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How can we improve safety culture in transport organizations? A review of interventions, effects and influencing factors.

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Abstract:

The main objectives of the present study are to a) map interventions that can be used to develop good safety culture in transport companies within road, sea, air and rail transport, b) assess expected effects of interventions on safety culture and safety outcomes and c) identify factors influencing safety culture change. By systematically reviewing the scientific literature, we identify 20 studies that describe and evaluate interventions to improve safety culture in road, rail, sea and air transport organizations. The review is reported according to PRISMA guidelines. The interventions studied vary widely in their comprehensiveness, but a lack of both standardized outcome measures and controlled evaluations means that it is difficult to compare different interventions, either within or across sectors. Most studies, however, report improvements in safety culture where this is measured. We find that attempts to understand the mechanisms of cultural change leading to behavioural change and improved safety performance are lacking. Although safety culture is an organizational measure, we only found one peer-reviewed study of an attempt to improve safety culture in a single air transport organization and no studies of this in the maritime sector. More studies of this were found in road and rail. We conclude that on the whole the reviewed safety culture interventions seem to be effective, but comprehensive and resource demanding. We suggest that future research should develop simpler interventions by focusing on the basic requirements of safety culture change. We contribute to this by identifying four key activities (*content*) which seem to be common in all the reviewed interventions, and eight key factors (*process*) influencing the success of efforts to influence safety culture. The basic requirements of safety culture change seem to be to institutionalize joint discussions of work place hazards facilitated by manager commitment and employee involvement.

1 Introduction

Transport accidents represent a serious public health problem. Recent data shows that 1.24 million people die each year on the world's roads and between 20 and 50 million people sustain non-fatal injuries (World Health Organisation, 2013). Numerous people lose their lives annually in maritime accidents, including 24,000 in the fishing sector alone (International Maritime Organisation, 2015). In 2015, 1,739

people were killed or seriously injured in railway accidents in the EU-28.¹ In comparison, there were on average 611 worldwide air traffic fatalities each year in the period 2006-2015.²

It is estimated that over a third of all fatal road accidents occurring in Europe are work-related (Adminaite, 2017; Nævestad, Elvebakk & Phillips 2015). Thanks to safety strategies targeting general road user safety behaviours, as well as improvements in technology and infrastructure, the number of road fatalities has steadily decreased (Elvik, Høye, Vaa & Sørensen 2009). To reduce road accident risks for all road users further, there is a need to encourage employers of people who drive for work to improve safety in their organizations (Adminaite, 2017). To do this it may help to learn from safety management strategies developed in the safer transport sectors such as aviation.

Traditionally, transport safety interventions have done little to address safety culture directly (Ward, Linkenbach, Keller & Otto 2010, Nævestad & Bjørnskau 2012). In this current paper we ask whether empirical research on attempts to improve safety culture in transport settings can be used to increase the extent to which it is accounted for by traditional transport safety interventions. Before we describe our aims more precisely, we provide background to the study by describing what safety culture is according to some main approaches, and summarising how it has been accounted for by the four main transport sectors in the developed world to date.

1.1 What is safety culture?

It is widely recognized that safety culture is important in organizational settings in hazardous industries (Nævestad, 2010a). The concept is usually traced to the 1986 Chernobyl disaster, which led to a shift of focus in the investigations and studies of safety in organizations. Several major accident investigations subsequently identified safety culture as a major contributing factor (e.g. Cullen, 1990; NASA, 2003).

Organizational safety culture can be defined as “safety relevant aspects of culture in organizations” (Hale, 2000; Antonsen, 2009; Nævestad, 2010a). These aspects may refer to a range of different cultural phenomena such as: “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).

As a consequence of the multiplicity of definitions and operationalisations of culture in organizations, it can be argued that the concept of safety culture is fuzzy, as it is abstract and ambiguous enough to lend itself to a range of different specifications. Researchers have pointed to a fragmented literature (Guldenmund 2007) and terminological confusion within safety culture research (Glendon 2008). However, in spite of this diversity in the specifications of safety culture, studies of organizational safety culture often seem to treat safety culture as shared and safety relevant ways of

¹ http://ec.europa.eu/eurostat/statistics-explained/index.php/Railway_safety_statistics

² <https://www.statista.com/statistics/263443/worldwide-air-traffic-fatalities/>

thinking or acting that are (re)created through the joint negotiation of people in social settings (Nævestad, 2010a).

Research on culture in organizations is often subsumed under two approaches: the functionalist and the interpretive approach (Glendon & Stanton 2000).³ Functionalist and interpretive scholars differ in their understanding of what safety culture is, their understanding of how safety culture should be measured, and their views on the manageability of safety culture (Nævestad 2010a). The functionalist approach views culture as a critical variable (Smircich, 1983) influencing certain outcomes: safety, reliability and so forth. Interpretive researchers, on the other hand, conceive of culture as a root metaphor (Smircich, 1983) for the organization, and approach organizations as if they were cultures.

These approaches give rise to different views on how to measure safety culture. It has been argued that the functionalist approach upholds a reified notion of culture, presupposing that it is an entity that one can measure and then evaluate the effects of (Antonsen 2009). Interpretive scholars, on the other hand, do not view organizational culture as a distinctive entity within the organization, but as an approach to the organization; as an aspect of all organizational phenomena. The former approach often tends to study safety culture quantitatively, as safety climate, while the latter approach tends to use qualitative methods,

Quantitative studies focus on identifying the key aspects of safety culture and their relations to safety outcomes. Safety culture is generally measured by means of safety climate questionnaires (Guldenmund, 2000), and safety climate can be conceived of as “snapshots”, or transient manifestations of safety culture (Flin et al 2000). We use the terms culture and climate interchangeably. The most studied and well-documented characteristic of a good safety climate is senior managers’ commitment to safety (Flin, Mearns, O’Connor & Bryden 2000; Pidgeon & O’Leary 2000). This is the prime factor in measurements of safety climate (Flin et al. 2000). Quantitative measurements of safety culture are necessary to compare scores over time, between organizations and to quantify the relationship between safety culture and safety outcomes. Qualitative studies focus on how safety culture provides a frame of reference that guides individuals’ interpretations of actions, hazards and their identities, and which motivates and legitimizes behaviours that have an impact on safety (Antonsen, 2009, Nævestad, 2010a).

Interpretive and functionalist scholars’ different views on what safety culture is give rise to diverging views on the issue of cultural management. Functionalist scholars presuppose that safety culture can be changed through various managerial efforts, indicating the wanted way of doing things in organizations (e.g. Schein 2004). Interpretive scholars, on the other hand, argue that changing and managing safety

³ These approaches can be referred to as ideal types (Weber 1997): analytical simplifications that do not exist in their pure form in reality. It is evident that the situation in the research field of safety culture is more complex than this ideal typical outline indicates. Although such simplifications are required to distinguish some of the major differences in research on safety culture, it is important to remember that not all safety culture scholars are explicit about their orientation (i.e. functionalist or interpretive). Safety culture research may be explicitly or implicitly interpretive or functionalist. It may also apply an explicitly or implicitly mixed approach (cf. Nævestad 2010b).

culture is a very demanding task, as organizations comprise sub-cultures, as cultures are created and recreated through group members' interaction and negotiation over meaning (e.g. Pidgeon and O'Leary 2000;). Thus, they uphold a bottom-up approach to culture change, and criticize the functionalist assertion that leaders initiate culture in organizations (Glendon and Stanton 2000).

While interpretive scholars tend to refer to culture as something the organization *is*, understood as the beliefs, attitudes and values of its members regarding the pursuit of safety, functionalist scholars refer to culture as something the organization *has* (Bate 1992) understood as the structures, practices, controls and policies designed to enhance safety (Department for Transport, 2004). The first way of thinking focuses on informal aspects of organizational safety, while the latter focuses on formal aspects of organizational safety. Although work on organizational safety must address both formal and informal aspects of safety, it may be useful to think of organizational safety culture as the informal aspects of safety in organizations in order to distinguish it from the formal aspects, specified as rules, procedures and so forth (Antonsen, 2009). We refer to the latter as safety structure, or safety management systems (SMS). SMS's typically comprise formal and systematic risk management through management policies and regular risk assessments which provide the basis for suitable measures to prevent identified risks, e.g. procedures, training (Nævestad et al., 2015).

1.2 Safety culture in transport

Road, rail, sea and air transport companies have in common that they employ human operators and move people or goods from place to place. They each deal with the same potential negative side effects related to their basic activities; i.e. accidents killing and injuring people. Professional transport is a time-critical task; delays in one transport assignment may often have negative impact on impending assignments, affecting a broad network of actors depending on the transport. Additionally, transport assignments in all the sectors are conducted under changing and sometimes challenging conditions, which often may involve a constant balancing between the consideration of efficiency versus safety. Moreover, even though the technology, infrastructure and socio-cultural contexts differ, companies in different transport domains face similar organizational challenges related to: (i) the human factors influencing operators' strengths and weaknesses; (ii) the organizational management systems developed to contain and reduce the effects of the operators' weaknesses and fully utilize their strengths; and (iii) safety culture. The idea that all transport companies – independent of mode – need to manage these challenges is supported by evidence that organizational safety culture is linked to management factors independent of transport domain (Bjørnskau & Longva, 2009).

The safety record of international airline companies or hazardous goods hauliers suggests that they have largely succeeded in managing safety and establishing positive safety culture, while the poorer safety record of some other transport branches suggests less success. Putting varying framework conditions to one side, it is clear that the latter may be able to learn from approaches taken by the former. This applies for instance to dealing with safety versus efficiency considerations, under varying conditions, while facing passengers or customers of goods. This line of argument is

reflected in the recent report on Safety Management Systems by the International Transport Federation (ITF). The aim of the report is to share experiences and learn lessons from applying SMS in different transport modes. The rationale here is similar to ours: on the one hand transport service providers in all sectors need to manage the risks they pose to employees, the public and the environment while operating in complex sociotechnical ecosystems; on the other hand, safety outcomes and the content and regulation of safety management approaches vary considerably across sectors. It is natural to ask whether safety outcomes vary in part due to varying approaches to factors like SMS and safety culture, and if so, what are the lessons to be learned.

Air. The safety culture level of aviation is used as a model for improving safety culture in oil and gas (Hudson 2003) and also in other industries and sectors. Reason (1997, 1998) provides a compelling description of the key facets of safety culture, using the formal and informal aspects of incident reporting in aviation as the model. His description of an informed safety culture seems to be the most cited in the field. He identifies five important aspects of safety culture. The first aspect is an informed culture, which means that the organization collects information about both accidents and incidents, and carries out proactive counter measures. The second aspect is a reporting culture, which means that all employees report their errors or near misses, and take part in initiatives to improve safety. The third aspect of safety culture is a just culture, which means that 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. A just culture is a key premise of a reporting culture. The fourth aspect is a flexible culture, which involves that the organization and the people in it are capable of adapting effectively to changing demands. The final aspect of safety culture is a learning culture, which means that the organization learns from incident reports, safety audits and so forth, resulting in improved safety. An informed and reporting culture is likely to foster a learning culture. Given the safety levels of aviation, and the fact that its practices have been used to derive safety culture theory, we might expect that much has been done to empirically evolve safety culture interventions in this sector.

Maritime. According to Ek, Runefors & Borrell (2014), seafaring is still among the most hazardous of occupations. Merchant shipping is known to have a high rate of fatalities caused by both occupational accidents on board vessels and shipping accidents, involving e.g. foundering, grounding (Ek et al 2014). Based on requirements laid by The International Maritime Organization's (IMO) International Safety Management (ISM) code (made statutory in 1998), it seems that the main safety prevention focus in the maritime sector is on structural, formal aspects of safety management systems, rather than safety culture as we define it. The ISM code was developed after several severe maritime accidents were found to be caused by human error and insufficient safety management systems. IMO's primary goal with the ISM code was to gradually create a new safety culture in the maritime industry (Kongsvik et al 2016). Ek et al (2014) argue that, at the time it was implemented, the ISM code's focus on human factors and safety culture was a novel approach in maritime safety regulation.

Rail. The application of the organizational safety culture concept in aviation and other sectors, has influenced safety practitioners, accident investigators and researchers involved in railway safety to apply the concept to rail (Bjørnskau & Nævestad 2013). 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). US railroad safety authorities have included safety culture in their regulatory repertory, through the Railroad Safety Improvement Act of 2008 (Amtrak 2015) Under the act, the Federal Railroad Administration (FRA) encourage railroad operators to build strong safety cultures by developing innovative methods, processes, and technologies to address the risk factors that cause accidents and injuries.

Road. Compared with other transport sectors, it seems that the safety culture perspective only has been applied to a limited extent in the professional road sector. (It seems that the majority, but not all, studies in this sector refer to heavy vehicles, i.e. heavy goods vehicles and buses). A literature review of safety management interventions that have been effective in reducing injury outcomes in heavy vehicle transport does not directly mention safety culture among the factors that have been found to reduce crashes/injuries (Mooren, Grzebieta, Williamson, Olivier & Friswell 2014). It is likely that this reflects a lack of implementation in the sector, rather than a lack of effect. Additionally, it seems that most national road safety authorities do not yet employ the safety culture concept systematically, despite the fact that research indicates that safety culture influences transport safety behaviour and safety outcomes in road transport organizations (cf. Department for Transport, 2004, Wills, Biggs & Watson 2005 and Davey, Freeman & Wishart 2006; Girasek 2012). Research suggest that safety culture may have great potential for improving traffic safety (American Automobile Association, 2007; Ward et al., 2010), and reviews of safety management strategies in professional road transport encourage the implementation of principles from the safety culture research (American Trucking Associations Foundation 1999; Short, Boyle, Schackelford, Inderbitzen, & Bergoffen, 2007). A recent development in the field of professional traffic safety is the EN ISO39001:2012 “Management systems for traffic safety”, which has been described as a safety management system (SMS) for traffic safety and a tool for building safety culture.

To summarise, recent research suggests that safety culture explains considerable variation in safety performance in various transport forms, and that it has considerable potential for improving safety in land- and sea-based transport, as well as some branches of the air sector (Ward et al 2010; Nævestad & Bjørnskau 2012; Bjørnskau & Nævestad 2013). Hence, more research is needed for the safety culture perspective to become as crucial across the transport sector as it is across hazardous industries (Nævestad, 2010a). In addition, it is crucial to clarify how this knowledge can be used to enhance transport safety, both by the transport companies themselves and by regulatory authorities aiming to improve the safety level in their respective transport sectors.

Study aims

The main objectives of the study are therefore to: 1) Map intervention measures that can be used to develop a good safety culture in road, sea, air and rail transport companies, 2) Assess expected effects of these measures on safety culture, safety behaviour and safety outcomes and 3) Identify the factors influencing safety culture change.

Our literature review identifies 20 studies of interventions to improve safety culture in road, sea, air and rail transport companies. The results indicate that the interventions often coincide with improved safety culture, safety behaviours and lower accident numbers, but that those aimed directly at improving culture, are comprehensive and resource demanding. We suggest that future practice should be more balanced, and focus on the fundamental requirements for successful change of broader safety culture. We contribute to this by identifying four key activities (*content*) which seem to be common in all the reviewed interventions, and eight key factors (*process*) influencing the success of efforts to influence safety culture.

2 Methodological approach

2.1 Systematic literature review

The purpose of the literature review was to review studies evaluating the effect of interventions aimed at improving safety outcomes by influencing safety culture. We describe the search using the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (Moher et al., 2009), where appropriate.

Search process. Search term combinations were evolved for each transport sector (air, maritime and road) by scanning titles retrieved within each transport sector. Initial search terms were based on an initial orientation of the literature from previous reports by the authors and preliminary searches. The search was undertaken for air, sea and road transport companies in September and October 2016 using ISI Web of Knowledge and Springer Link. A separate search was conducted for rail transport companies using the TRID database.

The final search terms by sector (for keyword, title and abstracts unless indicated otherwise) were.

- AIR: (safety AND intervention AND “air pilot”) or (safety AND intervention AND helicopter) or (safety AND training AND “air pilot”) or (safety AND training AND helicopter) or (safety AND “air pilot” NOT training)
- SEA: (maritime AND safety) or (seafarer AND safety) or (occupational AND maritime AND safety AND effect)
- ROAD: (safety AND intervention AND “truck driver”) or (work-related AND road AND safety) or (fleet AND safety) or (organizational AND intervention AND safety AND road) or (safety AND effect AND “professional driver”)

RAIL: Safety culture (keyword) AND campaign OR evaluation OR assessment OR intervention OR programme OR program OR training OR education OR regulat* OR authorities OR policy OR measure OR method.

Search terms were broader in the case of the maritime sector, because we found it necessary to keep the search terms broad to capture relevant articles.

Selection process. We used the following criteria inclusion:

- Written in English
- Publication year later than 1995
- Focuses on one of the selected transport sectors
- Makes first hand comments about the effect of an organizational-level intervention to improve safety outcomes by influencing safety culture

Studies matching these criteria were identified in a two-stage screen. In the first stage we screened “hits” obtained using search word combinations for studies on the effects of any organizational-level intervention to improve safety outcomes. In this first stage we screened titles or – if the nature of the study was not clear from the titles – abstracts. In the second stage of the screen, we selected the full abstracts of those studies identified from the first screen, and screened for organizational-level interventions that aimed to improve safety culture. Finally, studies identified from other sources were added to the selected articles. These were studies that the authors were familiar with from other projects, although three of the rail articles were identified through the reference list to the single rail article initially included (Zuschlaug, Ranney & Coplen 2016; cf. Fig. 1).

Bias. Potential subjective bias in selecting studies arose from deciding whether to include or exclude studies according to whether the intervention they described attempted to improve safety culture. To mitigate this, we identified criteria for inclusion: the studies did not need explicitly need to state that the intervention was aimed at improving “safety culture”, as long as the goal was to improve safety by influencing shared, safety relevant ways of thinking or acting. For example, we included studies of driver group discussions on road safety and studies of organizational-level safety campaigns, but we excluded a study of manager education on whiplash injuries, since the latter was regarded as addressing only a narrow aspect of safety relevant thinking or acting.

Data collection. We use the following questions as a systematic checklist in our presentation of the interventions:

I) Background. What is the focus of the intervention: one or several aspects of culture, focus on other elements than culture?

II) Content of the intervention. Who is supposed to implement the intervention, and what kind of activities does the intervention involve?

III) Evaluation of the intervention. Which effects/outcomes are studied, e.g. safety culture, safety behaviour, accidents/incidents, and how are they measured (e.g. Qualitative/quantitative, before and after study with control group)?

IV) *How effective is the intervention?* How effective are the interventions when it comes to influencing: a) safety culture, b) safety behaviours, c) safety accidents, incidents?

V) *Factors facilitating and impeding culture change.* We provide a systematic discussion of factors impeding or facilitating the implementation of the different interventions, and how results are affected.

3 Results

Figure 1 shows the numbers of search results and studies screened, assessed and included in the review, by transport sector. Studies were excluded from the first screen mostly because they did not assess active attempts to intervene at organizational level to improve safety levels. In the second screen, studies were excluded because they did not attempt to improve safety by addressing an aspect of safety culture.

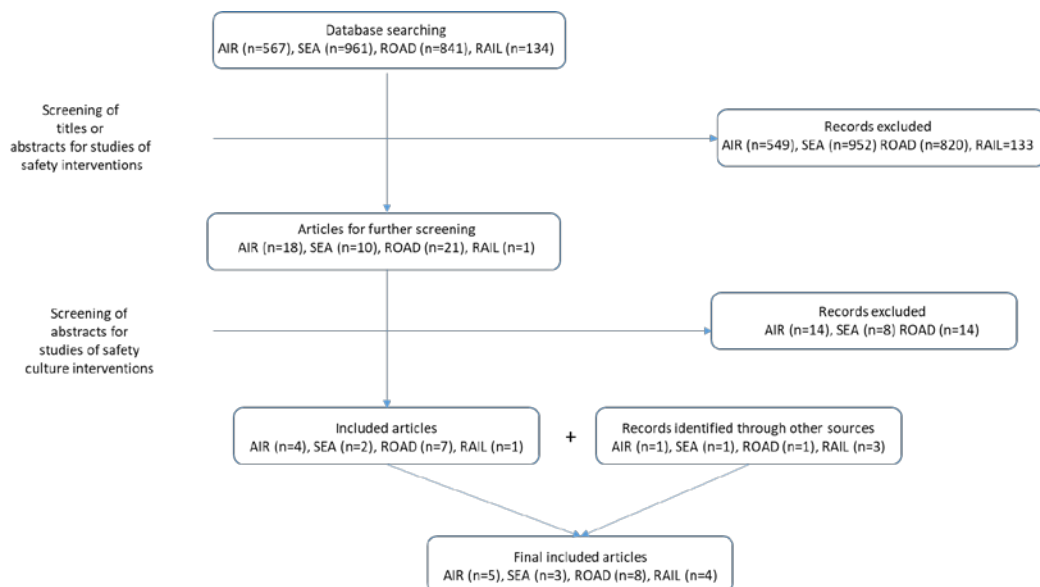


Figure 1. Search flow diagram.

We retrieved 20 studies describing the content and effects of interventions attempting to influence safety culture in transport organizations. There were 5 studies from air transport (Table 1), 3 from sea transport (Table 2), 4 from rail transport (Table 3), and 8 from road transport (Table 4). The results of our assessment of studies are described by sector below, as structured using the criteria set out above.

3.1 Studies of safety culture interventions in aviation

The studies retrieved dealt with 5 interventions, including one comprehensive program-type intervention (Edkins, 1998), a more focused program attempting to increase management safety commitment (Belland, Olsen, Lary, 2010), and simpler interventions targeting understanding of crew resource management (Boedigheimer, 2010) and of the latent causes of accidents (Teperi, Leppänen & Norros, 2015)

(Table 1). Surprisingly, only one of the studies described evaluated an attempt to increase safety culture in a single airline company focusing on one operational base, using another base as control (Edkins, 1998).

TABLE 1 HERE

Taken together, the studies suggest that effects of the different interventions on culture, behaviour and safety are positive, although none of the studies attempts to trace the effects of the intervention from safety culture to safety behaviour to organizational safety performance. Use of different effect measures makes it difficult to compare the effects of different types of intervention.

Several of the articles on interventions in aviation point to various factors that may have influenced improvements in safety culture. The INDICATE intervention described by Edkins (1998) explicitly deals with culture. The intervention was motivated by safety problems in regional airline sector, and was developed from reviews of common elements of existing safety programs, and in part on a model of organizational accident causation by Reason. Consequently, the intervention was comprehensive, requiring extensive resources over at least eight months. An operational safety manager was hired, and active participation from staff and managers was required in several focus groups and safety meetings. The program also had close cooperation with the Bureau of Air Safety Investigation, who took action based on outcomes from the program.

The cultural intervention described by Belland et al. (2010) was motivated by a spike in dangerous incidents involving aircraft, and involved a step change in management safety commitment. The latter may have been particularly important for the safety improvements observed, given that there is a strong command hierarchy in the US Navy, where the intervention was conducted. The intervention described by Boedigheimer (2010) was motivated by concerns about the effects on safety of replacing a whole fleet of helicopters. Thus a major organizational change was leveraged to achieve improvements in knowledge, attitudes and culture. Extending the scope of the courses to include other stakeholders such as ground crew was judged to be effective in limiting crew stress. Linking conclusions from fieldwork to recruitment processes helped elevate the importance of human resource management aspects of the training, and achieve a change in safety attitude throughout the organization.

3.2 Studies of safety culture interventions in maritime transport

We found relevant studies of only three interventions to improve safety culture in sea transport (Table 2). Lappalainen, Kuronen & Tapaninen (2012) give an assessment of regulatory change requirements on safety management systems on safety culture in the whole shipping sector in Finland and internationally, while the other two studies dealt specifically with the effects of bridge resource management training. We found no studies of an intervention to improve safety culture in a single shipping company.

TABLE 2 HERE

The sector-level study indicates that the introduction of international requirements on safety management systems was positive for both safety outcomes and safety culture, although this is based on interviews and literature review, i.e. there was no quantification of the effect on safety culture, nor on how this was manifest in terms of safety behaviours and performance (Lappalainen et al., 2012). The studies on bridge resource management training do not directly assess the effects on safety culture, but it should be noted that the observed changes to safety knowledge, attitudes and behaviour in these studies were generally poor (Röttger, Vetter & Kowalski 2016; O'Connor, 2011). Items measuring these aspects (e.g. safety knowledge and attitudes) are sometimes included in scales measuring maritime safety culture (cf. Håvold 2005).

It is possible to extract from Lappalainen et al. (2012) various factors that may have influenced change in safety culture. Maritime operators found it important that the ISM code placed formal requirements at the company. Top manager commitment, experience of ownership of the SMS for the personnel, reducing paperwork to manageable levels and communication between office and ship were identified as contributing to successful implementation of safety management systems. When it comes to factors impeding culture change, under-reporting of incidents, especially minor ones, is mentioned as an important factor. From the interviews, it was found that incidents are underreported, especially minor incidents. Increased paper work was also an important impeding factor. According to interviewees, who were generally satisfied with the ISM code, the documentation and reporting procedures of the SMS were too complicated and detailed. From the literature review, the most severe challenges identified for the implementation of the ISM code included resistance to change, too much paperwork, frequent staff turnover, lack of human resources, low level of education, and time pressure to register the SMS (in the implementation phase) (Anderson 2003 and Pun et al., 2012 in Lappalainen et al, 2012). Authors note however that the initial resistance toward the ISM, i.e. by people who felt the ISM discredited their professional competence, has decreased over time.

The studies in bridge resource management training imply that as a measure to influence safety culture, generalized training packages may be insufficient (Röttger et al., 2016; O'Connor, 2011). Rather, training may need to be based on a needs analysis tailored to specific work situations.

3.3 Studies of safety culture interventions in rail transport

We retrieved studies of four relevant interventions in rail transport, each of which is a comprehensive attempt to improve safety culture directly (Table 3). Two of these (Zuschlag et al., 2016 and Amtrak, 2015) were motivated by FRA activities on safety culture. From 1998 to 2012, the FRA Office of Research and Development initiated an evaluation program aimed at identification and evaluation of system-based safety culture interventions. Under the program, the FRA sponsored the implementation of pilot programs, such as Clear Signal for Action (CSA) and evaluated program effects (Ranney, Zuschlag, Morell, Copen, Multer & Raslear, 2013). This program was piloted at three sites (two in Union Pacific and one in Amtrak). The subsequent decision of these organizations to implement the program throughout their organizations appear to be inspired both by the success of the FRA-sponsored pilot,

and as a response to the Railroad Safety Improvement Act of 2008 (Ranney et al., 2013). In a general summary of findings from the entire research project, Ranney and colleagues (2013) argue that the implementation and success of these pilots illustrated to the railroad industry the value of both safety culture, and of objective evaluations. The other two interventions we found are included in the study by Roberts, Hetting, Webb, Colleary, Turner, Wang, Toussaint, Simpson & White (2015), and are also attempts to improve safety culture in single transport organizations.

TABLE 3 HERE

The effects of the interventions were generally positive in terms of safety culture (which is surveyed explicitly) and on safety behaviour and performance, although the Safe-2-Safer intervention is less positive (Table 3). The improved safety culture reportedly resulting from “Clear Signal for Action” (CSA) coincided with large drops in risk behaviours and accidents (Zuschlag et al., 2016). Except for Zuschlag et al (2016), none of the studies have been robustly evaluated with the inclusion of control groups.

Given the relevance and relative quality of the interventions described for rail transport, it is interesting to consider factors that may have influenced the change in safety culture. A clear motivation for the intervention initiated in Union Pacific was recognition of a negative rail safety culture, involving a command-and-control management style, reactive tendencies, and inclinations to inflict punishment for accidents and injuries (Zuschlag et al., 2016). The CSA intervention aimed to change these negative aspects of railway safety culture, by introducing the following aspects of positive safety culture, based on the research of e.g. Reason (1997): 1) non-disciplinary, 2) proactive, 3) systems-safety-analysis orientation, 4) cooperative and 4) sustainable. According to Zuschlag et al (2016), these safety cultural features will improve safety by creating an environment where individuals freely exchange information throughout the organization, in manners that are beneficial for safety.

CSA combined three core activities: (i) Peer-to-peer observation and non-confrontational feedback on safe working, based on a checklist of risky/safe behaviours developed from analyses of injury reports and working conditions. (ii) Continuous improvement through joint analysis of data (e.g. explanations of risky behaviour arising from peer-to-peer observations) and development of action plans by workers and managers, with support of steering committee. (iii) Safety-leadership development, which involves the training of managers to sponsor non-disciplinary proactive safety practices such as peer-to-peer feedback and continuous improvement. The intervention was thus comprehensive, requiring a considerable amount of resources in the test groups over a period of three years. Employee involvement and general willingness, high trust levels of newer employees and union cooperation were also viewed as facilitating implementation. On the other hand, the fully successful implementation of the intervention was limited by the initial poor relationship between managers and employees. Continuity was also challenging, partly hampered by a couple of key managers who quit to start in a new job in the rail company. Thus, it seems that the successful implementation of the intervention to some extent was contingent on the strong focus and dedication of particular managers.

The Safe-2-Safer program was initiated to meet the mentioned FRA requirement (Amtrak 2015). Despite having weaker effects on safety, the program was also comprehensive, consisting of two key activities: (i) Improving leadership on safety issues: training and coaching of management employees; (ii) Peer-to-peer observation process similar to that described above. The authors analyse why the program failed to improve safety despite its comprehensiveness. Firstly, it was one of several safety programs and initiatives in Amtrak, and not integrated in the overall safety plan. Secondly, there was failure to engage employees at all levels of the organization, possibly linked to the fact that voluntary observers often failed to observe compliance, and resistance among experienced employees. Thirdly, only a minority of members of the steering committee participated fully, which reflected their level of engagement. Supervisors and managers were confused about their roles, and they were shut out of the steering committee by design. This meant that many employees were unclear about who was leading the program and who to contact to discuss safety issues. Finally, not all unions participated in the program, and thus implementation varied between locations.

The authors also observed challenges that demonstrate how difficult and complex it is to attempt to change culture. Employees were not held accountable for unsafe practices as a result of managers over-compensating for a previous tendency to blame employees. Injury rates as a performance goal was removed, with the result that there were no easily measurable performance goals for safety, and managers were no longer held accountable for safety outcomes. The injury ratio was removed as a safety metric to encourage injury reporting. Unintended consequence of this was de-emphasizing the importance of reducing employee injuries. Also there were no incentives to reinforce success, and no targets were set for measuring progress toward program goals.

Both interventions included here from Roberts et al. (2015) were motivated by a recognition of poor safety records. The interventions were carried out in the New York City Transit Authority (NYCT) and the Washington Metropolitan Area Transit Authority (WMATA). The NYCT intervention began by mapping the extent to which rules were ignored, risk-taking occurred, employee involvement in safety and changes needed. A survey identified safety culture, expressed by behaviour, as a major problem, and identified a multitude of subcultures in the organization. The resulting intervention was comprehensive, involving visible management commitment, training, campaigns and promotion of collaborative analyses and discussions between managers, supervisors, employees and labour representatives. The WMATA intervention was also comprehensive. A safety and security subcommittee, was set up and safety culture survey revealed fear of reporting. Actions implemented included management changes, including safety in the mission statement, moving the safety department to under the general manager, and increase employees and resources committed to the safety department. A non-punitive close call reporting system was established, and a campaign to improve employee involvement was initiated.

From analysing the case studies presented, and comparing their essential elements, Roberts and colleagues note that targeting all eight key components of safety culture appears to lead to successful improvement of safety culture. The eight key

components they identified and focused on were strong leadership, employee/union shared ownership and employee involvement and a general focus on cooperation, effective safety communication, organizational learning, reporting and investigating systems in which employees have full confidence, employee recognition and rewards, and high levels of organizational (mutual) trust.

3.4 Studies of safety culture interventions in road transport

Our search identified eight relevant studies of safety culture interventions in road transport (Table 4). Generally, the interventions have a broad safety focus, i.e. safety culture is not the primary target of the interventions. Effects on safety culture are only measured (or assumed to happen) as an additional effect of a broader set of organizational safety measures (e.g. Goette, Spiegel, Tarr, Campanian & Grill, 2015). The exception is Naveh & Katz-Navon (2015), which is the only study we reviewed that attempts to explicitly link changes in safety culture to safety performance.

TABLE 4 HERE

The interventions vary widely in resource intensiveness. On the one hand there are relatively simple interventions (group discussions, training or company campaigns) aimed at improving driver safety (Gregersen, Brehmer & Moreén., 1996; Salminen, 2008). Only safety outcomes are evaluated by these studies, but in the case of Gregersen et al. (1996) the evaluation design is robust, and substantial improvements are observed. On the other hand, there are several occupational health and safety-based, comprehensive long-term attempts at improving road safety management in order to reduce accidents involving employees of large corporate enterprises who drive for work (Murray, White, & Ison, 2012; Murray, Ison, Gallemore & Nijar, 2009; Wallington, Murray, Darby, Raeside & Ison 2014). The latter studies are useful in their rich descriptions of the content and phasing of interventions targeting all levels of the organization. Again the results are largely positive, although due to the scale of intervention, results are largely based on descriptions of safety trends over time.

Naveh & Katz-Navon (2015) study a national authority-backed drive to improve road safety in diverse organizations employing drivers-for-work in Israel. It is based on an ISO-39001 intervention, and is a relatively robust, controlled evaluation, showing that reductions in safety violations coinciding with organizational changes were mediated by improvements in safety culture. Finally, Newman & Oxley (2016) describe a research-driven intervention to improve safety management for occupational drivers by targeting supervisory skills in the recognition and management of risky driver situations. Although the study claims improved safety culture, the effect is based on very low numbers.

The more comprehensive of the studies described above give detailed descriptions of factors facilitating cultural change, based on the experience of the researcher-practitioners involved. Wallington et al. (2014) claim that utilization of the data available to engage stakeholders to further develop the program helped the change process, as did use of online tools to lower intervention costs and increase availability of measures. Murray et al. (2009) claim that a key motivating factor for the

intervention was the appointment of a national HSE manager with transport experience (which led to identification of risk and action to address it). Membership of government sponsored benchmarking project was also important in helping to set baseline and industry targets, and get ideas from other organizations. Structuring the program using the (WIPE) fleet safety process model helped set out the business case in terms of ethical, societal, legal and financial reasons to focus on fleet safety. Employee consultation was also important to identify new safety improvements (e.g. vehicle specs., load security, driver training). External recognition of the program (rewards) was also key in program's perceived success. Barriers were also overcome by committed management champions at several levels of the organization. A drive for continuous improvement and learning from accidents (whether at fault or not) was also key.

Each of the Wallington et al (2009) and Murray et al (2012) interventions is based on premise that there are no "silver bullets" for improving occupational road safety, but combination of cultural-, management-, driver-, vehicle-, journey-, as well as societal-based factors are needed for success. However, studies of simpler interventions suggest that interventions need not be resource intensive to achieve positive safety culture effects. For instance, the effects on safety of Gregersen et al.'s (1996) group discussion measure are not dissimilar to the effects of the much larger, comprehensive and resource intensive studies of Murray et al (Table 4). Given this, it seems reasonable to conclude that driver-led group discussions are more cost effective than comprehensive programs, and may be far more viable for smaller transport companies with limited resources. Salminen (2008) point to two main strengths of the discussion method: (i) it encourages employee ownership of the process, by getting them to work together to suggest and implement solutions to traffic safety problems; and (ii) it leverages group pressure for safe driving behaviour. The drawback is that by focusing on drivers, the company level is excluded, raising the possibility of lack of managerial commitment to the change process. This raises questions about the extent to which organization-wide change in safety culture can be achieved by simpler, less resource-intensive interventions, and may also be linked to claims that Gregersen et al.'s (1996) findings are not generalizable (Murray et al., 2012).

Wallington et al. (2014) claim that there can be economical benefits of resource intense programs, as long as managers can be persuaded by a business-case to make an initial investment. The question then, however, may be whether the company can afford the initial investment in the first place. Many smaller road transport companies are known to operate with narrow profit margins, and it is interesting that several of the smaller companies targeted by FMCSA-sponsored management training intervention studied by Goettee et al. (2015) dropped out of the resource-demanding intervention when incentives were softened.

Regarding information in the other studies on factors facilitating change, Naveh & Katz-Navon (2015) claim that a focus on communicating and signalling management's priorities to employees was primarily responsible for creating a better safety culture. Newman and Oxley (2016) point to implementing agency's well-established procedures, policies and training programs, and focus on employee involvement. Newnam and Olxey (2016) also note that the agency was committed to

evidence-based research, which appears to have facilitated the implementation of the program. Furthermore, workshop attendance was made mandatory for the managers assigned to the program.

4 Summary and discussion

We have systematically retrieved and described 20 studies of interventions aimed at improving safety culture in transport.

The studies include a range of intervention types, from single measure interventions (e.g. implementation of checklists aiming to improve safety thinking) to longer term comprehensive, phased interventions containing a range of measures aimed at multiple levels in the organisation (e.g. Wallington et al., 2014). It is interesting that of four single measures implemented in Televerk and evaluated by Gregersen et al. (1996), the most effective in terms of safety improvements (group discussions) was that which is most in line with safety culture thinking, in that it is likely to engage drivers in safety improvements by developing new shared ways of thinking and acting about safety, framing and reframing work hazards (Nævestad 2010b). Reason's approach to safety culture is often given to justify the more comprehensive interventions on safety culture (e.g. Edkins, 1998). Despite evidence that one-off measures can be effective at improving safety, at least under certain conditions, the basis of practice in this area seems to be that a comprehensive safety engagement at all levels of the company is required for long-lasting and effective cultural change (Murray et al., 2012). However, due to the scarcity of controlled studies and lack of standardized outcome measures, it is difficult to compare the effects of different types of interventions either within or across sectors.

While effects on safety of comprehensive interventions are largely positive, the effects seem highly variable, and there are few attempts to understand the specific mechanisms of effect in terms of cultural change leading to behavioural change and improved safety performance at organizational level. However, one controlled evaluation of ISO-39001 implementation in diverse types of transport company does link improved safety outcomes to changes in safety culture (Naveh & Katz-Navon (2015)). Notably, in some studies authored by research-practitioners in the road sector, evaluation design appears to have been compromised due to a perceived need to invest resources to increase the comprehensiveness of the intervention (Murray et al., 2012).

While studies are available for the road and rail sectors describing attempts to improve safety culture in a single transport organization, only one example can be found for the aviation sector, and none for the maritime sector. This is surprising given that safety culture is normally studied at the level of the organization, and given the emphasis that authorities such as the FAA or IMO have placed on safety culture. Studies attempting to trace effects of a new emphasis or regulatory change by authorities largely support that it is successful, but its effects in terms of safety improvements at organizational level do not abound in the research literature.

The scarcity of peer-reviewed studies of interventions to change safety culture in the air sector is particularly surprising, given the political, social and commercial awareness that aviation safety has to be taken seriously (Hudson, 2003; O'Connor, Dea, Kennedy & Buttrey, 2011). The aviation industry is considered to have an exemplary high organizational safety culture level because of its well-functioning incident reporting systems, its positive attitudes to safety among personnel, clear standards, rigorous requirements and systematic safety management systems (Hudson, 2003; Reason, 1997). The high safety level in aviation is reportedly due to the existence of an effective safety culture enabling individuals to exercise initiative and fill the gaps of formal safety system (Hudson 2003: i9). It is therefore natural to ask how this sort of safety culture has come about. One idea is that facets of aviation safety culture cannot be viewed separately from the facets of safety management systems in aviation, which have evolved over time in response to legislation, the continuous, business-driven need for safety and consequent management commitment. Driven by the latter, and by the salience of structural safety elements, safety culture may thus be a natural by-product of the air sector's framework conditions: there may have never been a need to develop safety culture interventions empirically in the air sector. Another possibility is that we have not retrieved all relevant literature, e.g. case studies included in grey literature, and a search aiming to retrieve "hidden" studies may be informative. An example of such a publication is "Road map to a just culture" (GAIN 2004), which provides three short case studies of attempts to implement just cultures in aviation in Denmark, New Zealand, and the UK.

4.1 The expected effects of safety culture interventions

All of the reviewed studies report improvements in safety culture, and generally also improvements in safety behaviours and accidents and incidents, except for the Safe-2-Safer intervention which actually found an increase in unsafe behaviours (Amtrak 2015). The studies' methodological basis for concluding about safety culture improvements are, however, very different (cf. Table 1). Two of the studies; Edkins (1998) and Zuschlag et al (2016) employ high quality evaluation designs, i.e. a before and after study, with one or more control groups. These two studies also indicate that safety culture interventions improve safety culture, safety behaviours and reduce accidents. Based on the reviewed studies, we therefore conclude that safety culture interventions seem to be effective. We also conclude, however, that the reviewed interventions seem to require a comprehensive amount of resources and attention from managers and employees over periods from 8 months to several years. It is probably not coincidental that the interventions mostly are carried out in large organizations.

Given the generally positive results of the reviewed studies, it is not unlikely that this field is influenced by publication bias, meaning that there may be several safety culture interventions that are never reported in scientific publications because they were not found to have any effects, or because they have negative effects. It is important to bear this in mind, when concluding about the effects of safety culture interventions. Studies reporting unexpected and negative results are valuable, as they

may shed light on key factors influencing safety culture interventions. When such studies are not published, we are deprived of important information about why interventions fail.

4.2 Focus on key activities and influencing factors

In the introduction, we referred to a multiplicity of definitions and operationalisations of culture in organizations, suggesting that the concept of safety culture can be termed as fuzzy; lending itself to a range of different definitions and operationalisations (cf. Guldenmund 2007; Glendon 2008). Our literature review indicates that safety culture has different status in the different transport sectors, and this is reflected in the content of the safety culture interventions. In the maritime sector, the safety culture intervention may for instance be the implementation of an ISM code compliant SMS (Lappalainen 2012), and in rail, peer observation and correction of safety behaviour is a central element in the safety culture interventions (Zuschlag et al 2016, Amtrak 2015). Compared with other transport sectors, the safety culture perspective has to a little extent been applied to the road sector. It seems that most of the safety interventions in this sector take on a basic and broad occupational health and safety perspective (Wallington 2014; Newman and Oxley 2013).

In the introduction, we also referred to two different ideal-typical approaches to culture in organizations (i.e. functionalist and interpretive), upholding different views on what culture is, how it should be measured and whether it can be managed (cf. Nævestad 2010a). The reviewed studies indicate that safety cultural interventions seem to be effective, and that these interventions seem to have some traits in common. Thus, instead of focusing on the multitude of definitions, and the abstract status of the safety culture concept itself, it seems more fruitful for researchers and practitioners to try define these key practical elements of safety culture interventions and factors influencing their success. If we define these key practical elements, it is more likely that the safety culture concept can be of use within the different practical domains where it is applied.

Moreover, focusing on the identification of a few key practical elements of safety culture interventions is also useful, as it may be less resource-demanding and thus more realistic for organizations to implement such measures. As we find that the interventions are effective, but comprehensive and resource demanding, implemented in large organizations, future research should try do develop less resource demanding interventions that could be implemented in smaller companies with less resources.

In this paper, we therefore identify four key activities (*content*) which seem to be common in all the reviewed interventions, and eight key factors (*process*) influencing the success of these activities.

4.3 Key activities of the safety culture interventions

Although the content of the interventions that we have reviewed are adapted to the respective countries, sectors and organizations, most of them have a basic common content, as they all seem to focus on increasing risk awareness among managers and employees through four key activities:

- 1) Appointing a key person (generally a manager) to be responsible for implementing the intervention,
- 2) Institutionalizing joint discussions and risk assessments of work place hazards, involving managers and employees,
- 3) Implementing and monitoring measures based on these discussions and joint risk assessments, e.g. reporting systems, training and
- 4) Maintain effective communication about safety issues in the organization, in line with Reason's (1997) depiction of an informed safety culture.

The most important element in all the interventions seem to be to increase risk awareness through joint discussions of work place hazards between managers and employees. Risk awareness is a key objective of what Reason (1997) refers to as an informed safety culture, which is an important backdrop of many of the interventions that we reviewed. Developing an informed culture means to increase the organization's capability to identify and act on hazards, located both at the systemic level and at the sharp end, and subsequently to make the work place safer.

4.4 Factors influencing safety culture change

Our review indicates, however, that the *content* of safety culture interventions not is sufficient to bring about culture change. Safety culture change also seem to be contingent on the quality of the *process* of safety culture interventions. Based on our analysis, we identify eight factors influencing safety culture change. It is important to note that the factors influence each other and are partly overlapping. Although we present these as general factors, transcending sectorial boundaries, we clarify the factors that are more sector-specific.

1) Top manager commitment throughout the intervention period. This factor is highlighted in several of the intervention studies, and across all four transport sectors (e.g. Lappalainen 2012; Zuschlag et al 2016; Edkins 1998; Belland et al., 2010). Roberts et al (2015) point to the importance of strong leadership. Amtrak (2015) also describe how successful interventions are impeded by lack of management commitment and role confusion that decreases the visibility of management commitment. These findings are consistent with studies of safety culture in other sectors (cf. Flin et al 2000; Nævestad 2010a).

2) Employee engagement and support. A key factor influencing safety culture change is employee engagement with the change process and intervention measure(s) (e.g. Zuschlag et al, 2016; Newnam & Oxley, 2016). Engagement in the analysis of risks and creation and execution of subsequent action plans is given as reason why group discussions are relatively effective at improving safety (Salminen, 2008). Union

cooperation is also mentioned as key in several studies, and this is likely to encourage employee engagement (e.g. Zuschlag et al., 2016). Lacking employee involvement is also listed as an impeding factor in the Safe-2-safer intervention (Amtrak 2015), and in Roberts et al (2015) from public transport (i.e. bus, metro and rail).

3) *The relationship between managers and employees.* Another key factor influencing safety culture change, found in Zuschlag et al (2016) is distrust between managers and employees. In a similar vein, the Safe-2-safer intervention lists resistance among experienced employees and an unjust culture as impeding factors (Amtrak 2015). Previous research has also found that guilt, blame and power are serious obstacles for organizational learning related to safety issues (Reason 1998; Pidgeon & O'Leary 2000).

4) *Motivation for intervention.* A strong motivation for successful safety interventions is often apparent in the studies. This can be in terms of known safety problems (Edkins, 1998), high level of dangerous incidents (Belland et al., 2010), a wholesale change in technology (Gałązkowski, Wolkowski, Mikos & Stanislaw 2015) or recognition of poor safety culture (Zuschlag et al., 2016). It is notable that in the road sector, business drives are more salient as a motivating factor, and the potential benefits of safety improvements are often explained to management in terms of increased productivity (Murray et al., 2009; Murray et al., 2012; Wallington et al., 2014). Most studies, however, refer to serious accidents and poor safety records as a primary reason that organizational members are motivated to participate in the interventions. In this respect it is important to clearly communicate the effect of the intervention in terms of the reason for implementing it. Importantly the Safe-2-Safer intervention described by Amtrak (2015) was impeded by lacking motivation when performance goals (e.g. injury rates) were removed, as well as the incentives for success.

5) *Regulator focus on safety (culture) and support to companies.* Two of the most promising interventions that we review, Edkins (1998) and Zuschlag et al (2016), are motivated by a considerable regulator focus on safety and safety culture and regulator support to companies. The same applies to Goettee (2015). Regulator focus alone is however not sufficient, as indicated by the Safe-2-Safer intervention (Amtrak 2015). Moreover, some of the other (successful) interventions in the road sector does not seem to motivated by regulator focus on safety culture (e.g. Gregersen et al 1996; Salminen 2008; Wallington et al 2014).

6) *Clear and congruent implementation.* An important factor influencing safety culture change, found in the Safe-2-Safer intervention is unclear implementation. According to Amtrak (2015), the Safe-2-Safer intervention was one of several interventions and it was not integrated in the overall safety plan, and supervisors and managers were confused about their roles in the intervention. Lappalainen et al. (2012) also highlight the importance of avoiding unnecessarily complicated procedures during intervention implementation. The studies by Murray et al. (2009; 2012) also give support to the idea that comprehensive interventions should be coherent, structured, and congruent with existing organizational systems.

7) Reorganizations and other processes taking attention away from the intervention. In some cases, the studies report of negative effects of reorganizations, e.g. replacing managers who were key to the implementation of the interventions.

8) *The content of the intervention.* A key factor influencing employees' motivation to participate in the intervention is the content of the intervention. The evaluation of the Safe-2-safer intervention gives several examples of intervention traits which discouraged participation. It is important not to overlook the fact that employee involvement and support and motivation also is likely to be contingent on the content (e.g. activities, goals) of the intervention itself.

To sum up; in the introduction, we referred to two diverging approaches to safety culture management. While the functionalist approach focuses on the importance of top-down, management led processes in safety culture development, the interpretive approach indicates the importance of bottom-up processes involving employee groups. Above, we have indicated that positive safety culture development involves both top-down and bottom-up processes, and we have tried to specify the factors influencing these, based on the reviewed studies.

4.5 SMS and safety culture

Above we suggested that facets of aviation safety culture cannot be viewed separately from the facets of safety management systems in aviation. This is interesting, as it indicates how tightly interwoven formal (structure) and informal (culture) aspects of safety are (cf. Antonsen 2009). It may therefore be difficult to tell which comes first, and subsequently how to influence the safety level of a given transport sector. In a review of the safety outcomes of SMS, Thomas (2012) conclude that SMS typically includes include management policy, appointment of key safety personnel, reporting systems, hazard identification and risk mitigation, safety performance monitoring etc. (Thomas 2012). These aspects are not very different from the four key activities of safety culture interventions. Thus, it may be hard in practice to discern between safety culture interventions and SMS, although we should note that both refer to more or less formal measures implemented to influence how safety is dealt with in practice, i.e. organizational members' shared (and informal) ways of thinking and acting in relation so safety. Future research should explore further how to identify and simplify such formal measures in order to make them attainable for as many transport organizations as possible.

5 Conclusion

The reviewed safety culture interventions seem to be effective, but they are often comprehensive and resource demanding. Future research should therefore develop simpler interventions by focusing on the basic requirements of safety culture change. We contribute to this by identifying four key activities (*content*) which seem to be common in all the reviewed interventions, and eight key factors (*process*) influencing the success of efforts to influence safety culture. The most basic requirements of

safety culture change seem to be to institutionalize joint discussions of work place hazards facilitated by manager commitment and employee involvement. Safety culture is an ongoing process which is created and recreated in the daily interaction of organizational members, and it requires continuous safety commitment from both managers and employees.

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Table 1 Main aspects of the safety intervention studies in *AIR* transport, focusing on the content, evaluation and results

Author, year, country	Context	Content	How evaluated	Effect measure			Effect
				Culture	Behaviour	Safety	
Edkins (1998) Australia	Comprehensive program – INDICATE (Identifying Needed Defences In the Civil Aviation Transport Environment) – intended to improve safety performance in regional airlines.	Eight-month trial with 6 core activities (i) appointment of operational safety manager responsible for training, coordination, evaluation and improvement; (ii) proactive hazard identification by focus group with management; (iii) confidential hazard reporting system; (iv) regular safety meetings to address identified hazards; (v) safety information database allowing managers to monitor threats identified and actions taken; (vi) internal safety marketing for visible management commitment.	Before and after 8-month trial with test group (N=81) control group (N=72). Quantitative and qualitative assessment.	✓	✓	-	-Improved safety culture. -Improved reporting rates. -Lower hazard perception. -More actions taken on identified hazards
Boedigheimer (2010) US	Pilot reliability certification intervention by expanding Crew Resource Management training in an air operator. Aim is to improve knowledge of and attitudes towards reducing human error in the cockpit.	Classroom or online training curriculum with six themes including resource management and personal error and awareness control.	Controlled, quasi-experimental survey evaluation of change in knowledge and attitudes towards human error in cockpit evaluated before and after implementation of the training, in pilots in treatment (n=41) and control (n=62) groups.	(✓)	-	-	Significant improvement in safety attitudes and knowledge, but confounded by demographic differences between control and treatment group. Qualitative evaluation supports the result, and that treatment group more aware of minimal, yet critical lapses that may pass unnoticed.
Belland et al. (2010) US	Study of effect of increase in organisational safety commitment and support occurring from 1998 on, as result in “spike” of dangerous air incidents at US Navy air base.	Visible change in management commitment to safety, achieved by routine personal message on safety and command culture from Naval air commander, culture workshops, safety surveys, increased focus on HFACS and pilot qualification.	Retrospective analysis of mishap rate 10 years before and 10 years after the intervention.	-	-	✓	27% reduction in “Class A” mishaps per 100,000 flight hours in a single carrier air wing aviator group at treatment base cf. fleet control.
(Galazkowski et al., 2015) Poland	Assesses effectiveness of a systemic training program on human, technical and organizational competencies required on replacing an older “analog” HEMS fleet with new EC135 helicopters containing a high level of electronics and automation.	Competencies trained by air instructors and simulator guidance. Training based on human technical, and organizational causes resulting from incident analysis of before period	Non-controlled prospective before-after study.	-	✓	✓	Overall decrease in contribution of human factors to incidents from before to after period, despite a rise in flight hours. However, increase in relative level of human errors registered, indicating an increase in threat levels. Effectiveness based on low numbers of incidents (e.g. 56 in before period), with large variation in level of contributory human factors from year to year.

Teperi et al. (2015) Finland	Aim to change safety culture in air traffic control by changing “managers’ understanding of human risks, strengths and opportunities”.	Learning from incidents restructured, using a checklist tool that guides controllers and managers to consider systemic causes of incidents. Training in checklist lasts up to one day, with several minutes required for each subsequent incident analysis.	Survey with open questions to assess user experience at 27 units using the tool.	-	✓	-	Frequency at which individual characteristics are attributed as causal factors decreases with increased use of tool and understanding. No validation of tool in terms of effects on culture or safety.
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Table 2 Main aspects of the safety intervention studies in **MARITIME** transport, focusing on the content, evaluation and results

Author, year, country	Context	Content	How evaluated	Effect measure			Effect
				Culture	Behaviour	Safety	
Lappalainen et al (2012) Finland	Introduction of ISM (International Safety Management) code for international shipping, with requirement on safety management systems (SMS).	SMS requirements include proactive risk assessment, with assessment of risks, establishment of control measures, documentation of this, and a requirement for masters to “periodically” review their vessel’s SMS and report deficiencies to shore based management, Procedures for corrective action include measures to prevent recurrence, and annual mandatory internal safety audits.	a) Literature review of previous studies of the ISM code, and b) 94 interviews conducted with shipping companies, mariners and other maritime stakeholders in the Finnish shipping industry in 2008-2009	√	-	√	-Improved safety level -Improved safety culture
Röttger et al. (2016) US	Officer training on Bridge Resource Management.	Training given to junior sea officers by officers experienced in Crew Resource Management for helicopters. Focus on leadership commitment, communication, coordination, performance under stress, decision making, situation awareness, attitudes and motivation that can lead to ineffective / unsafe bridge resource management.	Prospective before/after evaluation of effect of training on knowledge, skills, attitudes, along with ratings of safety behaviour during real world exercises. Pseudo randomly assigned experimental group (n=57) with control (n=60) who receive non-relevant safety training course. However, final statistical analysis only performed on 79 complete cases. No direct measure of effect of safety culture.	(√)	√	-	Significant increase in knowledge on BRM only for experimental group, but no increase on other measures.
O’Connor (2011) US	Officer training on Bridge Resource Management.	Similar to above, but less comprehensive. US Navy officers trained for 14 h in the classroom, with 20 h simulator training.	Change in knowledge, attitudes in response to training in 166 US Navy officers.	(√)	-	-	No significant changes.

Table 3 Main aspects of the safety intervention studies in **RAIL** transport, focusing on the content, evaluation and results

Author, year, country	Context	Content	How evaluated	Effect measure			Effect
				Culture	Behaviour	Safety	
Zuschlag et al (2016) US	“Clear Signal for Action” intervention implemented in Union Pacific Railroad, after observations of negative safety culture. Based on safety culture theory of Reason (1997; 2003)	Implemented by Behavioural Science Technology (BST) Inc., to introduce non-disciplinary, proactive, systems-safety-analysis orientation, cooperative and sustainable. This was done by peer-to-peer feedback, continuous improvement through cooperation at all levels, and safety-leadership development.	Before and after pilot study with two experiment units and three control units Study conducted 2005-2008. Safety culture measured quantitatively before (N=195) and after (N=112) and in qualitative interviews before, during and after (N=53)	✓	✓	✓	-80 % drop in at risk behaviours -81 % drop in accidents -Improved safety culture
Safe-2-Safer (Amtrak 2015) US	Safe-2-Safer program in large US rail company, aimed at improving company safety culture, reducing costs and injuries.	Improved safety leadership and peer-to-peer observation process.	Safety culture was measured by a biennial employee survey, focusing on 10 aspects of safety culture Conducted from 2009-2013 (N=11,700 in 2013)	✓	-	✓	Small improvement in safety culture, reduction in unsafe working conditions (through p-2-p observation), but increase in injuries
Roberts et al (2015) US	Extensive program of measures to improve safety culture in New York City Transit Authority.	Baseline set and needs analysed with safety culture survey, increased inclusion of employee reps in accident investigations, multi-level cooperation at safety meetings, visible leadership and financial commitment, increased on-site inspections.	Two safety culture surveys in 2010 and 2013. Also focus on severe accidents, key statistics, employee views on safety and an FTA review.	✓	-	✓	Serious injuries appear to have declined. The second safety culture survey found improved reporting culture.
Roberts et al (2015) US	Extensive program of measures to improve safety culture in Washington Metropolitan Area Transit Authority.	Safety prioritized in mission statements, increased investment in safety department, roles and responsibilities clarified, “lessons learned” bulletins, safety hotline, non-punitive reporting.	Focus groups and safety culture survey in 2007 (N=756). Safety culture problems were found in the survey and measures implemented. Number of fatal accidents used as a measure of improvement.	✓	-	✓	The intervention was found to reduce fatal accidents from three every two years before program initiation, to two over nine years after program initiation.

Table 4 Main aspects of the safety intervention studies in **ROAD** transport, focusing on the content, evaluation and results

Author, year, country	Context	Content	Evaluation design	Effect measures			Effect
				Culture	Behaviour	Safety	
Gregersen et al., 1996) Sweden	Effects of 4 organisational interventions on road safety among drivers in the Swedish company Televerket. Interventions expected to influence safety culture include (i) driver-led group discussions and (ii) a 1-year company road safety campaign.	Group-discussions: drivers work together to discuss safety problems, identify solutions, make an action plan and act. Discussions and resulting measures evolve in several sessions over several months. Company safety campaign: presentations, information, visible campaign logo etc.	Robust, quasi-experimental prospective design, with measures of treatment and control groups for 2 years before and 2 years after the interventions. Five groups of company drivers (n=900-1000 in each group), with 4 test groups and 1 control group.	-	-	✓	Significant reductions in accident risks for driver training and group discussion interventions, from 0.16 to 0.08 accidents caused by company drivers per 10,000 km driven. Greatest accident cost reductions seen for group discussions.
Salminen (2008) Finland	Driver group discussion involving company electricians who drive cars and trucks for work.	As for Gregersen et al. (1996)	Before-after study of 172 electricians, exposed to discussion group method. No control, but compared with a similar group (n=179) receiving driver training.	-	-	✓	Large (72%) decrease in traffic accidents over 8-year follow-up period, despite no decrease in other work accidents. However, general traffic safety trends not accounted for. Cost-benefit analysis show savings; also improvements in safety audit outcomes, up to 2 years following driver training.
Murray et al. (2009)	Descriptive case study detailing comprehensive, “holistic” 5-year occupational road safety program targeting drivers-for-work employed by large company, Wolsey.	Program of events with several structural and cultural elements (e.g. competition, handbooks, focus groups, health training, eye checks, safety climate), involving researchers in collaboration with transport industry, and a champion in a health and safety role.	Study analyses effect of program on fleet audit results based on accident data from 7000 heating and plumbing distributor drivers (3000 vehicles).	-	-	✓	Almost 2-fold reduction of third party collisions per vehicle, and £500k savings on uninsured cost recoveries. The target company perceives many benefits of the program (e.g. improved compliance, performance management), but lacks supportive data.
Murray et al. (2012) Australia	Comprehensive 5-year attempt to improve road safety management through range of proactive, fleet manager, insurance and risk-led initiatives in drivers-for-work at Roche.	Mix of cultural and structural elements, but improving safety culture central. Key initiatives; driver risk assessment, monitoring and improvement; policy development and communication; process and outcomes evaluation; continuous review and refinement of policies, processes, programs. Intervention	Case-study type quantification of development of various safety behaviour and outcome measures over time.	-	✓	✓	100% compliance with risk assessment and improvement process. Reduction in insurance claims costs (56%), collision costs (55%) and claims per vehicle (down from 36 to 28%) from 2004 to 2009. But no accounting external trends or effect of which measure contributed most.

		targets fleet managers, drivers, risk managers and those who train and recruit drivers.					
Wallington et al (2014) UK	Case-study of long-term, data-driven extensive program targeting road safety in British Telecommunications (BT), with a fleet of approximately 35.000 vehicles.	Risks and costs established, and subsequent process structured by occupational Haddon matrix, with risk analyses and mitigation based on occupational health and safety principles. Effects of control measures (e.g. managers responsible for 5 or more drivers participate in a fleet safety coaching workshop) are monitored, and the measures are evolved accordingly. Measures cover levels of management culture and leadership, journey management, people, vehicle, and society/community.	Case study of long-term trends in collision numbers, rates and claims in British Telecom based on data from up to 95,000 workers. Company traffic safety trend compared to national trend.	-	-	✓	The overall claim rate (per 1000 vehicles) per year decreased notably and gradually from program initiation in 2001 to 2012. Compared with the general downward trend in the number of killed or severely injured in collisions in GB in the same period.
Goette et al (2015) US	Federal Motor Carrier Safety Administration (FMCSA) initiate training of new transport companies in the U.S., intended to foster a safety culture - based on research indicating that small entrant carriers were less safe than established ones.	Training/mentoring and testing carrier managers to improve understanding of applicable rules and regulations, and improve company compliance. Authority also guides and supports on record-keeping activities.	Cross-sectional design using a test group and a matched control group. "dose-response" Conducted from 2009-2013. N=117 in the first period and 177 in the second period. Self-selection challenge, as participation in test group was voluntary.	-	-	✓	Carriers that took part in the program had better safety outcomes than those who did not. Improvements were identified in the number of safety audit failures, roadside violations and crashes (up to 84 % reduction).
Newnam & Oxley (2016) Australia	"Safety Management for the Occupational Driver" (SMOD) research-based program, focusing on manager's role in work-related road safety in a small-scale implementation case study.	Program focuses on four supervisory skills: Motivation to improve driver safety ("prosocial motivation"), mindfulness (creating a safety climate where driver safety is prioritized and valued), role clarity, and self-efficacy. Supervisors are trained in safety management of drivers, by teaching them to identify situations that pose increased risk to drivers, and effectively managing these situations. The program runs a monthly 3-4-hour sessions covering safety leadership styles, feedback from a 360-degree survey, role play and group discussions. Supervisors implement the skills learnt from each session, and are encouraged to monitor their own management behaviour.	Before-after study (N=36) without a test group. Only 8 respondents answered the after study.	✓	✓	-	Improved safety climate. Improvements were also recorded on the four elements of the supervisory skills. However, very low number of participants.

Naveh & Katz-Navon (2015)	Intervention to improve organisational climate to improve road safety behaviour of drivers in diverse organisations, and their families.	Intervention designed and supported by the national road authority in Israel, and carried out by designated teams at organizational “unit”-level. Three-tier comprehensive multi-measure long-term intervention, (i) ISO-39001-driven policy change and data-driven risk analyses, action plans (practices (/procedures to address risks), manuals and training, (ii) visible management commitment and internal marketing supporting the policies (logos, tools, reward systems, road safety “ceremonies”); (iii) evaluation and continuous improvement.	Longitudinal before and after evaluation of intervention carried out by 51 “units” belonging to 11 organisations (selected from ca. 50 volunteer organisations), including bus, truck, high-tech and administration companies. An additional company with 5 diverse units randomly selected as control group. Baseline survey of road safety climate administered 3 months prior to intervention, and 12 months following start of intervention.	✓		✓	Average 75% reduction in traffic safety violations in intervention units, compared with an increase in control units. Increase in ratings of unit road safety climate in intervention units (decreased in control units). Multivariate statistical analyses and controls, with manipulation checks, confirm the effects, and find that the reduction in violations is mediated by change in safety climate. Improvements spilled over to drivers’ safe driving outside work, but not to family members’ driving.
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