorcyclist mortality in the United States, 1975-1978. American Journal of Public Health, 70(6), 579-585.
98. Wiegmann, D.A., Zhamng, H., von Thaden, Sharma, G., & Mitchell, A. (2002). Safety Culture: A review. Technical Report (ARL-02-3/FAA-02-2) prepared for the Federal Aviation Administration. Aviation Research Lab Institute of Aviation: Savoy, IL.
99. Wiegmann, D.A., Zhang, H., von Thaden, T., Sharma, G., & Mitchell, A. (2004). Safety culture: an integrated review. *The International Journal of Aviation Psychology, 14,* 117-134.
100. Williamson, A.M., Feyer, A.M., Cairns, D., & Biancotti, D. (1997). The development of a measure of safety climate: the role of safety perceptions and attitudes. *Safety Science, 25,* 15-27.

101. Yule, S. (2003). Senior Management Influence on safety performance in the UK and US energy sectors. Doctoral thesis, University of Aberdeen, Scotland.
102. Zhou, Q., Fang, D. & Mohamed, S. (2011). Safety climate improvement: Case study in a Chinese construction company. *Journal of Construction Engineering and Management, 137*, 86-95.
103. Zohar, D. (1980). Safety climate in industrial organizations: Theoretical and applied implications. Journal of Applied Psychology, 65, 96-102.
104. Zohar, D. (2010). Thirty years of safety climate research: Reflections and future directions. *Accident Analysis and Prevention, 42*, 1517-1522.

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