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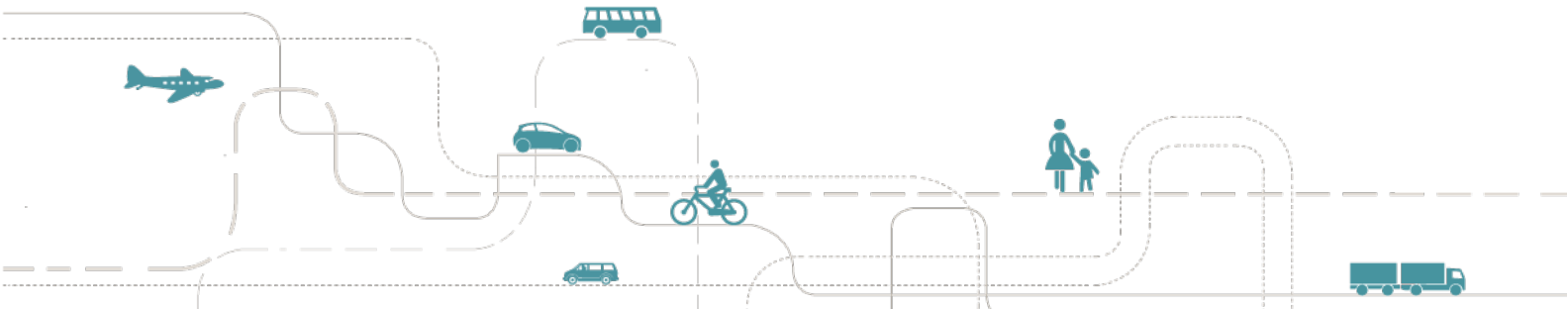
SAFETY CULTURE AND SAFETY PERFORMANCE IN TRANSPORT – A LITERATURE REVIEW



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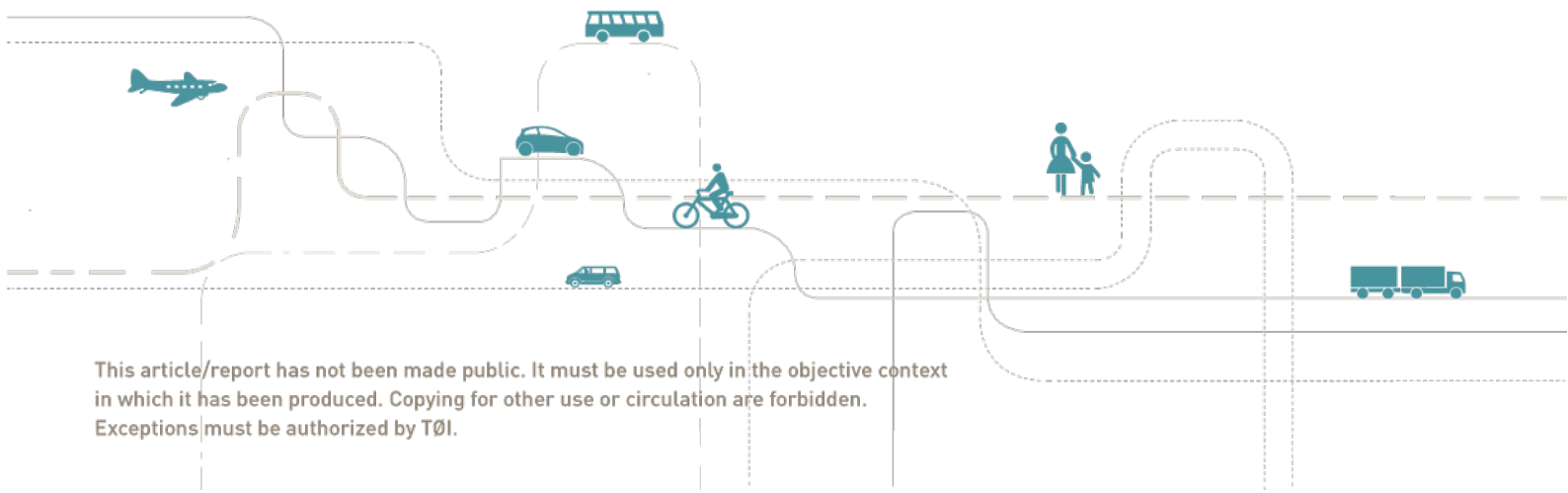

1 Introduction

The Swedish Transport Agency ("Transportstyrelsen") has engaged the Institute of Transport Economics (TØI) in Oslo, Norway to conduct a literature review to identify the association between safety culture and safety performance in the transport sector, i.e. how safety culture or safety climate relates to safety behaviour and in particular to accidents and injuries. Also other areas than transport may be relevant to study if there are few studies of the relationship in transport.

The present report provides the result of a literature review of relevant research literature on the association between safety culture, safety climate and safety performance. Relevant studies were provided by searching the following research databases: OVID Transport data base, BIBSYS, TRID database, Web of Knowledge, VTI's Library, Science Direct, and Google Scholar.

We have not made a very clear distinction between safety *culture* and safety *climate* in the literature search or in the report, even though this distinction has been subject to much debate in the research literature. Some scholars express the view that the two terms in practice appear to be used interchangeably (Guldenmund, 2000; Hopkins, 2006). However there seems to be more or less an agreement among scholars that safety climate can be viewed as a "snap shot" of the more general safety culture of an organization (Cox & Flin, 1998), and that it is this "snap shot" and not the general safety culture that is possible to measure by quantitative techniques. Safety climate is thus often measured and analysed by use of questionnaires providing safety climate scores e.g. (Bjørnskau & Longva, 2010; Flin, Mearns, O'Connor, & Bryden, 2000b; Kines et al., 2011). However, in the present report we use the term "safety culture" to cover both aspects – also the measurable "snap shot" usually referred to as safety climate.

Traditionally, one used so-called "lagging" indicators of safety assessment in organizations such as accidents, incidents, mishap rates etc. to measure safety levels. However, as safety has improved over the years organizational accidents now very seldom happen especially in High-Reliability Organizations (HROs). Thus one has started using "leading" indicators instead, such as safety culture/climate. Accordingly, many studies take the relationship between safety climate scores and actual safety for granted, and therefore this relationship is often not investigated.

There is accordingly a huge amount of safety culture/climate research that does not study the link to safety performance. However, the transport sector is not among the areas where safety culture/climate has been most frequently studied. Typically the most popular sectors for safety culture/climate studies are industries with catastrophic potentials like energy production sites, nuclear industries, chemical industries etc. Still, there are a substantial number of studies of safety culture/climate also within the transport sector.

In order to scope the review of relevant literature we need to draw some initial borderlines concerning the studies that are of greatest interest. As mentioned, the studies that link safety culture/climate in the transport sector to safety performance

are the ones of greatest interest. However we will also briefly present and discuss safety culture/climate studies within the transport sector that do not study the association with safety performance, and we will also present studies in other areas than transport that try to investigate the link between safety culture/climate and safety performance.

The document is outlined as follows. In chapter 2 we present first a general introduction to the safety culture concept and the research on safety culture and safety climate. In chapter 3 we present some key studies on the general relationship between safety culture and safety performance. In chapter 4-7 we proceed to present safety culture studies in the four different transport modes, aviation, maritime transport, rail and road. Chapter 7 also contains a short review of studies on national safety cultures. In chapter 8 we discuss the distinction between prospective and retrospective designs. Finally, in chapter 9 we sum up and conclude.

2 Organizational safety culture[1]

It is widely recognized that safety culture is important for safety in organizational settings (Nævestad 2010). In recent years, the concept of safety culture has both become established as a crucial management tool in the hazardous industries from which it originated, and it is being applied to an ever increasing range of different sectors and industries including transport. The safety culture concept has been used in efforts to analyze and improve safety in both aviation and rail for several years now. Furthermore, in the last few years, traffic safety scholars have started studying the role that safety culture may play in reducing risks in road transport. Early results suggest that the concept may have potential for improving road safety (Nævestad & Bjørnskau, 2012; Wiegmann, von Thaden, & Gibbons, 2007). It seems that the concepts of "traffic safety culture" and "road safety culture" are about to be included in the analytical toolbox of traffic safety researchers and practioners (Johnston, 2010; Kissinger, 2007; Wiegmann et al., 2007).

Hale and Hovden (1998) have identified three stages of safety management, the first mainly concerned with technical measures, the second focused on individual behaviour and the third focusing on ergonomics and sociotechnical approaches. Wiegman, von Thaden & Gibbons (2007) have argued that a fourth stage is developing: "the safety culture period." According to Nævestad and Bjørnskau (2012) and Özkan & Lajunen (2011) it is important to identify the content of safety culture within the road transport sector.

2.1 Organizational safety culture in accident investigations

The concept of organizational safety culture is usually traced to the 1986 Chernobyl disaster, which led to a shift of focus in the investigations and studies of safety in

[1] Section 2 is to a great extent based on the PhD thesis: "Culture, crises and campaigns: examining the role of safety culture in the management of hazards in a high risk industry" (Nævestad, 2010).

organizations. The reason for this is that the International Nuclear Safety Advisory Group (INSAG), convened by the International Atomic Energy Agency (IAEA) reported that an insufficient safety culture at the plant was an important cause of the accident (INSAG, 1986, 1991). In the years following the disaster, several major accident investigations have identified safety culture as a major contributing factor, for instance the Piper Alpha disaster (Cullen 1990)[2], the loss of space shuttle Columbia (NASA 2003) and the BP Texas City refinery disaster (The report of the BP US refineries independent safety review panel 2007).

2.2 Organizational safety culture provides resistance to hazards

The concept of organizational safety culture is not just evoked to understand why organizational accidents occur. Safety scholars stress that organizations with hazardous technological systems should implement good safety cultures in order to sustain maximum resistance to the hazards that they face (Reason, 1997, 1998).

The question of what constitutes good, or positive organizational safety culture is answered in several different ways, depending on our views of the main risk problems that organizations face, and how safety culture can be utilized to solve these problems (Nævestad 2010). The most studied and well documented characteristics of a good organizational safety culture are senior managers' commitment to safety (Cox & Flin 1998; Flin et al. 2000; Pidgeon & O'Leary 2000; DeJoy 2005). Besides from management commitment to safety, the most influential safety culture scholars often focus on the quality of organizational collection, analysis and dissemination of information in their descriptions of good or positive safety culture (e.g. Reason 1997; Westrum 2004; Hudson 2003; Pidgeon & O'Leary 2000). (Pidgeon & O'Leary, 2000). Reason (1997, 1998) holds that an informed culture, characterized by intelligent and respectful wariness is a safety culture:

> "In the absence of frequent bad events, the best way to induce and then sustain a state of intelligent and respectful wariness is to gather the right kinds of data. This means creating a safety information system that collects, analyses and disseminates information from incidents and near misses, as well as from regular proactive checks on the system's vital signs. All of these activities can be said to make up an *informed culture* – one in which those who manage and operate the system have current knowledge about the human, technical, organizational and environmental factors that determine the safety of the system as a whole. In most important respects an informed culture *is* a safety culture."
>
> (Reason 1998: 294).

Pidgeon and O'Leary (2000: 18) also stress the importance of shared care and concern for hazards, realistic and flexible rules about hazards and continual reflection

[2] The 1988 Piper Alpha disaster at the UK continental shelf is the deadliest oil rig disaster ever to occur. A hundred and sixty seven people died in the disaster. Cf.: http://www.oilrigdisasters.co.uk/

upon practice through monitoring, analyses and feedback systems. They refer to the latter as organizational learning (Pidgeon & O'Leary 2000).

Organizational safety culture is also important as a tool that can be used to assess the safety level of organizations. While traditional measures of safety levels use retrospective data on accidents and incidents ("lagging indicators"), safety culture data may provide predictive assessments that enable safety improvements without having to wait for accidents or incidents to happen ("leading indicators") (Antonsen, 2009).

2.3 The bewildered status of the concept

In 1997, James Reason ascertained that even though the concept of organizational safety culture is popular, it is not well understood (Reason, 1997). The concept is still popular. Already in April 2008, the majority of the twenty-five most downloaded papers on the webpage of the journal Safety Science were papers on safety culture/climate. "Safety Science" and "Work & Stress" published special issues on safety culture in 2000 and 1998 respectively. The editorials and other papers in these issues underline that the field of inquiry is quite young and that there is yet much to learn when it comes to defining and measuring safety culture and assessing the consequences of different types of safety cultures (Cox & Flin, 1998; Glendon & Stanton, 2000; Hale, 2000; Pidgeon, 1998) 2000; Guldenmund 2000). One of the most fundamental and controversial issue is whether it is even possible to measure safety culture (Haukelid, 2008).

Andrew Hale's (2000) Safety Science editorial was entitled "Culture's confusion", while Cox & Flin's (1998) Work & Stress editorial was entitled "Safety culture: philosopher's stone or a man of straw?" Moreover, Guldenmund (2000) worries that so many different meanings have been ascribed to the concept of safety culture over the years that it ends up referring to all and nothing. In a more recent review of the use of questionnaires in safety culture research, Guldenmund (2007) concludes that although more research efforts have been put into the safety- climate and culture concepts since the special issues in 1998 and 2000, "(…) the field is as fragmented and misunderstood as it was left by the reviewers and framework builders more than six years ago." (Guldenmund 2007: 725).

The "Journal of Occupational Health and Safety" also published a special issue on safety culture and safety climate in 2008 (Vol. 24, No. 3). In his editorial: "Safety culture: snapshot of a developing concept", Glendon (2008b) asserts that safety culture and safety climate are rapidly developing concepts within a number of disciplines. In his review of recent empirical articles (mainly from 2006) on safety culture/climate, in the same special issue, Glendon (2008a) concludes that the literature still is fragmented but that continuing terminological confusion is no barrier to making theoretical and methodological progress.

2.4 A definition of organizational safety culture

Given the extensive debate over the safety culture concept it is hardly surprising that there have been many different attempts to define "safety culture". One influential

scholar within the field, James Reason, identifies five important aspects of a safety culture (Reason, 1997):

a) **Informed culture:** The organization collects information about both accidents and incidents, and carries out proactive counter measures by the use of safety audits and surveys on safety climate.

b) **Reporting culture**: All employees report their errors or near misses, and take part in surveys on safety culture and so on.

c) **Just culture:** There is an atmosphere of trust within an organization that encourages and rewards its employees for providing information on errors and incidents, with the confidence of knowing that they will receive fair and just treatment for any mistake they make.

d) **Flexible culture:** The organization has the ability to change its practices.

e) **Learning culture:** The organization learns from incident reports, safety audits and so forth, resulting in improved safety.

In addition to these characteristics, Reason and others maintain that an organization's safety culture is tightly bound to its overall culture (Flin, Mearns, O'Connor, & Bryden, 2000a; Glendon & Stanton, 2000; Guldenmund, 2000; Haukelid, 2008), and also influenced by external conditions such as laws and regulations, governmental supervision, market situation and the like.

In recent years there has been a tendency among scholars to shift attention from the concept of safety culture to studies of organizational cultures and their effects on safety (e.g. Hale 2000; Guldenmund 2000; Hopkins 2006; Antonsen 2009). Earlier definitions of safety culture, including those of the International Nuclear Safety Advisory Group (INSAG 1991) and the Advisory Committee on Safety of Nuclear Installations (ACSNI 1993), quoted in a number of papers, treat safety culture as an empirical entity (Hale 2000). In fact, there is no such thing as "a safety culture" but different aspects of the larger organizational culture that can affect the organization's safety levels, as Antonsen (2009) puts it. In conformity with this view, safety culture should be specified as "safety relevant aspects of culture in organizations" (Nævestad 2010). Such aspects may refer to a range of different cultural phenomena, for instance: "observed behavioural regularities when people interact (language, customs and traditions, rituals), group norms, espoused values, formal philosophy, rules of the game, climate, embedded skills, habits of thinking, mental models, linguistic paradigms, shared meanings and 'root' metaphors or integrating symbols." Schein (1992: 8, in Guldenmund 2000: 225).

2.5 Safety performance

Safety performance can be and has been measured in numerous ways (Clarke, 2006). Traditionally, records of accidents, fatalities or injuries, have been used to measure safety performance. Within road transport these are still the most applied safety outcome indicators.

However, as mentioned, safety has improved over the years and organizational accidents now very seldom happen especially in High-Reliability Organizations

(HROs), such as in aviation. It follows that in many organizations accidents and injuries are not applicable as safety performance indicators, and some sort of safety indicator is used instead. So-called "micro accidents" or minor injuries have been used by Zohar (2000). The number of "near-misses", "incidents" or "close calls" has often been used to indicate safety critical events that can be recorded instead of actual accidents, when there are few real accidents cf. e.g. Morrow & Crum (2004).

However, in much of the safety culture research literature, neither accidents/injuries nor incidents/near-misses/close calls are used as safety performance indicators. Instead different types of safety behaviour have been applied, i.e. whether employees follow safety rules and procedures, wear safety equipments etc. (Cooper & Phillips, 2004; Glendon & Litherland, 2001). Such indicators are of course more distant to the real manifestations of risk than actual records of accidents and injuries.

In addition to safety performance indicators being more or less distant to the true risk manifestations, there is also another important distinction between self reports and other types of recordings of safety performance. Much of the research literature on safety culture and safety performance relies on self reports. Thus employees reply on the same questionnaire how they behave or how many incidents or accidents they have experienced during a period. Such self reports are however problematic both because of recollection bias, but in particular in this area because reporting of incidents etc. are often regarded as an important element within a good safety culture cf. Bjørnskau and Longva (2010). We will return to this issue in the discussion in chapter 8.

The preferred safety performance indicators are accordingly indicators as close as possible to accidents or injuries and that are not registered by way of self reports. However, as we shall see, most safety culture studies that have studied the association between safety culture and safety performance have used some sort of self reported safety behaviour as safety performance indicator.

3 General relationships between safety culture and safety outcomes

According to Zohar (2010) the relationship between safety culture and safety outcomes is well documented across industries and countries. And there exist several literature reviews and meta-analyses of safety culture/climate studies including also studies that have tried to link safety culture/climate to safety outcomes; safety behaviour, errors, incidents or accidents (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2006; Flin et al., 2000b; Nahrgang, Morgeson, & Hofmann, 2007; Yule, 2003).

Nahrgang et al. (2007) conducted a meta-analysis of 59 studies of work-related safety factors and concluded that there were significant negative relationships between overall safety climate and accidents/injuries and between management safety culture and accidents/injuries. Furthermore both of the safety climate measures were positively associated with workers' safe behaviour, well-being and satisfaction (Nahrgang et al., 2007).

Similar results are also found in another meta-analysis of workplace safety factors containing 90 studies (Christian et al., 2009). It should be noted that many of the same studies are included in these two meta-analyses. Christian et al. (2009) lists all studies included with detailed information about design, industrial sector, sample size, level of analysis, predictor and criterion constructs and information source. A total of 56 studies use either accidents or injuries as safety outcome variable, the others use some type of safety performance (safety participation, safety compliance). Based on their meta-analysis Christian et al. (2009) conclude that safety climate is positively linked to safety knowledge, safety motivation and safety performance, and negatively linked to accident and injuries.

The meta-analysis conducted by Clarke (2006) explicitly investigates into the relationship between safety climate, safety performance and occupational accidents and injuries. Results reveal a strong support for the hypothesized relationship between safety climate and safety performance (participation in safety activities and compliance with safety procedures), but the subsequent links to accident involvement were found to be weak.

Eight studies cited in Flin et al. (2000) link safety climate to safety performance (Alexander, Cox, & Cheyne, 1995; R. L. Brown & Holmes, 1986; Donald & Canter, 1994; Isla Díaz & Díaz Cabrera, 1997; Lee, 1998; Mearns, Flin, Fleming, & Gordon, 1997; Niskanen, 1994; Zohar, 1980).

According to Flin et al. (2000) only the studies by Brown & Holmes (1986), Zohar (1980), Isla Díaz & Díaz Carbrera (1997) and Niskanen (1994) revealed the hypothesized association between safety climate and safety performance. Furthermore, both Zohar (1980) and Isla Díaz & Díaz Carbrera (1997) used expert ratings as measurement of safety behaviour, not errors, accidents or injuries.

The literature review conducted by Steven Yule (2003) contains all the same studies as in Flin et al. (2000), but he has included a number of additional studies also investigating the association between safety climate and safety performance (K. A. Brown, Willis, & Prussia, 2000; Griffin & Neal, 2000; Hofmann & Stetzer, 1996; Mearns, Flin, Gordon, & Fleming, 1998; Mearns, Whitaker, & Flin, 2001; Neal, Griffin, & Hart, 2000; Ostrom, Wilhelmsen, & Kaplan, 1993; Smith, Cohen, Cohen, & Cleveland, 1978; Thompson, Hilton, & Witt, 1998; Tomas, Melia, & Oliver, 1999; Williamson, Feyer, Cairns, & Biancotti, 1997; Zohar, 2000).

According to Yule (2003) several studies identifies the expected association between safety culture/climate and safety outcomes (Donald & Canter, 1994; Isla Díaz & Díaz Cabrera, 1997). Donald & Canter (1994) report a statistical significant relationship between safety climate scores and accidents in the chemical industry. Similar results have been obtained within the offshore industry (Mearns, Rundmo, Flin, Gordon, & Fleming, 2004), hospitals (Neal et al., 2000). Although many of the studies reveal the expected association between safety climate and safety performance, some do not e.g. Mearns et al. (1998) and (Alexander et al., 1995). Both these latter studies use accidents as safety outcome variable.

4 Safety culture in aviation

4.1 Safety culture studies in aviation

Aviation provides an example of a high risk industry that has attained exemplary safety performance (Perrow 1999). In spite of its exemplary organizational safety culture, Wiegman et al. (2004), in O'Connor, O'Dea, Kennedy, & Buttrey (2011, p. 129) assert that few formally documented efforts have been made to assess safety culture within the aviation industry, with the exception of military aviation. This has, however, changed during the last decade (O'Connor et al. 2011).

The review provided by O'Connor et al. (2011) contains 23 studies of safety culture/climate within the aviation industry covering different employee groups such as aviators, cabin crew, ground handlers, maintainers and air traffic control. Also Nordic studies on safety culture in aviation have emerged during later years (Bjørnskau & Longva, 2010; Ek, Akselsson, Arvidsson, & Johansson, 2007; Lofquist, 2010).

Aviation has been a pioneering industry when it comes to applying the safety culture concept. Reason's (1997, 1998) descriptions of informed safety cultures uses, for instance, the formal and informal aspects of aviation incident reporting systems as a model.

The fact that an aircraft crash almost always will be disastrous led to a political, social and commercial awareness that aviation safety had to be taken seriously (Hudson, 2003). According to Hudson (2003), flying has become one of the safest means of transport because of the positive attitudes to safety in the industry. He asserts that positive attitudes to safety have been more important than systematic safety management systems (SMS) in bringing the aviation industry to its current safety level:

"A safety management system therefore defines sound systems, practices and procedures, but is never enough if practiced mechanically; an SMS requires an effective safety culture to flourish." (Hudson 2003: i9).

According to Hudson (2003), the aviation industry has an effective safety culture enabling individuals to exercise initiative and fill the gaps of formal safety system. Consequentially, the safety culture level of aviation is used as a model for improving safety culture in oil and gas (Hudson 2003).

A study comparing safety management developments in aviation and health care concludes that the adoption of Crew Resource Management (CRM) within aviation, was a decisive development in aviation safety management (Courtright, Stewart, & Ward, 2012). To cope with a disturbing number of aviation accidents in the 1980s CRM was developed to improve aviation safety. "Instead of focusing on technical skills, CRM helps pilots and crew members build the interpersonal and group interaction skills necessary to perform as high functioning teams" (Courtright et al. 2012, p. 292). Among the essential features of CRM is to voice safety concerns, to update and inform each other etc., features emphasized as key elements in a safety culture (Reason 1997). Furthermore, Courtright et al. (2012) maintain that CRM

revolutionized safety practices and cultures in the aviation industry and that health care ought to introduce similar evidence-based team training programs.

The aviation industry is considered to have an exemplary high organizational safety culture level also because of its well functioning incident reporting systems (Hudson 2003). As noted, descriptions of good safety culture often focus on the formal and informal aspects of information systems being used to collect, analyze and disseminate information on incidents and near-misses. Hudson (2003) argues that aviation has an advanced safety culture which is: *informed* (managers know what is going on and the workforce reports), *wary* (members of the organization maintain a high degree of vigilance), *just* ("no blame" culture, although some actions are totally unacceptable), *flexible* (can adapt rapidly to changes in circumstances) and *learning* (ready to do what needs to be done to improve) (Reason, 1997). According to Hudson (2003: i10) ".. the Australian Bureau of Air Safety Investigation was the first to use Reason's model for all its major reports, directing attention to organisational factors underlying aviation accidents."

4.2 Safety culture and safety performance in aviation

In aviation there are now several studies of safety culture/climate, but only a few try to link safety climate or safety culture to actual safety. One such study included in the review by Nahrgang et al. (2007) was a study of aviation maintenance based on a sample of 240 maintenance engineers working at the two main helicopter repair bases for the Australian Army (Fogarty, 2004). The study used structural equation modeling to analyze the relationship between a number of safety-relevant variables, and revealed strong relationships between safety climate and health, safety climate and morale (job satisfaction, commitment and personal responsibility), and a small relationship with fatigue. Together safety climate, health, morale and fatigue accounted for 45 percent of the variation in self-reported errors. This is a substantial effect, but the study did not reveal any direct effect of safety climate on errors; the effects from safety climate were all mediated by the other three variables (health, morale and fatigue).

The review conducted by O'Connor et al. (2011) revealed that the majority of studies did not attempt to establish the discriminative validity of the safety climate tools, i.e. the ability of the tool to differentiate between organizations or personnel with different levels of safety performance. According to O'Connor et al. (2011) only five of the 23 studies tried to establish such discriminative validity (Desai, Roberts, & Ciavarelli, 2006; Harris, 2000; Hernandez, 2001; Isla Díaz & Díaz Cabrera, 1997; Kao, Stewart, & Lee, 2009).

One of these studies was a study of safety climate among 970 maintainers at a US Marine Corps air wing (Harris, 2000). According to Harris (2000) there were no significant relationship between safety climate scores measured by the Maintenance Climate Assessment Survey (MCAS) and incidents. Similarly neither Hernandez (2001) obtained significant relationships between MCAS safety climate scores and incidents in aviation maintenance.

In a study of safety climate among ground handling staff from three different companies at a Spanish airport if was found that safety climate scores among respondents were consistent with expert ratings of safety at the same companies (Isla Díaz & Díaz Cabrera, 1997). Isla Diaz & Díaz Carbrera (2007) concluded that the safety climate questionnaire was able to discriminate between organizations with different levels of actual safety. However, the study does not link safety climate responses to real safety performance measures such as accidents, incidents or errors.

O'Connor et al. (2011) also refer to a study of safety climate attitudes among Taiwanese cabin crews (Kao et al., 2009). A total of 331 responses were obtained and results reveal significant links between high management commitment to safety and high crewmember participation in safety (Kao et al., 2009). The authors also found positive associations between safe cabin work environment and crewmember's individual safety behaviour. However the study did not reveal any significant association between management commitment and injury incidences. Kao et al. (2009) conclude that injury incidence might not be predicted by management commitment to safety. Given the fact that management commitment is one of the key elements in safety climate surveys and in the safety culture concept, such result may indicate a lack of association between safety culture and actual safety.

Finally, O'Connor et al. (2011) refer to a study based on 6361 responses from 147 US Naval squadrons (Desai et al., 2006) that found mean safety climate scores to be *positively* linked to minor and intermediate accidents, i.e. those reporting that safety climate is good also report more accident. No effects were found for major accidents. Desai et al. (2006) argue that this result is in accordance with a hypothesis that safety climate improves after accidents or incidents happen, i.e. that the organizations in question try to learn and manage to improve the safety culture. One could however argue that one should in general expect a *negative* association – that high safety climate scores would be associated with low accident rates – which also found in several studies mentioned. We will return to this issue in chapter 8.

Mearns and colleagues have developed and assessed a safety culture survey tool for use in European Air Traffic Management (Mearns et al., 2013). Their ambition is both to achieve good construct validity across different European countries as well as to obtain criterion validity, i.e. that the tool may discriminate between air traffic control units according to safety performance. To obtain criterion validity for the safety culture program (i.e. influence on actual safety performance) is difficult to demonstrate. However some supportive correlations are presented indicating that increasing efforts into reporting and learning reduces the number of serious incidents.

There are however also somewhat more pessimistic views on the recent developments in aviation safety. According to English & Branaghan (2012) pilot violations of rules and procedures are a serious and vexing problem for aviation, and an important causal factor in several contemporary accidents. To abide by safety rules and procedures is considered a key element in a good safety culture. Thus, increased rule violation may indicate a weakened safety culture.

Table 1 sums up the main results of studies in aviation linking safety culture to safety performance indicators.

Table 1 Overview of studies in aviation linking safety culture measures and safety performance indicators with information on registration procedures, type of study and effects.

Study	Sample	Safety culture measure	Safety performance indicator	Registration	Prospective?	Effect
Fogarty 2004	Military helicopter maintainers	Survey	Errors	Self reports	No	Positive, indirect
Harris 2000	Aircraft maintainers	Survey (MCAS)	Incidents	Self reports	No	No effect
Hernandez 2001	Aircraft maintainers	Survey (MCAS)	Incidents	Self reports	No	No effect
Diaz & Carbrera 1997	Ground handling	Survey	Behaviour	Expert ratings	No	Postive, direct
Kao et al. 2009	Cabin crews	Survey	Behaviour Incidents	Self reports	No	Positive & no effect
Desai et al. 2006	Aviation (Naval flight squadrons)	Survey	Accidents	Registered	No	Negative
Mearns et al. 2013	Air traffic controllers	Intervention Safety culture program	Incidents	Registered	Yes	Positive

5 Safety culture in rail transport

5.1 Safety culture studies in rail

The application of the organizational safety culture concept in various hazardous industries, like oil and gas and aviation, has influenced safety practitioners, accident investigators and researchers involved in railway safety to apply the concept to rail. Moreover, the concept of organizational culture is applied to different groups involved in rail, for instance train drivers, operators directing traffic, maintenance personnel and so forth. Moray (2006) gives a comprehensive review of safety culture research with relevance to rail safety.

The concept has been applied in investigations of rail accidents (Hopkins, 2005), studies of rail safety culture/climate (Farrington-Darby, Pickup, & Wilson, 2005) and in policy statements about rail safety (HSE, 2005). The investigation report of the UK Clapham Junction railway accident in 1988 (Hidden, 1989) actually suggests that a better safety culture should be promoted within British Rail (Hidden 1989: 167). Although it may have taken some time before the rail industry followed this recommendation, this realization of the importance of safety culture came very early, considering that the concept was introduced in the wake of the Chernobyl incident in 1986.

According to Hopkins (2005), safety culture became a prominent and often misunderstood concept in the media following the Australian Glenbrook rail crash in

1999. In his own analysis of this rail accident, Hopkins (2005) identifies four features of the organizational safety culture of the New South Wales Railways that contributed to the crash. First, the culture was very rule-focused. Second, the railway system was organizationally and occupationally fragmented – "a culture of silos". Third, there was a powerful culture of punctuality – a strong focus on running on time. Fourth, the railway culture was risk blind, even risk-denying.

An important safety cultural theme identified across studies on organizational safety culture in rail is the focus on running on time. This strong focus on punctuality was not only identified by Hopkins (2005). It was also identified as a crucial competing interest to safety in other rail accident investigations, for instance the Ladbroke Grove rail accident (Cullen, 2001) and the Clapham Junction accident (HSE 2005), and it was also identified in the in-depth interviews in British Rail following the Clapham Junction disaster (Guest et al. 1994 in Mearns & Flin (1999)).

Bjørnskau and Longva (2010) used the GAIN safety culture index (GAIN, 2001) to compare tram and metro train drivers with pilots and bus drivers. GAIN is an acronym for "Global Aviation Information Network". The questions in the GAIN-index are from the "Operator's Safety Handbook" (GAIN 2001). The GAIN-index comprises 25 questions concerning: 1) management attitude to and focus on safety, 2) employee attitude to and focus on safety, 3) reporting culture and reactions to incident reporting, 4) safety training and education, 5) general questions concerning safety in the organization in question. The results were as hypothesized, safety culture scores were better among tram and metro train drivers than among bus drivers, but not as good as among airline and helicopter pilots.

Another type of safety culture comparisons was performed by Johnsen, Vatn, Rosness & Herrera (2006) who investigated possible safety culture conflicts or discrepancies at rail interfaces (i.e. borders) and try to improve safety cultural interfaces by establishing a common "SafeCulture".

5.2 Safety culture and safety performance in rail

Guest et al. (1994), in Mearns & Flin (1999) examined safety culture in British Rail following the Clapham Junction accident, by means of thirty-three in-depth interviews. They concluded that it was possible to identify a safety culture among the permanent staff that was part of the organizational culture of British Rail. This organizational safety culture was characterized by: a belief in hierarchy and firm management, a belief in the value of technically sound and complex safety systems, a reluctance of those at lower level in the organization to accept personal responsibility and a sense of duty and commitment to running trains on time (Guest et al 1994, in Mearns & Flin 1999). The study was only partly successful in linking local safety cultures and accident rates.

A seminal article on "Safety culture in railway maintenance" (Farrington-Darby et al 2005: 41) reports that there has been little work on organizational safety culture and (un)safe behavior in rail track maintenance, compared to for instance oil and gas. Farrington-Darby et al.'s (2005) study, which is based on forty qualitative in-depth interviews, identifies forty primary factors that are considered to influence track

workers' behaviour and the organization's safety culture. These factors relate to different levels, from the specific level of behaviour of someone in a safety critical role, and at the middle level supervisors' visibility to more general factors like the quality of organizations' accident and incident reporting systems.

There are several studies that link safety culture to safety performance in rail transport. A survey of safety culture and safety behaviour among rail maintenance workers employed by a large North American railroad confirmed that safety culture factors were positively linked to safety behaviour (S. L. Morrow et al., 2010). The three investigated facets of safety culture; management safety, coworker safety and work-safety tension were significantly associated with safety behaviour. Work-safety tension evidenced the strongest relationship with safety behaviour.

A study among Japanese track maintenance train operators revealed significant associations between safety culture factors and accident/incident rate (Itoh, Andersen, & Seki, 2004). The study by Itoh et al (2004) applied a questionnaire called Train Management Attitudes Questionnaire (TMAQ) – based on similar questionnaires in aviation and sea transport (FMAQ (Helmreich, Merrit, Sherman, Gregorich, & Wiener, 1993) and SMAQ (Andersen, Garay, & Itoh, 1999)). Factor analysis revealed a seven factor structure, where two factors "morale" and "motivation" were significantly and negatively associated with accident/injury rates.

In Canada the Canadian Pacific Railway (CPR) has adopted a safety program called "5-Alive". The program focuses on increasing awareness of and compliance with important safety rules. After the introduction of the program in 2002 injury rates in Mechanical Services at CPR dropped significantly (FRA, 2006). The program does not apply the concepts "safety culture" or "safety climate", but since awareness and compliance with important safety rules are important aspects of a safety culture, we have included the study in the present review. Another North American study revealed that drastic revisions and reductions of rules improved safety culture in railroad companies and was followed by an incident rate reduction at one rail carrier (Kansas City Southern) (FRA, 2003).

Bjørnskau & Longva (2010) investigated the association between self reported accidents and serious incidents and safety culture scores, both among tram drivers, metro train drivers and bus drivers. Results were mixed. Drivers who had experienced one serious incident or accident scored generally better on the safety culture index than drivers reporting no incidents/accidents. However among drivers with more than one accident/incident there seemed to be a consistent tendency towards lower safety culture scores the more incidents/accidents drivers reported.

Metro train drivers scored better on the safety culture scale than did tram drivers. A similar picture was obtained on questions about rule following, where 70 per cent of metro train drivers said they never violate rules and procedures. Among tram drivers the share was 44 per cent, which is lower than the corresponding shares among bus drivers.

Table 2 sums up the main results of studies in rail linking safety culture to safety performance indicators.

Table 2 Overview of studies in rail linking safety culture measures and safety performance indicators with information on registration procedures, type of study and effects.

Study	Sample	Safety culture measure	Safety performance indicator	Registration	Prospective?	Effect
Morrow et al. 2010	Rail maintenance	Survey	Safety behaviour	Self reports	No	Positive, direct
Itoh et al. 2004	Track maintenance	Survey (TMAQ)	Accident/ injuries	Registered	No	Positive, direct
Fed. Railr. Adm. 2003	Maintenance mech. service	Intervention (awareness /compliance) "5-alive"	Injury rates	Registered	Yes	Positive, direct
Fed. Railr. Adm. 2006	Rail carrier	Interventioin Rule revisions	Incident rates	Registered	Yes	Positive, direct
Bjørnskau & Longva 2010	Tram and metro train drivers	Survey (GAIN)	Accidents Incidents Behaviour	Self reports	No	Positive and negative

6 Safety culture in maritime transport

6.1 Safety culture studies in maritime transport

Maritime transport has a reputation of bad safety culture (Perrow, 1999) although the concept "safety culture" has just quite recently been given attention within the maritime sector according to Håvold (2005). Similarly Håvold and Nesset (2009) maintain that still in 2009 there were only a few studies of safety culture at sea (Ek & Akselsson, 2005; Hetherington, Flin, & Mearns, 2006; Håvold, 2005) However, already in the 1990s Henning Boje Andersen developed and applied a safety attitude scale for maritime transport - "Ship Attitudes Questionnaire" (SMAQ) (Andersen et al., 1999) based upon Helmreich's "Flight Management Attitudes Questionnaire" (FMAQ) (Helmreich et al., 1993). The SMAQ/FMAQ can be interpreted as safety climate questionnaires.

Håvold (2005) applied a 40-item safety culture questionnaire, which was distributed to sailors onboard 20 vessels and to sea officers. Factor analysis confirmed factor structures from other industries. The study also revealed significant differences between occupations, nations, and vessels on one or more of the factors from the factor analysis. The study did not investigate the relationship to safety performance. Similar findings was revealed in larger study containing 141 vessels and 2558 responses (Håvold & Nesset, 2009). The latter study develops the safety culture concept further and defines "safety orientation" as an implementation of the safety culture concept. This is a very comprehensive study adopting a number of different safety culture scales.

Ek & Akselsson (2005) investigated safety culture among employees on board six Swedish passenger ships using observations, interviews and questionnaires. The

questionnaire used was similar to the ones Ek and colleagues have applied in the aviation industry (air traffic control and ground handling (Ek et al., 2007)). The study reveals safety culture levels in maritime passenger transport to be somewhat better then among ground handling employees at airports, but not as good as among air traffic controllers.

Hjorth (2012) has studied the safety culture onboard at total of eleven vessels trading in the Baltic sea in his licentiate thesis. The study applies an anthropological approach with the aim to understand and explain the safety culture in this particular type of maritime transport. Hjorth (2012) identifies several elements that needs to be improved to reach a better safety culture and in particular a more proactive safety management in accordance with Karl Weick's concept of "collective mindfulness" (Weick & Sutcliffe, 2001) .

An underlying assumption in safety management theories and safety culture principles is that of a good reporting of incidents and near-misses (Reason, 1997, 1998). According to several studies cited by Storgård and colleagues (Storgård, Erdogan, Lappalainen, & Tapaninen, 2012), incident and near miss reporting in the shipping industry is lacking. A Norwegian study of factors influencing reporting of accidents and near-misses among off-shore service vessels found reporting to be negatively associated with external organizational factors such as efficiency demands and quality of feed-back (Kongsvik, Fenstad, & Wendelborg, 2012). These associations were reported to be stronger than the associations with the safety culture components: (1) the captain's safety priorities, (2) the safety training, and (3) the general safety orientation on board. The study does not try to link safety culture scores to safety performance. The authors conclude that there is a need to take more external conditions into account when studying safety culture factors. The importance of the external structures the organization is placed within for safety culture has also been maintained by Bjørnskau and Longva (2010).

Antonsen (2009) presents an interesting study of the relationship between organizational (safety) culture among seafarers on offshore supply vessels in the North Sea. The study uses both an anthropological, qualitative approach with participant observations and interviews as well as a quantitative survey to the seafarers onboard such vessels. Antonsen (2009) identifies large discrepancies between actual behaviour and the proscribed behaviour according to rules and procedures. The seafarers state that written forms and procedures are desk work, barely relevant for how the actual work must be done. Similar results have been obtained by Knudsen (2009) and Lamvik (2002).

6.2 Safety culture and safety performance in maritime transport

The study by Håvold & Nesset (2009) also included safety behaviour as a safety outcome variable. Safety behaviour was measured by self reports in the form of assertions that respondents should respond to. Again different safety behaviour scales were used (Håvold, 2005; Mearns, Whitaker, Flin, Gordon, & O'Connor, 2000; Williamson et al., 1997).The authors conclude that the study confirms the usefulness of safety culture/climate factors as predictors of unsafe behaviour.

The influence of safety culture on seafarers' safety behaviour has also been investigated by Lu and Tsai (2010) by use of a safety culture survey combined with self reported safety behaviour. The study also revealed a positive relationship between safety culture and safety behaviour.

Although Antonsen (2009) did not investigate into the possible link between safety culture and safety behaviour, the survey included a specific item of safety behaviour, i.e. whether or not the seafarers complied with rules and procedures. Only 17 per cent in the sample stated that they never failed to comply by procedures, reflecting that written rules and procedures are not viewed as relevant guidelines for safe work among seafarers.

Interestingly, the same question was used by Bjørnskau & Longva (2010) in their survey to metro, tram and bus drivers. In fact Bjørnskau & Longva used the same question precisely because of the interesting results provided by the supply vessel survey. Both samples are Norwegian, and the wording in Norwegian was the same in the two studies. The wording of the question according to Antonsen was: "if you fail to comply with a procedure, what could be the reason for doing this?" The English wording used by Bjørnskau and Longva (2010) was: "if you bend rules and procedures, what are the reasons for doing so?"

Among the seafarers only a few (17 % of 258) replied that they never violated procedures (Antonsen, 2009, s. 1125). The rate is far below what was found in bus, tram and metro companies (Bjørnskau & Longva, 2010). It is however important to be aware of the fact that these vessels are employed by Statoil, one of the oil drill companies in the North Sea with very detailed and comprehensive safety procedures, that also the supply vessels must comply with. According to Antonsen (2009) the seafarers in his sample state that much written rules and procedures are inadequate or irrelevant for the safe practices onboard the vessels.

Table 3 sums up the main results of studies in maritime transport linking safety culture to safety performance indicators.

Table 3 Overview of studies in maritime transport linking safety culture measures and safety performance indicators with information on registration procedures, type of study and effects.

Study	Sample	Safety culture measure	Safety performance indicator	Registration	Prospective?	Effect
Håvold & Nesset 2009	Seafarers	Surveys scales	Safety behaviour	Self reports	No	Positive, direct
Lu & Tsai 2000	Seafarers	Survey	Safety behaviour	Self reports	No	Positive, direct

7 Safety culture in road transport

7.1 Safety culture studies in road transport

The organizational safety culture concept can also be applied to professional drivers in road transport (e.g. bus drivers, taxi drivers, truck drivers etc.) in the same manner as it has been applied to aviation, rail and maritime transport. Professional drivers in road transport are members of organizations with organization cultural traits that are relevant for safety, i.e. safety cultures (cf. Nævestad 2010). However, compared to aviation and rail, the safety culture concept has only recently been given attention in road transport.

An American review of best practices in preventing commercial motor vehicles (Short, Boyle, Schackelford, Inderbitzen, & Bergoffen, 2007) emphasizes safety culture's potential to reduce commercial motor vehicle accidents. The report refers to a literature review of best practices to improve safety conducted by the American Trucking Association Foundation (ATAF, 1999) and concludes by maintaining that the next logical step in safety improvement will be to implement the principles from the safety culture literature.

One interesting approach has been developed by Newman and Von Schuckman (2012) who have developed the ordinary Driver Behaviour Questionnaire (DBQ) to an "Occupational Driver Behaviour Questionnaire" (ODBQ) which utilizes a theoretical model to assess the impact of the broader workplace context of driver behaviour. The ODBQ is interesting, but it lacks the focus on management commitment to safety, reporting of incidents etc. that are central in safety culture surveys.

The "Transportation Companies' Climate Scale", is a recently developed safety culture scale for transport companies (Öz, Özkan, & Lajunen, 2013). According to Özkan & Lajunen (2011) factor analysis of the scale items yielded three factors, a) general safety management, b) specific practices and precautions, and c) work and time pressure.

As already mentioned, Bjørnskau and Longva (2010) found bus drivers to exhibit the poorest safety culture in an comparison with airline pilots, helicopter pilots, tram and metro train drivers. The authors suggest that these results probably can be seen to reflect the different external conditions of the various transport modes. Aviation has traditionally had a very strong focus on safety, and safety rules and procedures in this sector is strongly regulated by international treaties. Rail transport also has a strong safety focus, with strict national safety regulations and a separate supervisory authority. Bus transport, being part of the road transport system, is not subject to similar safety regulations (Bjørnskau & Longva, 2010).

An American study among 116 trucking firms studied the association between four item safety culture scale and management practices (Arboleda, Morrow, Crum, & Shelley Ii, 2003). The authors found significant associations between perceived safety culture and drivers' fatigue training, driver opportunity for safety input and top

management commitment. Driver scheduling autonomy was not significantly associated with perceived safety culture.

7.2 Safety culture among non-professionals in road transport

As noted, safety culture is a concept that arose from an organizational context, relating to the Chernobyl incident. The concept has, however, been associated with other analytical units, e.g. industries, patients, occupations and so forth (Hudson 2003). These units may either be smaller or larger than organizations, they may be subunits within organizations (e.g. occupational groups), or organizations may be subunits within them (e.g. industries). The common denominator of these units is, however, that they are social units. Culture is a social phenomenon that is created in the interaction between people.

Safety culture is to a great extent a concept that is examined with the intention to influence (e.g. Reason 1997). We should probably have this in mind when we consider the analytical units and levels to which it has been applied. In our view, the safety culture concept is by and large associated with organizations, as these units can be subjected to influence. Edgar Schein, who is one of the most influential organizational culture scholars, asserts for instance that management and culture are two sides of the same coin (Schein, 2004). He outlines "six primary embedding mechanisms" that managers can use to shape culture: what managers pay attention to, measure and control on a regular basis, how managers react to critical incidents and organizational crises, how managers allocate resources, deliberate role modeling, teaching and coaching, how managers allocate rewards and status, and how managers recruit, select, promote and excommunicate (Schein 2004: 246). Critical organizational culture scholars, on the other hand, remind us of the importance of subculture within organizations and argue that managers' abilities to influence culture are overestimated (Martin 2005).

In spite of the tendency to relate safety culture to organizations, culture is not a phenomenon that is restricted to organizations. The concept applies to all social units: communities, cities, nations, civilizations and so forth. It is therefore not surprising that the concept of safety culture has been applied to communities and societies in recent years, referred to for instance as "traffic safety culture" (Kissinger, 2007; Nævestad & Bjørnskau, 2012).

Road safety is a vast research area and numerous surveys on driver behaviour have been conducted. These surveys normally use some standard questionnaire like the frequently used Driver Behaviour Questionnaire (DBQ) (Parker, Reason, Manstead, & Stradling, 1995) where respondents are individual private drivers and not employees etc. Thus ordinary safety culture questionnaires are normally inadequate when subjects are private road users.

7.3 Safety culture and safety performance in road transport

Sharon Clarke has conducted a meta-analysis of the relationship between safety culture and safety performance (Clarke, 2006). A total of 35 studies were included, mostly from manufacturing industries but the analysis also included one large American study of safety culture and safety performance among 116 road haulage firms (P. C. Morrow & Crum, 2004). This study concluded that fatigue was associated with close calls (conflicts, incidents) and that safety practices like the establishment of a strong safety culture can offset important fatigue-inducing factors associated with truck driving work. There were however no significant direct relationships between safety culture and accidents, or between fatigue and accidents.

Bjørnskau and Longva (2010) investigated and compared safety culture index scores between transport modes. On an aggregate level they found the expected correspondence between actual safety scores and safety culture index scores; helicopter and airline pilots exhibited a better safety culture according to the safety culture index than drivers of trams and metros, and the latter exhibited a better safety culture than bus drivers. This corresponds well with accident risk levels between these transport modes. However, Bjørnskau and Longva (2010) did not find that those drivers that scored best on the safety culture index were the ones with the best individual accident records. They put forward several hypotheses to explain this seemingly contradictory result, which will be commented in more detail below.

In a time series study covering 17 different organizations Hale and colleagues (Hale, Guldenmund, van Loenhout, & Oh, 2010) studied the relationship between safety culture interventions, monitored safe behaviour, and reports of incidents and accidents/injuries. They hypothesized that safety culture interventions would increase safe behaviours and decrease accidents and injuries. They also expected safety culture interventions to *increase* the number of reported incidents since a reporting culture is a key component of a safety culture (Reason, 1997). The study contained a number of different production types, and three of them were more or less part of the transport industry: distribution/warehousing, rubbish collection & treatment, air cargo handling. Results were mixed. Positive results, in one of seven outcome measures, were obtained for half of the sample. Of the three transport related industries, it was only in distribution/warehousing that an effect of the safety culture interventions could be identified, and only for reporting of dangerous situations.

Wills, Watson and Biggs (2006) report significant associations between safety culture factors and self reported driver behaviour by use of a modified version of Glendon and Litherland's (2001) safety culture questionnaire and a modified version of the Driver Behaviour Questionnaire (Lawton, Parker, Manstead, & Stradling, 1997). The sample consisted of 323 employees who drove a motor vehicle at least once during an average working week. The study reveals significant links between safety culture and DBQ factors such as driver error, driver distraction and driver violations. The study did not investigate whether safety culture was linked to accidents or incidents.

The study by Özkan and Lajunen (2011) mentioned above revealed a significant association between work and time pressure and accidents among Turkish

professional drivers. The earlier mentioned study by Öz et al. (2013) also reveals a relationship between DBQ factors and safety culture factors, and in particular a close link between work and time pressure and the frequencies of violations and errors. However, possibly due to the limited sample (N=223) they do not try to establish the relationship between safety culture and accidents or incidents.

An Australian study investigated the relationship between different driver behaviour scales and accident involvement among nearly 5000 Australian drivers from a large Australian company (Davey, Freeman, & Wishart, 2006). The scales investigated were the Driver Behaviour Questionnaire (DBQ), the Driver Attitude Questionnaire (DAQ) and a Safety Climate Questionnaire (SCQ) adopted from Wills and colleagues (Wills, Biggs, & Watson, 2006; Wills, Watson, et al., 2006). Results revealed significant associations between accident involvement and annual driving distance, errors (DBQ) and work pressure (SCQ). However, there were no significant link between violation factors (DBQ) and accidents nor between safety culture factors like rules, communication, procedures and management commitment and accidents. The authors do not provide detailed information about the type of company from which the respondents are recruited, but it seems that respondents are ordinary employees driving to work and not professional drivers. If so, the company management is probably not particularly concerned with traffic safety, and it is perhaps not surprising that organizational climate issues do not contribute significantly to traffic accidents among such employees. It is perhaps more surprising that the DBQ-violations variables do not contribute to accident involvement.

In a Portuguese study based on survey responses from 356 drivers and technicians in a transportation organization, the authors try to link safety culture scores and safety behaviour by using the Theory of Planned Behaviour (Ajzen, 2002) to model mediating variables (Fugas, Silva, & Melia, 2010). This is an interesting approach and the study reveals a positive association between safety culture and compliance safety behaviour, but there is no direct effect. The effect is mediated by the "perceived behavioural control". The effect from perceived behavioural control to compliance safety behaviour is however substantial.

Finally, an American study of the relationship between safety culture and different outcome variables among 31 commercial truck and bus companies (Boyle, Peng, Neyens, & Short, 2010) identified key factors of safety cultures by use of factor analysis. However safety culture levels were not linked to accidents or injuries.

Table 4 sums up the main results of studies in road transport linking safety culture to safety performance indicators.

Table 4 Overview of studies in road transport linking safety culture measures and safety performance indicators with information on registration procedures, type of study and effects.

Study	Sample	Safety culture measure	Safety performance indicator	Registration	Prospective?	Effect
Morrow & Crum 2004	Road haulage firms	Survey	Close calls Conflicts Incidents	Self reports	No	Positive, indirect
Bjørnskau & Longva 2010	Bus drivers	Survey (GAIN)	Accidents Incidents Behaviour	Self reports	No	Mixed effects
Wills, Watson & Biggs 2006	Employees Private drivers	Survey	Behaviour (DBQ)	Self reports	No	Positive, direct
Özkan & Lajunen 2011	Professional drivers	Survey (TCCS)	Accidents	Self reports	No	Positive, indirect
Öz, Özkan & Lajunen 2013	Professional drivers	Survey	Behaviour (DBQ)	Self reports	No	Positive, direct
Davey, Freeman & Wishart , 2006	Employees Private drivers	Survey (SCQ)	Behaviour (DBQ) (DAQ)	Self reports	No	Mixed
Fugas, Silva & Melia, 2010	Drivers, employees	Survey TPB	Behaviour	Self reports	No	Positive indirect

7.4 National road safety cultures and safety performance

There are numerous studies that compare road safety culture between countries, the most famous being the SARTRE studies (SARTRE4-Consortium, 2012). Studies like SARTRE typically use questionnaires to compare driver attitude and driver behaviour between countries (Rundmo, Granskaya, & Klempe, 2012; Wallén Warner, Özkan, & Lajunen, 2009; Warner, Özkan, Lajunen, & Tzamalouka, 2011; Öz et al., 2013). However, few have linked road traffic driving culture to accidents with disaggregated data.

Even if such studies can be viewed as studies of the relationship between safety culture and actual safety, they differ from the typical safety culture studies by the type of questionnaire items applied (Warner et al., 2011; Öz et al., 2013). Given the fact that road traffic is dominated by individual, private road users, traditional safety culture questionnaires with their focus on management's safety orientation, reporting of incidents etc. are not suitable (Nævestad & Bjørnskau, 2012). [3]

[3] Different national safety cultures have also been identified in other transport modes. The mentioned CRM-training in aviation received quite different responses and results depending on the crews' nationality. And Håvold (2007) identifies distinct national differences in seafarers safety orientation based on survey 2,558 seafarers from 27 countries. He identified five national (cultural) characteristics were calculated using Hofstede's Value Survey Model 94. Henning Boje Andersen studied safety culture among Swedish and Danish construction workers building the Øresund bridge between Sweden and Denmark. The study revealed clear safety culture differences. Swedish construction workers seemed to have better safety attitudes than their Danish colleagues (Andersen, personal communication).

8 Discussion

8.1 Prospective versus retrospective designs

Prospective research designs measure accidents *after* the safety culture has been measured, whereas retrospective designs compare the accident history with current safety culture or climate levels.

Grote (2012) argues that safety culture is only useful as a "leading indicator helping to identify norms and assumptions that potentially hurt safety performance. When used as part of post hoc explanations for accidents and incidents, safety culture tends to obscure the picture because by focusing attention on very broad assessments of norms and values it distracts from manifest organizational and management problems" (Grote, 2012: 1990).

Grote exemplifies the point by referring to the explanations given for the BP Texas City accident where it was concluded that lack of safety culture was an important reason for the accident. However this explanation was not sufficiently backed by detailed analyses of the mechanisms at play. Thus inadequate safety culture will often serve as post hoc "explanation" without necessarily providing much insight.

Some studies link safety culture scores and safety behaviour at the same point in time. Thus they neither "explain" accidents or incidents nor try to predict accidents or incidents. Such studies often reveal significant relationships. For instance Seo (2005) found significant links between safety culture and safety behaviour in a study of US grain workers.

According to Johnson (2007) most studies trying to measure safety culture are preoccupied with construct validity and lack predictive validity. However he identifies a few safety culture studies aiming to predict safety behaviour and/or accident/incident involvement (Cooper & Phillips, 2004; Gillen, Baltz, Gassel, Kirsch, & Vaccaro, 2002; Hofmann & Mark, 2006; Hofmann & Stetzer, 1996).

However the study of Cooper & Phillips (2004) merely establishes a link between safety behaviour and safety training, not between safety culture and accidents. The study of Gillen et al. (2002) is in fact not a prospective study – it reveals opinions about safety culture among injured construction workers. The study of Hofmann & Mark (2006) is however a prospective study that reveals a significant relationship between safety culture and medication errors. And Johnson (2007) found safety culture scores to directly predict safe behaviour and injury severity (lost workdays) and indirectly predict injury frequency through the mediating effect of safe behaviour in a study among manufactory workers. Zohar (2010) states that ".. safety-climate scholars' research .. we have achieved an enormous task of validating safety climate as a robust leading indicator or predictor of safety outcomes across industries and countries" (Zohar 2010).

According to Clarke (2006), inadequate safety culture is in fact not significantly correlated with accidents in retrospective designs in her metaanalysis of the association between safety culture and accidents. Only prospective designs demonstrate significant relationships with accidents..

Among the studies of the relationship between safety culture/climate and safety outcomes in the transport sector, there are just a few studies that are prospective studies. One is the study by Mearns et al. (2013), which reveals a correlation between increased efforts into reporting and learning in a Air Navigation Service Provider and a subsequent reduction in the number of serious incidents – indicating a true causal relationship. Two reviewed studies from the North American Rail industry are also prospective in the sense that they study safety outcomes after safety culture factors have been manipulated (FRA, 2003, 2006).

With retrospective designs it is in principle not possible to decide which way the causal direction goes. A positive link between safety culture and safety performance will normally be judged as evidence of safety culture increasing safety. However the study of Desai et al. (2006) obtains the reverse relationship, that accident rates are positively correlated with safety culture scores. As mentioned Desai et al. (2006) argue that the result is in accordance with a hypothesis that safety culture improves after accidents or incidents happen, i.e. that the organization in question tries to learn and manages to improve its safety culture.

Similarly Hale et al., (2010) argue that a "rise in reports of dangerous situations should be interpreted as positive evidence that awareness of danger and openness to report and tackle safety issues is increasing. We do not see it as evidence of increasing danger." (Hale et al. 2010, p 1030).

8.2 Self-reports of safety performance are problematic

In general the links between safety culture and actual safety performance are often weak (Clarke, 2006). Bjørnskau & Longva (2010) did not find any clear link between individual safety records and perceived safety culture. On the contrary, they found that those drivers who had reported one serious incident or accident were the ones who perceive the safety culture to be best, as opposed to those who have had no reported serious incidents or accidents.

According to Bjørnskau & Longva (2010) there are three important reasons for the lacking effect. First, one has to remember that the questions about safety culture all concern how a single employee perceives the general safety culture in their company, and are *not* about his/her own behaviour. The study did reveal a close link between one's personal behaviour (Rule following) and incidents and accidents, but not between an individual's perception of safety culture and their safety record.

Second, a key element of a good safety culture is that employees trust management to the point that they are willing to report their own errors and incidents. This is undoubtedly an important reason for the test results; those who perceive the safety culture to be good are precisely the ones who dare to report their incidents.

Third, it is also possible that those who had experienced a serious incident or accident discovered that management gave them just treatment, and focused on finding the true causes behind the incident. Accordingly, drivers who experienced accidents or incidents may perceive the safety culture as better than those who had not had any accidents or incidents precisely because of this experience of fair and just treatment after the incident or accident.

All these different explanations may be true, which indicates that the relationship between safety culture and actual safety should preferably be analysed by the use of prospective studies where safety outcomes are registered in a period after safety culture is mapped in order to secure a proper causal relationship. In addition because reporting of mishaps, errors, incidents or accidents are central for a good safety culture, safety outcomes should preferably not be registered by use of self reports.

9 Conclusion

There is fairly good evidence of the association between safety culture and safety performance in correlation studies and retrospective designs, in particular when safety performance is measured by use of self reported safety behaviour. There is less support for the hypothesized link between safety culture and accidents/injuries. In retrospective designs some studies reveal a negative relationship – accident/injury rates are lower when safety culture is good, whereas others find the opposite relationship arguing that accident and injuries will improve safety culture.

Indeed several studies find a reverse relationship between safety culture and accidents/injuries in retrospective studies. This has been interpreted as an indication of learning from accidents, i.e. that safety issues are given more focus and thus a better safety culture develops if there has been accidents or injuries. Another and perhaps more likely mechanism is that reporting of errors, injuries, mishaps etc. is an essential component of a good safety culture. Thus in organizations where there is a good safety culture more of the injuries and accidents that happen are reported.

Either way, a major problem with retrospective studies (and mere correlations) is that is in principle not possible to determine the causal relationship between safety culture and accidents or injuries.

In prospective designs where changes in accident/injury rates are registered after safety culture improvements, the causal link is much less problematic. There are however few such studies in the literature, and very few among safety culture studies in transport. Nevertheless, the few studies that exist seem to indicate that improved safety culture reduce accident and injury rates.

Most of the studies reviewed have used some kind of safety behaviour as outcome variable, and not accident or injury rates. These studies generally reveal the expected association between safety culture scores and safety behaviour (wearing protective clothes, hard hats etc.). This hardly surprising and the validity of such measures as true indications of safety is questionable. One could perhaps argue that such consistencies are to be expected. Because of the well-known tendency for people to reduce cognitive dissonance it would be difficult for people to state that they do not themselves act safely when they state that safety training is good, managers show great safety concerns etc.

Another possible problem is that the mere use of safety equipment is not in itself a proof of safe behaviour. There is a vast research literature about behavioural adaptation from road safety research showing that safety equipment can be utilized for other purposes than increased safety ("risk compensation"). According to

Haukelid (personal communication) some offshore workers removed the glasses in the safety goggles so as to appear to use them, because they were penalized for non-use. This is of course not safety behaviour, but could be classified as such by an expert if not detected.

Many safety culture studies have placed most emphasis on the construct validity of the concept. However, during later years the criterion validity of the concept, i.e. the association between safety culture and safety outcomes has been investigated in a number of studies, also within transport. There are however important methodological issues that must be dealt with in such studies, both concerning the problem of causality in retrospective designs and the variables used to measure safety performance.

If we refrain from studies i) outside transport, ii) retrospective studies, and iii) studies that use behaviour and not accidents or injuries as dependent variables, we are left with only a handful of studies within transport. These studies indicate a positive relationship between safety culture improvements and safety outcomes.

There is accordingly a need for more studies of the relationship between safety culture and safety outcomes in the transport sector, in particular predictive studies that are not hampered by the methodological problems identified.

10 References

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