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Can we examine safety culture in accident investigations, or should we? ☆

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ABSTRACT

Considerable attention has been paid to safety culture since the 1986 Chernobyl nuclear power station accident. Researchers have studied it and companies and regulators have applied it to enhance safety. However, few research studies have been conducted that establish a link between safety culture and operational or process safety and methods used to assess safety culture, primarily questionnaires, have been criticized on methodological grounds. One way to enhance system safety is through applying the lessons of investigations of accidents of process safety to remediate organizational shortcomings identified in the investigation. Rather than attempting to assess safety culture directly, examining company actions and decisions directly after an accident can allow investigators to make inferences about safety culture at the time of the accident. This study suggests a method to directly examine the role of organizations in accidents by identifying the nature of organizational errors and describing the logic that can link these errors to accident causation. The application of this method in several accident investigations is described.

1. Introduction

There has been a considerable amount of attention devoted to safety culture recently, both by researchers seeking to better understand it and companies seeking to apply it to enhance the safety of their operations. Some have applied it retroactively, to explain incidents and accidents. As a 2007 editorial in this journal noted (Baram and Schoebel, 2007, p. 632), "it has become convenient for investigators of accidents to aggregate their findings about contributing factors and hold an organization accountable for an accident by concluding that it had an inadequate safety culture." But is investigating safety culture as a potential cause of an accident warranted? Given what is known about safety culture, is it reasonable that accident investigators, using investigative techniques that meet the requirements of accident investigations, assess the role of a company's safety culture in the cause of an accident? To answer these questions, it is necessary to examine safety culture and the ways it is currently assessed.

The term safety culture was used initially by the International Atomic Energy Agency (IAEA) in reference to the April 1986 Chernobyl nuclear power station accident. Following the accident the International Nuclear Safety Advisory Group or INSAG published protocols for nuclear power facilities to enhance their safety culture (INSAG, 1991), so that reactor operational safety would be improved. Since then researchers have devoted considerable attention to the topic and regulators and companies have endeavored to improve operational safety by applying safety culture to their industries and to their operations, respectively. In the United States the Nuclear Regulatory Commission, the government agency that regulates civilian nuclear power plants, formally endorsed the application of safety culture principles in that industry, proposing elements of a positive safety culture to guide their licensees (Nuclear Regulatory Commission, 2011), as did another United States regulator (e.g., Bureau of Safety and Environmental Enforcement, 2013).

Yet safety culture, despite its origins in an accident investigation and its increasing acceptance by companies and regulators, has rarely been directly addressed in investigations of operational accidents. In this paper I raise the question of whether safety culture can and should be examined in accident investigations and if not, I consider alternative methods that may address a company's role in an accident. These methods can allow investigators to make inferences about aspects of an organization's culture from the findings of an accident investigation.

☆ The views expressed in this article are those of the author and not those of the National Transportation Safety Board or any agency of the United States government.

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2. Safety culture

To understand safety culture the meaning of culture should first be examined because safety culture is considered an element of a particular type of culture, that of companies or organizations. Thomas et al. (2003, p. 454), define culture as:

> Systems of values, attitudes, beliefs, and behavioral meanings shared by members of a social group (society) and learned from previous generations. Culture itself, a group level construct, is neither genetic nor about individual behavior. However, it exists within the knowledge systems of individuals, which are formed during childhood, and reinforced throughout life.

Because culture is formed by beliefs, interpretations, and behaviors, it is considered to be "deep seated," or as Antonsen (2009) describes, "conservative." Culture, he writes (2009, p. 249), is "not something that changes rapidly." Traditionally, culture has been applied to large groups of people, such as those inhabiting nations and geographic areas, and members of tribes and religions. Hofstede (1980, 1991), among prominent contemporary cross-cultural researchers, initially identified four dimensions (later adding a fifth) that distinguished national cultures. He derived the dimensions from multivariate statistical analyses of responses to Likert-type questionnaires administered to employees of a multi-national corporation. Hofstede's work has been criticized on a variety of grounds (e.g., Fang, 2003; McSweeny, 2002), including his use of questionnaires to measure cultural characteristics. Nevertheless, although Hofstede's measurement methods and conclusions have been criticized, the influence of culture has not; it is a widely accepted construct that effectively distinguishes groups of people according to dimensions or characteristics of behaviors, norms, and values.

Studies of characteristics that distinguish among cultures of large groups of people have also been conducted on smaller groups. When applied to those within organizations, the particular category is referred to as organizational culture. Schein (1990, 1996) described characteristics that "cut across a whole social unit" of organizations and companies. That is, employees of corporations can be distinguished from those of other corporations by their organizational beliefs and behaviors, differences that would be present even among employees of corporations engaged in similar endeavors. Those differences have been attributed, in part, to the employees' acculturation through their affiliation with their respective organizations.

Since the Chernobyl accident the study of organizational culture has been further applied to the safety characteristics of organizations engaged in high risk operations, that is, to their operational safety, i.e., safety culture. As Hopkins (2006, p. 876) describes,

> Every organisation has a culture (or perhaps a series of subcultures) and that culture can be expected to impact on safety. Understanding how this happens can provide insights into ways organisational cultures need to be modified to give a higher priority to safety.

Guldenmund (2000) suggests that safety culture, consistent with other types of culture, is a relatively stable multidimensional construct, with characteristics and aspects shared by members of the organization.

Nonetheless, both the study and application of safety culture has not been without criticism. Silbey (2009), for example, disparages the widespread but uncritical use of the concept, and its use as an explanation for organizational and technological shortcomings. Similarly Reiman and Oedewald (2007, p. 748) note:

> The sometimes careless and vague use of the term safety culture has resulted in criticism among academic organizational researchers. According to them the concept of safety culture has become a catch-all concept for psychological and human factors issues in complex sociotechnical systems.

2.1. Defining safety culture

Such criticism may be due to the absence of a commonly accepted definition of safety culture. As Guldenmund (2000) observed, "the concepts of safety culture and safety climate are still ill-defined and not worked out well; there is considerable confusion about the cause, the content and the consequence of safety culture and climate ... and the consequences of safety culture and climate are seldom discussed (p. 247)." More recently, an editorial in this journal (Baram and Schoebel, 2007, p. 633), presented a similar view, "there is considerable confusion," it observed, "about what safety culture means and controversy over how to deal with the concept's many implications for complex organizations."

Unlike national culture, a concept that is widely understood and accepted, safety culture calls for an understanding of safety, which has proven challenging to operationally define and measure. As Stoop and Dekker (2012) suggest, "safety is a difficult performance parameter to measure accurately due to its stochastic nature ... safety is an emergent property, which is difficult to express in quantifiable parameters, such as the frequency and severity of accidents, incidents and occupational diseases (p. 1428)."

Further, because the rate of accidents in high risk systems is (fortunately) low, despite the occurrence of the accident at Chernobyl, defining measures of system safety is difficult. As Lofquist (2010, pp. 1521–1522) observed, "academic contributions have increased our understanding of the underlying organizational dynamics of how safe systems contribute to unacceptable outcomes, [but] all [of the cited contributions] fall short of defining a true systems perspective for measuring safety as a process within high-risk industries..."

Several definitions of safety culture have been proposed. Wiegmann et al. (2004, p. 124) define it as "an enduring characteristic of an organization that is reflected in its consistent way of dealing with critical safety issues," characterized by organizational commitment to safety, management involvement and employee empowerment with regard to safety issues, a system that rewards employees for safety behaviors, and a system that encourages the reporting of safety concerns. Richter and Koch (2004, p. 705) define it as "the shared and learned meanings, experiences and interpretations of work and safety – expressed partially symbolically – which guide peoples' actions towards risks, accidents and prevention."

Grote (2012) suggests that characteristics of a "common denominator" of safety culture include safety policy, safety resources and responsibilities, risk identification and mitigation, standards and procedures, human factors based system design, safety training, safety performance monitoring, incident reporting and investigation, auditing, continuous improvement, and management of change. The Nuclear Regulatory Commission, in its 2011 safety culture policy statement, identified characteristics of "a positive safety culture," including leadership safety values and actions, problem identification and resolution, personal accountability, work processes (the process of planning and controlling work activities so that safety is maintained), continuous learning, environment for raising concerns, effective safety communication, respectful work environment, and questioning attitude. Some of the elements of safety culture that have been proposed are observable; however, many address norms, attitudes and styles of behavior, e.g., leadership commitment, that are not. Further, as will be discussed subsequently, the incorporation of established programs that manifest "good" safety culture, such as risk identification and mitigation programs, a key element of safety management systems, do not assure safe operational practices.

In general it can be said that safety culture describes the commitment of an organization's employees, at all its levels, to valuing the safe operation of the system and practicing those values in the manner in which they interact with that system. For researchers and accident investigators, focusing on employee interactions with the system and their values regarding those interactions may allow inferences to be made regarding the organizational safety culture. However, there has not been agreement on the manner in which such inferences can be made.

2.2. Studying safety culture

The study of safety culture and that of safety climate have been intertwined. In general, safety culture refers to an aspect of organizational culture, while safety climate refers to a measure of safety culture, a distinction that will be explored further shortly. Reason (1998) also proposed the concept of a "safe culture," one that he equated to an informed culture which, as he explained,

> ...is one in which people, at all levels, do not forget to be afraid. They know where the "edge" without having to fall over it. (p. 302).

Flin et al. (2000) describe safety climate as, "a snapshot of the state of safety providing an indicator of the underlying safety culture of a work group, plant or organization (p, 178)." Walker (2010) found potentially large differences between the two. As he wrote, (p. 333)

> It is an important distinction because safety climates are only an articulation of safety cultures. They are not synonymous operatives and there is not always fidelity between the two.

Zohar (2010) identified relatively strong inverse correlations between safety climate and safety outcomes, using measures of occupational rather than process safety. The correlations indicated an association between higher scores on safety climate measures, and lower incidence of occupational injuries. Mearns et al. (2003) assessed the relationship between safety climate and occupational injury rates among employees of offshore oil installations. Scores on the assessment of safety climate were compared to the accident rates of employees among different installations over two consecutive years. Relationships of varying strengths between safety climate and safety, as measured by the rate of occupational injuries, were found among the installations. Those with the most favorable safety climates were found to have the lowest occupational injury rates; however limitations in the data and the methodology made the results only suggestive.

Neal and Griffin (2006) studied the relationship between perceived safety climate and subsequent safety-related behaviors and occupational injuries, over time, in an Australian hospital. They distributed questionnaires several times over a five-year period to employees, mostly nurses but also administrative and other personnel, and assessed such incidents as needle stick injuries. The authors found relationships between safety climate and individual safety motivation, and inverse relationships between safety climate and the number of occupational accidents, over a two-year period.

Grabowski et al. (2010) examined the relationship between safety culture and safety in ocean-going ship operations. They distributed safety climate questionnaires to company employees on both vessels and in offices, including managers and line employees, then compared responses to the questionnaires to measures of safety, both process and personal. These measures included frequency of system accidents and incidents, "near misses" or occurrences that almost became accidents or incidents, on the job injury frequency, classification society audit results (specific to the marine industry), and government vessel inspection findings. The authors found significant correlations between measures of safety climate, i.e., questionnaire results, and safety performance using the safety metrics suggested.

Morrow et al. (2014) examined the relationship between safety climate and process safety at United States nuclear power facilities. They administered questionnaires that, among other things, incorporated IAEA safety culture characteristics, to nuclear power plant employees at different facilities. They then compared the questionnaire results to parameters of operational safety among the facilities to determine whether differences in the questionnaire results were related to differences in safety. The performance parameters included unplanned immediate reactor shutdowns, Nuclear Regulatory Commission inspection findings, and others. Moderate relationships were found between the measures of safety climate and the safety parameters; the higher the levels of safety climate, the lower the number of negative safety parameters at the nuclear facility.

2.3. Measures of safety culture

As can be seen, the use of questionnaires to measure characteristics of safety culture is common. For example, Kines et al. (2011) developed the Nordic Safety Climate Questionnaire or NOSACQ-50, a questionnaire designed to assess safety climate. The instrument has gained considerable acceptance, as evidenced by its translation into multiple languages and its widespread administration to measure and identify safety climate in high risk industries.

Nonetheless, this method has not been without criticism. Guldenmund (2007), in perhaps the most comprehensive examination of the use of questionnaires in safety culture research, cites several methodological issues with the use of these instruments to assess safety culture. "Within organisations," he writes,

> The groups we can assume to have a common culture are often not large enough to average out the random influences. Furthermore, the scales that are used to record the responses (Likert scales, preference scales, indices of importance or significance) are assumed to be at the (quasi-) interval measurement level, but this is at least doubtful. This principally means that calculating means, variances, correlations and other linear transformations is not allowed. Again, with large populations this would not be such a problem, but within most studies of organisations, so far published in the safety climate literature, it probably is (p. 726).

Criticism of the use of questionnaires to assess safety culture is perhaps best summarized in *Safety Science's* 2007 editorial. "While safety researchers have relied mainly on questionnaires," it stated, "other assessment methods may be more illuminating." Suggested techniques include "in-depth interviews, simulations and role playing." (Baram and Schoebel, 2007, p. 635).

In recent years some researchers have used ethnographic measures to examine safety culture as well. Antonsen (2009), for example, distributed safety culture questionnaires to offshore drilling platform workers, both before and after the platform had sustained an operational accident, to determine if indicators of the accident could have been discerned beforehand. He also conducted in-depth interviews with over 150 workers, both those working on the platform and those in company headquarters, to further elicit safety culture information. He found that the pre-accident questionnaire failed to detect safety issues that were identified after the accident. The discrepancies included a pre-accident belief in a level of procedural compliance and reporting of incidents and accidents that was, in practice, considerably less than that revealed in the investigation, in post-accident questionnaires, and in post-accident interviews. He suggested that platform employees may have become complacent toward safety, thus creating a ''blind spot'' with regard to the safety hazards that the pre-accident questionnaires failed to detect. As he explained (2009, p. 252),

> The basic assumptions that in many ways form the core of culture are impossible to grasp through survey results. To gain information about culture requires a more interactive assessment, where the insiders (organizational members) and outsiders (researchers) of a culture engage in a process of joint inquiry to uncover cultural assumptions.

Walker (2010) conducted an ethnographic assessment of a grain company's safety culture by working there as a temporary or part-time employee (referred to as ''contingent worker'') over a two-year period, providing him with what he described as a ''bottom up perspective.'' In this capacity he was able to earn a level of trust among workers and thus obtain insights to a degree that would have been difficult otherwise. He found, among other observations, that the workers had developed a ''counterculture'' to the official safety pronouncements of management, as provided by the safety specialist, in his monthly meetings with employees. He noted that (p. 339),

> The men either blatantly ignore Lonnie [the company safety specialist] during his presentation and his attempts to discuss [safety] or they actively challenge the company's ideas of safety. Given their experience with inconsistent bureaucratic rules and their own high stakes it is quite logical that the men resist this intrusion. This is a way the men maintain boundaries around their informal counterculture and control over their work.

Walker illustrated that ethnographic assessments of safety culture, while resource intensive in the two years that he worked at the company, enabled him to obtain a more sophisticated and nuanced assessment than one potentially possible through other assessment techniques.

Antonsen (2009) observed that accident investigations reveal much about the extent to which operator procedures match company manager beliefs, an indication of an organization's safety culture. Procedures form the core of safe operational practices and complex systems and employees of these systems recognize the importance of adhering to them. This can be seen, for example, in the almost total reliance on checklists by airline pilots during critical flight phases, both during routine and non-routine situations. While blind adherence to procedures can be safety limiting, the extent to which employees follow procedures when not being observed or monitored by supervisors or managers reveals much about a key element of safety culture.

The discrepancy between employee safety beliefs and operational practices was seen in the investigation of a marine accident, in which a large vessel struck a highway bridge while the crew unsuccessfully attempted to pass under it, severely damaging the bridge as a result (National Transportation Safety Board, 2013). Investigators found that the company operating the vessel had exceeded regulatory requirements in a number of ways and audit results of the vessel's safety management system consistently found relatively insignificant areas of improvement, both indications of ''good'' safety culture. Company personnel believed that the safety practices on that vessel were good and that its personnel on the vessel practiced good safety habits. Yet the accident revealed that practices on the vessel deviated considerably from what could be described as those consistent with a ''good'' safety culture. Rather, investigators noted that ''due to the vessel's good safety record and the company's reliance on proactive safety measures and a crew of well-trained, experienced deep-sea mariners to provide a high level of safety, the company became complacent regarding the safety of the vessel's operations.'' (p. vii).

In this respect, the National Transportation Safety Board echoed Amalberti (2001), in his description of the difficulties posed by consistent safety performance of high risk systems. ''An incident free system,'' he wrote, (p. 120)

> becomes mute and its safety can no longer be tuned. Investments stop being direct at safety and are earmarked towards improving performance.

This suggests a potential paradox of safety culture, i.e., that the absence of accidents may obscure from an organization actual system safety, enhancing company beliefs in the positive aspects of their safety culture, beliefs that may be unsupported.

Inconsistencies between company beliefs and system safety were also noted in the findings of the Chemical Safety and Hazard Investigation Board, in its investigation of the March 2005 BP Texas City refinery accident. They discovered that BP managers believed that their safety culture was good because occupational injuries had been reduced, largely in response to the advice of consultants the company had brought in to occupational safety. Yet, company oversight of process safety was poor. As the Chemical Safety Board wrote (2007, p. 144),

> As personal injury safety statistics improved, BP Group executives stated that they thought safety performance was headed in the right direction. At the same time, process safety performance continued to deteriorate at Texas City. This decline, combined with a legacy of safety and maintenance budget cuts from prior years, led to major problems with mechanical integrity, training, and safety leadership.

3. Accident investigation and safety culture

Although accident investigations have addressed discrepancies between management beliefs and operator practices, the ability to directly assess a company's safety culture in an accident investigation is difficult for several reasons. If measuring traits of safety culture through questionnaires, such as those traits suggested by the Nuclear Regulatory Commission (2011), issues remain about their validity. Moreover, the effects of an operational accident on company employees may be considerable, representing the failure of often years of personal and organizational effort, not to mention the effects on employee attitudes of coping with the potential consequences of injury, death, or property and/or environmental damage resulting from the accident. Although culture is considered a stable element, questionnaires, regardless of their quality, largely measure attitudes, traits that are not necessarily stable.

If using ethnographic techniques on the other hand, the time needed to adequately assess the organizational culture and its relationship to safety will largely exceed the time constraints of investigations. If assessing safety culture through the presence of safety management systems, risk mitigation and identification, both of which are critical elements of these systems and hallmarks of proactive safety policies, are only effective against those risks that are recognized. To what degree should investigators cite a company in an accident investigation for not recognizing the risks that led to an accident, particularly if, as is often the case, few other companies in that industry had identified those risks as well?

Moreover, even if a company embraces, implements, and maintains safety culture characteristics, it is not assured that an accident will not occur, as the Chemical Safety and Hazard Investigation Board observed in its investigation of the 2005 Texas City refinery explosion. Thus accident investigators cannot rely on the presence or absence of safety cultural traits to assess the role of a company in an accident. Investigators need to establish a cause and effect relationship in an accident, relying on readily identifiable performance measures, and the presence or absence of such aspects of an organization's culture as managerial commitment to safety does not satisfy the need for a logical, direct link between a factor and the accident, nor is that a readily identifiable parameter. Thus, even if managers were found to not be committed to safety, a finding that would certainly be to the detriment of the result of a safety culture assessment, operations may still be conducted safely because of other factors in place. Consequently, given the methodology used to assess culture and the parameters used to define safety performance, there is little assurance that having a "good safety culture" will translate into few operational accidents.

3.1. Accident investigation requirements

The objectives of accident investigations are similar to those of empirical research in that both seek to explain observed truth, empirical research in testing theory and accident investigation in determining the causes of an accident. Both also rely on the use of measurable and definable parameters to enable conclusions to be drawn. Yet each has different requirements because of the different purposes they serve and each uses different methods to meet those requirements. LeCoze (2013), for example, highlighted the need to apply the lessons of accident investigations to public policy to improve public safety, a consideration that rarely applies to empirical research. Dekker (2015) identified four purposes of accident investigations, epistemological, that is, establishing what happened; preventive, identifying pathways to avoid future accidents; moral, tracing the transgressions that were committed and reinforcing moral and regulatory boundaries; and existential, finding an explanation for the suffering that occurred. These purposes, which have little relevance to researchers, affect the conduct of accident investigations. For example, the existential and moral needs Dekker identified, and the public policy implications LeCoze noted, are served by the direct role of governments in investigations. Relying on government rather than industry to conduct such investigations, for example, satisfies the public need for answers to what happened, and the need for reassurance that action will be taken to address the shortcomings that led to the accident.

Empirical research is overseen through peer review and/or experimental replication; accident investigations are subject to governmental review. While differences exist in the manner in which countries conduct their investigations, in general government agencies or representatives typically conduct such investigations (LeCoze, 2013). For example, after the 1987 sinking of the ferry Herald of Free Enterprise, an accident in which 193 passengers and crew died, the government of the United Kingdom appointed a jurist to oversee the investigation, a practice common in many countries (Sheen, 1987). Accident investigations are typically conducted within a limited time frame, constraints that researchers generally do not face. Empirical research can be conducted years after theory had been developed, a time frame that would be unacceptable in the investigation of major accidents.

Further, analytical rules of accident investigations tend to be legalistic, based on logical consistency and the preponderance of evidence, rather than statistical, based on inferential or multivariate statistics and probability theory, as in many (but not all) research studies. The methods used to prove causal relationships are thus qualitatively different, and using an empirical research method to assess the quality of proof used with the preponderance of evidence is unwarranted. In this manner, accident investigations rely on sample sizes typically consisting of one event to describe causal relationships, thus resembling the case study method of research, a sample size that would fail to meet the prerequisites of inferential statistics necessary for much of empirical research. This can be seen, for example, in the implementation of crew resource management training for pilots in commercial aviation, a policy implementation that was largely based on only a few highly visible aircraft accidents that occurred in the 1970s (Salas et al., 2001).

Rather than relying on large sample sizes, accident investigations rely on a considerable amount of data, from a variety of sources, to reach their conclusions, unlike empirical research where relatively few parameters are examined. An investigation of an air transport aircraft accident, for example, would examine, at a minimum, hundreds of parameters from flight data recorders, recorded crew member conversations from cockpit voice recorders, air traffic radar data, numerous parameters of engine and aircraft system performance, interviews with eyewitnesses, airline, airport and regulatory personnel, as well as government, airline, and aircraft design/manufacture records on the aircraft, the crew, the airline, and the regulator.

In addition, constructs, which have specific utility to advance theory, are rarely directly assessed in accident investigations because of the difficulty in measuring or assessing them, although they may be used after the fact to explain the events leading up to the accident. By contrast, research is often conducted to support or refute the viability of constructs within particular theories. Accident investigations deal with the real, that is, specific actions or decisions, and their relationship to the accident. Ultimately, accident investigations rely on standards of counterfactual logic, where investigators strive to determine whether an accident would have occurred in the absence of specified events, and whether the events would have occurred in the absence of specified errors and/or system malfunctions (Australian Transport Safety Bureau, 2007; Coury et al., 2010).

Finally, based on the facts gathered, accident investigators develop a logical explanation of the events that led to the accident. This generally leads to the identification of errors committed by individual operators or operator teams (including maintenance personnel), failures of some mechanical component or system, failures that may have been the result of an operator error, and/or errors in actions, inactions and/or decisions of organizational managers. Although some investigative agencies shy away from identifying operator errors, the practice is still commonplace among such investigative agencies as the United States National Transportation Safety Board, the British Air Accidents Investigation Branch and Marine Accidents Investigation Branch, and the French Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile, when investigators believe that this is warranted.

3.2. Organizational errors

A company's role in accident causation needs to be assessed, if for no other reason than to enable it to develop effective remediation strategies and techniques to prevent future accidents. Reason (1990) referred to the errors of company managers, who develop and oversee the systems in which an accident occurred, as errors committed at the blunt end, in contrast to system operators, whose errors are committed at the sharp end. He referred to these blunt end errors as "latent errors" because they tend to remain hidden, as pathogens that remain hidden the human body can, under the right conditions, cause illness when defenses are weakened. Similarly, latent errors can lead to accidents when organizational defenses are weakened. Reason subsequently (1997) described several accidents, which he referred to as "organizational accidents," in which the latent errors of managers allowed fairly obvious operational safety shortcomings to continue unabated. Although errors of individual operators directly caused the accidents, Reason attributed the actual cause to the errors of those responsible for overseeing operations because they created the conditions that allowed the operators to commit the errors, or failed to provide effective mitigation to reduce the likelihood of operator errors. His influence on accident investigations has been considerable, with some investigative agencies incorporating Reason's model of organizational accidents into their analytical protocol (Australian Transport Safety Bureau, 2007).

Dekker (2002) provided a framework for investigating the type of operator errors that Reason described. However, his focus was on operator errors and not on those of the organizational managers operating the systems. Dien et al. (2004) defined organizational accidents as those caused by "global organisational conditions which may be at the origin of the local conditions or have an impact on the direct or immediate causes [of an accident]." These include what they referred to as "recurrent factors," which included "weaknesses in the organisational culture," a "complex and inappropriate" organization, limited feedback from operations (including analysis of incidents and accidents), production pressures, and failure to properly oversee breaches in safety, what they referred to as "failure of the control organisations."

Goodman et al. (2011) described a series of conditions to be met for errors to be considered organizational rather than individual. These include, (p. 154)

> First unintended deviations from organizational expectations ... [regarding] work activities; second, the ... actions of multiple individuals who are acting in their formal organizational roles and working toward organizational goals; third, [both of which] ... can potentially result in adverse organizational outcomes; and, finally, ...[both of which] are primarily caused by organizational conditions (i.e., they cannot be explained solely or even primarily in terms of idiosyncratic features of individuals).

Thus, to distinguish individual from organizational errors, errors that may otherwise be similar, organizational errors would be those made at the organizational rather than the individual level, pertaining to actions and decisions at a level higher than those of system operators. These descriptions of organizational deviations and errors, although including elements that are typically associated with safety culture, can provide a foundation upon which investigators can directly assess the role of organizations in accidents that occurred in their systems, without attempting to directly assess safety culture. By applying other proposed elements, such as Dien et al.'s (2004, p. 148) "recurrent factors" of shortcomings in such organizational elements as oversight, procedures, and training, factors that are routinely examined in the course of accident investigations, with other guidance the authors proposed, and with the conditions both Goodman et al. (2011) describe, a method to identify organizational errors in accidents can be developed.

Nonetheless, even with a method of identifying organizational errors, a method is needed with which investigators can determine whether a company can be faulted for its errors. That is, even if the company actions or decisions led to the errors or malfunctions that are directly linked to an accident, the company may not necessarily be considered responsible for having a role in the accident, depending on the circumstances in which the company errors occurred. This critical issue that investigators must address has not been extensively examined. For example, Reason (1997) described a method to investigate accidents known as Tripod-Beta, developed for the oil exploration and production operations of a division of Royal Dutch Shell, and now widely used as an investigative tool. Tripod-Beta is incorporates the framework of Reason's organizational accident theory into software that analyzes a company's role in an accident, among other outputs. By identifying elements of the incident, with the hazards that were present to include Reason's active and latent errors or failures as well as preconditions, Tripod-Beta determines how the incident or accident occurred, including the actions or decisions of the company that led to the event. The software, as other investigative programs, provides a structured approach to investigations, a particular benefit to those with little experience conducting accident or incident investigations. However, those overseeing the use of Tripod-Beta strongly recommend that investigators using the program receive training to use it, and accreditation in Tripod-Beta use is offered.

Yet, few government investigative agencies use software marketed by third parties to analyze accident causes and the relationships among accident variables in their investigations; the programs are often too inflexible to allow investigators to address the distinctive aspects of the investigations that they undertake. The Australian Transport Safety Bureau, for example (2007), described the analytical approach they employ, one that is similar to nearly all major governmental transportation investigative agencies, and their method suggests a logical reasoning approach that allows them to retain the flexibility needed to fully attend to the myriad elements that make each accident unique. Further, investigators weight the value of the considerable data they obtain, and assess them differently when the data conflict, since the sources of data and methods of collection affect data reliability and thus their value to the investigation. Software packages cannot do so and thus are unable to determine how to deal with conflicts in the data that often arise in investigations.

To distinguish organizational action or decision errors from those of individual operators, investigators need to make one final determination as to whether a company should be considered responsible for its errors. To do so, investigators need to assess whether the identified company errors were contrary to (1) information available to the organization (or more accurately its managers) that demonstrated that such a practice was not safe, and/or (2) self-evident information that such a practice was unsafe. With these, the organizational factors that created the conditions that allowed the operator errors to be committed can be addressed, thereby enabling investigators to directly examine an organization's role in the accident. Using this method to examine company actions and decisions directly allows investigators to make inferences about elements of a company's safety culture at the time of the accident, with a higher degree of accuracy than would likely carried out by a direct assessment of safety culture.

The Chemical Safety Board used such an approach in its investigation of the 2005 BP refinery explosion in Texas City, Texas (Chemical Safety and Hazard Investigation Board, 2007). Investigators first identified the factors that caused the explosion, and from those identified the company actions, inactions, and decisions that allowed those factors to develop and lead to the accident. The organizational errors the Chemical Safety and Hazard Investigation Board cited included, among others, failure to repair faulty equipment, deferring maintenance because scheduling pressures allowed little time for maintenance, inadequate oversight of procedures, failure to follow procedures, signing off uncompleted procedures as having been conducted, insufficient training because of training budget cutbacks, inadequate staffing, and inadequate and in some cases nonexistent investigations of previous similar incidents.

Putting these elements together results in a four step process to identify organizational factors in an accident investigation, with the steps to be undertaken listed in the prescribed order. These are,

1. **ESTABLISH FACTORS THAT ARE**
    a. Identifiable
    b. Assessable

2. **DETERMINE IF THESE ARE ORGANIZATIONAL FACTORS**
    1. Unintended deviations from organizational expectations
    2. Multiple individuals acting in their organizational roles
    3. Created by organizational conditions

3. **RELATE THESE FACTORS TO THE CAUSE OF THE ACCIDENT**
    1. Would the organizational errors have occurred if the company had responded differently
    2. Would the accident have occurred in the absence of these errors

4. **DETERMINE WHETHER THE ORGANIZATION IS RESPONSIBLE**
    1. Acting/deciding contrary to available information
    2. Acting/deciding contrary to self-evident information
    3. Failing to act/decide when warranted

3.3. Two accidents

The National Transportation Safety Board directly assessed organizational actions, inactions, and decisions in its investigation of an accident that occurred in Washington, DC, on June 22, 2009. A subway train, operated by the Washington Metropolitan Transit Authority (WMATA), struck the rear of a stopped train in clear weather, during daylight. Eight passengers and the train operator were killed and 52 other passengers were injured in the accident (National Transportation Safety Board, 2010).

Trains were being operated at the time of the accident in automatic train control mode, in which operators monitored but did not control train movements. Train movements were controlled electronically by electrical signals sent through track circuitry to sensors on the trains. These sensors received and acted on commands to accelerate, decelerate, or stop the trains, as needed, based on track parameters and the proximity of trains ahead. However, because of faults of several months' duration in the electrical circuitry near the accident site, inaccurate commands were being provided to moving trains. This meant that on occasion clear track information, i.e., no stopped train ahead, was erroneously provided electronically to the moving train when stopped trains were present, thus directing the automatic train control to continue moving the train. In the accident the moving train was directed to continue at regular speed into a standing train ahead. The train operator saw the standing train but was unable to stop before the collision occurred.

About five years before the accident, WMATA had sustained a similar incident, in which failures in track circuitry allowed two trains to come dangerously close to each other. In that incident the train operator was able to deploy emergency brakes in time to avoid a collision. That incident led WMATA to recognize that track signal components were failing, and it initiated a program to upgrade the track signaling system, a program that was to be done in stages over several years. Six months before this accident the transit authority tested the circuitry of the track section involved in the accident and found it to be failing. It replaced the components two months before this accident, but again the replaced components failed to provide accurate information. Six days before the accident, after the circuitry on the accident track section was again found to unreliably recognize the presence of stopped trains, additional maintenance was carried out. However, after the maintenance was performed the electrical signals were again found to be unreliable. Nonetheless, WMATA failed to address the systemic issue of repeated failures on the same track section after maintenance had been performed on it, and it failed to order slowed train movements in the affected track section.

Thus, despite the considerable information indicating that the safety of trains traversing that section of track was at risk, WMATA managers neither changed its maintenance of that track section or as important, modified train operations in that track section in response to the possibility of spurious track signals. By not recognizing that delaying effective maintenance jeopardized the safety of rail operations in the affected track sections, WMATA managers committed errors of inaction. The organization was held responsible because its managers were aware that inaction was unsafe, and it was their responsibility to act otherwise given the information available to them. Moreover, this determination regarding the organization's actions and decisions, although made after an investigation of a major accident, described elements of WMATA's safety culture perhaps better than a direct assessment of the culture through typical measurement methods could have done. Investigators concluded that:

> The apparent tendency among many managers to tolerate various failures and malfunctions in the ATC (automatic train control) system was also likely influenced by their perceptions of past system performance. This may explain why WMATA officials had designated track circuit alarms in the OCC (operations control center) as requiring no specific response and why neither WMATA ATC technicians nor maintenance officials placed a high priority on addressing track circuit bobbing[1] and loss of train detection. The ... low priority that WMATA Metrorail managers placed on addressing malfunctions in the train control system before the accident likely influenced the inadequate response to such malfunctions by ATC technicians, OCC controllers, and train operators (National Transportation Safety Board, 2010, pp. 101–102).

Identifying the specific actions or decisions of the organization also enabled investigators to suggest specific remediation strategies to prevent future accidents, a key objective of accident investigations (Dekker, 2015).

This method of examining organizational factors can also be applied to organizations not typically addressed by either accident investigator s or by researchers. For example, in 2003 the United States Department of Justice's Inspector General (IG) examined the Federal Bureau of Investigation's (FBI) failure to identify the espionage activities of one of its own agents, Robert Hanssen, who had been selling state secrets to the then Soviet Union (Department of Justice, 2003). The FBI failed to recognize Hanssen as the perpetrator of the espionage despite years of effort trying to identify the person responsible for revealing state secrets, after it first learned that those secrets had been compromised. As a result of Hanssen's espionage and the FBI's continued failure to identify and apprehend him, over a multi-year period in which they were actively engaged in searching for the culprit, several Soviet citizens Hanssen had identified as working for the Americans were executed, some of whom were identified after the FBI had begun its efforts to identify the source of the state secrets.

When the FBI learned that government secrets were being revealed to the Soviet Union, their agents focused on Central Intelligence Agency (CIA) personnel rather than on FBI agents, despite personnel in both organizations having access to the information that Hanssen had sold. For several years after learning of the espionage, the FBI continued to focus exclusively on CIA personnel as the source of the espionage. In that interval Hanssen committed a number of security violations that warranted, at a minimum, additional oversight, if not outright arrest and prosecution.

For example, before initiating his espionage activities, Hanssen, attempted to directly and covertly contact a Soviet agent in an effort to initiate his selling of government secrets, an effort that was not only unsuccessful but led to a formal Soviet diplomatic protest to the US government. Yet, the FBI did not follow up on

[1] A track circuit malfunction in which a track circuit transitions from vacant, to occupied, to vacant again with no train traffic present.

his activity; Hanssen explained that he had been attempting to lure a Soviet agent to spy for the United States against that person's country, an act that, if true, would have required prior authorization. After Hanssen began his espionage, an FBI agent found thousands of dollars in cash in Hanssen's bedroom (an amount inconsistent with his salary) and reported that to his supervisors, but again no follow up action was taken. Hanssen also, on several occasions, accessed the FBI's computerized tracking case system without authorization, a system that recorded all access efforts. It was later determined that he had done so to obtain information that he later sold to the Soviet Union, leading in part to the funds that had been discovered in his bedroom.

The IG identified numerous examples of FBI inaction in the face of evidence that action was warranted. Thus, repeated FBI inaction in the face of information demonstrating that action was needed played a role in the events. In its report IG investigators described a relationship between FBI organizational errors and the "accident" of its failure to identify Hanssen. As the IG concluded:

> Most of the deficiencies discussed in our report are of longstanding vintage and reflect the cumulative decisions of many FBI employees, including the Directors and senior managers who failed to remedy serious flaws in the FBI's personnel, document, and information security programs; the Directors and senior managers who failed ... to resolve how important FBI human sources and operations had been compromised; the unwillingness of line personnel ... to reconsider initial conclusions and judgments in the face of investigative failures, and senior managers' failure to insist that they be revisited; the supervisors and colleagues who ignored Hanssen's pattern of security violations and his obvious lack of suitability for handling sensitive information; and the managers who provided such lax supervision of Hanssen that he was able to spend much of his time on nonwork related matters, or worse, committing espionage. These were widespread failings (Department of Justice, 2003, p. 26)

4. Discussion

I raise the question of whether we can examine safety culture in accident investigations, or whether we should attempt to do so. The answer, I believe, is that the research argues against both. A commonly accepted definition of safety culture, unlike that of culture, is not available. Shortcomings in measuring safety culture through questionnaires have been raised. Ethnographic methods require more time to conduct a study than is reasonably available to investigators. Directly assessing a construct such as safety culture after the fact of an accident, in an effort to gauge its state before an accident, is not supported by the findings of research and of accident investigations. Finally, the link between safety culture and process safety is only suggestive as most of the research into such a relationship has been largely based on measures of occupational safety and safety climate, not process safety and safety culture. As the Chemical Safety and Hazard Investigation Board observed, focusing on occupational safety does not necessarily relate to enhanced operational or process safety. Moreover, as Antonsen (2009) and the National Transportation Safety Board (2013) found, both company managers and operators may well believe that their processes are safe, beliefs that would be expected to affect the results of a direct assessment of safety culture, only to discover that the contrary is true from the results of an investigation. Thus, limitations in our understanding and measurement of safety culture preclude direct assessment of safety culture in accident investigations.

Nonetheless, this is not to denigrate the need for recognizing the value of safety culture and applications of its elements to enhance operational safety. It is intuitive that "good" safety culture can enhance safety. However, directly assessing safety culture in an accident investigation can be ineffective or worse, misleading. Rather, as Antonsen (2009) observed, post-accident investigations are more thorough and thus can identify more aspects of an organization's culture than can be obtained through administration of a questionnaire. As a result, the considerable data that accident investigations typically collect can better describe a company's actual practices in system operations than could be obtained from most direct assessments of safety culture.

Further, the value of companies and regulators endeavoring to address safety culture has not been determined. While research into safety culture has furthered our understanding of the construct, given the inherent conservatism of culture and the difficulties in trying to change cultural norms, the effort to do so would be both considerable and prolonged. Moreover, the need for accident investigators to use identifiable and assessable measures in their work would hold true for company managers as well. To illustrate, the Nuclear Regulatory Commission (2011), cited among its nine safety culture factors that it wanted its licensee's to address, (1) effective safety communications, (2) respectful work environment; and (3) questioning attitude. Few would disagree that these are important elements of a safety culture. But the Commission did not provide guidance on how to engender such traits nor how to determine whether these traits have been effectively embraced by employees. Implementation methods were not published and were left to individual Nuclear Regulatory Commission offices to work out with the licensees. Given such policies as written, companies would not know how to engender questioning attitudes among its operators, for example, and if engendering them, how to determine whether such attitudes had been accepted, not to mention that even if company personnel had embraced such attitudes, they would not know whether its employees were operating the systems safely.

The highest safety priority of any company engaged in high risk operations should be to operate those systems safely, and if addressing safety culture is conducted at the expense of operational safety then the effort would be self-defeating. Further, methods have been developed to directly maintain and enhance operational safety, methods such as safety management systems, line operations safety assessments or LOSA, and reading out electronic recorders on air transport aircraft cockpits, ocean going vessels, and locomotive cabs, among others. These methods provide risk identification and mitigation techniques, as well as, in the case of the latter two, methods to observe and assess real time line operations in the absence of company managers present during the operations. By directly addressing system operations, as these methods do, and focusing on operational safety issues as manifested by employees operating the systems in their day to day work, it can be argued that managers would have greater success enhancing operational safety than they would by indirectly by addressing safety culture traits, many of which, in any event, would be difficult to change in the short term and difficult to assess the extent to which such traits had changed.

Company practices identified in the course of an accident investigation, such as those suggested in this study, can reveal much about its safety practices, and hence provide insights, albeit indirectly, into company safety culture. It can be argued that these, rather than safety climate data, provide a more accurate description of an organization's culture than can be obtained by means other than that obtained through extensive ethnographic efforts (see Mumaw et al., 2000; Walker, 2010). Organizational factors such as procedural compliance, parameters almost always examined in accident investigations, do not insure safety in and of themselves, but they form the foundation of safe operational practices, provide insights into an organization's culture, and shortcomings in their application can be identified in an accident investigation and addressed through remediation techniques.

Such inferences would not be affected by the circumstances of the accident as would other measures of safety culture. Both the Chemical Safety and Hazard Investigation Board (2007) and the National Transportation Safety Board (2013), for example, identified organizational complacency with regard to their operations in their respective investigations, a complacency that few direct assessments could have recognized, yet researchers had noted this potential phenomenon (Amalberti, 2001) earlier. Managers in both organizations involved in the accidents believed that their operations were safe because they had made special efforts to enhance operational safety, precisely the types of efforts that would have been favorably recognized in safety culture assessments.

The difference between perceived safety and actual safety, as determined through investigations, may provide a fertile avenue of research. How can managers recognize whether their beliefs regarding the operational safety of their systems are accurate, and what measures can they use to identify flaws in operational safety, particularly after taking additional efforts to maintain or enhance safety? Additional research is recommended to establish the extent of such a relationship. To accomplish this, measures of safety in high risk industries, measures demonstrated to be amenable to safety culture enhancements, need to be defined, and the mechanisms by which safety culture affects process safety, as defined by those metrics, need to be better understood. Retaining the services of consultants to highlight safety deficiencies, or continued positive safety audits may, as demonstrated, provide managers with misleading information regarding the safety of their operations.

At present, questions remain about the organizational factors that can lead to accidents and how they do so. For example, because no company can continue to function without adequate revenue, the question as to the extent to which financial conditions can affect organizational conduct related to operational safety and the conditions under which this could occur are largely unanswered, nor is it known whether the answers would vary across high risk industries. In addition, it is not known whether organizational factors apply equally across industries or whether some factors are more influential in some industries than in others. Not only are systems across industries different but their methods of operator selection and training are different, and the role of procedures, management and their regulators are different as well.

The more that can be understood about the mechanisms through which organizational factors affect operational safety in high risk industries, the more company managers can do to address those factors and mitigate potential opportunities for error. The findings of such endeavors can benefit researchers, companies, and the regulators that oversee those organizations.

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