Improving Traffic Safety Culture in the United States

The Journey Forward

Safety Culture

What is it?
How can we measure it?
What can we do to change it?

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A review of safety culture theory and its potential application to traffic safety

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Overview

Over the past several years, organizations in high-risk industries such as nuclear power and aviation have become increasingly aware of the role that safety culture plays in shaping reliable and safe operations. As a result, safety professionals working in other industries and transportation modalities such as manufacturing, construction, chemical and petroleum processing, and traffic safety have also begun contemplating the role that safety culture might play in mitigating risk within these settings. The purpose of the present chapter, therefore, is to (1) briefly review and synthesize previous safety culture literature, (2) discuss the challenges of moving beyond safety culture as simply an intuitive explanation of accidents to actual measurement and change, and (3) analyze the similarities and differences between traffic-safety systems and other high-risk industries that may impact the applicability of the safety-culture concept across these domains. The paper concludes with recommendations for future research on the topic of safety culture as applied to traffic safety.

Introduction

Why do accidents happen?

At first blush, the question “why do accidents happen” may seem simple. However, in reality the answer to this question is rather complex. Views about why accidents occur range from philosophical explanations such as the “just-world hypothesis” (i.e., that bad things happen to bad people) to more scientific explanations that seek empirical casual mechanisms (Reason 2000). Even within the scientific community, views concerning the causes of accidents vary considerably, which can greatly impact the nature of interventions employed to improve safety.

Several historians and authors note that theories of accident causation have evolved systematically over the years (e.g., Heinrich 1950; Gordon et al. 1996; Wilpert 2000). For

example, the first stage of scientific theorizing about the causes of accidents is commonly referred to as the technical period, during which developments in new mechanical systems were rapid and most accidents were viewed as being caused by mechanical malfunctions, particularly in the structural integrity and reliability of equipment (Wiegmann and Shappell 2001). The second stage is known as the period of human error, where limitations of the human operator rather than catastrophic mechanical malfunctions were identified as the source of system breakdowns, shifting the attention of safety analyses from mechanical aspects to the person directly involved in committing the error (Rochlin and Von Meier 1994; Coquelle, Cura, and Fourest 1995). The third stage is referred to as the sociotechnical period, during which the negative impact that poor ergonomics and systems design have on the interaction between humans and technical factors was often cited as a cause of errors and accidents. Finally, recent years have witnessed the development of a fourth stage, which is often called the "safety culture" period (Gordon et al. 1996; Wilpert 2000). This approach recognizes that operators are not performing their duties or interacting with technology in isolation, but rather they are performing as coordinated teams embedded within a particular organizational culture.

The beginning of the safety culture period of accident investigation and analysis can be traced back to the nuclear accident at Chernobyl in 1986 in which a "poor safety culture" was identified as a factor contributing to the accident by both the International Atomic Energy Agency and the OECD Nuclear Agency (Cox and Flin 1998; Mearns and Flin 1999; Pidgeon 1998). Since then, safety culture has been discussed in other major accident inquiries and analyses of system failures, such as the King's Cross Underground fire in London and the Piper Alpha oil platform explosion in the North Sea (Cox and Flin 1998; Pidgeon 1998), as well as the crash of Continental Express Flight 2574 (Meshkati 1997), the Columbia Space Shuttle accident (CAIB 2003), and the explosion at the British Petroleum refinery in Texas City (CSB 2005).

In general, safety culture has been found to be important across a wide variety of organizations and industries. For example, safety culture has been associated with employees' safety-related behavior in industries such as manufacturing (Cooper and Phillips 2004; Griffin and Neal 2000), shipping (Hetherington et al. 2006), chemical processing (Hofmann and Stetzer 1996), and building maintenance (Wallace and Chen in press). Safety culture also appears to predict on-the-job injury and accident rates in manufacturing firms (Varonen and Mattila 2000; Zohar 2000), offshore oil and gas companies (Mearns, Whitaker, and Flin 2003), and also in broad cross-organizational studies of workers in general (Barling, Loughlin, and Kelloway 2002; Huang et al. 2006). While initial studies of safety culture took place in jobs that have traditionally been considered high-risk, organizations in other areas are increasingly exploring how safety culture is expressed in their fields (e.g., retail: DeJoy et al. 2004). Overwhelmingly, the evidence suggests that while safety culture may not be the only determinant of safety in organizations (cf. Smith et al. 2006), it plays a substantial role in encouraging people to behave safely. Accordingly, the concept of safety culture may also prove applicable to traffic safety. While relating safety culture to the various facets of traffic safety presents unique challenges (which are discussed in detail below), the broad base of support across domains for the importance of safety culture in general suggests that it is worth considering in this context.

In the remaining portions of this chapter, we will (1) present an overview and synthesis of the safety culture and safety climate literature, (2) discuss the challenges of moving from the intuitive concept of safety culture to actual measurement and change, and (3) examine the relationship between traffic safety systems and other high-risk industries that influence the applicability of the safety culture concept across these domains.

What is safety culture?

As previously mentioned, the current interest in the term "safety culture" can be traced directly to the findings of the Chernobyl nuclear accident in 1986. Since then, numerous definitions of safety culture have abounded in the safety literature. In fact, our earlier review of the literature revealed several diverse definitions of the concept (Wiegmann, Zhang, and von Thaden 2001; Wiegmann et al. 2002). These various definitions of safety culture are presented in Table 2 in the Appendix.

While diverse, there appear to be several commonalities among these various definitions of safety culture across industries. Considering these commonalties among definitions, a global definition of safety culture can be formulated. This definition is:

> *Safety culture is the enduring value and priority placed on worker and public safety by everyone in every group at every level of an organization. It refers to the extent to which individuals and groups will commit to personal responsibility for safety, act to preserve, enhance and communicate safety concerns, strive to actively learn, adapt and modify (both individual and organizational) behavior based on lessons learned from mistakes, and be rewarded in a manner consistent with these values.*
> (Wiegmann et al. 2002).

It should be noted that the proposed definition of safety culture is stated in neutral terms. As such, the definition implies that organizational safety culture exists on a continuum and that organizations can exhibit a safety culture ranging from excellent to poor. However, not all definitions in the literature make this assumption. Some suggest that safety culture is either present or absent within an organization. Nevertheless, it is clear from the initial introduction of the term within various operational environments that safety culture is assumed to be a component of an organization that can be continually improved rather than simply instilled (e.g., IAEA 1986 as cited in Cox and Flin 1998). Obviously, such a distinction is important when it comes to both measuring and changing safety culture within an organization.

What about Safety Climate?

Although the debate over the definition of safety culture has not reached unanimous agreement, the similar term "safety climate" has been used almost interchangeably in the literature and has added to the confusion. Furthermore, our previous review of the literature (Wiegmann et al.

2001; Wiegmann et al. 2002) indicated that, from the time the term was first highlighted by Zohar (1980), the literature has not presented a generally accepted definition of safety climate either (see Table 1 in the Appendix).

As indicated in Table 2, many safety climate definitions have commonalities and differ from safety culture definitions in important ways. Therefore, based on these common themes, a general safety climate definition can also be derived:

> *Safety climate is the temporal state measure of safety culture, subject to commonalities among individual perceptions of the organization. It is therefore situationally based, refers to the perceived state of safety at a particular place at a particular time, is relatively unstable, and subject to change depending on the features of the current environment or prevailing conditions.* (Wiegmann et al. 2002)

In brief, safety culture, as defined in the literature, is commonly viewed as an enduring characteristic of an organization that is reflected in its consistent posture with critical safety issues. On the other hand, safety climate is viewed as a temporary state of an organization that is subject to change depending on the features of the specific operational or economic circumstances.

What are the indicators of an organization's safety culture?

While many different models of safety culture have been proposed, our previous research in the aviation industry (e.g., Wiegmann et al. 2002) has identified at least four essential elements or organizational indicators of safety culture. As illustrated in Figure 1, these include the organization's commitment to safety, the involvement of operational supervisors in safety-related activities, the formal safety system of the organization, and the organization's informal safety system. We review each of these briefly below.

Organizational Commitment. The *organizational commitment to safety* refers to the degree to which an organization's senior management prioritizes safety in decision-making and allocates adequate resources to safety. In particular, an organization's commitment to safety is reflected by three major components, including (1) **Safety Values**—Attitudes and values expressed (in words and actions) by upper management regarding safety, (2) **Safety Fundamentals**—Compliance with regulated aspects of safety, such as training requirements, manuals and procedures, and equipment maintenance, and (3) **Going Beyond Compliance**—Priority given to safety in the allocation of company resources (e.g., equipment, personnel time) even though they may not be required by regulations.

Operational Personnel. This factor refers to the degree to which those directly involved in the supervision of employees' safety behavior are actually committed to safety and reinforce the safety values espoused by upper management (when these values are positive). These include (1) **Supervisors/Foremen**—their involvement in and concern for safety on the part of supervi-

sory and "middle" management at an organization, (2) **Maintenance Supervision**—those who are responsible for ensuring that priority is given to safety, effectively managing, maintaining, and inspecting the safety integrity of the equipment/tools, and (3) **Trainers**—the extent to which those who provide safety training are in touch with the actual risks and issues associated with performing a particular job.

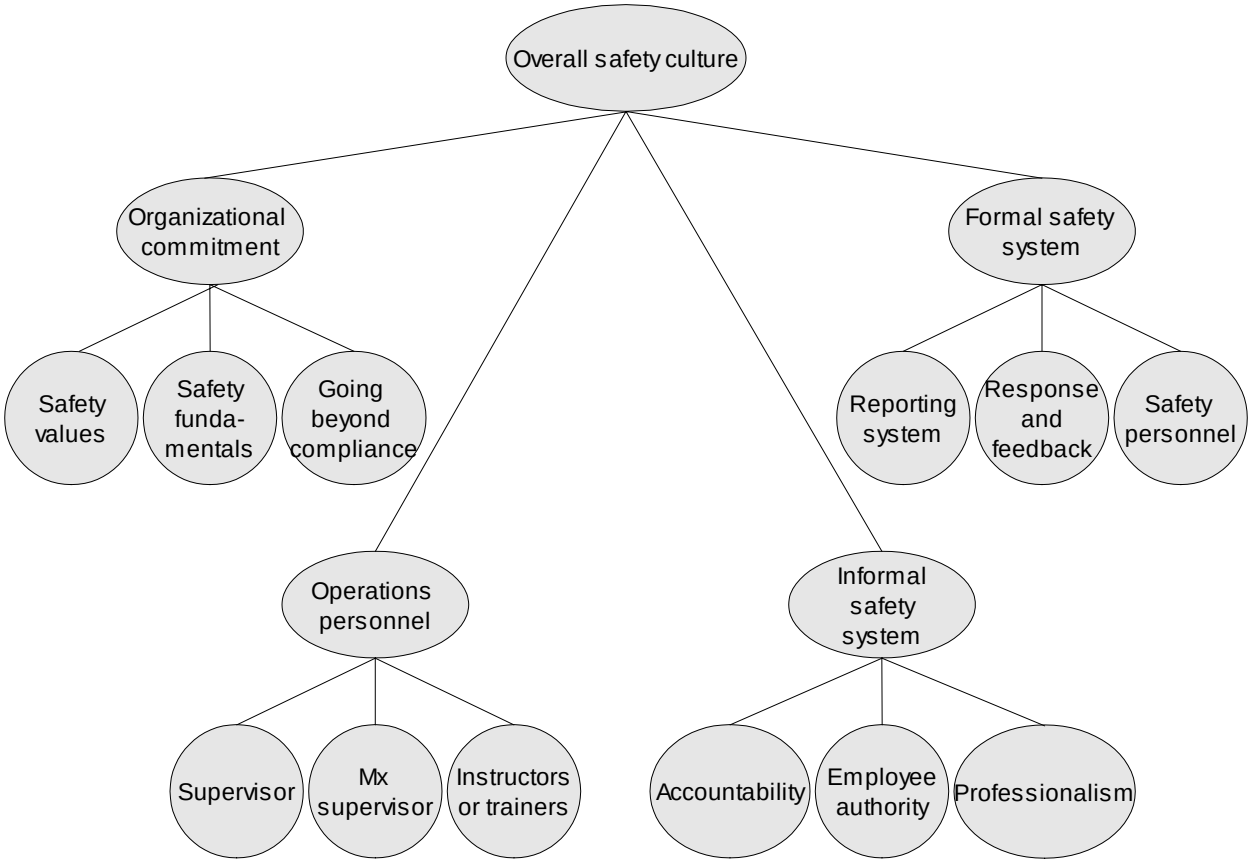

Figure 1. Organizational indicators of safety culture. Adapted from Gibbons, von Thaden, and Wiegmann (2006).

Formal Safety System. The *formal safety system* refers to the processes for reporting and addressing both occupational and process safety hazards. Such formal systems include: (1) **Reporting System**—Accessibility, familiarity, and actual use of the organization's formal safety reporting program, (2) **Feedback and Response**—Timeliness and appropriateness of management responses to reported safety information, and dissemination of safety information to workers and (3) **Safety Personnel**—Perceived effectiveness of and respect for persons in formal safety roles (e.g., Safety Officer, Vice President of Safety).

Informal Safety System—In contrast to the formal safety system, the *informal safety system* refers to the unwritten rules pertaining to safety behavior, including rewards and punishments for safe and unsafe actions and the manner in which such rewards and punishments are instituted in a just and fair manner. Specifically, the informal safety systems include such factors as

(1) **Accountability**—The consistency and appropriateness with which employees are held accountable for unsafe behavior, (2) **Authority**—Authorization and employee involvement in safety decision making, and (3) **Employee Professionalism**—Peer-culture employee-group norms pertaining to safe and unsafe behavior.

Can safety culture be changed?

The question of whether or not safety culture can be intentionally changed is difficult to answer. On one hand, the fact that safety culture has been cited as a contributing or causal factor in many accidents suggests that, at least in the minds of some safety professionals, safety culture can be changed. After all, factors are not generally cited as "causal" to accidents if they can't be manipulated or changed (Wiegmann and Shappell 2003). For example, gravity is rarely, if ever, cited as a cause of an aviation accident, even though one might argue that most aviation accidents involving collision with terrain are due to gravity. Given we cannot change gravity, it would be silly and futile to cite it as a causal factor to accidents. Therefore, in practice, citing a variable as "causal" generally implies that something can be done to change it or at least effectively mitigate its impact on safety. Consequently, it appears that to some researchers and safety professionals, safety culture is amenable to manipulation and intentional change (Wiegmann et al. 2002).

Not all researchers or practitioners, however, would agree with the assumption that (safety) culture can be intentionally manipulated (Creswell 1998). These individuals argue that, like all aspects of culture, safety culture is an emergent property of a particular society, industry, or organization, generated by its unique history and individual members (Smircich 1983). Furthermore, individuals within a culture are often unaware of the impact their culture has on their behavior. Culture often guides the activities of groups and organizations at a subconscious level. According to this perspective, therefore, people do not shape their culture; rather their culture shapes them in often unpredictable and unforeseeable ways. This is not to say, however, that cultures don't change or that all cultures are the same. Rather, culture is considered beyond direct manipulation or intentional change. The fact that one might believe a culture can be intentionally changed is in itself a reflection of the culture to which one belongs.

Debates about cultural change may never be fully resolved, and at present they remain almost entirely within the philosophical rather than the empirical realm. In particular, those who espouse the position that safety culture is directly amenable to manipulation and change have yet to provide solid empirical data supporting this conclusion. While there are a growing number of anecdotal and case studies to help bolster such claims, the number of systematic studies is frustratingly small. Even research on safety climate is limited. For example, Zohar (2002) implemented a safety training intervention for supervisors and measured the subsequent effects on safety performance in their units. Results suggested that both safety climate and rate of "microaccidents" improved. However, Cooper and Philips (2004) report mixed results from a pre- and post-test study of changes in safety climate and safety behavior. Safety climate improved following a safety intervention, but actual observed safe behavior improved very little in most cases. Part of the problem can be attributed to the manner in which safety culture and/or

safety climate are defined (as stated previously). Another related reason, however, is that the existing methods to measure safety culture and organizational change are quite diverse and somewhat unsophisticated.

How is safety culture measured?

Currently, there are no standardized or "off the shelf" tools that can be used across domains or even within a single domain to measure safety culture (Cox and Flin 1998). However, a variety of methods or tools have been proposed. These tools can be classified as either quantitative or qualitative methods.

Quantitative approaches attempt to numerically measure or score safety culture using procedures that are often highly standardized and calibrated, such as highly structured interviews, surveys and questionnaires, and Q-sorts (Wreathall 1995). In quantitative measurement strategies, organization members usually serve as respondents who react to a standard set of stimuli or questions provided by researchers (Rousseau 1990). Quantitative methods are relatively easy to use in cross-sectional comparisons, generally simple to implement in different organizations and by other researchers, and straightforward to interpret according to a common, articulated frame of reference (Wreathall 1995).

Some researchers have argued that safety culture cannot be completely understood through traditional quantitative methods, which attempt to break down a phenomenon in order to study its individual components. Rather, it is best understood using methods that effectively capture the nature or essence of the activity that is being studied (Creswell 1998; cf. Glaser and Strauss 1967; cf. Suchman 1987). Furthermore, while an organization's culture is revealed in its general patterns of attitudes and actions, the deeper structure of its culture is often not immediately interpretable by outsiders (for example, the "informal" safety system). Studying organizational culture, therefore, requires the use of qualitative methods, such as ethnographic approaches, including intensive and extensive observations and employee interviews, focus group discussions, historical information reviews, and case studies (Wreathall 1995). With qualitative measurement strategies, organization members usually serve as informants, who interact directly or indirectly with researchers, using their own terms and concepts to express their point of view (Rousseau 1990). Therefore, through qualitative measurement, intensive and in-depth information can be obtained using the focal group's own language (Schein 1991).

There is general consensus among researchers that both qualitative and quantitative methods have unique potential for assessment and theory testing. There is a benefit to combining methods to gain a comprehensive understanding of safety culture. Nonetheless, quantitative approaches, especially surveys of individuals' responses, are often more practical, in terms of time and cost-effectiveness (Wreathall 1995). Consequently, surveys and questionnaires have been widely used to assess safety culture within a variety of industries, such as nuclear power, aviation, chemical processing, construction, and manufacturing. The key in any safety-culture improvement program is to develop effective measures to evaluate the current state of a particular safety

culture, as well as to determine whether interventions have been effective in achieving the desired cultural change. Both quantitative and qualitative techniques can contribute to this goal.

Does the concept of safety culture apply to traffic safety?

Whether or not the concept of safety culture applies to traffic safety may depend upon the level of analysis that is employed. The original safety-culture concept was developed to account for the impact that a specific organization's culture has on safety-related behavior of a specific workforce. Therefore, the concept applies directly to the level of an organizational unit, which is a generally well-defined entity and clearly bounded system. Consequently, the concept should directly apply to any organization or agency that affects or interacts with traffic-safety issues, including federal and state agencies, urban-planning committees, public transportation departments, road construction companies, and the like. Internally, these organizations could draw heavily upon the rapidly growing research literature regarding safety culture in other industries to improve their own safety cultures.

In particular, the health care industry may prove to be an especially appropriate model for those involved in traffic safety. Specifically, within both health care and traffic systems, accidents occur relatively frequently but generally involve only a small number of individuals at any one time. This makes health care a better model for traffic safety than industries such as aviation or nuclear power, where accidents involve rare breaches in process safety and are often catastrophic. Second, safety culture in health care organizations must encompass both employee safety and public safety. Many studies of safety culture in industries other than aviation and nuclear power, such as manufacturing, construction, or retail, emphasize the prevention of occupational injuries but do not explore the ramifications of the organization's safety culture for the public (cf. Barling and Frone 2004; DeJoy 1996; DeJoy et al. 2004). Hence, health care and patient safety efforts may provide a better parallel for traffic safety when it comes to the application of the safety-culture concept to the general public.

The application of the safety-culture concept to traffic safety becomes much more tenuous when traffic safety culture is considered at the community or societal level. At this level, the boundaries of the system can be relatively ill defined, and members of the driving public are not employed as drivers by any organization (society). Yet different cities do appear to have distinct driving cultures, as evidenced by differences in overall accident rates (Allstate Insurance Company 2006) and road rage behaviors (Prince Market Research 2006). Many traffic safety interventions also implicitly assume the existence of a safety culture. For example, many campaigns are aimed at influencing cultural values, such as "friends don't let friends drive drunk." Others, such as traffic cameras or signs announcing that speed limits will be enforced by radar, attempt to influence drivers' perceptions of the contingencies associated with safe or unsafe behavior. Many safety culture theorists argue that these perceived contingencies are the heart of safety culture (cf. Zohar 2003). Further, many if not all of the elements that make up a

strong positive safety culture in an organization have analogs at the community level. Therefore, we will briefly consider how each organizational indicator of safety culture might apply in a community setting within the context of traffic safety culture:

As stated previously, *organizational commitment to safety* refers to the degree to which an organization's senior management values safety, prioritizes safety in decision-making, and allocates adequate resources to safety. In the community, the best analog for "senior management" in regard to traffic safety is the government (city, state, and federal). Government decision-makers are responsible for ensuring adequate safety resources, such as well-maintained roads, clear and helpful signage, and sufficient law enforcement personnel. Governments also set policies regarding safety, including training and licensure programs, as well as laws and ordinances. The true values and priorities of federal and community leaders are typically conveyed to the driving public through their actions. For example, if intersections with high accident rates are only addressed after a fatal accident, it is easy for drivers to infer that the municipality's commitment to safety is low.

In traditional organizations, *operational personnel's involvement in safety* refers to the degree to which supervisors or middle managers monitor their employees' safety behavior and reinforce the safety values espoused by upper management. However, most (nonprofessional) drivers do not have supervisors in the formal sense. There are, however, public employees who are responsible for monitoring safety and setting a positive safety example. Law enforcement, of course, is the primary "supervisor." A positive safety culture at this level might best be expressed through consistent and fair monitoring and enforcement of all safety-related behavior. Where there are gaps in enforcement, drivers are encouraged to think they can "beat the system" instead of being encouraged to be safe. Both law enforcement and public transportation personnel can set a positive example of safe behavior. Furthermore, individuals who provide driver education and training, as well as those who are responsible for testing, evaluating, and licensing drivers, serve a supervisory capacity whose behavior might also be linked to the particular safety culture within a community.

The *formal safety system* in most organizations refers to processes for reporting and addressing safety hazards. While law enforcement is part of this system in relation to traffic safety, a community with a strong positive safety culture will also ensure that there are mechanisms for reporting hazards. When there is a power outage at a specific traffic light, is it quickly restored? How many complaints must be received about a poorly maintained road before it is scheduled for repair? Many communities track accident data, but are these data put to use in a proactive fashion? While individual drivers may not be willing to file formal reports on their own "incidents" or "near misses," studies suggest that many drivers are quite willing to respond to anonymous surveys about the safety of their driving behavior (Prince Market Research 2006). A community with a strong formal safety system might engage in such surveys regularly with a view to identifying hazardous trends.

The *informal safety system* poses perhaps the greatest challenge to a culture of traffic safety. As stated previously, this system refers to the unwritten norms regarding safety in an organization—does the peer culture promote safe or unsafe behavior? What are the expectations regarding

accountability for unsafe behavior? Do individuals have authority to improve safety? Changing such norms is difficult, especially for communities in which dozens of different peer groups exist. Yet the success of many safety interventions is dependent upon such cultural change. Laws requiring specific safety behaviors are often unpopular, difficult to enact, and difficult to enforce (e.g., seat belt laws, motorcycle helmet laws). Increasing the frequency of these behaviors, therefore, often involves lengthy public awareness and education campaigns. The long-term success of many such campaigns offers hope that changing informal safety culture is possible, if not easy.

Summary and recommendations

The purpose of the present chapter was to summarize and integrate the numerous reports and studies that have been conducted to define and assesses safety culture, as well as the application of the concept of safety culture to traffic safety. While there is yet no uniform agreement concerning the topic of safety culture, there is growing consensus on its definition, relevant parameters, methods of measurement, and amenability to change. While research suggests there may be general indicators of safety culture that are universal, specialized measures must be designed for specific populations or industries. Identifying population or industry-specific indicators for traffic safety presents a larger challenge as many different types of organizations and agencies promote and facilitate traffic safety, and indicators are likely to vary accordingly. An interagency collaborative approach combining qualitative and quantitative methods may prove necessary to uncover the true nature of safety culture in traffic safety.

Given that the concept of safety culture was originally developed to describe the influence of factors within a specific organization, the concept should be directly applicable to federal, state, and local agencies. Future research should therefore focus on identifying the relevant organizational indicators of safety culture within these agencies, how to best measure traffic safety culture, and what can be done to effectively change or improve safety cultures within agencies, if required. Experience suggests that pilot testing such measures and giving employees opportunities for input often provide valuable insights. If multiple organizations of the same type are included in the focus groups and pilot studies, it becomes possible to develop a general measure of safety culture and establish benchmarks that can be used across organizations in that sector.

While the concept of safety culture has been fundamentally applied to organizations or groups, it has yet to be systematically applied to the population at large. Indeed, the application of the safety culture concept to the community or societal level may be more difficult, given the boundaries of the system are relatively ill defined. Nonetheless, there is a vast amount of anecdotal evidence that safety cultures do vary across regions within the United States (U.S.), as well as between the U.S. and other countries (e.g., European nations). In this chapter, we have provided some suggestions for how the safety culture concept may be applicable to society in general. Still, several challenges exist. Identifying specific indicators of safety culture and developing appropriate methods for assessing and initiating cultural change become substantially more complex at the community or societal level. These efforts will require significant collaborations across the U.S., as well as with other countries interested in traffic safety culture. Whether or not such efforts are successful, however, may itself depend upon the prevailing safety culture.

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Biographical statements

Douglas Wiegmann, Ph.D. is an NIH Roadmap Scholar in the Department of Surgery at the Mayo Clinic. He is also an associate professor of Human Factors and Psychology at the University of Illinois (currently on academic leave). He received his Ph.D. in psychology in 1992 from Texas Christian University and has served as an accident investigator for the NTSB and the United States Navy. Dr. Wiegmann has officially consulted on many major accident investigations of national significance, including the crash of TWA Flight 800, the Columbia Space Shuttle accident, the August 2003 east coast blackout, and the evaluation of the process safety culture at British Petroleum's North American refineries as a result of the March 2005 explosion at Texas City. Dr. Wiegmann has published extensively on the topics of human factors and system safety, including a best-selling book entitled *A Human Error Approach to Aviation Accident Analysis: The Human Factors Analysis and Classification System.* He has twice received the Aerospace Human Factors Association's Williams E. Collins Award for outstanding publications. Other major awards include the Flight Safety Foundation's Admiral Louis de Florez Award and the Aerospace Medical Association's Harry G. Moseley Award, both for significant contributions to aviation safety. He has also received the American Psychological Association's prestigious Earl A. Alluisi Award for early career achievement in the field of Applied Experimental and Engineering psychology.

Terry L. von Thaden, Ph.D. is an assistant professor in Human Factors and Information Science at the University of Illinois. She holds an M.S. in Safety and Health/Human Factors from the University of Southern California's Institute of Safety and Systems Management, and a Ph.D. in Information Science from the University of Illinois. Her research involves methodologies for measuring the culture of safety and information behavior in high-risk, safety critical sociotechnical systems including transportation and medicine. She recently received a $300K grant from the Federal Aviation Administration to advance research in safety culture by developing an integrative model of system safety and risk management for commercial airline operations. Dr. von Thaden is a past Fellow of Zonta International, The Transportation Research Board, and the National Institute for Occupational Safety and Health, and is a member of the Phi Kappa Phi and Beta Phi Mu Honor Societies.

Appendix

Table 1. Definitions of safety climate. From Wiegmann et al. (2002).

Source/Industry	Definitions
(BASI 1996) Civil aviation—Australia	The procedures and rules governing safety within an organization are a reflection of its safety climate, which is centered around employees perceptions of the importance of safety and how it is maintained within the workplace.
(Cheyne, Cox, Oliver, and Thomas 1998) Manufacturing—UK and France	Safety climate can be viewed as a temporal state measure of culture, which is reflected in the shared perceptions of the organization at a discrete point in time.
(Dedobbeleer and Beland 1991) Construction—US	Safety climate is viewed as an individual attribute, which is composed of two factors: management's commitment to safety and workers' involvement in safety.
(Flin, Mearns, Gordon, and Fleming 1998) Offshore oil and gas—UK	Safety Climate refers to the perceived state of safety of a particular place at a particular time. It is, therefore, relatively unstable and subject to change depending on features of the operating environment.
(Flin, Mearns, O'Connor, and Bryden 2000) Review of various industries (only one aviation related study)	Safety climate is the surface features of the safety culture discerned from the workforce's attitudes and perceptions at a given point in time.
(Griffin and Neal 2000) Manufacturing and Mining Australia	Safety climate should be conceptualized as a higher-order factor comprised of more specific first-order factors. First-order factors of safety climate should reflect perceptions of safety-related policies, procedures, and rewards. The higher order factor of safety climate should reflect the extent to which employees believe that safety is valued within the organization.
(Hofmann and Stezer 1996) Utilities—US)	Safety climate is operationalized as perceptions regarding management's commitment to safety and worker involvement in safety-related activities.
(Mearns, Whitaker, Flin, Gordon, and O'Connor 2000) Offshore oil—UK	Safety climate is defined as a "snapshot" of employees' perceptions of the current environment or prevailing conditions which impact upon safety.
(Minerals Council of Australia 1999) Minerals—Australia	Safety climate refers to the more intangible issues in the company, such as perceptions of safety systems, job factors, and individual factors.
(Yule, Flin, and Murdy 2001) Conventional power—UK	Safety climate is defined as the product of employee perception and attitudes about the current state of safety initiatives at their place of work.
(Zohar 1980) Manufacturing, including metal, food, chemical, and textile—Israel	Safety climate is a particular type of organizational climate, which reflects employees' perceptions about the relative importance of safe conduct in their occupational behavior. It can vary from highly positive to a neutral level, and its average level reflects the safety climate in a given company.
(Zohar 2000) Manufacturing—Israel	Group level safety climate refers to shared perceptions among group members with regard to supervisory practices.

Table 2. Definitions of Safety Culture. From Wiegmann et al. (2002).

Source/Industry	Definitions
(Carroll 1998) Nuclear power—US	Safety culture refers to a high value (priority) placed on worker safety and public (nuclear) safety by everyone in every group and at every level of the plant. It also refers to expectations that people will act to preserve and enhance safety, take personal responsibility for safety, and be rewarded consistent with these values.
(Ciavarelli and Figlock 1996) Naval aviation—US	Safety culture is defined as the shared values, beliefs, assumptions, and norms which may govern organizational decision making, as well as individual and group attitudes about safety.
(Cooper 2000) Theoretical	Safety culture is a subfacet of organizational culture, which is thought to affect member's attitudes and behavior in relation to an organization's ongoing health and safety performance.
(Cox and Cox 1991) Industrial gases—European	Safety culture reflects attitudes, beliefs, perceptions, and values that employees share in relation to safety.
(Cox and Flin 1998) Theoretical (Lee 1998) Nuclear reprocessing—UK (Wilpert 2000) Theoretical in context of nuclear power	The safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management.
(Eiff 1999) Aviation—US	A safety culture exists within an organization where each individual employee, regardless of their position, assumes an active role in error prevention and that role is supported by the organization.
(Flin, Mearns, Gordon, and Fleming 1998) Offshore oil and gas—UK	Safety Culture refers to entrenched attitudes and opinions which a group of people share with respect to safety. It is more stable [than safety climate] and resistant to change.
(Helmreich and Merritt 1998) Aviation—US	Safety culture (p 133): a group of individuals guided in their behavior by their joint belief in the importance of safety, and their shared understanding that every member willingly upholds the group's safety norms and will support other members to that common end.
(McDonald and Ryan 1992) Theoretical in context of road transportation (Mearns and Flin 1999) Theoretical (Pidgeon 1991) Theoretical (Pidgeon and Oleary 1994) Theoretical in context of aviation	Safety culture is defined as 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.
(Mearns, Flin, Gordon, and Fleming 1998) Offshore oil and gas—UK	Safety culture is defined as the attitudes, values, norms and beliefs which a particular group of people share with respect to risk and safety.
(Meshkati 1997) Transportation industry—US	Safety culture is defined as 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.
(Minerals Council of Australia 1999) Mineral industry—Australia	Safety culture refers to the formal safety issues in the company, dealing with perceptions of management, supervision, management systems, and perceptions of the organization.
(Pidgeon 2001) Theoretical in context of driver behavior	A safety culture is in turn the set of assumptions, and their associated practices, which permit beliefs about danger and safety to be constructed.