



# How can regulatory authorities improve safety in organizations by influencing safety culture? A conceptual model of the relationships and a discussion of implications

Tor-Olav Nævestad<sup>\*</sup>, Ingeborg Storesund Hesjevoll, Rune Elvik

*Institute of Transport Economics, Gaustadalléen 21, NO-0349 Oslo, Norway*

## ARTICLE INFO

### Keywords:

Safety culture  
Regulatory authorities  
Safety outcomes

## ABSTRACT

Regulators have increasingly started to focus on safety culture. The causal link between regulatory initiatives to improve safety culture and a potential decline in accidents may, however, appear like a “black box”, involving social processes that seem hard to foresee and influence. We need a better conceptual understanding of this. The aims of our study are to: 1) Map studies of regulatory efforts to influence safety culture in companies, 2) Use the identified studies to develop a conceptual model of the analytical relationships between regulatory initiatives to improve safety culture and accidents in these studies, including the factors influencing these analytical relationships and 3) discuss practical implications. The review is reported according to PRISMA-guidelines, and focuses on professional transport (aviation, sea, rail, road) and the Norwegian petroleum sector. Our review indicates at least six analytical relationships, mediating between regulatory attempts to influence organizational safety culture and accidents. These are between: 1) Rules and regulators, 2) Regulators and companies, 3) Managers and employees in the companies, 4) Organizational members’ shared ways of thinking and acting, which are the two key elements of safety culture, 5) Safety culture and safety behaviour, and between 6) Safety behaviour and accidents. Regulatory attempts to influence safety culture may fail or succeed at each level, through factors involved in the different relationships.

## 1. Introduction

### 1.1. Background and aims

Since the safety culture concept first was used in the wake of the Chernobyl accident in 1986, it has become broadly accepted that safety culture is important for safety in organizational settings, not only in hazardous industries, but also in a range of different sectors and industries (Nævestad, 2010). The relationship between organisational safety culture and safety outcomes (e.g. behaviours, accidents, incidents) is robustly documented in cross sectional studies both in different industries and countries (e.g. Bjørnskau and Nævestad 2013). Additionally, high quality studies of safety culture interventions, with pre- and post-measurements, test and control groups, indicate that safety culture interventions may involve 60% reductions in accident risk (Gregersen et al, 1996), 80% reductions in accidents (Zuschlag et al., 2016), and 80% reductions in at risk behaviours (Zuschlag et al., 2016). Investigations following large-scale accidents in organisational settings

also point to negative safety culture aspects as an important contributing cause (Nævestad, 2010).

The recognized importance of safety culture for safety in organisations has motivated regulators in different industries and sectors to include safety culture in their formal repertory. While nuclear safety authorities (Grote and Weichbrodt, 2013; Bernard, 2018); and aviation authorities (ICAO, 2021) are considered to be regulatory pioneers in the field, other sectors have since followed, e.g. Norwegian petroleum authorities (Kringen, 2009), US railroad safety authorities (Zuschlag et al., 2016) and the Swedish Transport Safety Authority (Nævestad and Phillips, 2018). In a recent literature review discussing experiences from some of these early regulatory adopters of the safety culture concept, Nævestad et al. (2019) categorize the specific regulatory initiatives applied into 11 more general strategies that regulators may utilize when attempting to influence organisational safety culture. They discuss pros and cons with the strategies, and underline that this is a field of research in which more knowledge is needed.

The fact that regulators have started paying attention to safety

<sup>\*</sup> Corresponding author.

E-mail address: [ton@toi.no](mailto:ton@toi.no) (T.-O. Nævestad).

cultural factors is promising, as we know that organizational safety culture (Bjørnskau and Nævestad, 2013) and safety climate (Zohar, 2010) are closely related to safety outcomes. Research from the Norwegian petroleum sector, where the petroleum safety authority (PSA) in 2002 introduced a provision requiring a positive HSE-culture, indicates that the cultural perspective on safety may provide new insights and a further improvement of safety in the regulated companies (Bye et al., 2016; Kongsvik and Gjørund, 2016; Antonsen et al., 2017; Le Coze and Wiig, 2013). Moreover, regulators from the aviation branch of the Swedish Transport Agency, which has safety culture audits as part of their regulatory strategy, report that the safety culture concept provides an important perspective which is omitted in a purely rule-based command and control approach to regulation (Nævestad and Phillips, 2018).

Although studies from the early regulatory adopters of the safety culture concept report of promising results (in addition to some initial difficulties), the causal link between regulatory initiatives to improve safety culture and a decline in accidents may appear like a “black box”, involving social processes that seem hard to foresee and influence. The mentioned studies from the Norwegian petroleum sector report for instance that regulators used a lot of time and energy implementing the new HSE-culture provision, and that companies responded to the provision in ways that were unanticipated and not necessarily intended by the regulator (Bye et al., 2016; Kongsvik and Gjørund, 2016). Kongsvik and Gjørund (2016) refers to companies’ responses to the Norwegian PSA as “translations”. This denotes the relationship between regulators and companies, represented by their management. When companies take their translations further, attempting to influence the safety culture of their employees, regulators’ safety culture initiative enters into a new social process, that may involve new translations. Research shows that managerial attempts to influence organizational safety culture is not a straightforward matter, and that subcultures may redefine or even resist intended messages (e.g. Nævestad, 2010).

Thus, it seems that the hypothesized causal link between regulatory initiatives to improve safety culture and potential reductions in operator accidents involve several analytical relationships. In the sharper end of this link, we find operator behaviours and accidents. The ultimate aim of safety culture interventions is to generate safe behaviours and reduce the number of accidents and injuries. Research indicates, however, that the relationships between culture, behaviour and accidents also should be clarified in future research. Ward et al. (2010) argues that the theoretical link between safety culture and safety behaviours often is omitted in research, and that the applicability of the safety culture perspective is dependent on developing a theoretical model to explain this relationship. Neither is the relationship between safety behaviour and accidents straightforward, as research has found that some types of errors and violations are more closely related to accidents than others (De Winter and Dodou, 2010). In this paper, we argue that it would benefit both regulators and the research field to develop a theoretical or conceptual foundation to understand how regulators can improve safety in organizations by improving safety culture. This would complement the existing research on regulatory strategies to influence organisational safety culture (Nævestad et al., 2019).

The aims of our study are therefore to: 1) Map studies of regulatory efforts to influence safety culture in companies, 2) Use the identified studies to develop a conceptual model of the analytical relationships between regulatory initiatives to improve safety culture and accidents in these studies, including the factors influencing these analytical relationships and 3) discuss practical implications.

By fulfilling these aims, the paper will show how regulatory attempts to improve safety culture may feed into the organisations they regulate, with the safety culture of these institutions changing as a consequence. The paper will also examine how potential changes in organisational safety culture may lead to changes in safety behaviours in the organisations and potential reductions in accidents. Thus, the paper develops a conceptual model of hypothesized causal relationships starting with regulatory initiatives to improve safety culture and ending in reductions

in accidents.

## 1.2. Safety culture in transport and petroleum

The primary interest in this paper is safety regulation in professional transport. Transport accidents represent a serious public health problem. More than 1.35 million people die each year on the world’s roads, and between 20 and 50 million people sustain non-fatal injuries (WHO, 2021). Numerous people lose their lives annually in maritime accidents, including 24,000 in the fishing sector alone (International Maritime Organisation, 2015). In 2017, there were 1 855 significant railway accidents in the EU, with a total of 977 fatalities and 763 persons seriously injured (Eurostat, 2019). In comparison, there were in average 472 worldwide air traffic fatalities each year in the period 2009–2018 (Statista, 2020).

Based on these numbers, it has been argued that new approaches to safety and safety regulation should be introduced, to contribute to increased transport safety, especially in the road sector. Safety culture has been introduced as such a perspective (Ward et al., 2010). Consequentially, regulators in transport have started focusing on safety culture in recent years. The international safety management system (SMS) rules in aviation (ICAO, 2021) states for instance that the purpose of the required SMS is to foster a positive safety culture. Similar SMS aiming to facilitate safety culture are legally required in the maritime sector (Kongsvik and Gjørund, 2016), and in rail transport (European Rail Agency, 2020).

The present study also includes Norwegian petroleum, as it is the only sector in the world where regulators have introduced an explicit requirement that companies should have a sound HSE-culture. This sector is included in order to learn from one of the most direct (and most studied) regulatory effort to influence safety culture in companies.

## 2. Safety culture and regulation

Most safety scholars seem to agree that organizational safety culture can be defined as shared and safety relevant ways of thinking or acting that are (re)created through the joint negotiation of people in social settings (Nævestad, 2010). This is the definition we follow in the present study. Safety culture is studied both qualitatively and quantitatively. Based on Antonsen (2009) and Nævestad (2010), the qualitative definition of safety culture is that it represents shared frames of reference that guide individuals’ interpretations of actions, hazards, and their identities, and which motivates and legitimizes behaviors that have an impact on safety, and that such shared frames of reference are created through interaction within groups. The quantitative definition of safety culture defines it as safety climate, which can be conceived of as «snapshots», or manifestations of safety culture, measured by means of quantitative surveys (Flin et al., 2000). Safety climate is also defined as perceptions of the value and importance of safety in a given context. The most studied and best documented characteristic of a good safety climate aspect in safety climate studies, independent of sector, is senior management commitment to safety, followed by employee perceptions of safety management systems (e.g. work permit systems, safety philosophies) and perceptions of and attitudes to risk (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. Safety culture and climate are often used interchangeably. We also do so in the present paper.

Descriptions of the safety culture approach often explains its relevance by distinguishing between formal and informal aspects of organisational safety (Antonsen et al., 2017). The formal aspects refer to descriptions of “how things should be done” in the organisation, provided in e.g. procedures, routines, and when systematized: the safety management system (SMS). SMS typically comprise formal routines and measures enabling the organization to work systematically with safety through continuous improvement, involving the identification, analysis

and correction of risk, e.g. through the appointment of key safety personnel, reporting systems, risk assessments, safety training, safety procedures and safety performance monitoring (Thomas, 2012).

Regulation generally refers to public interventions to manage and reduce unintended side-effects of industrial activities for the safety and well-being of people and the environment (Antonsen et al., 2017; Baldwin et al., 2012). In the traditional meaning of the term, regulation refers to an agency's application of rules or instructions that are implemented to achieve certain purposes (Baldwin et al., 2012). When used in a more general sense, regulation may refer to all forms of influences, (e.g. economic and social), also the ones that were not intended as regulation (Antonsen et al., 2017; Baldwin et al., 2012). It is generally argued that safety culture as a regulatory concept is more compatible with the general understanding of regulation than the traditional "command and control" approach (cf. (Antonsen et al., 2017), indicating that safety culture regulation involves more, or something else than "checking compliance" (Nævestad et al., 2019).

Finally, it is generally difficult to assess the influence of safety regulation and different regulatory practices on accident risk. A previous review concludes that there are few robust statistical examinations of the effectiveness of safety inspectorates on accident risk (Elvik and Elvebakk, 2016). Comparing long term trends, the statistical analyses of Elvik and Elvebakk (2016) indicate that safety performance has improved, at least in rail transport, after the establishment of an independent safety inspectorate in the sector.

### 3. Methods

The purpose of the review was to identify and analyze studies focusing on regulatory efforts to influence safety culture in companies in professional transport (aviation, sea, rail, road) and in the Norwegian petroleum sector. We describe the search and the analysis, using the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher et al., 2009).

#### 3.1. Search strategy and search words

The literature study draws on our previous reviews. Based on our previous systematic literature searches (Nævestad et al., 2018), we were familiar with the different key concepts in the transport sectors. When searching for studies in the petroleum sector, we developed relatively broad and general search terms (cf. Table 1). The search in petroleum is based on the search described in Nævestad et al. (2019). We searched for relevant studies within the transport sectors and in petroleum in using ISI Web of Knowledge and ScienceDirect. The final systematic searches were conducted in January 2021, updating searches done in 2018, focusing on publications ranging back to 1995 (cf. Fig. 1). Table 1 presents the search terms for each sector. These were applied for keyword, title and abstracts.

**Table 1**  
Search words in the studied sectors.

Sector	Search words
Air:	Safety AND (intervention OR training OR program OR effect) AND ("air pilot" OR helicopter OR airline)
Sea:	Safety AND (maritime OR seafarer OR ((occupational OR organisational) AND maritime)) AND (effect OR program OR intervention)
Road	Safety AND (intervention OR effect OR program) AND ("truck driver" OR "professional driver" OR (road AND (work-related OR fleet OR organisational OR organizational OR occupational)))
Rail	Safety AND (intervention OR training OR program OR effect) AND (rail OR railway)
Petroleum	"Safety culture" OR HSE OR "Health, Safety and Environment" AND Norway

#### 3.2. Criteria for selecting publications to include or exclude

When selecting publications to include, we used four criteria.

- Written in English.
- Publication year later than 1995.
- Focuses on one of the selected transport sectors, or the Norwegian petroleum sector.
- Provides a description about an initiative to improve safety outcomes by influencing safety culture (e.g. rule, advice, funding, design of intervention, support), with some kind of regulatory involvement.

#### 3.3. Three-stage screen

Studies fitting these four criteria were identified through a three-stage screen. In the first stage, we screened the "hits" that we obtained by means of our combinations of search words in the sectors studied (cf. Table 1). The purpose of this first screen was to identify efforts and interventions focusing on improving safety (cf. search flow diagram) in the studied sectors. We first screened the titles of the studies. If it was difficult to judge the relevance of the studies based on the titles, we also examined the abstracts. In the second stage, we focused on the studies' abstracts. The purpose of the second-stage screen was generally to identify studies of initiative to improve safety outcomes by focusing on safety culture. In this stage, we did not focus on the parties responsible for introducing the initiatives. If it was difficult to judge the relevance of the study based on the abstracts, we also examined the full texts of the studies. In the third stage, we examined whether the initiatives to influence safety outcomes by influencing safety culture had involved regulators at any stage. To examine this, we read the whole papers. Finally, studies identified from other sources were added to the selected studies. These were studies that the authors were familiar with from other projects, cf. (Nævestad et al., 2018, 2019), and also studies that were mentioned in some of the studies retrieved in the literature search.

#### 3.4. Potential bias

First, potential subjective bias in selecting studies to include in the review is related to our definition of safety culture, which is "shared and safety relevant ways of thinking or acting". Thus, if the initiatives in the studies aimed at improving safety outcomes by influencing shared and safety relevant ways of thinking or acting, they were included (cf. Nævestad et al., 2018). This means that e.g. training programs focusing on increasing risk awareness, rules requiring safety management systems aiming to induce new ways of thinking and acting in the organisations, regulatory audit strategies focusing on safety culture aspects etc. were included. Thus, the reviewed studies did not need to explicitly state that they focused on safety culture to be included in our review. Second, it may be difficult to evaluate what a regulatory based initiative to improve safety outcomes by influencing safety culture is (cf. third stage). Following Nævestad et al., (2019), we focused on whether the studied initiative involved regulators at any stage. Thus, we included several different types of actions and roles involving regulators, e.g. new rules, strategies, audit schemes, advice to companies, communication (leaflets, websites etc.), funding, design of interventions, support to research, pilot studies etc.

#### 3.5. Criteria for comparing the reviewed studies

We use the following points as a checklist in our presentations of the regulatory efforts to influence safety culture in companies in Tables 2 and 3:

- I) Study, country and sector: name of the authors, year, country and sector.
- II) Method, and sample



Fig. 1. Search flow diagram.

- III) Analytical relationships. Which analytical relationships between regulatory efforts to improve safety culture and accidents are examined in the studies?
- IV) Influencing factors. Which factors influencing the analytical relationships between regulatory efforts to improve safety culture and accidents are examined in the studies?
- V) Outcomes. What are the safety outcomes of the studied interventions? Weaknesses and strengths.

### 3.6. Development of the model depicting analytical relationships

We analyzed the identified studies to develop a conceptual model of the analytical relationships between regulatory initiatives to improve safety culture and accidents in these studies, including the factors influencing these analytical relationships. The identification of analytical relationships involved making conceptual models of relationships (i. e. with boxes and arrows) between actors and/or concepts from each study. This was done by two researchers to ensure inter-rater reliability. The analysis of factors influencing these relationships involved the identification of factors influencing the outcomes of the relationships between the identified actors/concepts (i.e. influencing the arrows between the boxes). This knowledge was summarized through thematic analysis (Welsh, 2002), which involved grouping of the identified relationships and influencing factors from each study into more general categories, based on similarities. Some analytical relationships and influencing factors were not included in the conceptual model, as they only were identified e.g. in one study or two studies (e.g. the relationship between companies and consultants). The final results of the thematic

analysis are shown in Fig. 2 and this is based on the information in Tables 2 and 3.

The thematic analysis involved a combined deductive and inductive approach. The process was deductive, as the identification of analytical relationships to some extent was contingent on our preexisting knowledge about analytical relationships between key variables (e.g. aspects of safety culture, safety behaviours and accidents) in studies of safety culture. The process was also inductive, as it involved the identification of analytical relationships which are new or not commonly explicated (e.g. between rules/strategies and regulators), and as it involved the combination of all the identified links into one model with a hypothesized causal chain ranging from the abstract level of regulatory rules to the concrete level accidents. Through this process, we were able to combine the knowledge from the studies into one comprehensive conceptual model.

## 4. Results

### 4.1. Search flow diagram

In Fig. 1, we present the search flow diagram, presenting the three-stage screen described in section 3.3. The figure shows the search results in each screen, studies excluded, and studies included for further screening. In the first screen, studies were excluded mostly because they did not involve studies of efforts to influence safety. In the second screen, studies were excluded largely as they did not fit our criteria for initiatives focusing on safety culture (“shared and safety relevant ways of thinking and acting”). In the third screen, studies were primarily

**Table 2**

Studies of safety culture regulation in transport: focus, methods, depicted analytical relationships between regulatory initiatives to improve safety culture and accidents, factors influencing the relationships, and reported outcomes of the regulatory efforts.

Study/country/sector. Focus.	Method/sample	Studied analytical relationships	Factors influencing each relationship	Outcomes of the studied interventions (S = strengths, W = weaknesses)
<p><b>Patankar (2019)</b> Aviation. Maintenance. International. Focus: Maintenance resource management (MRM) programs, focusing on teamwork, communication, error causation and behaviour change. Applies Crew Resource Management (CRM) programs to maintenance.</p>	<p>Broad overview of the MRM training programs since 1989 and the research on its effects.</p>	<p><u>Regulators and interventions/rules:</u> the MRM programs were first voluntary, but eventually required legally.</p> <p><u>Regulators and companies:</u> cooperate in the development and research on MRM programs</p> <p><u>Managers and employees:</u> participate in the MRM training programs.</p> <p><u>Shared ways of thinking and acting:</u> the programs focused on influencing behaviour change through influencing attitudes and awareness (i.e. ways of thinking).</p> <p><u>Safety culture and safety behaviours:</u> focus on behaviour change (e.g. reporting) following culture change (e.g. no blame culture)</p> <p><u>Behaviours and accidents:</u> Some of the studies reported both improved safety behaviours and fewer accidents due to the interventions</p>	<p>Accidents creating a need for improvements. Regulatory competence/background: MRM programs were based on the existing CRM programs</p> <p>Common problem definition and competence. Regulatory strategy: to initiate research-based programs. Develop trust between managers and employees. Employee involvement. The first generation of MRM focused on attitudinal change, the second on behavioural change.</p> <p>Normative influences on behaviours: the focus of the MRM training is to create a strong sense of safety commitment and responsibility. MRM programs focused on reducing maintenance errors, improving reporting of errors and incidents. Improved behaviours related to fewer incidents and injuries.</p>	<p>MRM programs were effective in improving safety attitudes, safety behaviors (among 40% of participants), and there were also reductions in lost-time injuries and ground damage incidents. MRM programs are also coupled to improvements in safety culture.</p> <p>W: Not a systematic scientific study. S: Provides a broad overview of relevant research, focusing on MRM and effects on attitudes, behaviour, culture and injuries/incidents.</p>
<p><b>Nævestad and Phillips (2018)</b> Transport and nuclear. Sweden. Focus: New regulatory strategy: sector authorities audit safety culture as part of their company audits.</p>	<p>Interviews with 40 people from Authorities and companies. Relationships studied qualitatively.</p>	<p><u>Regulators and strategies/rules:</u> regulators in different sectors made sense of the safety culture audit strategy and the rules</p> <p><u>Regulators and companies:</u> companies respond to regulatory input</p> <p><u>Managers and employees:</u> negotiate over meaning and translate regulatory input and company response</p> <p><u>Reciprocal effects between shared thoughts and actions:</u> the translations may lead to new ways of thinking which may lead to new ways of acting and vice versa</p>	<p>Challenges related to the integration of the strategy in road and maritime sector.</p> <p>More relevant regulatory competence in air and rail (and SMS requirements) Regulatory approaches and strategies Company characteristics</p> <p>System implementation as safety culture development</p>	<p>Good experiences from regulators and companies in aviation, asserting that safety culture provides an important perspective.</p> <p>W: No measurements of culture or accidents. Possible sample bias among authority interviewees. S: Good in-depth data of context.</p>
<p><b>Nævestad, Hesjevoll and Phillips (2018)</b> (international) (aviation, sea, road, rail)</p>	<p>Systematic literature review of safety culture interventions in transport organisations. Identifies 20 studies of safety culture interventions. Five describe some sort of regulatory involvement. Relationships studied qualitatively and quantitatively.</p>	<p><u>Regulators and companies:</u> Some of the reviewed interventions are developed, and/or championed by regulatory authorities</p> <p><u>Managers and employees:</u> make sense of regulatory inputs and company responses</p> <p><u>Shared thoughts and actions:</u> sensemaking may lead to new ways of thinking which may lead to new ways of acting and vice versa</p> <p><u>Safety culture and safety behaviours:</u> Some of the studies reported both improvements in safety culture and behaviours due to the intervention</p> <p><u>Behaviours and accidents:</u> Some of the studies reported both improved safety behaviours and</p>	<p>More relevant regulatory competence on safety culture in air and rail (and SMS requirements)</p> <p>Trust between managers and employees, Managers' safety commitment, The existence of subcultures, Employee involvement</p> <p>Implementation of SMS is a strategy for safety culture development in air, maritime sector and rail</p> <p>Competing variables Employee involvement and engagement</p> <p>Especially violations were related to accidents</p>	<p>Identifies 20 studies of safety culture interventions. Five describe some sort of regulatory involvement.</p> <p>Two of the most promising interventions were motivated by a considerable regulator focus on safety and safety culture and regulator support to companies. W: Difficult to conclude about key elements. S: Provides good discussion of commonalities.</p>

(continued on next page)

Table 2 (continued)

Study/country/sector. Focus.	Method/sample	Studied analytical relationships	Factors influencing each relationship	Outcomes of the studied interventions (S = strengths, W = weaknesses)
Zuschlag et al (2016), USA, Rail. The US Federal Railroad Administration (FRA) organized a safety culture intervention evaluation program in the period 1998–2012. Focus: Clear Signal for Action”	Before and after pilot study (2005–2008) with two experiment units and three control units Safety culture measured quantitatively before (N = 195) and after (N = 112) and in qualitative interviews before, during and after (N = 53). Relationships studied qualitatively and quantitatively.	fewer accidents due to the interventions <u>Regulators and consultants:</u> The intervention was designed and implemented by a consultancy firm, and evaluated by US Dep. of Transportation  <u>Regulators and companies:</u> company responded to regulatory input <u>Managers and employees:</u> negotiation and sensemaking related to the intervention  <u>Shared ways of thoughts and ways of acting:</u> changes in behaviour may start with changes in attitudes and vice versa <u>Safety culture and behaviours:</u> changes in safety culture lead to changes in behaviours <u>Behaviours and accidents:</u> changes in behaviours lead to fewer accidents	This relationship is not discussed in detail, but the consultancy (BST) had experiences from developing interventions in several industries Shared problem definition, Regulatory specificity  Trust between managers and employees, managers’ safety commitment, the existence of subcultures, employee involvement Reciprocal effects between shared ways of thinking and acting  Competing variables influencing behaviours  The relationship was especially mediated by violations: 80% reduction and 81% reductions in accidents	80% drop in at risk behaviours, 81% drop in accidents, improved safety culture. W: Difficult to conclude about most effective elements. S: before and after study with control. Qualitative and quantitative. Robust study.
Goette et al (2015), USA, Road. Training programme	Cross-sectional design using a test group and a matched control group. (2009–2013) N = 117 in first period and 177 in second period. Relationships studied quantitatively.	<u>Regulators and companies:</u> training programme initiated by the Federal Motor Carrier Administration <u>Managers and employees:</u> make sense of the programme <u>Behaviours and accidents:</u> The study finds that the safety culture measures involve reductions in roadside violations	Shared problem definition, regulatory specificity  Managers’ safety commitment  Reduction in violations is related to reductions in crashes	Improvements in: a) safety audit failures, b) roadside violations and c) crashes (up to 84% reduction). W: Potential self-selection, as participation in test group was voluntary. S: Relates safety culture and behaviours.
Naveh and Katz-Navon (2015), Israel, Road.  1) ISO-39,001-driven policy change and data-driven risk analyses, action plans manuals and training, 2) visible management commitment and internal marketing 3) evaluation and continuous improvement.	Before and after evaluation of intervention carried out by 51 “units” belonging to 11 organizations. Company with 5 diverse units randomly selected as control group. Relationships studied quantitatively.	<u>Regulators and companies:</u> Intervention designed and supported by the national road authority in Israel <u>Managers and employees in the companies:</u> intervention carried out by designated teams at organizational “unit”-level <u>Shared ways of thinking and acting:</u> changes in behaviour may start with changes in attitudes and vice versa <u>Culture and behavior:</u> changes in safety culture lead to changes in behaviours  <u>Professional and private behaviour:</u> Improvements spilled over to drivers’ safe driving outside work, but not to family members’ driving.	Regulatory specificity  Managers’ safety commitment  Changing behaviours through changing attitudes, system implementation as safety culture development Competing variables influencing behaviours in addition to culture, normative influences on behaviours Issue for future research.	75% reduction in traffic safety violations in intervention units, compared with an increase in control units, improved road safety climate in intervention units (decrease in control units). W: No measure of accidents. S: before and after study with control. Robust study.
Amtrak (2015) USA, Rail. Pilot program and evaluation sponsored by the Federal Railroad Administration (FRA). Focus: Safe-2-Safer program	Safety culture survey focusing on 10 aspects conducted biannually, in the period 2009 to 2013 (N = 11,700 in 2013). Relationships studied quantitatively.	<u>Regulators and consultants:</u> The rail company received advice and assistance with the intervention from consultants and regulator <u>Regulators and companies:</u> Through the 2008 Railroad Safety Improvement Act, the FRA requires railroad companies to build strong safety cultures. In 2009, the company developed and implemented the Safe-2-Safer program as a response to this. FRA also prohibited retaliation	The consultancy had experiences from developing interventions in several industries, Shared problem definition Regulatory specificity Translation	Small improvement in safety culture, reduction in unsafe working conditions, but increase in injuries. W: Difficult to conclude about the relationship between safety culture and injuries. S: May indicate factors impeding safety culture change.

(continued on next page)

Table 2 (continued)

Study/country/sector. Focus.	Method/sample	Studied analytical relationships	Factors influencing each relationship	Outcomes of the studied interventions (S = strengths, W = weaknesses)
<p>Lappalainen et al. (2012), Finland, Maritime.</p> <p>The national maritime authority implements and audit compliance with the international ISM code, which requires safety management systems (SMS).</p>	<p>a) Literature review of studies on the ISM code, and b) 94 interviews with shipping companies, mariners and other stakeholders in the Finnish shipping industry in 2008–2009.</p> <p>Relationships studied qualitatively.</p>	<p>and intimidation when employees report injuries.</p> <p><u>Managers and employees:</u> negotiate over the meaning and make sense of the program</p>	<p>Trust between managers and employees, The existence of subcultures, Lacking employee involvement</p> <p>Competing variables</p>	<p>The study relates an improved safety level and an improved safety culture to the ISM code. W: Does not measure or analyze safety culture and accidents. S: Provides in-depth qualitative data.</p>
		<p><u>Safety culture and behaviours:</u> Peer-to-peer observation of safety behaviour central in intervention</p> <p><u>Behaviours and accidents:</u> Increase in reported injuries in spite of the peer-to-peer observation of behaviour</p> <p><u>Rules and regulators:</u> regulators had to make sense of the new ISM code</p> <p><u>Regulators and companies:</u> companies made sense of the code with help from regulators</p> <p><u>Managers and employees:</u> negotiate over system requirements</p> <p><u>Shared thoughts and actions (structure and culture):</u> introduced by the ISM code</p> <p><u>Culture and behaviours:</u> new ways of acting due to system requirements</p> <p><u>Behaviours (or culture) and accidents:</u> The relationship between safety culture and safety improvement is implicitly/explicitly hypothesized to be mediated by safety behaviours (reduction of human errors)</p>		
<p>Murray et al (2009), UK, Road</p>	<p>Analyses effect of program on fleet audit results based on accident data from 7000 heating and plumbing distributor drivers (3000 vehicles).</p> <p>Relationships studied quantitatively.</p>	<p><u>Regulations and companies:</u> Intervention partly motivated by safety and health, transport, and corporate regulations, not least the joint Health and Safety Executive/ Department for Transport Guidance on Work-Related Road Safety.</p> <p><u>Safety culture/structure measures and accidents:</u> The relationship between safety culture/structure measures and accidents is implicitly/explicitly hypothesized to be mediated by behaviours.</p>	<p>Regulatory specificity, Company translations of the joint Health and Safety Executive/ Department for Transport Guidance on Work-Related Road Safety.</p> <p>Presumably fewer violations that are related to accidents.</p>	<p>Improvement in audit scores for organisational leadership, improved culture, combined with accident reduction. Almost 2-fold reduction of third-party collisions per vehicle, and £500 k savings on uninsured cost recoveries.</p> <p>W: No control. Difficult to conclude about most effective elements. S: Provides in depth understanding of safety measures and effects in the company.</p>

excluded as they did not entail regulatory involvement at any stage, according to the criteria described in section 3.3.

We retrieved 17 studies describing regulatory efforts to influence safety culture in transport organizations and in petroleum. Figure one indicates 18 studies, but this is due to the fact that Nævestad et al. (2018) was retrieved in both the search for road and rail. This is a study which covers all transport sectors. The same applies to Nævestad and Phillips (2018), which is identified “through other sources” and counted as air in the figure, although it also covers all transport sectors.

4.2. Overview of the studies

Table 2 presents an overview of studies of safety culture regulation in transport, while Table 3 presents studies from the Norwegian petroleum sector. The two first columns sums up the main characteristics of the studies (cf. aim 1), while column three and four provides the basis for developing the conceptual model (cf. aim 2). Finally, column five tells what we can learn from the studies when it comes to outcomes, and thus

how we may use them to draw practical implications (cf. aim 3).

4.3. Analytical relationships between regulatory initiatives to improve safety culture and accidents

In this study, we review two lines of research to develop a conceptual model of how regulators can improve safety in organizations by improving safety culture. Nine of the studies concern transport (Table 2) and eight of the studies concern the HSE-culture provision of the Norwegian PSA (Table 3). The studies from transport and petroleum have different focus. Most of the studies from petroleum focus on regulators, and or companies. These studies do largely not examine whether, or how the HSE-culture requirement leads to changes in safety culture, safety behaviour or accident trends in petroleum companies, although they do study how the requirement led to development and implementation of organisational safety culture campaigns in the companies, aiming to improve safety culture and safety behaviours. Thus, these studies do not provide information about the successfulness of the “ultimate aim” of

**Table 3**

Studies of safety culture regulation in Norwegian petroleum: focus, methods, depicted analytical relationships between regulatory initiatives to improve safety culture and accidents, factors influencing the relationships and outcomes of regulatory efforts. The regulatory initiative in all these studies is the PSA's HSE-culture provision, which was introduced in 2002.

Study/country/sector. Focus.	Method/sample	Studied analytical relationships	Factors influencing each relationship	Outcomes of the studied interventions (S = strengths, W = weaknesses)
<a href="#">Nævestad et al (2019)</a> Identification and discussion of strategies regulatory authorities can use to influence safety culture in organizations	Systematic literature review from petroleum, the nuclear industry, and rail.	<u>Rules and regulators:</u> regulators make sense of rules and strategies.  <u>Regulators and companies:</u> companies make sense of the new regulations and communicate with regulators <u>Managers and employees:</u> negotiate over meaning and translate the inputs to their context.  <u>Reciprocal effects between shared thoughts and actions:</u> the translations may lead to new ways of thinking which may lead to new ways of acting and vice versa. <u>Safety culture and safety behaviours:</u> Some of the studies reported both improvements in safety culture and behaviours due to the intervention <u>Behaviours and accidents:</u> some studies reported both improved safety behaviours and fewer accidents due to the interventions	Comprehensive regulatory competence on safety culture in the nuclear industry. Abstract concept Shared problem definition. Regulatory specificity. Different regulatory approaches in the sectors. Company translations. Trust between managers and employees, Managers' safety commitment, The existence of subcultures, Employee involvement. Implementation of SMS is a strategy for safety culture development in the nuclear industry, and rail  Competing variables  Especially violations were related to accidents	Identifies and discusses 5 rule-based and 6 advisory-based strategies. Some strategies lead to learning among regulators and companies. Other lead to improved safety culture, safety behaviours and fewer accidents. Identified outcomes are also contingent of the studies' methods/focus. W: Does not relate strategies to outcomes (i.e. accidents). S: Identifies strategies based on pioneer sectors.
<a href="#">Antonsen et al (2017)</a> Norway, Petroleum. Authorities' and companies' experiences with the HSE-culture provision	Interviews with 8 representatives from authorities and 13 representatives from companies Relationships studied qualitatively.	<u>Rules and regulators:</u> had to make sense of the new HSE-culture provision  <u>Regulator and companies:</u> To respond to the HSE-culture provision, companies started processes of sensemaking and negotiation of the meaning of the HSE-provision	Abstract concept: HSE-culture is an "intangible" concept, ill-suited for a command and control approach to regulation. Regulatory approaches and strategies, abstract concept, company translation, company characteristics	The provision led to confusion in the start, but eventually also learning and new regulatory practices. Served as a sensitizing concept for both the regulator and the industry, increasing the capacity of both parties to address informal and systemic aspects of safety. W: Does not analyze the relationship between safety culture and accidents. S: Provides good in-depth analysis of sensemaking.
<a href="#">Bye et al (2016)</a> Norway, Petroleum. Function of the 'culture' concept in communications from the regulatory authorities to the industry	Document analysis and six interviews with regulators about the documents. Relationships studied qualitatively.	<u>Rules and regulators:</u> had to make sense of the new provision  <u>Regulators and companies:</u> companies had to make sense of the new provision  <u>Culture and behaviour:</u> link pointed out by regulators  <u>Culture and accidents:</u> regulators and companies related culture to accidents	Abstract concept: the plasticity of the HSE-culture concept allowed for several different approaches. The plasticity of the concept allowed for many different HSE-culture approaches in the regulated companies Regulatory approaches and strategies Regulatory specificity Several definitions were also used by the regulator HSE culture was typically used to characterise organisations with frequent rule violations Culture may be a stumbling block for learning, when used in accidents investigations, as it may hinder the focus on more specific causes	"Double-edged sword". Making sense of the HSE-culture involved learning, but the concept could also be a "stumbling block" for learning. W: Does not directly analyze the relationship between safety culture and accidents. S: Provides a good analysis of the function of the culture concept in communication between regulators and companies.
<a href="#">Kongsvik and Gjøvsund (2016)</a> , Norway, Petroleum Two companies' "translations" of the HSE requirement of the Norwegian PSA	14 interviews with people from two companies. Relationships studied qualitatively.	<u>Regulators and companies:</u> companies had to make sense of the HSE-culture provision	Culture is an abstract concept, which has to be "translated" by companies Companies' translations are influenced by company characteristics, like history, complexity and strategy.	Companies' translations were shaped by company characteristics. The translations are understood as learning of new perspectives on safety. The translations also brought forth outcomes that were unanticipated by the regulators. W: Does not analyze the relationship between safety culture and accidents.

(continued on next page)



Table 3 (continued)

Study/country/sector. Focus.	Method/sample	Studied analytical relationships	Factors influencing each relationship	Outcomes of the studied interventions (S = strengths, W = weaknesses)
<a href="#">Le Coze and Wiig (2013)</a> Norway, Petroleum Approach the proceduralization of safety through the perspectives of risk regulation and safety culture.	Six interviewees with regulators in the PSA, including previous research. Relationships studied qualitatively.	<u>Rules and regulators:</u> regulators made sense of the HSE-culture provision  <u>Regulators and companies:</u> companies made sense of the HSE-culture provision	HSE-culture is a polysemous concept Background: The PSA engineers were used to the man-technology-organisation (MTO) model Companies came up with different conceptualisations of HSE-culture, because of the ambiguity of the concept and the: Low degree of regulatory specificity Company characteristics Uncertainty related to the actual enforcement of the provision Integration challenges: Difficult to integrate the HSE-culture provision within the other activities of the PSA Difficult to integrate HSE-culture with supervisory practices The context of ordinary audits was unsuitable for making "cultural diagnoses" Critical organisational discontinuities The follow up was not deeply entrenched in the organisation No systematic analysis of how HSE culture was related to the existing regulatory requirements Several competing and related approaches Abstract concept Safety challenges: shared problem definition/point of departure The intention with the provision was to create a dialogue with the industry Companies responded by developing safety programmes Interpretive challenges and translation	S: Provides a good analysis using the concept of translations. Relating to the HSE-culture requirement, the regulators and companies learn about management aspects not covered by traditional approaches. Results that were unanticipated by the regulators. W: Does not analyze relationship between safety culture and accidents. S: Provides good in-depth analysis of the PSA's challenges.
<a href="#">Kringen (2013)</a> , Norway, Petroleum Based on <a href="#">Kringen (2009)</a> , but discussed in light of a new theoretical framework.	Field work, interviews, document analysis and literature review. Relationships studied qualitatively.	<u>Rules and regulators:</u> regulators had to made sense of the HSE-culture provision and integrate it into their regulatory practices  <u>Regulators and companies:</u> companies had to translate the HSE-culture provision to their context and respond to it	Difficult to make sense of the concept and develop an audit standard  Companies reacted through "impression management"; seemingly doing something with HSE-culture.	The HSE culture provision involved high interpretive costs, but it also involved learning. W: Does not analyze the relationship between safety culture and accidents. S: Provides good in-depth analysis of the PSAs situation.
<a href="#">Karlsen and Valen (2010)</a> Norway, Petroleum	Discourse analysis of key documents. Relationships studied qualitatively.	<u>Rules and regulators:</u> regulators had to made sense of the HSE-culture provision and integrate it into their regulatory practices <u>Regulators and companies:</u> companies had to translate the HSE-culture provision to their context and respond to it	Difficult to make sense of the concept and develop an audit standard  Companies reacted through "impression management"; seemingly doing something with HSE-culture.	The HSE-culture concept was not ready/suitable a to be used as a regulatory concept. This made it difficult to develop a standard related to auditing. W: Does not analyze the relationship between safety culture and accidents. S: Provides good insights about the safety culture discourse.
<a href="#">Kringen (2009)</a> Norway, Petroleum Comprehensive PhD dissertation on the first years of the HSE-culture provision.	Field work, interviews, document analysis and literature review. Relationships studied qualitatively.	<u>Rules and regulators:</u> regulators had to made sense of the HSE-culture provision and integrate it into their regulatory practices  <u>Regulators and companies:</u> companies had to translate the HSE-culture provision to their context and respond to it  <u>Culture and behaviour:</u> Provides an anthropological discussion of the relationship between culture and behaviour	Ambiguous and abstract concept Integration challenges Technical background/competence of regulators High interpretive costs and frustration for regulators (but also learning) Shared problem definition Companies had to translate the HSE-requirement and make sense of the abstract culture concept Discuss safety programs as a response to the provision	High interpretive costs, frustration, learning, unanticipated consequences. W: Does not quantitatively analyze the safety outcomes of the HSE culture provision. S: Provides an extremely good overview of the situation and the context.

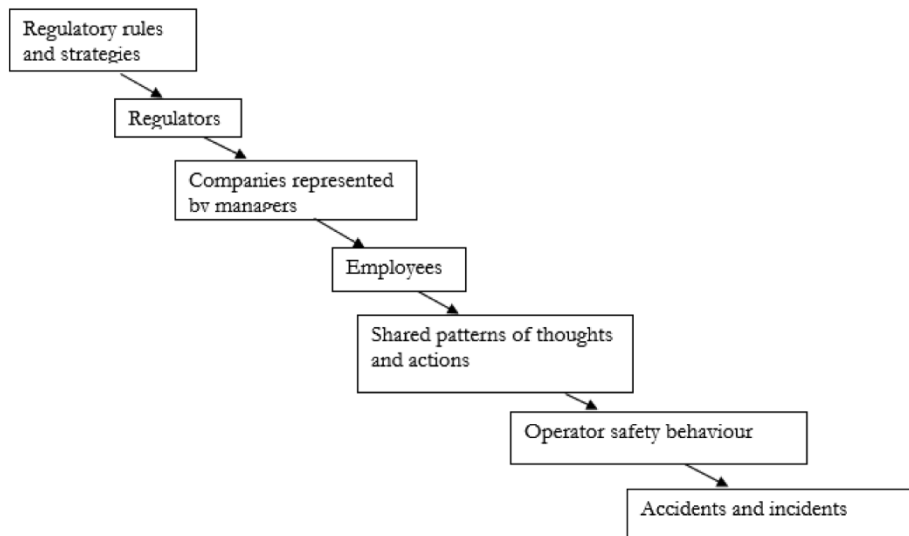


Fig. 2. Conceptual model of six analytical relationships between regulatory attempts to improve safety and operator accidents.

safety culture regulation, which is to reduce accidents. The studies from petroleum are generally qualitative, and they focus on processes of sensemaking and social negotiation.

The studies from transport are studies of interventions that are supported and/or designed and/or implemented by regulatory agencies. In contrast to the studies from petroleum, these studies focus less on the sensemaking processes among regulators and companies and more on the consequences of regulatory influences on the company and work group level and on the individual operator level. As a consequence, the reviewed studies from petroleum and transport focus on different analytical relationships and actors.

When combining these two lines of research, we get a picture of six relationships between regulatory efforts to influence safety culture and accidents, between (cf. Fig. 2):

- 1) Rules and regulators.
- 2) Regulators and companies.
- 3) Managers and employees in the companies.
- 4) Organizational members' shared ways of thinking and acting.
- 5) Safety culture and safety behavior.
- 6) Safety behaviour and accidents

We expand more on these relationships below.

**1) Rules and regulators.** The relationship between official rules/strategies and regulators is studied in 10 of the studies. This relationship is included in all of the studies from petroleum, which describe how the regulators had to make sense of the new HSE-culture provision, and the factors influencing these processes. The relationship is also the focus of Nævestad & Phillips' (Nævestad and Phillips, 2018) study of the Swedish Transport Agency (STA), where regulators have to make sense of the new safety culture strategy of the STA and review this in light of the existing rules in the sectors, and also in Lappalainen et al. (2012) study of the ISM code, which describes how regulators made sense of the ISM code requirements.

**2) Regulators and companies.** The relationship between regulators and companies is studied in all the reviewed studies. One of the criteria for including studies is that they involve safety culture initiatives with some type of regulatory involvement. All of the studies describe how companies make sense of and respond to such initiatives, indicating the importance of this relationship.

**3) Managers and employees in the companies.** This relationship is examined in the studies focusing on transport. Regulators may facilitate processes of safety cultural change and organizational learning within

organizations, which managers in organizations may respond to by developing safety culture campaigns or other internal learning processes (Bye et al., 2016; Kongsvik and Gjørund, 2016; Antonsen et al., 2017). The reviewed studies indicate that, when such processes are implemented, the development of safety culture in the organizations is shaped by the relationship between managers and employees (Zuschlag et al., 2016; Goettee et al., 2015; Naveh and Katz-Navon, 2015).

**4) Organizational members' shared ways of thinking and acting.** The reciprocal effects between shared ways of thinking (e.g. shared attitudes) and shared ways of acting (shared behaviours) denote the two key elements in our definition of safety culture. This relationship is discussed in six of the studies, in their descriptions of how safety culture change may be induced, e.g. through information campaigns (Zuschlag et al., 2016; Naveh and Katz-Navon, 2015), or through the implementation of safety management systems (Lappalainen et al., 2012; Nævestad et al., 2018, 2019; Naveh and Katz-Navon, 2015; Nævestad and Phillips, 2018).

**5) Safety culture and safety behavior:** We may assume that most of the reviewed studies implicitly assume that the influence of safety culture on accidents is mediated by safety behaviours, in line with the argument presented by Bye et al. (2016). The link between safety culture and safety behaviour is however only discussed explicitly in three of the reviewed studies (Lappalainen et al., 2012; Naveh and Katz-Navon, 2015; Zuschlag et al., 2016).

**6) Safety behaviour and accidents:** All of the studies take a relationship between safety culture and accidents (or safety performance) as their explicit or implicit point of departure, but only a few of the studies also examine how this relationship is mediated by safety behaviours (e.g. Zuschlag et al., 2016; Goettee et al., 2015; Naveh and Katz-Navon, 2015). The reviewed studies, focusing on the relationship between safety behaviours and accidents largely focus on violations (e.g. Zuschlag et al., 2016; Amtrak, 2015; Naveh and Katz-Navon, 2015).

#### 4.4. Factors influencing the analytical relationships

##### 4.4.1. The relationship between official rules/strategies and regulators

Reviewing the relationship between official rules/strategies and regulators, we have identified four factors that may influence this relationship. The first is the *abstract and ambiguous character of the culture concept*, which is underlined in the studies of the Norwegian HSE-culture provision and in the study of the STA's safety culture strategy. The second influencing factor is that *sensemaking may involve high interpretive costs*. All studies from petroleum mention (albeit with different

concepts) what Kringen (2009) refers to as the high interpretive costs and frustration that the HSE-culture provision brought forth. The third influencing factor is *Regulatory backgrounds, competence and judgments*, which the reviewed studies also found to influence regulators' conceptualisation of culture (Kringen, 2009; Lappalainen et al., 2012; Nævestad and Phillips, 2018). The fourth influencing factor is *Challenges related to the integration of culture into the regulatory strategy* and the regulatory activities and existing rules governing these activities. This is noted in studies from petroleum, of the STA (Nævestad and Phillips, 2018) and the study of the ISM code (Lappalainen et al., 2012). The situation was different in aviation, where regulators applied already known CRM principles to MRM (Patankar, 2019).

#### 4.4.2. The relationship between regulators and companies

Reviewing the relationship between regulators and companies (mainly represented by their managers) we identified five influencing factors. The first is *Shared problem definition*. In most of the studies, it seems that the background for the increased regulatory and company focus on safety culture is a joint agreement that the safety level in the sector is stagnating, and that new perspectives and interventions are required (Goettee et al., 2015; Lappalainen et al., 2012; Zuschlag et al., 2016; Grote and Weichbrodt, 2013; Patankar, 2019). The second is *Regulatory approaches and strategies*. It seems that most of the reviewed regulatory interventions apply function-based and advisory-based approaches, probably, as the safety culture concept is ill-suited for a "command-and-control" approach, as Antonsen et al (2017) puts it. In contrast, four of the studies from the transport sectors are evaluations of organizational interventions that are supported and/or designed and/or implemented by regulatory agencies (Zuschlag et al., 2016; Goettee et al., 2015; Naveh and Katz-Navon, 2015; Patankar, 2019). The third influencing factor is *Regulatory specificity*. The reviewed studies indicate considerable differences when it comes to regulatory specificity, i.e. the extent to which safety culture and/or the safety culture interventions are specified and operationalized for the companies by regulators. In the one end of the continuum, we have the organizational interventions that are supported and/or designed and/or implemented by regulatory agencies (Zuschlag et al., 2016; Goettee et al., 2015; Naveh and Katz-Navon, 2015; Patankar, 2019). These are specific, consisting of pre-defined theoretical models and implementation steps. In the other end of the continuum, we have the Norwegian HSE-culture requirement, which leaves it up to the companies to specify what constitutes 'a sound HSE culture', and how to achieve it. The fourth factor is *Companies' translations*. Low regulatory specificity leaves it up to the companies to specify safety culture and safety culture interventions in petroleum (Kongsvik and Gjørund, 2016; Antonsen et al., 2017; Kringen, 2009) and in road (Murray et al., 2009). In rail, company translations developed as a response to the Railroad Safety Improvement Act, together with consultants (Zuschlag et al., 2016; Naveh and Katz-Navon, 2015). The fifth factor is *Company characteristics*. Several studies indicate that company efforts to make sense of the safety culture concept, e.g. as "required" by regulators, are influenced by company characteristics (Kongsvik and Gjørund, 2016; Nævestad and Phillips, 2018).

#### 4.4.3. The relationship between managers and employees in the companies

Based on our review, we argue that four influencing factors are important in this relationship. The first is *The level of trust between managers and employees*, which is a key factor influencing the relationship between managers and employees in companies (Zuschlag et al., 2016; Nævestad et al., 2018; Amtrak, 2015). The second is *Managers' expressed safety commitment*, which is key in studies from the maritime sector, rail and road (Goettee et al., 2015; Lappalainen et al., 2012; Naveh and Katz-Navon, 2015). The third influencing factor is *The existence of sub-cultures*. Some of the studies indicate that employees' reception of managerial attempts to influence safety culture (and the reception of managerial communication in general) are contingent on the existence of sub-cultures (Lappalainen et al., 2012; Zuschlag et al.,

2016; Amtrak, 2015). These studies indicate that sub-cultures may respond negatively to managerial attempts to influence culture. The fourth influencing factor is *Employees' involvement and engagement*, as the reviewed studies indicate that employee involvement and engagement may be a way of dealing with resistance from sub-cultures, albeit with mixed success. In the successful case of Union Pacific (Zuschlag et al., 2016), employees were involved while lacking employee involvement is listed as an impeding factor in the less successful Safe-2-safer intervention (Amtrak, 2015). In the maritime sector, Lappalainen et al. (2012) notes that the resistance from sub-cultures waned as systems became more user friendly, and as the "old generation" of seafarers was replaced. It seems that one of the key purposes of the MRM programs was to increase trust between managers and safety awareness and commitment through employee involvement (Patankar, 2019).

#### 4.4.4. The relationship between shared ways of thinking and shared ways of acting

Above we saw that the reviewed studies indicate that organisational safety culture change comes about in the dynamic between "top-down" processes initiated from the management and "bottom-up" processes based in sub-groups. We will now look even closer at the processes of safety culture change, discussing whether the dynamic between "top-down" and "bottom-up" processes start by changes in organisational members' shared patterns of thoughts or shared patterns of actions, which are the two key elements in our definition of safety culture. This discussion is important for regulators, as it may provide an indication of whether safety culture change among organisational members start with new ways of acting (e.g. behaviour change) or new ways of thinking (e.g. attitude change), and subsequently which of these processes that regulators should facilitate.

The review indicates three factors influencing the dynamic of safety culture change, involving the interplay between shared ways of thinking and acting. The first is: *Culture change starts with changes in shared ways of thinking* (e.g. new attitudes, norms, frames of reference). Several interventions focus on influencing shared ways of thinking in order to change shared ways of acting, e.g. through information campaigns and awareness training (Naveh and Katz-Navon, 2015; Patankar, 2019). The second factor influencing safety culture change is: *Culture change starts with changes in shared ways of acting*. Some researchers underline the limited possibilities to change peoples' attitudes, and argue in favour of influencing shared patterns of thinking by shaping shared patterns of behaviour (cf. Reason, 1997; Weick and Sutcliffe, 2007). Thus, some of the studied safety culture interventions focus on facilitating safety behaviour change (e.g. Zuschlag et al., 2016; Amtrak, 2015). Shared patterns of meaning may arise from shared patterns of action, as group members collectively negotiate and adapt their shared beliefs to their shared patterns of behaviour, e.g. through the mechanism of cognitive dissonance. This line of reasoning is probably the reason why Weick and Sutcliffe (2007: 114) argue that: "We think culture is something an organization has that eventually becomes something an organization is. Organizations act their way into what they become". The third influencing factor is *System implementation as safety culture development*. Our review indicates that one way that organizations may "act their way into what they become", is through the introduction of safety management systems (Lappalainen et al., 2012; Nævestad et al., 2018; Naveh and Katz-Navon, 2015; Nævestad and Phillips, 2018). Such systems could, according to the cognitive dissonance and sensemaking mechanisms shape shared safety behaviours and perhaps shape shared ways of thinking about safety, reinforcing the shared ways of acting (cf. Nævestad et al., 2019). Implementing an SMS largely concerns implementing certain routines and ways of doing things in the organization, e.g. carrying out risk assessments, document the process, developing procedures and training new employees etc. (Lappalainen et al., 2012; Nævestad et al., 2018; Naveh and Katz-Navon, 2015). An expressed aim of many SMS is that these new ways of acting shall lead to new ways of thinking (Kongsvik and Gjørund, 2016; Lappalainen et al., 2012; Naveh

and Katz-Navon, 2015; Nævestad and Phillips, 2018).

To conclude, the reviewed studies indicate that safety culture change may start both with changes in shared ways of thinking and changes in shared ways of acting (including SMS implementation) and that the relationship between these is reciprocal.

#### 4.4.5. The link between safety culture and safety behaviour

The reviewed studies indicate that not all behaviours are in accordance with the shared patterns of behaviour prescribed by safety culture. Thus, people who are members of safety cultures may act in other ways than prescribed by their safety cultures.

Reviewing the relationship between organizational members' shared ways of thinking and acting (i.e. safety culture) and safety behaviours, we identified two influencing factors. The first is *Competing variables influencing safety behaviour* in addition to safety culture. A popular definition of safety culture is that it refers to "what you do when you are alone and nobody watches" (Kelly, 2013). Although this definition is interesting, we must remember that our behaviours also are likely to be influenced by a range of different variables, competing with safety culture, e.g. sex, employee driving experience, whether the employee is a professional driver etc. (Zuschlag et al., 2016; Nævestad et al., 2015; Naveh and Katz-Navon, 2015). Thus, "what we do when nobody watches" is also dependent on a range of other factors than safety culture. The second factor is *Normative influences on behaviours*. When safety culture competes with other potential factors (age, sex, experience) in influencing our behavior, its success depends on the strength of "normative influences on behavior". Patankar (2019) describes that the focus of the MRM training was to create a strong sense of safety commitment and responsibility. Explaining why safety climate may influence drivers at work, even when they are out driving on the road far from their managers and colleagues (and even also when they drive in their leisure time), Naveh and Katz-Navon (2015) state that safety climate's implicit expectations are often socially translated into shared norms: informal rules creating pressures for conformity. They suggest that changes in behaviors produced by social norms may be a result of two processes: compliance and internalisation. Lappalainen et al. (2012) describe the latter process applying to younger maritime personnels' internalized attitudes to the ISM-code, acquired through their education.

#### 4.4.6. Safety behaviour and accidents

The reviewed studies, focusing on the relationship between safety behaviours and accidents largely focus on violations (e.g. Zuschlag et al., 2016; Amtrak, 2015; Naveh and Katz-Navon, 2015). Thus, we see that especially violations are related to accidents. This indicates that the most important influencing factor in the relationship between safety behavior and accidents is violations, and that safety culture measures aimed at preventing accidents should target violations. Patankar (2019) also relates the reporting of incidents to injuries and incidents.

## 5. Concluding discussion

### 5.1. Analytical relationships and influencing factors

The main contribution of the paper is the conceptual model (Fig. 2) of six analytical relationships between regulatory attempts to improve safety and operator accidents, which we developed in section 4.3. Our review indicates that regulatory efforts to reduce the number of accidents by focusing on safety culture is a complex issue. First, there are at least seven different levels and six relationships, mediating between regulatory attempts to influence organizational safety culture and accidents.

Our discussion indicates that safety culture regulation is a complex issue, because of these levels and relationships. Regulator attempts to influence safety culture are mediated through these different levels and relationships, and we discuss how they may fail or succeed at each level,

by highlighting factors influencing the relationships.

It is important to note that our conceptual model merely represents a hypothesized causal link, which should be examined further in future research. It is also important to note that the list of influencing factors is not exhaustive. Our conceptual model is limited by our analysis of the reviewed studies. We hope nevertheless that our model contributes to theoretical developments, and that it can provide regulatory authorities with both a new way of understanding their role when it comes to safety culture development and practical advice on how they can try to do this.

### 5.2. Practical implications for regulators

#### 5.2.1. What does it mean to regulate safety culture?

Our discussion of the studies from petroleum indicates that it may be argued that safety culture is an unsuitable regulatory concept, as "checking companies' compliance" may be difficult (e.g. Kringen, 2009; Antonsen et al., 2017). The reviewed studies indicate, however, that regulation of safety culture may involve several different things, targeting different analytical levels. The reviewed studies indicate that regulators may influence safety culture in companies e.g. through developing guidelines and leaflets (Murray et al., 2009), developing audit strategies (Nævestad and Phillips, 2018), training programmes (Goettee et al., 2015; Patankar, 2019), by designing and/or supporting interventions (Naveh and Katz-Navon, 2015; Zuschlag et al., 2016; Amtrak, 2015), or by developing a HSE-culture provision, as indicated by the studies from petroleum (cf. Table 3).

These examples indicate that regulation involves all kinds of influence, not just the activities that are preconceived in the traditional "command and control approach" (e.g. checking rule compliance). Thus, it seems including safety culture as a regulatory tool requires a shift in the perspective of regulators (Antonsen et al., 2017; Nævestad et al., 2019). Safety culture can be perceived as a more relevant regulatory concept when regulation also is more broadly defined. In accordance with this, Nævestad et al. (2019) refer to advisory-based strategies to regulate safety culture, which often are combined with function-based rules and companies' self-regulation.

#### 5.2.2. Which analytical level should regulators target?

It is difficult to conclude which of the reviewed regulatory strategies that are the most effective, since they study different outcome variables, and as the methodologies of the reviewed studies differ substantially. The reviewed studies indicate that regulatory efforts to influence safety culture may target different analytical levels in our hypothetical causal chain, involving different levels of specificity, uncertainty and opportunities for learning. The PSA's HSE-culture requirement target the highest analytical level in our model, it involves a relatively low level of specificity and a relatively high degree of uncertainty. In the other end of the general-specific continuum, we have the organizational interventions that are supported and/or designed and/or implemented by regulatory agencies (Zuschlag et al., 2016; Goettee et al., 2015; Naveh and Katz-Navon, 2015; Patankar, 2019). These are specific, consisting of pre-defined theoretical models and implementation steps. These initiatives target the "lower level" in the hypothetical causal chain. Then which analytical level should regulators target; and should regulatory measures to influence safety culture be general or specific? An interesting feature of the reviewed (successful) interventions and regulatory efforts in transport is that they combine both general and specific traits. First, they all have general "policy statements"; e.g. the STA strategy, the manager safety commitment focus (Goettee et al., 2015; Lappalainen et al., 2012; Naveh and Katz-Navon, 2015; Zuschlag et al., 2016; Amtrak, 2015; Patankar, 2019). Second, they also include specific operationalisations or instructions: the 28-point safety culture audit checklist of the STA, ISM-audit checklist, 39,001 SMS elements, MRM program elements (Zuschlag et al., 2016; Goettee et al., 2015; Naveh and Katz-Navon, 2015; Patankar, 2019). Thus, a hypothesis that could be examined in future research is whether a combination of general and

specific approaches may provide an appropriate combination of learning, uncertainty, risk and control.

### 5.2.3. Does safety culture regulation involve too much uncertainty?

It can be argued that safety culture regulation may involve too much uncertainty, because of the abstract and general character of the culture concept (Kringen, 2009; Grote and Weichbrodt, 2013). Antonsen et al. (2017) argue, however, that the safety culture concept is not more abstract and general than other concepts that are used within function-based regulation, e.g. “good seamanship”, “all activities shall be prudent”). Thus, this critique may be applied to function-based regulation in general, and not just the culture concept.

Additionally, our study indicates that the use of safety culture as a regulatory tool is a complex issue, involving a high level of uncertainty, and many possibilities for failure or unintended results at each of the analytical levels in our hypothetical causal chain, because of the influencing factors. One possible conclusion of our review could be that regulatory efforts to prevent accidents by focusing on safety culture therefore involve too much uncertainty, and too many possible (“compliant”) responses from the companies to be considered as a viable regulatory strategy.

On the other hand, this can be viewed as a strength. Regulation of safety culture is well aligned with the increasing tendency of function-based regulation, where companies get the opportunity to develop and define their own ways of complying with regulations, e.g. developing safety management systems and/or interventions to improve their safety culture, which are in accordance with their situation (e.g. history, personnel, culture, competence, resources), their needs etc. In this context, there are no predefined way of complying with regulations, as an important point is to generate learning, processes of continuous improvements and living systems. In this context, regulatory activities focus more on auditing the quality of the systems and the processes of continuous improvement.

As noted by Nævestad et al. (2019) and Antonsen et al. (2017), the main strength of the safety culture approach is that it directs our attention to the informal aspects of safety management in a systematic way; how “things are actually done” in organisations, which often may be in conflict with the formal systems describing “how things should be done”. Several accident investigations find a discrepancy between these two aspects of safety management (Antonsen, 2009). Moreover, several of the reviewed studies indicate that efforts to influence safety culture often is related to reductions in accidents (Zuschlag, 2016; Gregersen et al., 1996; Bjørnskau and Nævestad, 2013). Thus, it seems important to equip regulators with the perspectives and tools to focus systematically on informal aspects of safety (see also: Nævestad et al., 2019).

## 5.3. Methodological limitations and questions for future research

### 5.3.1. The linear progression depicted in the model is an oversimplification

The linear progression depicted in Fig. 2 represents an over simplified process, that can be problematized in several ways. In several of the cases, there are for instance feedback loops from the lower levels to the higher levels. Employees and/or companies may for instance provide feedback to regulators in manners that lead to reformulation of regulatory rules and strategies. Moreover, employees also influence their managers’ attempts to shape culture. Thus, perhaps the elements in the model also could have been depicted in a more circular way, with mutually influencing elements, instead of depicting the regulatory level as the level “where it all starts”. The reason that we depict the model in a linear fashion, starting with the regulatory level is based on our focus on the regulatory level and our premise of the possibilities and limits of regulatory influence, using safety culture as a regulatory tool. Thus, by discussing all the influencing factors, we have included the premise of complexity, feedback loops and uncertainty in the model. This is an important issue for future research.

### 5.3.2. Compliance as an implicit precondition of the linear model

It is also important to note the premise of compliance that may be seen as an implicit precondition of the linear model: the relationships between many of the different analytical levels in the model are so to speak defined by the level of compliance. This means that if the addressee of the level in question complies successfully, the regulatory intention is successfully “transmitted” to the next level. This illustrates that compliance itself is a multi-level phenomenon, which concerns each analytical level in the model (Cf. Kvalheim and Dahl (2016) for a discussion of the relationship between safety culture and compliance.)

### 5.3.3. The positive contribution of the human element

The underlying assumption of humans as a source of failure, given lacking compliance, in the linear model underestimates the potentially positive contribution of the human element. The human element may also be a source of resilience, flexibility and innovation in organisations, which may enable organisations to bounce back from safety threatening conditions. This is the focus in e.g. the high reliability organizations (HRO) research, which focuses on high risk systems that perform far better on organizational safety than one should expect, given the fact that they are defined as high risk systems (Weick et al., 1999). One of the important factors evoked by HRO researchers to explain this is culture. Thus, one of the main strengths of the safety culture concept is that it directs attention to, and may strengthen this positive force of the human element in organisations.

### 5.3.4. The relationship between safety culture and safety outcomes

There is much debate about the relationship between safety culture and safety outcomes. This is probably related to the fact that this relationship is methodologically challenging to measure. The review includes nine studies which mainly rely on qualitative methods (Lappalainen et al., 2012; Nævestad and Phillips, 2018, Antonsen et al., 2017; Bye et al., 2016; Kongsvik and Gjørund, 2016; Kringen, 2009; Lappalainen et al., 2012; Kringen, 2013; Le Coze and Wiig, 2013). The outcome measures in these studies are generally learning and new perspectives on safety, views on safety culture and the general views on safety and challenges in the sector. The main strengths of the qualitative studies are the focus on translation processes, social negotiation over meaning and factors influencing these processes. The main limitation of these studies is that they generally do not quantify these outcomes or relate them to safety outcomes further down the hypothesized causal chain of the model in Fig. 2 (i.e. safety behaviour and accidents).

The review includes five studies that mainly rely on quantitative methods, and which focus on safety behaviours and accidents. Assessing the quantitative relationship between safety culture and safety outcomes is, however, not straightforward. A previous study concludes that it is important to discern between the different study designs (Bjørnskau and Nævestad, 2013). Prospective research designs measure accidents after the safety culture has been measured, whereas retrospective designs compare the accident history with current safety culture levels. In retrospective studies it is in principle not possible to decide which way the causal direction goes. Thus, prospective studies are generally considered better. Bjørnskau and Nævestad (2013) report examples of retrospective designs which find (unexpected) positive relationships between safety culture and accidents. This can be related to learning and implementation of measures to improve the safety culture after accidents. Additionally, (unexpected) positive relationships between safety culture and accidents/incidents can also be attributed to the fact that a positive safety culture involves a high level of trust, and a high focus on reporting incidents to learn. Thus, improvements in safety culture may be followed by a higher level of reported incidents, which may give the impression of a lower safety level. Five of the reviewed studies are prospective intervention studies (Zuschlag et al., 2016; Goette et al., 2015; Naveh and Katz-Navon, 2015; Amtrak, 2015; Murray et al., 2009). These studies follow intervention and control units over time, to study the effect of safety culture interventions in the intervention units,

although not all of the prospective intervention studies employ control units (cf. Murray et al., 2009). Four of the five prospective studies report improvements in safety culture, and generally also improvements in safety behaviours and accidents and incidents. Although these four studies report improvements in safety culture, safety behaviours and accidents, the studies' methodological robustness differ. Zuschlag et al. (2016) employs, however, a high-quality prospective evaluation design (before and after study, with control groups), and this study indicates improved safety culture, 80% drop in at risk behaviours and 81% drop in accidents. The study of Naveh and Katz-Navon (2015) also employ a robust design, and although it does not include accidents as an outcome measure, it finds a 75% reduction in traffic violations in the intervention units.

### 5.3.5. Individual accidents versus organisational accidents

Finally, it is important to note the difference between individual and organizational accidents, (Reason, 1997; Grote, 2012). It refers both to different categories of accidents and different etiologies. In individual accidents, a specific person or a group is both the agent and the victim of the accident (Reason, 1997). Organizational accidents, on the other hand, are rare and often catastrophic events with multiple causes involving many people operating at different levels (Reason, 1997). We choose for the sake of simplicity to focus on accidents at the individual level in the present paper, but our discussion could have been expanded to also include the role of safety culture when it comes to preventing organizational accidents.

### CRedit authorship contribution statement

**Tor-Olav Nævestad:** Conceptualization, Writing - original draft, Writing - review & editing, Methodology, Validation. **Ingeborg Store-sund Hesjevoll:** Writing - original draft, Methodology, Validation. **Rune Elvik:** Writing - original draft, Validation, Methodology.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Acknowledgements

We are very grateful to the Swedish Transport Agency "Transportstyrelsen", which has funded this research. The work with the article has also been financed by the Transport2025 program of the Norwegian Research Council.

### References

Statista (2020) <https://www.statista.com/statistics/1031953/us-general-aviation-fatalities/>.

Amtrak (2015). Safety and security: opportunities exist to improve the Safe-2-Safer program, (Audit Report OIG-A-2015-007, February 19, 2015).

Antonsen, S., 2009. The relationship between culture and safety on offshore supply vessels. *Saf. Sci.* 47, 1118–1128.

Antonsen, S., Nilsen, M., Almklov, P.G., 2017. Regulating the intangible. Searching for safety culture in the Norwegian petroleum industry. *Saf. Sci.* 92 (2017), 232–240.

Baldwin, R., Cave, M., Lodge, M., 2012. *Understanding Regulation: Theory, Strategy, and Practice*. Oxford University Press, Oxford.

Bernard, B., 2018. Safety culture oversight: an intangible concept for tangible issues within nuclear installations. *Safety* 4 (45).

Bjørnskau, T., Nævestad, T.-O., 2013. Safety culture and safety performance in transport – A literature review. TØI-Working-paper-50267, Oslo.

Bye, R.J., Rosness, R., Dalseth Røyrvik, J.O., 2016. 'Culture' as a tool and stumbling block for learning: the function of 'culture' in communications from regulatory authorities in the Norwegian petroleum sector. *Saf. Sci.* 81, 68–80.

De Winter, J.C., Dodou, D., 2010. The Driver Behaviour Questionnaire as a predictor of accidents: a meta-analysis. *J. Saf. Res.* 41 (6), 463–470.

Elvik, R., Elvebakk, B., 2016. Safety inspectorates and safety performance: a tentative analysis for aviation and rail in Norway. 11 s. *Safety* 2 (2).

Eurostat (2019). [https://ec.europa.eu/eurostat/statistics-explained/index.php/Rail\\_accident\\_fatalities\\_in\\_the\\_EU](https://ec.europa.eu/eurostat/statistics-explained/index.php/Rail_accident_fatalities_in_the_EU).

European Rail Agency (2020) [https://www.era.europa.eu/activities/safety-management-system\\_en](https://www.era.europa.eu/activities/safety-management-system_en).

Flin, R., Mearns, K., O'Connor, P., Bryden, R., 2000. Measuring safety climate: identifying the common features. *Saf. Sci.* 34, 177–192.

Goette, D., Spiegel, W., Tarr, R., Campanian, C., Grill, L., 2015. Overview of Federal Motor Carrier Safety Administration Safety Training Research for New Entrant Motor Carriers. The SAGE Corporation, Motor Carrier Services.

Gregersen, N.P., Brehmer, B., Morén, B., 1996. Road safety improvement in large companies. An experimental comparison of different measures. *Accid. Anal. Prev.* 28 (3), 297–306.

Grote, G., 2012. Safety management in different high-risk domains – all the same? *Saf. Sci.* 50, 1983–1992.

Grote, G. & Weichbrodt, J. (2013). "Why regulators should stay away from safety culture and stick to rules instead", in *Trapping Safety into Rules: How Desirable and Avoidable is Proceduralization of Safety?*, Editors: Corinne Bieder, Mathilde Bourrier, pp. 225-240, Ashgate.

ICAO, 2021. ICAO Annex 19, Safety Management [https://www.skybrary.aero/index.php/ICAO\\_Annex\\_19\\_Safety\\_Management](https://www.skybrary.aero/index.php/ICAO_Annex_19_Safety_Management). (accessed on Jan. 21).

International Maritime Organisation (2015). Fishing vessel Safety <http://www.imo.org/en/OurWork/Safety/Regulations/FishingVessels/Pages/Default.aspx>.

Karlsen, J.E. H. Valen (2010) The social construction of HSE culture: A case study from the Norwegian petroleum industry, in Ale, Papazoglou, Zio (Eds.), *Reliability, Risk and Safety*, Taylor and Francis Group, London.

Kelly, D. (2013). When No One Is Watching. How Do You Define A Safety Culture? <http://www.ecmag.com/section/safety/when-no-one-watching>.

Kongsvik, T., Gjøsum, G., 2016. HSE culture in the petroleum industry: lost in translation? *Saf. Sci.* 81, 81–89.

Kringen, J., 2009. *Culture and control: regulation of risk in the Norwegian petroleum industry*. Ph.D. dissertation Center for Technology, Innovation and Culture, Faculty of Social Sciences. University of Oslo.

Kringen, J. (2013). Proceduralization and regulation of culture: experiments on the frontiers of risk regulation, in C. Bieder, M. Bourrier (Eds.), *Trapping Safety Into Rules. How Desirable or Avoidable Is Proceduralization?*, Ashgate, Farnham.

Kvalheim, S.A., Dahl, Ø., 2016. Safety compliance and safety climate: A repeated cross-sectional study in the oil and gas industry. *J. Saf. Res.* 59, 33–41.

Le Coze, J.-C., Wiig, S. (2013). Beyond procedures: Can 'Safety Culture' be regulated? In: Bieder, C., Bourrier, M. (Eds.), *Trapping Safety Into Rules. How Desirable or Avoidable Is Proceduralization?* Ashgate, Farnham.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. (2009). PRISMA Group: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement *BMJ*, 339.

Murray, W., Ison, S., Gallemore, P., Sing Nijjar, H. (2009). Effective Occupational Road Safety Programs. A case study of Wolseley. *Transportation Research Record*, NO: 2096, pp.55-64.

Naveh, E., Katz-Navon, T., 2015. A longitudinal study of an intervention to improve road safety climate: climate as an organizational boundary spanner. *J. Appl. Psychol.* 100 (1), 216–226.

Nævestad, T.-O. (2010). *Cultures, crises and campaigns: Examining the role of safety culture in the management of hazards in a high risk industry*. Ph.D. dissertation, Centre for Technology, Innovation and Culture, Faculty of Social Sciences, University of Oslo.

Nævestad, T.-O., Phillips, R.O. (2018). The relevance of safety culture in professional transport: Comparing experiences of regulators and companies from four sectors, TØI-Report.

Lappalainen, F.J., Kuronen, J., Tapaninen, U., 2012. Evaluation of the ISM Code in the Finnish shipping companies. *J. Maritime Res.* 9 (1), 23–32.

Nævestad, T.-O., Phillips, R.O., og Elvebakk, B., 2015. Traffic accidents triggered by drivers at work - a survey and analysis of contributing factors. *Transport. Res. Part F: Psychol. Behav.* 34, 94–107.

Nævestad, T.-O., Hesjevoll, I.S., Phillips, R.O., 2018. How can we improve safety culture in transport organizations? A review of interventions, effects and influencing factors. *Transp. Res. Part F: Traffic Psychol. Behav.* 54, 28–46.

Nævestad, T.-O., Hesjevoll, I.S., Ranestad, K., Antonsen, S., 2019. Strategies regulatory authorities can use to influence safety culture in organizations: lessons based on experiences from three sectors. *Saf. Sci.* 118, 409–423.

Patankar (2019) Chapter 13 - Maintenance Resource Management for Technical Operations, in Kanki B.G. J. Anca and T.R. Chidester et al (eds.) *Crew Resource Management* (3.Ed), 357-405.

Reason, J., 1997. *Managing the Risk of Organisational Accidents*. Ashgate, Aldershot.

Thomas, M.J.W., 2012. A systematic review of the effectiveness of safety management systems. No. AR-2011-148. Australian Transport Safety Bureau.

Ward, N.J., Linkenbach, J., Keller, S.N., Otto, J., 2010. White Paper on Traffic Safety Culture, in the series: White Papers for "Toward zero deaths: a national strategy for highway safety" – White Paper No.2. Montana State University.

Weick, K.E., Sutcliffe, K.M., Obstfeld, D., 1999. Organizing for high reliability: processes of collective mindfulness. *Res. Org. Behav.* 21, 81–123.

Weick, K.E., Sutcliffe, K.M., 2007. *Managing the Unexpected. Resilient Performance in an Age of Uncertainty*, 2nd ed. Jossey Bass, San Francisco.

Welsh, E., 2002. Dealing with data: using Nvivo in the qualitative data analysis process. *Forum: Qualitative Social Research* 3 (2).

World Health Organisation. Fact sheet on road traffic injuries: <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries>.  
Zohar, D., 2010. Thirty years of safety climate research: Reflections and future directions. *Accid. Anal. Prev.* 42 (5), 1517–1522.

Zuschlag, M., Ranney, J., Coplen, M., 2016. Evaluation of a safety culture intervention for Union Pacific show improved safety and safety culture. *Saf. Sci.* 83, 59–73.