

Review

Strategies regulatory authorities can use to influence safety culture in organizations: Lessons based on experiences from three sectors



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ABSTRACT

The relationship between safety culture and safety outcomes is well documented across industries and countries, and regulators in different industries have increasingly included safety culture in their repertory. Safety culture is, however, a fairly new regulatory concept, and it seems that knowledge is lacking on pros and cons and expected outcomes of strategies that regulatory authorities can use to improve safety culture. The aims of our study are therefore to: (1) Map descriptions of regulatory efforts to influence safety culture in companies; (2) Identify strategies employed by regulatory authorities to influence safety culture; (3) Describe (regulators' and companies') experiences with, and results of the strategies; (4) Discuss pros and cons of the strategies (possibilities and challenges). The paper also provides a more general discussion of whether it is possible to regulate safety culture, and subsequently what it means to regulate safety culture. The paper is based on experiences from three sectors that have introduced safety culture in their regulatory repertory: (1) The Norwegian petroleum industry, (2) North American rail, and (3) The nuclear industry. The experiences are studied in a systematic literature review reported according to PRISMA guidelines. Our discussion indicates that to include safety culture in the regulatory repertory may involve a range of different strategies, e.g. auditing safety culture, introducing new rules, providing information, providing assistance with self-measurements etc. The study identifies and discusses 5 rule-based and 6 advisory-based strategies that regulators may utilize when attempting to influence organizational safety culture.

1. Introduction

1.1. Background and aims

The relationship between organizational safety culture/climate and safety outcomes is robustly documented in studies reporting experiences across organizations, industries and countries (Zohar, 2010). The crucial importance of safety culture is also documented in a range of accident investigations (e.g. Cullen, 1990; NASA, 2003; National Commission of the Deepwater Horizon Oil Spill and Offshore Drilling, 2011). Safety culture generally refers to safety relevant aspects of culture in organizations (Hale, 2000). Although several different definitions of safety culture exist, most of them concern shared and safety relevant ways of thinking or acting that are (re)created through the joint negotiation of people in social settings (cf. Cooper, 2000; Guldenmund, 2000; Nævestad, 2010a), which is the definition we follow in the present study. Safety climate refers to manifestations or snapshots of safety culture, usually obtained by means of quantitative surveys (Flin et al., 2000; Guldenmund, 2007).

As a consequence of the increased acceptance of safety culture as a decisive factor for organizational safety, regulators in different industries have increasingly started to focus on safety culture in their audits and in their contact with companies (Kongsvik et al., 2016;

Antonsen et al., 2017). This applies for instance to Norwegian petroleum authorities (Kringen, 2009), North American railroad safety authorities (Amtrak, 2015; Lewis et al., 2007) and the Swedish Transport Safety Authority (Nævestad and Phillips, 2018). Regulators in the nuclear sector were probably the first to focus on the concept after it was launched by the International Atomic Energy Agency (IAEA) in the wake of the Chernobyl accident. IAEA has provided several guidelines, tools and publications since then, to support regulatory authorities in its member states (IAEA, 1991, 2002, 2016). Safety culture is, however, a fairly new regulatory concept, as it only in recent years has become used among regulators from several different sectors, in addition to the nuclear sector.

Given the importance of organisational safety culture for safety outcomes, it is positive that regulators have included safety culture in their regulatory repertory (cf. Kongsvik et al., 2016). Risk regulation can be defined as public interventions to manage and reduce unintended side-effects of industrial activities for the safety and well-being of people and the environment (Baldwin et al., 2012, Antonsen et al., 2017). This has traditionally been done by applying rules or instructions that are implemented to achieve certain purposes (Antonsen et al., 2017). The early studies of safety culture regulation indicates, however, that the safety culture concept not necessarily fits well with this traditional regulatory approach (Kringen, 2009; Kongsvik et al., 2016; Bye

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et al., 2016; Antonsen et al., 2017). Safety culture is inherently polysemous, in the sense that its meaning varies heavily depending on the context in which it is used, and the methods through which it is studied (cf. Kringen, 2013, Edwards et al., 2013; Le Coze and Wiig, 2013). Thus, it is relevant to ask whether it is possible to regulate culture at all, or whether the costs are higher than the benefits (cf. Grote and Weichbrodt, 2013). On the other hand, it is also relevant to ask what it means to regulate safety culture, and whether the inclusion of safety culture in the regulatory repertory (cf. Kongsvik et al., 2016) requires a new understanding of what risk regulation is, and what the role of risk regulators is. Risk regulation may also be used in a more general sense, referring to all forms of influences, and not just the rule-based approach (Antonsen et al., 2017).

Accordingly, the studies of regulators in different industries that have started to focus on safety culture in their contact with the companies, indicate that they use several different methods to exert influence on the regulated organizations; not only rules. It is not unreasonable to believe that some lessons can be drawn from the experiences of regulators that have started to focus on safety culture. Currently, little is, however, known about the different strategies that regulatory authorities can use to influence safety culture in the regulated organisations. To our knowledge, no studies have so far attempted to identify and discuss such strategies. Knowledge is also lacking on the pros and cons and expected outcomes of strategies that regulatory authorities can use to influence safety culture. Although early studies report of promising results, social processes that seem hard to foresee and influence are also described (Kringen, 2009; Bye et al., 2016; Kongsvik et al., 2016). Nævestad et al. (in preparation) argue that the causal link between regulatory initiatives to improve safety culture and safety outcomes may appear like a “black box”, involving social processes that seem hard to foresee and influence.

The aims of our study are therefore to: (1) Map descriptions of regulatory efforts to influence safety culture in companies; (2) Identify strategies employed by regulatory authorities to influence safety culture; (3) Describe (regulators’ and companies’) experiences with, and results of the strategies; (4) Discuss pros and cons of the strategies (possibilities and challenges). To fulfil these aims, we have conducted a literature review in accordance with the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). Fulfilling the four aims of the study, the paper also provides a more general discussion of whether it is possible to regulate safety culture, and subsequently what it means to regulate safety culture.

The paper is based on experiences from three sectors that have introduced safety culture in their regulatory repertory: (1) The Norwegian petroleum industry; (2) North American rail; and (3) The nuclear industry. The first reason that these three sectors were chosen is that they each have a strong regulatory focus on safety culture. The second reason is that the regulatory authorities in the three sectors seem to employ different means in their focus on safety culture. The nuclear sector is included in the study, as it was the first sector to use the safety culture concept, and as it has a strong coherent focus on safety culture using a range of different means: audit tools, training, organisational self-measurement and self-development tools. The Norwegian petroleum sector is included in our study, as it to our knowledge is the only sector in the world where the regulator made as an explicit demand that companies should have a sound HSE-culture. North American rail is included, as it developed SMS rules applying to safety culture and supported a wide range of research activities to develop knowledge about safety culture interventions.

2. Safety culture regulation in three sectors

2.1. The nuclear sector

The International Atomic Energy Agency was established in 1957,

as an autonomous organization which reports to the United Nation’s General Assembly and Security Council. The IAEA currently includes 168 member states. As part of their work to promote nuclear safety, the IAEA publishes safety standards which provide a robust framework of fundamental principles, requirements and recommendations to ensure safety. Several of these standards involve safety culture, either directly or indirectly (IAEA, 1991, 1992, 1997, 2006, 2013). There are three categories within the IAEA Safety Standards Series: Safety Fundamentals, presenting basic objectives, concepts and principles, Safety Requirements, establishing the requirements that must be met to ensure safety and Safety Guides, which recommend actions, or procedures for fulfilling the safety requirements. It is important to note, however, that, the IAEA’s safety standards not are legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations (IAEA, 2002).

The IAEA Safety Requirement GS-R-3 (IAEA, 2006) is directly linked to safety culture. This standard requires nuclear organizations to implement management systems which promote and support a strong safety culture by for instance reinforcing a learning and questioning attitude at all levels of the organization and providing the means by which the organization continually seeks to improve its safety culture. (IAEA, 2006: 6). Furthermore, the standard provides five characteristics of a strong safety culture (IAEA, 2009, 2016): (1) Safety is a clearly recognized value; (2) Leadership for safety is clear; (3) Safety is integrated into all activities; (4) Safety is learning driven and (5) Accountability for safety is clear.

2.2. The Norwegian petroleum sector

In 2002, the Norwegian Petroleum Authority made an explicit demand in safety regulations that enterprises must have a sound Health Safety and Environment (HSE) culture. Although it is widely recognized that Norwegian oil companies have worked successful on safety through the years, various safety researchers asserted that the results of the work on HSE began to break down at the end of the 1990s, and that safety levels actually deteriorated in some areas (Haukelid, 2008). Based on this situation, Norwegian politicians stated that the Norwegian petroleum industry was in need of a “cultural effort”. This ambition is reflected in the first White Paper on HSE in the Norwegian petroleum industry (White Paper No. 7 (2001–2002)) and the HSE-culture provision. According to Kringen (2009), the PSA’s interest for safety culture was also inspired by its importance for safety management in the aviation sector and the nuclear industry. The PSA underscored that the HSE-culture requirement was functional, leaving it up to the companies to specify what constitutes ‘a sound HSE culture’, and how to achieve it. No explicit definition of HSE culture was given in the regulations or the guidelines (Bye et al., 2016). However, after the HSE-culture requirements, the PSA presented the intentions with it in seminars, publications and other channels. The PSA also published an advisory booklet to clarify the relation between culture and HSE, underlining that it is up to each company to define the meaning of “sound HSE culture” (Antonsen et al., 2017).

2.3. North American rail

The U.S. Federal Railroad Administration (FRA) implemented several voluntary programs explicitly aiming to improve safety culture in the industry. From 1998 to 2012, the FRA Office of Research and Development initiated an evaluation program aimed at identification and evaluation of system-based safety culture interventions. Under the program, the FRA sponsored the implementation of different pilot programs, and evaluated their effects (Ranney et al., 2013). Additionally, the Rail Safety Improvement Act enacted by the US congress in 2008, required, among other things, that the FRA declares more regulations to improve rail safety. In part as a response to this act, the FRA issued in 2016 a rule that mandated commuter- and intercity

passenger railroad companies to develop and implement safety management system (SMS) (in their terminology a system safety program), consisting of risk-based management programs and hazard analyses (FRA, 2016). Among other things, the rule requires that the railroad companies design their SMS so that it promotes and supports a positive safety culture (p. 58/§ 270.101(b)). Herein it also lies that railroads must describe their safety culture, and how the success of the safety culture is measured. The FRA suggests that railroad companies base their assessment of safety culture on 10 elements that, according to them, supports a strong safety culture in this sector. Each railroad company may, however, select how to measure safety culture best in their operations, but it is expected that such a measure can be correlated with actual safety outcomes. The requirement became operative in March 2017 (FRA, 2017).

As a consequence of the Canadian Railway Safety Act, railways have since 2001 been required to implement and maintain a SMS. While the current SMS regulation (updated in 2015) does not explicitly target safety culture, related publications, including a review of the railway safety act conducted by an advisory panel and notes from the SMS working group, describes a positive safety culture both as a goal of the SMS requirement, and as a prerequisite to fully implement it (Lewis et al., 2007). The Canadian railway safety act was reviewed in 2007 both overall (Lewis et al., 2007) and with a specific focus on the safety management systems (SMS Aviation Safety Inc, 2007). A recommendation of the general 2007 evaluation was that “Transport Canada, Rail Safety Directorate and the railway industry must take specific measures to attain an effective safety culture” (Lewis et al., 2007, p. 72). In response to this, an SMS working group was formed that provided the industry with additional tools to improve SMS implementation. This included: (1) Tools for self-measurement; (2) A safety culture check list; (3) Examples of best practices; (4) Guidance on how to integrate the core principles of SMS, and (5) Definition and description of a positive safety culture was provided. Evaluations of these additional tools were unfortunately not identified.

3. Theoretical approach

3.1. Organizational safety culture

The investigation of the Chernobyl accident is ubiquitously cited as being responsible for coining the term safety culture, although the concept’s research origins date further back (e.g. Turner, 1978; Zohar, 1980). For several decades, the term has been used to describe the making of several man-made disasters, (e.g. Cullen, 1990; NASA, 2003; National Commission of the Deepwater Horizon Oil Spill and Offshore Drilling, 2011). The term is notoriously polysemous, in the sense that its meaning varies heavily depending on the context in which it is used, and the methods through which it is studied (cf. Pidgeon, 1998; Kringsen, 2013; Edwards et al., 2013; Le Coze and Wiig, 2013). In spite of this methodological and conceptual flexibility, most studies seem to presuppose that safety culture refers to shared and safety relevant ways of thinking or acting that are (re)created through the joint negotiation of people in social settings (Nævestad, 2010a), which is the definition we follow in the present study.

The popularity of the term probably has to do with it lifting behaviour and the antecedents of behaviour to a collective level: When two or more individuals collaborate to solve recurring problems, or conduct repeated work tasks, they tend to develop practices that are experienced to be effective and efficient (Antonsen, 2009). This points to an important distinction in the literature where safety culture is often explained by discerning between formal and informal aspects of safety. Although work on organizational safety must address both formal and informal aspects of safety, it may be useful to think of organizational safety culture as the informal aspects of safety in organizations in order to distinguish it from the formal aspects of safety in organizations, specified as rules, procedures and so forth (Antonsen, 2009). We may

refer to the latter as safety management systems (SMS). SMS typically comprise formal routines and measures enabling the organisation to work systematically with safety, by identifying and correcting risks, e.g. appointment of key safety personnel, risk assessments, safety training, safety procedures and safety performance monitoring (Thomas, 2012).

It is generally argued that different methods give access to different layers of culture, and that qualitative methods are more likely to enable researchers to identify “deeper” layers of culture than quantitative methods (e.g. Guldenmund, 2007). Qualitative studies focus on how safety culture guides individuals’ interpretations of actions, hazards and their identities, and motivates and legitimizes behaviours that have an impact on safety (Antonsen, 2009; Nævestad, 2010a, 2010b). This approach underlines that defining risk always involves some extent of social construction (Douglas and Wildavsky, 1982; Ferroff et al., 2012), indicating the importance of a cultural perspective on risk. Quantitative studies focus on developing and validating scales for measuring “shared and safety relevant ways of thinking or acting”.

3.2. Regulation

We refer to risk regulation as public interventions to manage and reduce unintended side effects of industrial activities. The prime objective of a safety regulator will thus be to exert influence on the regulated organizations, in order to avoid unwanted consequences like accidents and environmental discharge (cf. Baldwin et al., 2012; Antonsen et al., 2017). The relevance of safety culture as a regulatory concept is not straightforward. On the one hand, it can be argued that safety culture should be included as a regulatory concept, given its importance for safety outcomes (cf. Bernard, 2014, 2018). On the other hand, it can be argued that the concept is too abstract and polysemous, requiring too much competence, energy and efforts, compared to its benefits (Grote and Weichbrodt, 2013). As indicated, above, it seems that our stance to these arguments to some extent is contingent on our understanding of what regulation is, and what it could be.

First, we have referred to a restricted, or traditional understanding of risk regulation, referring to an agency’s application of specific rules or instructions that are implemented to achieve certain purposes (Baldwin et al., 2012; Antonsen et al., 2017). It is argued that safety culture does not fit well with this traditional “command-and control” type of regulation. As the concept is ambiguous and contested, it is difficult to define those who comply and those who do not comply (Antonsen et al., 2017). Thus, those who favour this type of regulation will be skeptical to including safety culture as a regulatory concept.

Second, there is also a more general understanding of risk regulation, referring to all forms of influences (e.g. economic and social), including unintended (Baldwin et al., 2012; Antonsen et al., 2017). This often involves purpose-based rules, which formulate norms as guidelines, leaving the exact implementation open to the subject of the norm (Burgemeestre et al., 2009). Purpose-based rules also tend to involve more self-regulation, e.g. as the regulated companies develop safety management systems and key performance indicators to evaluate whether they fulfil the intentions of the purpose-based rules. This often involves more general and open definitions of compliance, e.g. highlighting the quality of processes of continuous improvement. In this context, high quality processes of self-development and self-measurement of safety culture could be defined as compliance, as the focus is more on organisational processes of continuous improvement. Thus, those who favour this type of regulation, are likely to be more positive to including safety culture as a regulatory concept.

Increased purpose-based regulation and self-regulation also tend to involve a tendency towards a more advisory regulatory role, providing companies with examples and guidance on how to develop strategies to comply with more generally formulated principles or functions (OECD, 2002). Nævestad and Phillips (2018) refer to this as an advisory-based regulatory approach. The advisory function of regulators highlights that regulation is also a relation between regulators and the industry, where

the influence of regulation is closely linked to supervisory activities exceeding the command and control perspective. In the advisory function, the aim is to detect weak signals of danger and solve problems without having to invoke serious sanctions like fines, prosecution or banning companies from conducting activities.

It is evident that the choice of the type of regulation, to a great extent is contingent on the subject of the regulation. Thus, most regulatory regimes comprise a mixture of rules and purposes. It is nevertheless argued that there is an increasing tendency to adopt purpose-based regulation, as the latter is more flexible and allows for more innovation when it comes to adopting best practices (Elvebakk, 2015).

4. Methodological approach

We have conducted a literature review in accordance with the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). The purpose of the literature review was to identify and review studies focusing on regulatory initiatives to influence safety culture in companies in the Norwegian petroleum sector, in the nuclear sector and in North American rail.

4.1. Search strategy

We searched for relevant studies within the three sectors using ISI Web of Knowledge and ScienceDirect. Searches were conducted in November 2018–February 2019. Table 1 presents the search terms for each sector. These were applied for keyword, title and abstracts. We applied more general search words for the Norwegian petroleum sector in an attempt to capture a broader scope of studies. In the two other sectors, we also included terms like intervention, program and training to include general interventions to improve safety, which we could define as interventions aimed at improving safety culture, based on the criteria described below.

4.2. Inclusion and exclusion criteria

When selecting publications to include, we used four criteria.

- Written in English.
- Publication year later than 1995.
- Focuses on one of the three sectors
- Provides a description about the effect of a regulatory-based initiative (e.g. rule, advice, funding, design of intervention, support) to influence safety culture.

We identified studies matching these four criteria through a two-stage process. First, we identified relevant studies using search word combinations for studies on safety efforts and interventions in each of the studied sectors (cf. search flow diagram, Fig. 1). In this stage, we examined titles, but if the characteristics of the study were not clear based on the titles, we also examined the abstracts. In the second phase, we looked at the abstracts of the studies (and full texts when needed) to find studies of regulatory-based efforts to improve safety culture. To identify regulatory-based initiatives, we often had to examine the whole papers, focusing especially on the introduction, the description of the initiative or the intervention to look for text describing the role of the

regulator, the acknowledgments, and we also searched the paper using key words like (e.g. authority, regulator). Finally, studies identified from other sources were added to the selected studies. These were studies that the authors were familiar with from other projects, or which were discovered reading the reference lists of the retrieved studies.

4.3. What is a regulatory strategy to influence safety culture?

First, it may be unclear what initiatives to influence safety culture refers to. To be included, the studies did not explicitly need to state that the initiatives aimed at improving “safety culture”, as long as the goal was to improve safety by influencing shared, safety relevant ways of thinking or acting (what we refer to as safety culture). Thus, according to this definition, training courses or education programs focusing on increasing risk awareness or developing new ways of thinking about and/or acting on risks through joint discussions of workplace hazards could be included. The same could also apply to the implementation of safety management systems, aiming to influence shared ways of acting in the organisation, e.g. by introducing new procedures and technologies for the reporting of incidents. Second, it may be unclear what a regulatory-based initiative to influence safety culture may be. Initiative is a rather abstract concept, which may include several different types of actions and roles. We operationalise this as e.g. new rules, audit schemes, advice to companies, communication (leaflets, websites etc.), funding, design of interventions, support to research, pilot studies etc. Regulators’ efforts to influence safety culture in companies may take different forms, and the levels of prescription may be very different.

Analysing the different initiatives that we identified in the review (Tables 2–4), we classify them as different strategies. Thus, while the initiatives refer to the descriptions of the measures in the reviewed studies, strategies refer to our analyses of these initiatives. First, we focus on the role and the approach of the regulator: Is the initiative rule-based, purpose-based, advisory-based, system-based, etc.? Or did the role of the regulator involve other actions, like e.g. funding or supporting research or measures aimed at improving safety, designing pilot studies etc? Based on similarities and differences between specific regulatory initiatives, we group them into more general categories of strategies.

4.4. Data collection

Presenting the regulatory efforts to influence safety culture in companies in Tables 2–4 we use the following points as a checklist:

- (I) Study (name of the authors, year), country and sector
- (II) Method and sample. What kind of methods are applied (qualitative, and/or quantitative)? How many interviewees or respondents are involved? What kind of research design is applied? (qualitative case study, quantitative evaluations with before and after measurements and control groups? Prospective, retrospective, cross-sectional).
- (III) Regulatory strategy. What is the role and strategy of the regulatory agency in relation to the studied effort to influence safety culture (e.g. rule-based, function-based, advisory-based, funding, designing, supporting etc.)?
- (IV) Reported experiences of the strategies. What are regulators’ and

Table 1
Search words in the studied sectors.

Sector	Search words
Petroleum	“Safety culture” OR HSE OR “Health, Safety and Environment” AND Norway
Nuclear	(nuclear OR IAEA) AND (“safety culture” OR “Health, Safety and Environment”) AND (intervention OR training OR program OR effect)
Rail	Safety AND (intervention OR training OR program OR effect) AND (rail OR railway)

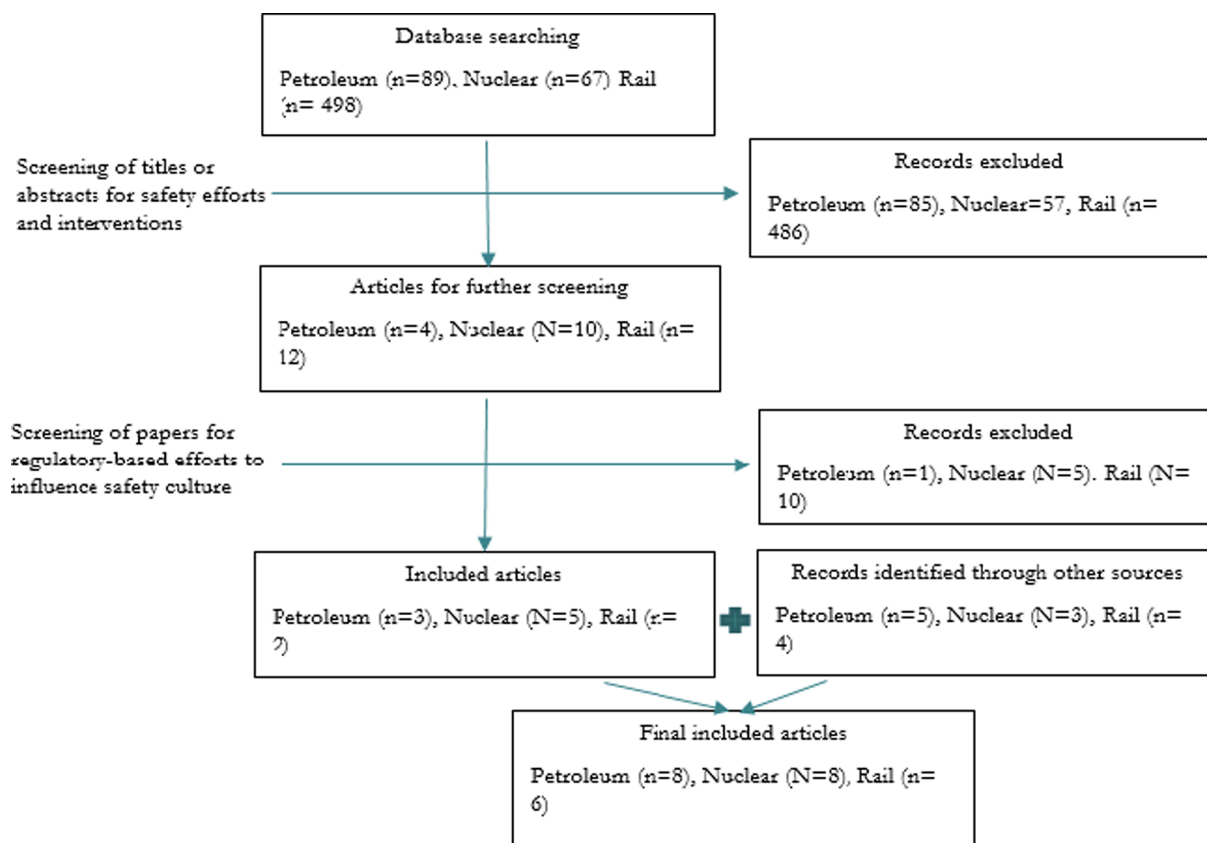


Fig. 1. The numbers of search results and studies screened, assessed and included in the review.

companies’ experiences with the strategies? Are the strategies resource demanding? Do they require high levels of competence? Do they involve a high level of uncertainty and unexpected or unwanted results?

- (V) Regulatory results. What are the results of the regulatory efforts to influence safety culture? Is safety culture improved? Are safety behaviours improved? Are accidents reduced? And finally, are these results robustly evaluated?

5. Results

5.1. Description of the reviewed studies

Fig. 1 shows the numbers of search results and studies screened, assessed and included in the review. Studies were excluded from the first screen mostly because they did not involve studies of efforts to influence safety. In the second screen, studies were excluded because they did not involve regulatory attempts to improve safety by addressing an aspect of safety culture.

As indicated by Fig. 1, more than half of the studies were retrieved through other sources. These other sources were “grey literature”, i.e. authority reports, and book chapters or conference papers which were not identified in our systematic review of scientific publications. The latter publications were identified reading reference lists of the retrieved publications. We included them as we wanted to include the most important publications reporting experiences from regulatory efforts to audit or focus on safety culture.

Table 2 presents an overview of studies of safety culture regulation in the nuclear sector. It should be noted that we were unable to retrieve full information from some of the studies due to language barriers.

Table 3 presents studies of safety culture regulation in the

Norwegian petroleum sector. All of the studies concern one regulatory initiative: the 2002 PSA’s HSE-culture provision. We also include Grote and Weichbrodt (2013). Although this study is general, it is highly relevant, and it is presented in a book following two studies focusing on the PSA provision. Grote and Weichbrodt’s (2013) discussion can therefore be interpreted in this context.

The studies of safety culture regulation in North American rail are presented in Table 4. These safety culture initiatives in these sectors are made up of several programs; the most important being: Clear signal for action, Participatory rules revision, Safe-2-Safer, Confidential Close Call Reporting System (C³RS), Investigation of Safety-Related Occurrences Protocol (ISROP). These programs are evaluated and described in a relatively high number of publications; published in scientific journals and by regulatory authorities. When it comes to the latter, we do not present all of the research reports in Table 4. We aim, however, to present evaluations of the most important programmes, and thus we present research reports describing these (published e.g. on the FRA website), if evaluation of the programs have not been presented in scientific journals.

Based on similarities and differences between specific regulatory initiatives described in Tables 2–4, we group them into more general categories of strategies. In the following, we present and discuss 5 rule-based and 6 advisory-based strategies that regulators may utilize when attempting to influence organizational safety culture

5.2. Rule-based strategies to influence safety culture

5.2.1. Introducing a safety culture requirement

Regulators may “require that companies have a “good” or “sound” safety culture, like the Norwegian PSA did in 2002. Kringen’s (2009) study indicates that introducing safety culture as a regulator concept

Table 2
 Studies of safety culture regulation in the nuclear sector: focus, method/sample, regulatory strategies, reported experiences and results of regulatory efforts.

Study/country/sector. Focus.	Method and sample	Regulatory strategy	Reported experiences	Regulatory results
Bernard (2018) Belgium	Case study using the safety culture oversight (SCO) model	Safety culture Audit	The safety culture oversight model provides the regulator with a better view of the strengths and weaknesses of a nuclear installation	The SCO model provides the regulator with the opportunity to promote safety culture enhancements, identify topics to be improved and monitor the directions taken by a licensee
O'Mara, et al. (2015)	Quantitative survey before and after the training programme.	The design of the training was based on the IAEA Systematic Approach to Training (SAT)	Results demonstrated improvement across all elements of skills and knowledge required to undertake decontamination	Training is a fundamental part of good safety culture. It is stated that the intervention has led to a clear improvement in safety culture, but this is not measured directly
Bernard (2014)	Conceptual development and description of the safety culture oversight (SCO) model	Safety culture Audit.	The safety culture oversight model provides a new way of regulation, between the compliance and the performance-based approach: responsive regulation. Requires training and field coaching	Argues in favour of a focus on the deep cultural factors that impact safety: The cultural frames of reference through which hazards are perceived
Mod Ali (2008) Malaysia	General description of a regulator led programme for continuous safety culture improvement	Training of company representatives to conduct organisational self-measurements and self-development. Performing audits of the continuous improvement process	Maintaining and improving safety culture is a continuous process	Results of the programme are not evaluated
Mengolini and Debarberis (2008) Netherlands	A review of regulatory safety performance indicators from: IAEA and OECD	Indicators of safety culture aimed at facilitating continuous improvement, involving self-measurement and self-development	Suggests a continuous improvement approach involving focus group discussions where participants identify relevant safety activities. Staff are made responsible for specific activities; thus guaranteeing their motivation and commitment. Approach is in line with the IAEA aspects of safety culture	Results of the suggested indicators and programme are not evaluated
Mengolini and Debarberis (2007) Netherlands	Interviews, field observations and self-assessment	Self-assessment and self-improvement process based on IAEA guidelines	Intervening in organisations is difficult. Continuous improvement processes require joint efforts from managers and employees	Improved safety culture
Obadia et al. (2007) Brazil	A safety culture self-assessment was performed at the IEN in 2001 and 2003, based on the IAEA safety culture framework	Safety management system and safety culture self assessment	Significant organizational changes towards safety culture improvement can be achieved by implementing safety management systems	Increase in the safety culture institutional mean index score, which is a safety performance indicator, from “regular” to “satisfactory”
Engel et al. (2001) Germany	General review of experiences found in evaluations of simulator training of nuclear facility personnel in Germany	Rules for simulator training, describing requirements for trainers, facilities and evaluation	Results indicate positive assessment by all participants, i.e. attendees, operators, and the Simulator Center	Ultimately, simulator training contributes to the safety culture in German nuclear technology. This is, however, not evaluated directly

Table 3
 Studies of safety culture regulation in the Norwegian petroleum sector: focus, method/sample, regulatory strategies, reported experiences of regulators/companies and results 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 and sample	Reported experiences and results
Antonsen et al. (2017) Norway, Petroleum. Authorities' and companies' experiences with the HSE-culture provision	Interviews with 8 representatives from authorities and 13 representatives from companies Qualitative assessment.	Positive and negative: Companies' and regulators' efforts to make sense of HSE culture involved learning, but also results that were unanticipated by the regulator.
Bye et al. (2016) 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. Qualitative assessment.	Positive and negative "Double-edged sword". By introducing the HSE culture provision, the regulator explored a new and untraditional approach, which involved learning. The plasticity of the 'HSE-culture' concept legitimated different HSE approaches, some of which were unanticipated. Using the HSE culture concept in accident investigations could be a stumbling block for learning.
Kongsvik et al. (2016), Norway, Petroleum Two companies' translations of the HSE requirement of the Norwegian PSA	14 Interviews with people from two companies. Qualitative assessment.	Positive and negative: The two companies' efforts to comply with and translate the HSE culture provision involved learning, but also unanticipated consequences, The companies' translations were shaped by their structures, histories, key personnel etc.
Grote and Weichbrodt (2013). (general) Regulatory requirements for companies to show proof of having, or working towards a good safety culture	Conceptual and analytical discussion, based on previous research.	Regulatory focus on safety culture may have detrimental effect for safety in high risk organisations as they use energy to understand what safety culture is, instead of other issues.
Le Coze and Wiig (2013) 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.	Introducing safety culture as a regulatory concept may involve learning and focus on safety management aspects not covered by traditional approaches. However, the polysemous nature of the concept makes it difficult to regulate safety culture.
Kringen (2013), Norway, Petroleum Based on Kringen (2009), but discussed in light of a new theoretical framework.	Field work, interviews, document analysis and literature review.	Introducing safety culture as a regulatory concept may involve (too?) high interpretive costs; it may lead to confusion and may distract attention away from more tangible and operational issues. (Supports Grote and Weichbrodt's (2013) conclusion?) However, addressing safety culture may also trigger reflection, promote broader perspectives and involve learning.
Karlsen and Valen (2010) Norway, Petroleum	Discourse analysis of key documents.	The legalisation of a premature HSE-culture concept makes it difficult to map and develop a standard related to auditing. "Impression management": organisations may act as if they do something about the issue.
Kringen (2009) Norway, Petroleum Comprehensive PhD dissertation on the first years of the HSE-culture provision.	Field work, interviews, document analysis and literature review.	The introduction of the HSE culture provision involved high interpretive costs, and frustration in its first years. The concept was new and unfamiliar. Making sense of the provision involved learning, and unanticipated responses from the companies. Organizational discontinuities caused a loss of momentum in the follow up of the provision, which eventually did not appear as fully integrated within the regulatory agency.

does not necessarily lead to improved safety culture in the first years of its use. The concept was hard to define and operationalize in audits and in accident investigations. The concept was also new and unfamiliar for several of the involved parties, especially the more technically oriented staff (Kringen, 2009). The main challenge with safety culture as a regulatory object is that it is abstract and ambiguous (Bye et al., 2016; Kongsvik et al., 2016). As early as in 1963, anthropologists criticized the ambiguous nature of concept, referring to more than 160 different definitions (Kroeber and Kluckholm 1963 in Kringen, 2009). Thus, the challenge with a broad functional safety culture requirement is that it legitimizes a very broad range of approaches in regulated companies, some of which may be unexpected (Bye et al., 2016; Kongsvik et al., 2016). However, although results may be unpredictable, the high level of uncertainty may also represent an opportunity. The research of Bye et al. (2016), Kongsvik et al. (2016) and Antonsen et al. (2017) indicates that the uncertainty related to safety culture as a regulatory concept may be productive and lead to learning and new perspectives both for regulators and the regulated. RAC (undated) also report that after the 2007 SMS rule review, in Canadian rail, which recommended a systematic focus on safety culture, there were no common understanding of safety culture, or the initiatives required to measure and strengthen it. This was, however, developed through the work of a steering committee and working groups.

Introducing a safety culture requirement	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> - Learning for regulators and companies - Focus on safety management aspects not covered by traditional approaches. 	<ul style="list-style-type: none"> - The abstract and ambiguous character of the concept - Unexpected or unwanted results - High interpretive costs - Difficult to combine with existing approaches(?)

5.2.2. Auditing safety culture

Regulators may audit safety culture in companies, and this does not necessarily have to be based on explicit regulatory requirements concerning safety culture. Several of the reviewed studies use audits as a regulatory strategy. Mod Ali (2008) from the Malaysian context also perform audits of the continuous improvement process in companies. Auditing without a requirement has the potential to avoid ontological discussions about what safety culture is, and thus high interpretive costs, by focusing on specific checklist questions. The IAEA provides a practical guideline for auditing safety culture (IAEA, 2013). The Safety Culture Oversight Process (SCOP) follows six steps, e.g. engage in a dialogue, collect and analyse data from several sources etc. The IAEA also provides an interesting safety culture checklist for regulators, with

Table 4
Studies of safety culture regulation in North American rail: focus, method/sample, regulatory strategies, reported experiences of regulators/companies and results of regulatory efforts.

Study/country/sector. Focus	Method and sample	Regulatory strategy	Reported experiences	Results
Railway Association of Canada (RAC) (undated)	Description of how the 2007 rail safety act review set forth collaborations between regulators, railways, and labour unions to define, develop and strengthen safety culture. Combined with a overview of the development in accident risk from 2006 to 2016	<ul style="list-style-type: none"> – SMS-rule focusing on safety culture development – SMS guide with recommendations: “achieving an effective safety culture” – Self-assessment of safety culture through checklist – Training – Employee engagement programs – Employee safety/security phone line 	After the 2007 review there were no common understanding of safety culture, or the initiatives required to measure and strengthen it. A steering committee and working groups were established.	Definitions, safety culture checklists and strategies were developed by the steering committee and working groups. Reductions in the risk of main track and non-main track accidents: from about 3.5 per Billion Gross Ton-Miles in 2006 to about 2 in 2016. (Based on preliminary data in 2016) Competing variables or trends (e.g risk decrease) are not discussed.
FRA (2016) Confidential Close Call Reporting System (C3RS). From 2007 to 2015.	Pilot study of successful implementation and effects of safety culture in the US and Canada. Interviews with stakeholders and data on implementation.	FRA sponsored a Lessons Learned Team to evaluate the pilot study. Cooperation with NASA. Employees report close calls to a neutral third party. Data is analysed by a team which suggests corrective action	The implementation of the program was perceived as successful, measured by the number of received reports. Several new railroads are participating.	High increase in reported incidents. Several corrective actions implemented based on the reports. Safety culture outcomes were not evaluated/reported at this stage.
Zuschlag et al. (2016), USA, Rail. Clear Signal for Action” intervention implemented in Union Pacific Railroad, after observations of negative safety culture.	Before and after pilot study with two experiment units and three control units Study conducted 2005–2008. Safety culture measured quantitatively before (N = 195) and after (N = 112) and in qualitative interviews before, during and after (N = 53)	Supporting pilot interventions. From 1998 to 2012, Federal Railroad Administration (FRA) initiated an evaluation program focusing on safety culture interventions. Intervention designed and implemented by consultants (BST) and evaluated by US Dep. of Transportation.	Development of positive labour-managements relations were key to the success, as well as management commitment and employee engagement and involvement. Safety culture improvement is an ongoing process.	80% drop in at risk behaviours 81% drop in accidents Improved safety culture
Amtrak (2015) USA, Rail. Safe-2-Safer program in large US rail company, aimed at improving company safety culture, reducing costs and injuries.	Safety culture was measured by a biennial employee survey, focusing on 10 aspects of safety culture Conducted from 2009 to 2013 (N = 11,700 in 2013)	Pilot program and evaluation sponsored by the Federal Railroad Administration	It is challenging to study the relationship between safety culture improvements and recorded incidents (e.g. injuries), as an improved safety culture generally will involve increased reporting of incidents.	Small improvement in safety culture, reduction in unsafe working conditions, but increase in injuries
FRA (2006) Investigation of Safety-Related Occurrences Protocol (ISROP)	Initial review of surveys (N = 626, 125 answered ISROP questions), interviews (N = 83), and focus groups, examination of over 100 ISROP reports	ISROP is standardized process developed by the Canadian Pacific Railroad for conducting thorough and systematic incident investigations.	Also perceived as too time-consuming for less serious injuries and possibly confusing for investigators who do not use it often.	Survey results indicated improved scores on 10 items before and after ISROP. ISROP was considered more helpful than previous investigation approaches, particularly in identifying contributing factors and corrective actions.
Ranney and Nelson (2004) Participatory rule revision.	Qualitative interview data and incident data from three railroads and one in-land barge line.	Participatory rules revision as an instrument of safety improvement in the U.S. railroad industry is presented	Rule revision may increase safety, as comprehensive and over-lapping rules might contribute to poor compliance because of confusion and disagreement about which rules are to be followed.	Interview data provided evidence for an impact on the safety culture. Analysis of incident data found a significant impact of the intervention on incident rates at one rail carrier, while incident rate declines at two other carriers could not be attributed to the intervention with confidence.

questions for each of the subdimensions comprising their model of safety culture (IAEA, 2002). Bernard (2014) describes a new safety culture oversight (SCO) model, suggesting that this provides a new way of regulation, focusing on the deep cultural factors that impact safety. In a later publication, he provides an example of how the safety culture oversight model works in practice, based on a case study from the Belgian nuclear sector (Bernard, 2018). The SCO is a holistic approach, involving systematic collection of safety culture data from the companies, collected in any contact with the licensees (inspections, meetings, phone calls). The factual observations are recorded in an observation sheet (e.g. in Excel) aimed at describing factual and contextual issues. The focus in the sheet is to describe how and why a recorded observation is linked to safety culture. The case study which is described in the paper is based on 199 SCO observations gathered through a three year period, aimed at identifying the deeper patterns of meaning underlying several different aspects of safety culture in the organization. The example illustrates how safety culture observations are fully integrated in the inspectors’ daily practices. As argued by Bernard (2018), the example illustrates that a single observation is not sufficient to provide an overall picture of the safety culture; this requires a large number of observations, collected in the daily practices of the inspectors, followed by systematic analysis. On the other hand, it is also conceivable that it may be difficult for regulators to obtain insights about the “deeper layers” of safety culture. It seems to require a high level of competence. Moreover, it is not given that organisational members are comfortable with providing information that may have negative repercussions for their organization. This indicates the importance of trust in this type of regulation in general and safety culture audits in specific.

Based on our research, we may however assume that auditing without a requirement, will generate learning among regulators, but not necessarily among companies, as companies will not necessarily have to find ways to comply with a culture requirement and thereby learn (cf. Kongsvik et al., 2016). This could be an argument in favour of basing safety culture audits on a safety culture requirement. Such a requirement may be followed up in different manners. Given the abstract and ambiguous character of culture, it seems fruitful to have a “functional” safety culture provision, which (to some extent) leaves it up to the companies to define and operationalize it (Bye et al., 2016; Antonsen et al., 2017). However, to avoid unexpected and unwanted results, it also seems important to provide guidelines on the specific aspects of safety culture. This is probably why regulators in both rail and the nuclear sector provide both general declarations of intentions and more specific guidelines, exemplifying possible ways of implementing safety culture.

Auditing safety culture (without a requirement)	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> – Focus on safety management aspects not covered by traditional approaches. – Potential to avoid ontological discussions and high interpretive costs by focusing on specific checklist questions – Likely to generate learning among regulators 	<ul style="list-style-type: none"> – Difficult to legitimize legally? – Requires (a high level of) competence? – Involves (a high level of) subjective assessment? – Will it generate learning among companies? – Are employees comfortable with providing information that may have negative repercussions?

5.2.3. Facilitating changes in safety culture by introducing new rules

Given that the main challenge with safety culture as a regulatory object is that it is abstract and ambiguous, a feasible alternative would perhaps be to introduce more specific rules or requirements, aimed at especially safety critical issues. This strategy could focus on the most important safety (cultural) challenges within different sectors. This was done in the US railway sector, which prohibited companies from

punishing employees reporting injuries. This was a response to negative safety culture in US railroad organizations, characterized by lack of trust between employees and managers, involving inclinations to inflict punishment for accidents and injuries (Zuschlag et al., 2016). To build a just, reporting safety culture, the Federal Railroad Administration (FRA) legally prohibited retaliation and intimidation when employees report injuries. This is an interesting strategy, which may be time-limited, and address the most pressing safety challenges in a given sector or industry.

A control-and-compliance logic may also be used to change culture. Engel et al. (2001) asserts, for instance, that rules for simulator training led to improvements in German nuclear safety culture. As noted by Nævestad et al. (in preparation), several safety interventions are based on the theoretical assumption that “thought precedes action”. This is a typical premise of attitude and information campaigns; to make people act differently (and safer) you must make them think differently. This was probably the motivation behind employee engagement programs in Canadian rail (RAC, undated). Safety scholars like Weick and Sutcliffe (2007) and Reason (1997), on the other hand, also indicate that people may start to think differently once they start to act differently. This may be facilitated by the mechanism of cognitive dissonance, which refers to the discomfort of holding two or more conflicting cognitions. This line of argumentation indicates that changes in safety culture (shared patterns of acting and thinking) may come about because of changes in rules (cf. Nævestad et al., in preparation). It seems that this mechanism could be evoked to explain e.g. changes in attitudes to public smoking in countries that in recent years have introduced restrictions on this, changes in public attitudes towards the use of safety belt in cars, after the introduction of laws mandating seat belt use in several countries, etc. The influence of the cognitive dissonance mechanism is of course provided that people start behaving in accordance with the new rules and change their (shared patterns of) thoughts accordingly. However, such collective processes of sensemaking may be fairly unpredictable, as subcultural sources of meaning could provide alternative interpretations of the rules, and thus no changes in neither behavior, nor ways of thinking (cf. Nævestad et al., in preparation). Mengolini and Debareris’ (2007) state that the IAEA guidelines focus too little on employees’ reception of interventions and subcultures within organizations. It is also important to remember that peoples’ behaviours are influenced by more factors than rules. It seems that these issues was the point of departure for the participatory rules revision intervention (Ranney and Nelson, 2004) in Rail. This was based on the assertion that comprehensive and over-lapping rules might contribute to poor compliance, because of confusion and disagreement about which rules are to follow.

Introducing specific safety cultural requirements/new rules	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> – Can target specific safety-critical challenges within sectors – Can be used for limited periods – New rules may make people act differently, and thus think differently because of cognitive dissonance (and thus lead to changes in shared ways of thinking and acting: culture) 	<ul style="list-style-type: none"> – Collective processes of sensemaking may be fairly unpredictable – Rules could be violated if they are not perceived as meaningful – Sub-cultures may challenge the rules and provide alternative interpretations of them

5.2.4. Implementing culture through systems

The approach of implementing safety culture through SMS has been chosen in both North American rail and in the nuclear energy sector. In these sectors, the national rules require companies to implement SMS (and thereby to indirectly implement safety culture). In their study from the nuclear sector, Obadia et al. (2007) study the implementation of a safety management system and safety culture self assessment process,

and results indicated improvements in safety culture. The FRA Confidential Close Call Reporting System (C3RS) can also be viewed as a way of developing safety culture through system implementation. It provides the opportunity for employees to report close calls to a neutral third party, which anonymised the data and submitted them to an analysis group which worked out corrective actions. RAC (undated) also mentions an employee safety/security phone line as one of several measures implemented in Canadian rail. The SMS regulation in US railroad requires that the railroads design their SMS so that it promotes and supports a positive safety culture. Additionally, the SMS regulation in the Canadian rail sector describes a positive safety culture both as a goal of the SMS requirement, and as a prerequisite to fully implement it (Lewis et al., 2007). As noted, the Canadian SMS regulations of 2001 was reported to improve safety culture in the rail industry. An SMS guide with recommendations on how to achieve an effective safety culture was developed and provided to the railroad companies after the 2007 review of the Canadian Rail Safety Act (RAC, undated). The IAEA Safety Requirement GS-R-3 (IAEA, 2006) requires nuclear organizations to implement management systems to promote a strong safety culture. IAEA has published a specific Safety guide for management systems for nuclear installations (IAEA, 2009) which lists further recommendations on how to fulfil the requirements for facilitating a strong safety culture.

The premise of this approach seems to be that safety culture change will come about as a consequence of a comprehensive SMS focus on safety. Theoretically, we may hypothesize that SMS's may shape shared safety behaviours and subsequently shape shared ways of thinking about safety, reinforcing the shared ways of acting, in line with the line of reasoning above (cf. Reason, 1997; Weick and Sutcliffe, 2007; Nævestad et al., in preparation). Shared ways of thinking and acting about safety are the two elements in our definition of safety culture. Several studies of safety culture, including accident investigations, find however a discrepancy between the SMS and safety culture; between the formal ways of doing things and the informal, actual ways that things are done (Antonsen, 2009). Mengolini and Debarberis (2007) criticizes the IAEA safety culture guidelines for providing too much of a top-down structured approach to safety culture, focusing on formal management tools (e.g. feedback systems, management commitment), and not involving employees sufficiently. It is important to note that the focus on SMS must not overshadow the fact that safety culture denotes the informal aspects of safety within organizations; “the way things actually are done”, as opposed to the formal routines and procedures (cf. Antonsen, 2009). This indicates how decisive safety culture are in organizations: an SMS must be supported by the safety culture. If employees lack knowledge, understanding and motivation to behave in accordance with the SMS, a discrepancy between the SMS and their safety behavior is likely to arise. Antonsen et al. (2017) conclude that HSE-culture served as a sensitizing concept that increased both parties’ ability to address both informal and systemic aspects of safety. Wrapping up all these interesting questions, we may conclude that we need more research examining SMS implementation as a strategy of implementing safety culture.

Implementing culture through systems

Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> - Provides a systematic and holistic approach to safety management - Acting according to SMS may make people act differently, and thus think differently because of cognitive dissonance - SMS elements may be more concrete than safety culture, as it focuses on formal elements like training, procedures, risk assessments, etc. 	<ul style="list-style-type: none"> - Procedures could be violated if they are not perceived as meaningful - Sub-cultures may challenge procedures and provide alternative interpretations of them - If the SMS is poorly implemented, there will be a gap between formal and informal aspects of safety; i.e. poor safety culture - Companies may risk focusing more on formal aspects of safety, than what they do in practice (i.e. their safety culture)

5.2.5. Using safety culture in accident investigations

Introducing safety culture as a regulatory concept may also involve using it in accident investigations. This may provide an opportunity to discover systematic patterns underlying decisions and/or behaviours in organisations. Thus; individual behaviours are not seen as isolated incidences, but part of an organisational context. As a consequence, using culture in accident investigations involves a considerable potential for learning. This is, however, not unproblematic. Kringen (2009) state that the Norwegian Petroleum Safety Authority initially viewed it as a (too) drastic measure to label companies with a label of “bad HSE-culture” after accidents. Such a reference may put a general negative label on the organization in question. Moreover, Bye et al. (2016) also criticizes the use of the safety culture concept in accident investigations, as the explanatory power of the concept might lead to the premature closure of a search for the specific causes of an undesired behaviour or decision. In this context, they suggest that safety culture may be a stumbling block for learning. They conclude that it is necessary to go beyond the general reference to “poor HSE-culture” when explaining accidents, focusing more specifically on decisions and their organizational contexts. As we have noted above, providing reliable descriptions of culture in organisations may require a lot of time and thorough analysis requiring a high level of competence, and training. With a high level of analysis required, conclusions may also be criticized for being subjective and perhaps speculative. Accidents may, however, also provide new entries to interpreting safety culture in organisations, and this could both be a challenge and a benefit. However, accident investigation processes can be improved, by e.g. training investigators and standardizing the process. ISROP from North American rail is a standardized process developed by the Canadian Pacific Railroad for conducting thorough and systematic incident investigations (FRA, 2006). The evaluation of this indicated positive results, but also some challenges.

Using safety culture in accident investigations

Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> - May provide a picture of systematic patterns underlying decisions and/or behaviours in organisations - Thus; individual behaviours are not seen as isolated incidences, but part of an organisational context. - Involves a considerable potential for learning 	<ul style="list-style-type: none"> - Too drastic to label companies with a bad safety culture after accidents? - Explanatory power may lead to premature closing of search for specific causes of behaviour - May require a high level of competence? - May require a high level of analysis, which may be perceived as subjective (?)

5.3. Advisory-based strategies to influence safety culture

5.3.1. Providing tools for self-measurement

Both the US and the Canadian SMS regulations require railroad companies to conduct self-measurement of safety culture, and describe how it promotes safety. A general self-assessment tool is available at the website of Transport Canada, including a safety culture check list. The IAEA (2016) provides several tools for safety culture assessments, both for companies themselves and for regulators. The Independent Safety Culture Assessment (ISCA) is based on data from questionnaires, interviews, focus groups, document reviews and observations. This data is compared with the IAEA normative framework for strong safety culture (IAEA, 2009, 2016). Mengolini and Debarberis (2007) study a self-assessment and self-improvement process based on IAEA guidelines, and report improved safety culture results. Obadia et al. (2007) also study a safety culture self-assessment process. RAC (undated) also mentions self-assessment of safety culture through checklist, as one of the key measures implemented in Canadian rail. Self-measurement of safety

culture may be an important first step in safety culture improvement, as they may enable group discussions about the safety culture and serve as an important input to continuous improvement processes (Ek et al., 2014). However, such evaluations often seem to require a considerable amount of time and resources (Grote and Künzler, 2000). This especially applies to the assessment tools provided by the IAEA, e.g. the Independent Safety Culture Assessment (ISCA). This tool is based on data from questionnaires, interviews, focus groups, document reviews and observations, and the collected data is compared with the IAEA normative framework for strong safety culture (IAEA, 2009, 2016). We have seen that both qualitative and quantitative methods are used by researchers to study safety culture. Although such rigorous method triangulation contributes to a better empirical basis for drawing conclusions, it requires considerable competence, economy and time. Qualitative methods are especially time consuming, and they require a level of training, equality and trust with the studied people which may be hard to attain in self-assessments (Grote and Künzler, 2000). Future research should therefore examine less research demanding approaches. There are free web-tools offering self-administered surveys generating measurements of safety culture (e.g. Nævestad and Bjørnskau, 2012). Such tools may provide anonymous measurements, that may serve as basis for collective reflection and learning (Richter, 2003; Nævestad, 2010b). Thus, the qualitative aspect of safety culture could be attended to through group discussions of survey results. The Swedish Labour Inspection Authority “Arbetsmiljöverket” provides such a tool on its website. This is a low-cost solution, which especially could be important in sectors with few resources to develop their own self-measurement tools. Such web-tools may provide opportunities for comparison with other companies in the same sector, and they could be designed to generate output on the most important challenges. It seems, however, that this strategy is contingent on a certain level of trust between managers and employees: If the safety culture is poor, e.g. with low levels of trust between managers and employees, employees’ reporting may be influenced. It is also likely that post discussions aiming to correct cultural challenges will be negatively influenced. If lacking trust is the problem, it is not likely that employees will trust management in the safety culture development process neither.

Providing tools for self-measurement	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> – May be a potential first step in an improvement process – May be a premise for learning and joint discussion of safety culture aspects – Enables comparisons with future situations and other organisations – Repeated measures may enable assessments of the efficiency of measures 	<ul style="list-style-type: none"> – May require a considerable amount of time and resources – Interpretation and analysis may require competence – Contingent on a certain level of trust between managers and employees – May require a web tool, or other technology enabling data collection and analysis – Anonymity must be ensured

5.3.2. Providing tools for self-development of a positive safety culture

Regulators providing tools for organisational self-development of a positive safety culture may offer a cheaper solution to cultural development than e.g. involving external consultants. Studies have found that self development processes through group discussions may lead to decreased accident risk (e.g. Gregersen et al., 1996). The studies from rail indicates that safety culture change comes about through institutionalised discussions of hazards involving managers and employees (Amtrak, 2015; Zuschlag et al., 2016). In accordance with this approach, and IAEA guidelines, Mengolini and Debarberis (2008) suggest a continuous improvement approach involving focus group discussions where participants identify relevant safety activities. Staff are made responsible for specific activities, thus guaranteeing their motivation and commitment. Such processes may also be facilitated by web-

tools or other technologies. These may not only provide self-measurement and learning through discussion of the results; they may also provide tools for self-improvement, describing steps required to establish a positive safety culture. Mengolini and Debarberis (2007) show that the implementation of IAEA guidelines on safety culture led to improved safety culture at a Dutch research reactor. In this case, the IAEA Guidelines were adapted and implemented through development of a safety improvement plan, and the use of improvement teams who were motivated and empowered to find causes and propose/implement solutions. Safety culture was measured by means of surveys, field interviews and observations. In the literature, such processes are typically described as “continuous improvement”. Moreover, Obadia et al. (2007) study a safety culture self assessment process. Mengolini and Debarberis (2007) state that the IAEA guidelines do not provide a viable way of measuring the effectiveness of the safety culture improvement program. They relate this to the fact that the industry lacks good indicators of safety culture, which have been found to have a high predictive validity, or an established relationship with safety outcomes.

Self-development of safety culture may, however, involve social processes that may be relatively hard to foresee and influence (cf. Bye et al., 2016; Kongsvik et al., 2016). Mengolini and Debarberis (2007) stress that employee involvement and subcultures must be taken into account when safety culture interventions are developed. Experiences from North American rail indicates that lacking trust between managers and employees and between regulators and the regulated are key factors influencing the outcomes of efforts to improve safety culture (Amtrak, 2015; Zuschlag et al., 2016). It is therefore important that regulators and companies wanting to improve safety culture are aware of the general processes in which culture are (re)created and the potential pitfalls involved in the process.

Providing tools for self-development of a positive safety culture	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> – May offer a cheaper solution to cultural development than e.g. external consultants – Studies have found that self development processes through group discussions may lead to decreased accident risk 	<ul style="list-style-type: none"> – May require a considerable amount of time and resources – Contingent on a certain level of trust between managers and employees – May involve social processes that may be relatively unpredictable

5.3.3. Providing real examples safety culture interventions

Authorities could increase companies’ understanding of what it means to implement a positive safety culture by providing good and concrete examples of how companies work with safety culture, within their respective sectors. In this way, companies considering safety culture interventions may have concrete examples of what it means and what it requires of them. IAEA provides rich examples of good (and ineffective) safety culture practices in different publications e.g. IAEA (1997), which presents leadership techniques to improve safety culture, and underlying causes of good and poor safety performance. Good practices are described for requirements at policy level, for government and regulatory organizations, for managers and for personnel. In US rail, the FRA provides descriptions of, and results from other pilot studies of safety culture interventions. These are well documented and thereby available as example cases from their website. Transport Canada also provides concrete examples of safety culture interventions in rail, including, a definition and description of a positive safety culture. This strategy seems especially important in sectors with a low focus on safety, where companies have fewer examples of companies working systematically with safety culture.

Providing real examples safety culture interventions	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> – May provide good and inspiring examples – May increase companies' understanding of what it means to work with safety culture measures 	<ul style="list-style-type: none"> – There is not necessarily one single correct solution – Examples could be interpreted as blueprint solutions – Do not necessarily take into account that organisations are different – Regulators may risk that companies reply “we did exactly as you told us, but we experienced an accident”

5.3.4. Training of managers and employees

Above, we listed lacking competence as a common challenge related to the development of good safety culture measures. Training of managers and employees therefore seems to be a relevant measure. Several of the reviewed studies, especially from the nuclear sector, focus on training and education. O'Mara et al. (2015) study training based on the IAEA Systematic Approach to Training (SAT). Mod Ali (2008) study training of company representatives to conduct organisational self-measurements and self-development. Engel et al. (2001) also describe the effects of training on nuclear safety culture. IAEA provides comprehensive training to facilitate safety culture improvement. The Safety Culture Continuous Improvement Process (SCCIP), which includes e.g. a three-day senior management workshop in order to strengthen safety culture leadership skills (training) is a good example. This strategy also seems especially important in sectors with low focus on safety culture, and where organizational safety management is less developed than in other sectors. Training was also a central measure aimed at developing a positive railroad safety culture in Canadian rail, following the 2007 review of the SMS rules (RAC, undated).

Training of managers and employees	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> – Competence is listed as a common challenge related to the development of good safety culture – May increase companies' understanding of what it means to work with safety culture measures – May create a common language and understanding among regulators and companies 	<ul style="list-style-type: none"> – May be resource demanding – May only attract those who are motivated – Unmotivated people are not necessarily susceptible to training

5.3.5. Financial support as a motivational tool

The experiences from the three sectors indicate that, due to a functional focus on safety culture, companies are given considerable freedom to define their own approaches to safety management and safety culture interventions. Research from Canada indicates that this may lead to varying degrees of implementation in the industry, partly due to a culture of mistrust within and between railroads and the regulator (SMS Aviation Safety Inc., 2007). If the companies “who need it most” fail to implement SMS requirements, including a positive safety culture, this is especially challenging. It seems that companies' motivation to work with safety is a key factor that it may be challenging to influence for regulators. One way could be to highlight the economical benefits of SMS and safety culture implementation. Another way could be that regulators provide limited financial support to companies that are willing to implement SMS or safety culture measures (e.g. lower fees). In US rail, the FRA provides financial support for railroad companies who enroll in voluntary programs meant to improve safety and safety culture. This could motivate companies with the least resources (that probably need it the most) to participate. A potential challenge is that companies participate merely to get the financial support, rather

than based on a wish to improve their safety culture.

Financial support as a motivational tool	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> – Companies' motivation is a key challenge, and financial support could increase motivation – Could be an important measure for companies with few resources 	<ul style="list-style-type: none"> – Companies may participate with the primary objective of financial support, depending on the size of the support – “Wrong” type of motivation (?)

5.3.6. Supporting research and pilot studies

The reviewed studies from North American rail indicates that supporting and facilitating pilot studies of safety culture interventions is a relevant regulatory strategy. It seems that this strategy was applied in a context where more information and knowledge about relevant measures to improve safety culture and safety records was needed. The main benefits with this approach is that research-based knowledge provide a good basis for policies. Moreover, results of the studies will be more relevant for regulated companies if they are conducted within their own sector. Possible challenges with this approach is that it is demanding to design robust evaluations, that the duration of the evaluations may be long and that several studies often are required to draw solid conclusions. However, the studies from North American rail may provide good examples for other regulatory agencies.

Supporting research and pilot studies	
Potential opportunities:	Potential challenges:
<ul style="list-style-type: none"> – Research-based knowledge provide a good basis for policies – Relevant studies may provide good examples – Pilot studies can be combined with extensive literature reviews – Provide regulators with research based on the most relevant empirical context 	<ul style="list-style-type: none"> – It is demanding to design robust evaluations (with pre-post measurements and control groups) – The duration of the evaluations may be long – Several studies are often required to draw solid conclusions

6. Discussion

6.1. Including safety culture in the regulatory repertory may involve a range of different strategies

We started the paper by stating that several regulators have included safety culture in their repertory (cf. Kongsvik et al., 2016). Our discussion indicates that to include safety culture in the regulatory repertory may involve a range of different things, e.g. auditing safety culture, introducing new rules, providing information, providing assistance with self-measurements, supporting and or funding pilot studies, implementing safety management systems etc. In the present study, we have categorized these different initiatives into 5 rule-based and 6 advisory-based strategies regulatory authorities can use to influence safety culture in organizations. We define such strategies as general plans/visions or specific measures (e.g. methods, techniques, rules), which potentially could facilitate changes in shared and safety relevant ways of thinking and acting in organisations (i.e. safety culture). The strategies do not necessarily have as an explicit intention to influence safety culture. It is for instance agreed that safety management systems often can be viewed as a measure to implement safety culture. Our data from the nuclear industry and rail indicates that safety culture change may be an explicit aim of SMS, but not necessarily.

6.2. Is it possible to regulate safety culture?

6.2.1. Culture is not a distinct controllable entity

A very relevant issue that should be dealt with in the present paper is whether it is possible to regulate safety culture at all. When discussing this, it is important to remember that culture is not a distinct controllable entity. Students of safety culture or organisational culture are sometimes accused of reification, which means that they seem to assume that culture is a distinct entity within the organization, which can be controlled and manipulated to fulfil certain purposes. On the contrary, the reviewed studies seem to indicate that safety culture is not a distinct and controllable entity, but rather a dynamic, complex and changing set of resources that people draw on and influence and negotiate in their lives. Instead of asserting that there is culture in organisations, we should rather view organisations as cultures, or as multiple configurations of cultures, which may be more or less important depending on the context and the question at hand (Martin, 2005). Culture is an inevitable aspect of social life, and it may have both good and bad consequences for safety. Moreover, our identification of safety culture is also contingent on how we define it, and which aspects we focus on. Thus, it is evident that our discussion of regulation of safety culture does not concern the regulation of culture as a distinct entity within the organization, but rather limited and safety relevant cultural aspects and their indicators, or as antecedents of culture. Such aspects or antecedents are provided in guidelines describing safety culture aspects and the elements they are comprised of (e.g. IAEA, 2009, 2016). Clearly such aspects and elements are related to more basic underlying cultural aspects which fall way out of the scope of safety culture regulation.

6.2.2. Safety culture emerges through interaction between people

Safety culture emerges through interaction between people, and it is not given that formally powerful actors (e.g. managers) are more important than employees in this process. Based on this, scholars have also questioned whether it is possible to manage culture at all (cf. Haukelid, 2008). The studies from petroleum indicates how organisational members drew on their cultural references (e.g. professional backgrounds, organisational environments, company history) to make sense of and translate the HSE-culture provision. Moreover, the studies from rail indicate how the organisational members' receptions of the efforts to influence safety culture were contingent on the relationships between employees and managers in the organisations. The reviewed studies indicate, however, that although the (re)creation of safety culture often is a relatively democratic process, regulators and/or managers may often set the premise for these processes by defining the agenda of interaction processes. From a regulators' or managers' perspective, it seems that the challenge is the uncertainty and lack of control of how the meaning of the agenda is received and interpreted. The studies from the Norwegian petroleum sector indicate high interpretive costs, frustration and confusion (in addition to learning). Le Coze and Wiig (2013) suggest that some would argue that the Norwegian experience with HSE-culture regulation was a failure, due to lacking consensus in the PSA and challenges related to the companies. Grote and Weichbrodt (2013: 226) refer to the high interpretive costs as an argument that regulators should “stay away from culture and stick to rules instead”.

6.2.3. Is safety culture a too abstract regulatory concept?

As noted, Kringen (2009) refers to an anthropological study from 1963, referring to over 160 definitions of culture, to shed light on PSA personnels' complaints that it was difficult to regulate an abstract concept. In spite of theoretical and conceptual disagreements about how to understand culture, it is however important to note that it may be easier to define positive safety cultural practices, or aspects of safety culture, than the culture concept itself. This is indicated by the detailed descriptions provided by the IAEA of safety culture aspects. According

to the IAEA, one of the key characteristic of a strong safety culture is that “safety is learning driven”. This means for instance that open reporting of deviations and errors is established and supported, that internal and external assessments, including self-assessments contribute to continuous improvement, that safety performance indicators are tracked, trended, evaluated and acted upon, that there is systematical development of individual competence and that external and internal assessments, including self-assessments, are used. These traits or indicators of the safety culture aspect “safety is learning driven” are more concrete and thus less difficult to evaluate than the abstract safety culture object itself. Thus, safety culture is not necessarily more abstract than existing regulatory concepts, especially not when focusing on concrete aspects of safety culture. Our study has indicated that more research is needed on the relationship between safety culture aspects and relevant outcome measures.

6.2.4. Safety culture concerns the informal aspects of safety management

An interesting response to the line of argumentation put forward above, is that if we rather refer to the more specific elements of safety culture (e.g. reporting practices, no-blame culture), then why should we use the safety culture concept at all, especially if we may risk terminological confusion and trouble? The answer is that the general safety culture concept directs our attention to the informal aspects of safety management (Antonsen, 2009) 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”. Thus, it seems important that regulators maintain this focus in their approach to understanding safety; as part of their analysis; as an additional approach to the “command and control” approach. This is illustrated by Bernard's (2014, 2018) descriptions of the Safety culture oversight model.

6.2.5. Redefining the content of regulation and regulatory concepts

As a consequence of the abstract and ambiguous character of the safety culture concept, Antonsen et al. (2017) asserts that the culture concept is ill-fitted for a regulatory command and control approach; it is difficult to define when companies are compliant (i.e. if they have a “sound” HSE-culture), and challenging to sanction companies for having the “wrong” culture. This does not necessarily mean that safety culture is unsuitable as a regulatory concept in general, although it perhaps would require an expansion or redefinition of what a regulatory concept is. Bernard (2014) argues that including safety culture as a regulatory tool requires a shift in the perspective of regulators. As the purely rule-based regulatory approach seem to become less common among regulatory authorities, the role of the regulators and also their relationships with companies are changing. In this new context, regulators do not only provide rules, perform inspections and identify non-conformities; they also provide companies with information about concepts and approaches, they may sponsor and/or design interventions, provide companies with feedback on their safety management systems, arrange seminars on relevant topics, provide examples of good practices etc. These regulatory activities are exemplified in the reviewed studies. When we understand regulation in a broad sense, referring to these different activities, the role of the regulator becomes more blurry (Antonsen et al., 2017).

Based on this discussion, it is probably more relevant to ask “where safety culture can be regulated”. The type of regulatory articles and audits that we have discussed in the present paper largely presuppose a purpose-based regulatory regime. In this context, safety culture is not necessarily as exotic as it may appear at first glance. The Regulations relating to health, safety and the environment in the petroleum activities and at certain onshore facilities (The Framework Regulations) § 10 states for instance that:

“The activities shall be **prudent**, based both on an individual and an overall assessment of all factors of relevance for planning and implementation of the activities as regards health, safety and the

environment.”

The definition of “prudent” will depend on the context, and it is difficult to provide clear-cut lines of demarcation defining cases that fulfil and cases that fail to fulfil these criteria. Thus, it is also difficult to issue non-conformities based on this article. On the other hand, we may argue that the point of purpose-based regulations is to develop overall, holistic requirements. In this case, safety culture fits well within the regulatory regime, especially if there is a tradition for trust between the parties. In a context with prescriptive rules and considerable distance between regulators and the regulated, it seems that it would be unwise to introduce purpose-based requirements. Thus, the most important question does not seem to be whether safety culture can be regulated, but the conditions that must be present for safety culture to be included in the regulatory portfolio of rules and instruments.

6.3. Which strategy is the most effective?

6.3.1. The methods of the studies differ

Our review indicates that the regulatory strategies to some extent are different in the sectors, although several of them also were overlapping. In petroleum, the role of the regulating authority was to introduce a new rule, or “policy statement.” In rail, the role of the authorities was to design, support and/or evaluate the outcomes of interventions. In the nuclear sector, the role of authorities involved a broad spectrum of measures: from providing general policy statements to providing specific guidance on the elements of aspects of safety culture and how these can be enhanced and evaluated.

Based on our review, it may be tempting to ask which regulatory strategy that is the most effective. It is, however, important to note that the methods and designs of the reviewed studies influence the conclusions we can draw based on them. Our review indicates that the methodological approaches applied in the reviewed studies in the different sectors differ substantially. The studies from the petroleum sector are largely qualitative, while the studies from rail are quantitative. This is largely a result of the focus of the studies and the studied regulatory strategies. The studies in petroleum are qualitative, as their focus is the reception of the new HSE-culture provision among regulators and companies, focusing on translation, negotiation and communication between different actors. Such a focus requires qualitative studies, in order to open up for the meanings that the HSE-culture requirements had for different actors, the contexts influencing these ascriptions of meaning and how the meanings were developed in the interaction between the involved parties. In their conclusions, these studies point to learning, but they also stress that the learning involved high interpretive costs. Effects on safety culture, safety behaviour or accidents are not assessed quantitatively in these studies.

Most of the organizational interventions in rail are robustly evaluated, with study and control groups, pre and post measurements. Although it is difficult to directly compare the success of the reviewed regulatory initiatives, we can at least conclude that these robustly evaluated interventions indicate positive changes in safety culture, safer behaviours, and reductions in the number of accidents/incidents. This does not mean that these measures necessarily are more effective than the measures in the other sectors, merely that we have more systematic knowledge about their outcomes. The systematic knowledge is, however, a good argument for regulators to focus on safety culture. It must be noted, however, that the interventions probably have higher direct costs than e.g. new rules/ provisions, although the studies point to high indirect costs (“interpretive costs”).

Safety culture is generally not measured directly in the studies from the nuclear sector, but assumed to be influenced through other measures, as these measures are argued to be a central element of safety culture. Mengolini and Debarberis (2007) state that the industry lacks good indicators of safety culture, which have been found to have a high predictive validity, or an established relationship with safety outcomes.

This indicates a very important area for future research.

6.3.2. The facilitation of organisational self-development processes

In this paper, we have discussed potential opportunities and potential challenges of 11 different regulatory strategies to influence safety culture in organisations. Summing up the different pros and cons, it would be interesting to identify the strategies with the most significant opportunities and the least serious challenges. Before we do that, it is however tempting to take a step back and look more at all of the discussed strategies to examine what they have in common: it is evident that the explicit/implicit purpose of all of them is to facilitate systematic organisational self-development processes in the regulated companies; or “continuous improvement”. The underlying purpose of all of the strategies is to make organisations do something to improve their own safety culture. Our paper indicates that the (challenging) role of regulators is to find the appropriate strategies to motivate companies to engage in self-development processes, and to help them along the way, without giving direct instructions. Nævestad and Phillips (2018) state that the most basic element in this process is to institutionalize joint discussions and risk assessments of work place hazards, involving managers and employees in organisations. Thus, it seems that what we need more research on is: (a) how regulators best can motivate companies to start such processes, (b) how regulators best can facilitate such processes once they have begun and (c) whether different means of facilitations produce different results.

7. Conclusion

In this paper we have argued that it is positive that regulators have included safety culture in their repertory, as a means of pushing the regulated industry to include informal aspects in their efforts to improve safety. Our discussion indicates, however, that to include safety culture in the regulatory repertory may involve a range of different strategies. We have identified 11 regulatory strategies to influence safety culture, and we argue that the explicit/implicit purpose of all of them is to facilitate systematic organisational self-development processes in the regulated companies: to make organisations do something to improve their own safety culture. Our study indicates that regulatory efforts can set forth such processes, and potentially reduce accidents and injuries. Although we have concluded that more research clearly is needed to illuminate the outcomes of different regulatory strategies to influence safety culture, we have summed up pros and cons and results of the discussed strategies, based on available experiences.

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