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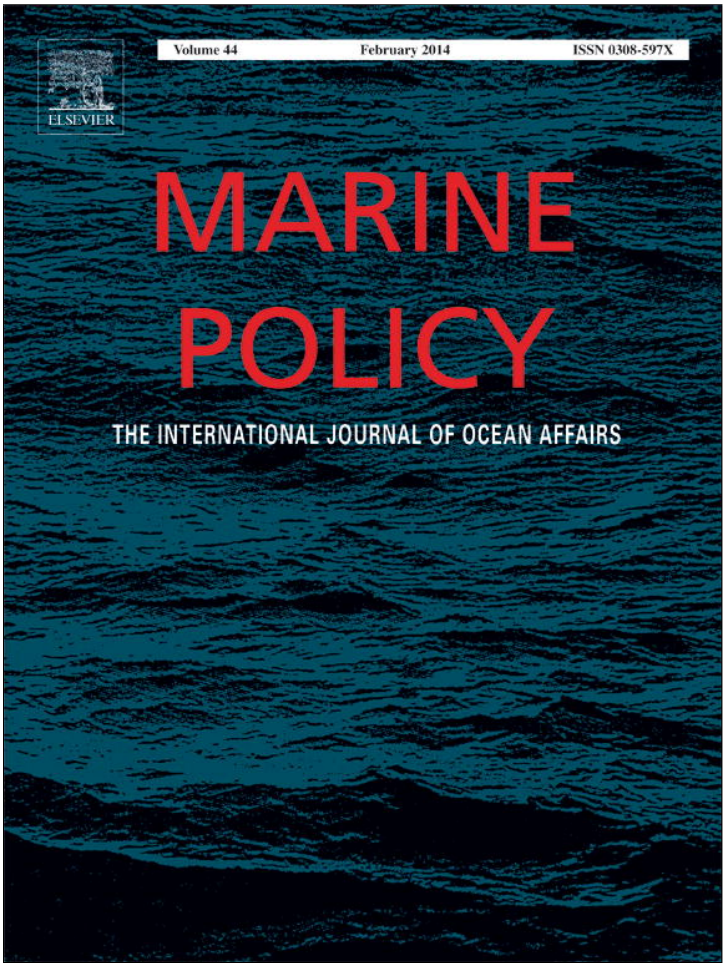
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Relationships between safety culture aspects – A work process to enable interpretation ☆

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ABSTRACT

Knowledge about the existing safety culture in a maritime organization such as in shipping companies or on board ships can enable the formulation of effective interventions to maintain and improve safety culture and safety in the organization. When assessing the safety culture, questionnaires developed for this purpose are often used. This paper proposes a work process that facilitates the analysis and interpretation of the relationships between safety culture aspects using questionnaire data. The work process includes the use of variable cluster analysis where the cluster solutions are presented in dendrograms. These were found to be an excellent way to visualize complex relationships in the quantitative data and to facilitate the understanding of the safety culture concept. Results are presented from applying the statistical process to safety culture data from six Swedish ships in international traffic. The visualized safety culture results can enable group discussions about safety on different organizational levels and can constitute an important input to the continuous improvement processes for safety and safety culture.

1. Introduction

Although mortality rates for seafaring have declined greatly over the course of the 20th century, seafaring has continued to remain amongst the most hazardous of occupations. Merchant shipping is known to have a high rate of fatalities caused by occupational accidents and maritime disasters [1,2]. Human and organizational factors account for the vast majority of unanticipated significant problems associated with the design, construction, and operation of ships. For example, Moore et al. [3] found that most accidents result from a compounding sequence of breakdowns in physical components, human error, and organizational failures.

Technology and automation are often introduced to increase efficiency and safety, reduce workload, reduce human involvement and the effect of human error. However, the human-automation interaction can have consequences for human work and safety as the automation can create new error pathways and delay opportunities for error detection and recovery [4]. The human role in the system is complex since a person's individual characteristics and states, abilities and competencies affect decision-making and performance on board. The human in the system is both error inducing and an important source of expertise for decision-making and recovery [5].

While the human and system aspects are vital for safety, the organizational aspect also has a fundamental influence on safety [6]. The capsizing of the *Herald of Free Enterprise* just outside the Belgian port of Zeebrügge in 1987, with the loss of 193 lives, is one important example. It emphasizes the organizational aspect of having a poor safety culture on different levels in a shipping company [7]. Corporate safety cultures shaped by the degree of commitment to safety on the management level are often highlighted as the overriding factor for safety performance. Conflicting safety and production goals, ineffective communication, time pressure, and fierce competition in a complex industry environment, can very likely lead to the stretching of safety margins (often unconsciously), and the migration of behavior towards the boundary of acceptable performance [8], also known as a “drift into failure”. A safety culture that stresses proactive measures for maintaining safety in an organization is a vital counterforce to the possible drift into failure. Thus, to maintain and improve safety and efficiency in safety critical maritime organizations, knowledge is needed about the safety culture and the way it is expressed in attitudes, behaviors, and artifacts. Questionnaires developed for this purpose are often used when assessing an organization's safety culture. The analysis and interpretation of questionnaire results can provide more knowledge about the maritime safety

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culture concept and contribute to the formulation of effective interventions to maintain and improve safety and safety culture on board ships.

This paper proposes a work process that facilitates the analysis and interpretation of the interrelationship between safety culture aspects in an organization using questionnaire data. In the process, safety culture results are visualized in dendrograms, which facilitates the combination of a qualitative understanding of the phenomenon of safety culture and quantitative evidence from questionnaire data. The visualized results can enable group discussions about the safety culture and serve as an important input to continuous improvement processes. This paper also presents safety culture results from applying the work process to questionnaire data from six Swedish ships in international traffic.

2. Safety culture and safety management

Before describing the proposed work process, theoretical assumptions and notions about safety culture and its relationship to safety management will be presented.

A safety culture reflects individual, group and organizational attitudes, values, and behaviors concerning safety. Safety management relates to the formal safety practices and responsibilities documented in a safety management system. A well-developed safety culture in an organization is an enabler for maintaining and improving safety performance, the emphasis placed on safety work and improvement processes for safety [6]. Safety culture has been shown to be a robust leading indicator or predictor of safety outcomes across industries and countries [9–11]. Research indicates that organizations and companies that have well-developed, functional and proactive health and safety management are likely to experience fewer work-related accidents and incidents [12]. The important reciprocal relationship between safety culture and safety management is emphasized in Cooper's [13] model of safety culture. It encompasses subjective internal psychological factors (i.e., people's attitudes and perceptions of safety and safety culture), observable safety-related behaviors (safety performance) and objective situational features (e.g., structure of the organization, safety management systems, and working procedures) [13].

Definitions of safety culture usually include a proactive stance to safety [14]. Learning in an organization is also associated with a proactive approach to safety. This means collecting, monitoring, and analyzing relevant information on safety and health and thus having updated knowledge about how work and safety are functioning. In this way, a learning culture [6] is created where one learns from the safety information gathered and reported, and is willing to introduce changes when needed.

2.1. *Safety culture and safety management in the maritime setting*

The International Maritime Organization (IMO) stresses the importance of safety culture on vessels, in shipping companies and in the shipping industry as such. The IMO states that “An organization with a ‘safety culture’ is one that gives appropriate priority to safety and realizes that safety has to be managed like other areas of the business. For the shipping industry, it is in the *professionalism* of seafarers that the safety culture must take root.” This professionalism is determined by attitudes and performance, very often shaped by the culture of the shipping company [15].

The IMO also stresses the importance of safety management systems in shipping. And, in accordance with Cooper's safety culture model, IMO recognizes the bi-directional link between safety culture and safety management. The IMO's International Safety Management (ISM) Code provides a standard for the safe management and operation of ships and for pollution prevention. The ISM Code is mandatory and establishes safety management objectives. It requires that a safety management system be established by whoever is responsible for the operation of the ship. The philosophy underlying the application of the ISM Code supports and encourages the development of a safety culture in the shipping industry. The Code constitutes a system of self-regulation of safe ship operation as well as occupational safety and health on board. The Code requires procedures to ensure safe operation, the management of risk, procedures for reporting and analyzing accidents and conformities, and procedures for internal audits and reviews [16].

The efficacy of the ISM Code has been investigated in several studies but no definitive indication has been provided. Tzannatos and Kokotos [17] found that the Code had a positive outcome in Greek shipping. After examining accidents involving Greek-flagged ships between 1993 and 2006 (i.e., before and after the implementation of the ISM Code), the implementation of the ISM Code led to an overall reduction of human-induced accidents (from 64% to 52%), although Greek-flagged ships still maintained their dominance in shipping accidents. In the pre-ISM period, tankers and Ropax vessels were also deeply linked to human-induced accidents, but implementation of the ISM Code managed to remove this link [17]. However, the ISM Code has been criticized because of the increased amount of paperwork and bureaucracy. Moreover, the standardization of the management of safety and the demand for written procedures are perceived by many seafarers as going against common sense, experience, and the professional knowledge of seamanship [18].

For effective self-regulation of safety and occupational safety and health to be achieved, the implementation of safety management systems must go hand in hand with employer's safety commitment and employee's participation in safety management decision-making [19]. These factors are very much associated with the safety culture in an organization. Employee participation in decision-making will enhance their commitment to take action and implement changes when needed [20]. Good communication and listening skills across organizational levels, groups and individuals strengthens a shared situational awareness of risk and safety [21]. Effective communication and employee participation are also factors that drive organizational change [20,22]. Effective employee participation is often hindered by job insecurity, which correlates with poor communication between employees and managers [23].

Bhattacharya [24] examined if employment and social conditions that support effective implementation of self-regulation are present in the maritime context. The study showed that managers and seafarers were operating with fundamentally different understandings of the purpose and use of the ISM Code, resulting in a gap between its intended purpose and practice. A critical factor was the lack of seafarers' participation in the management of workplace health and safety, which was traced back to the seafarers' poor employment conditions (job insecurity) and low-trust relationships with their managers [24]. In the study the seafarers feared being blamed for shipboard incidents and near-misses which led to poor communication and under-reporting. A critical part of a safety culture is the establishment of a just culture in which responses to incidents and accidents are considered to be just. This creates an open and reporting culture.

Efficient safety management systems all include the collection of safety information from the operational production system in order to learn from accidents and incidents and thus provide a basis for continuous safety improvement [6,25,26]. Studies show that under-reporting constitutes a major problem in the maritime industry [27–29]. Oltedal and McArthur [30] found that a higher reporting frequency in the Norwegian merchant fleet was related to enhanced safety training, a trusting and open relationship among the crew, performance of proactive risk identification activities and feedback on reported events. Lower reporting was related to efficiency demands and lack of attention to safety from shore personnel.

2.2. Safety culture aspects studied

The work process proposed in this paper for analyzing and interpreting the interrelationships between safety culture aspects can be applied to data from any safety culture questionnaire. In the current study, the process was applied to questionnaire data on safety culture aspects studied on board six Swedish passenger ships in international traffic [31]. The current approach to safety culture is focused on good organizational learning and is based on nine aspects of safety culture found in the safety culture literature [32]. Four of the aspects – *Learning, Reporting, Justness and Flexibility* – are based on the perspective that a safety culture is equivalent to an informed culture [6], where an organization is proactively updated on human, organizational and technical issues. A *Learning* organization has both the will and the competence to learn from experience and safety information, and the readiness to implement improvements. To support the ability to make relevant safety information visible, it is vital to have a *Reporting* culture, that is, an organization that has succeeded in creating trust and commitment that results in good reporting of incidents and anomalies among crew members and officers. This is closely connected to a *Just* culture, which enhances the seafarer's willingness to make such reports. A *Flexible* culture manifests respect for skills, experiences and abilities among the seafarers. The perceived *Work situation* aspect comprises issues such as time pressure, fatigue, adequate training in work practices and safety routines, clarity in rules, and access to suitable equipment. These issues can affect seafarers' work performance as well as their ability to live up to established safety rules and demands. *Safety-related behaviors* are made up of perceived individual and organizational behaviors such as prioritizing, taking responsibility, risk taking, orderliness, and pressure from different levels in the organization to take short cuts. *Attitudes towards safety* are expressed in, for example, individual and organizational attitudes about the importance of safety, distribution of work and responsibilities, and encouragement of safe practices. Functioning routines for *Communication* in normal daily work are vital to assure that the right people in an organization are kept informed of the state of the system (e.g., the amount of and the clarity in the communication between work groups and different levels of the organization). The last aspect, *Risk perception*, involves how the individual perceives such things as the risk of harming others, and having an influence on safety in one's work.

Two vessel types were represented among the six passenger vessels studied: passenger/cargo ferries (Ropax) and high speed crafts (HSC). The two types of vessels have a somewhat differing safety organization. The Ropax has a crew of fixed size and a fixed safety organization. On the HSC, though, the size of the crew (especially in the catering department) varies with the number of passengers over seasons. This variation also requires a more flexible safety organization concerning the size and the fact that crew members can be placed in varying positions in the safety organization. Does this difference affect the characteristics of the safety culture?

2.3. Aim

This paper proposes a work process that can facilitate the investigation and interpretation of the relationships between safety culture aspects studied using questionnaires in maritime organizations such as on board ships. The application of the process can yield increased knowledge about the maritime safety culture concept, knowledge that can enable improvements in safety culture and safety management. The work process includes the use of variable cluster analysis, which investigates the relationship between variables based on their correlations. The paper presents safety culture results gained from applying the work process to questionnaire data concerning nine safety culture aspects investigated on six Swedish passenger ships in international traffic [31].

3. Methods and material

3.1. Proposed work process

The proposed work process that enables the analysis and interpretation of the relationships between safety culture aspects includes the following steps:

1. Compilation of safety culture aspects.
2a. Applying a missing data analysis and estimation to the questionnaire dataset.
2b. Determining the internal consistency of the safety culture aspects.
3. Applying a variable hierarchical cluster analysis.
4. Interpreting and discussing results.

Each step is described in the following sections.

3.2. Compilation of safety culture aspects

In the current case, the approach to assessing safety culture was to select safety culture aspects that have been previously investigated in other research studies. Each aspect was represented in a questionnaire by a number of relevant items. The questionnaire can be found in [32]. To arrive at a measure for each aspect, an average score of the responses was calculated on the items that belonged to the aspect. All in all, 110 items represent the nine aspects in the questionnaire. The aspects were not designed using factor analysis, instead each aspect was designed to relate to a specific sub-aspect of safety culture. The aspect could be about the effects of a safety culture or could be a prerequisite for the existence of a safety culture (see Section 2.2.). The items included for each aspect reflect different facets of the aspect. Thus, the items included were based on pre-understandings and assumptions built on theories about conditions in an organization that were proven or assumed to be related to risk and safety and different safety culture aspects.

3.3. Applying a missing data analysis and estimation to the questionnaire dataset

3.3.1. Material

The passenger shipping study [31] was performed on six passenger/cargo ships (two high speed crafts [HSC] and four passenger/cargo ferries [Ropax]), in three shipping companies. The ships operated on routes in the Baltic Sea and the Kattegatt. All ships sailed under Swedish flag and with Swedish crews. A total of 528 (out of 711) seafarers on the six ships completed the safety culture questionnaire. Questionnaire response rates, average age, and average time at sea for the respondents, number of passengers, and car capacity for each ship in the three shipping companies are presented in Table 1.

During data collection the first author performed research visits of two to three days on each ship and during this time the questionnaire was administered to all crew members with

Table 1
Questionnaire response rates (%), average age, and average time at sea for the respondents, number of passengers, and car capacity for each passenger vessel in three shipping companies (A, B, and C).

Company	Vessel	% (n/N)	Age M (range)	Years at sea M (range)	No. of passengers	No. of cars
A	Ropax A	80 (57/71)	39.6 (20–64)	17.3 (.8–46)	300	155[a]
	HSC A	93 (52/56)	36.2 (21–59)	14.1 (.0–37)	600	175
B	Ropax B	64 (77/120)	44.1 (20–64)	20.3 (.5–48)	1300	300
	HSC B	61 (70/114)	37.2 (21–63)	13.9 (.5–35)	900	200
C	Ropax C1	96 (192/200)	37.7 (18–63)	10.7 (.0–40)	2852	360
	Ropax C2	53 (80/150)	39.6 (18–62)	15.6 (.0–43)	1916	306

Ropax = RORO passenger vessel, HSC = High Speed Craft vessel. N = crew size.

[a] Number of trucks.

the help of officers from the deck, engine, and catering departments. All crew members filled in the questionnaire independently during their shift or when off-duty and after completion put the questionnaire in an envelope which was then closed. The closed envelopes were gathered in a box on board. The filled-in questionnaires were thereafter sent to the first author by mail. During the first authors visit on board she was available to answer questions from individual crew members concerning specific items in the questionnaire.

3.3.2. *Missing data analysis*

It is important to accurately estimate the missing values in the questionnaire data set since this might influence the results in a way that is difficult to acknowledge when the results are later interpreted. There is a range of methods available to estimate missing data. However, two methods are generally considered to give the most accurate results: Expectation maximization (EM) and multiple imputation (MI). The EM method is based on the assumption that the missing data is completely randomly distributed both with regard to other variables in the dataset and to background variables. The MI method makes no such assumption about independence of other variables but yields several parallel datasets (usually three to five) that must be assessed individually and the results combined. Datasets that fails to demonstrate independence of background variables are difficult to estimate, but the MI method is generally considered the most adequate [33].

Based on the above discussion, the pattern of missing data was first analyzed for signs of independence of other variables in the dataset, commonly referred to as “missing completely at random” (MCAR). This investigation made use of Little's MCAR test [34]. In the current case, the result was statistically significant. Therefore, the hypothesis that the missing data was not randomly distributed was accepted. It should, however, be noted that since Little's MCAR test is sensitive to departures from normality [33], it is possible that the failure to reject the null hypothesis is due to departures from normality regardless of the pattern of missing data in the dataset. However, methods for dealing with datasets with non-random patterns are also adequate for dealing with datasets with random patterns. Hence, a false positive will not lead to the application of inadequate methods of missing data estimation.

Since the application of Little's MCAR test failed to prove that the missing data were randomly distributed across the dataset, the extent to which the pattern was independent of background variables, commonly known as “missing at random” (MAR), was assessed. To investigate this, a new dataset was created with a single dummy variable, which was coded as “1” for non-response and “0” for response. A multivariate analysis of variance (MANOVA) was performed on this new dataset to check the significance of background variables. Statistical significance was found on a number of background variables inferring that the missing data was not missing at random. This led to the conclusion that multiple imputation should be used to approximate the missing data.

As the cluster analysis method depends on the covariance matrix and not on the questionnaire responses per se, it is possible to perform the analyses on only a single imputation if there are no statistical significant differences between the covariance matrixes of the different imputations. To investigate this, Box's M test was performed using the data grouped according to the imputation (in total three different imputations) and also using a dataset where the missing data was estimated using the expectation maximization (EM) technique. The result was highly non-significant. Thus, it was concluded that either dataset could be used in the cluster analyses without having a significant effect on the results. It was decided to apply the EM estimated dataset in the cluster analyses.

3.4. *Determining the internal consistency of the safety culture aspects*

Cronbach's coefficient alpha tests were used to determine the reliability or internal consistency of the safety culture aspect scales. High alpha values indicate that items representing an aspect refer to this same underlying aspect. The analysis was performed using the methodology introduced by Schmitt [35], where the Cronbach's alpha values were compared to (corrected) correlations between aspects, not to a fixed cutoff value. Schmitt convincingly argues that this procedure is more adequate for assessing the internal consistency than using a (arbitrary) cut-off value. To demonstrate a high degree of internal consistency, the Cronbach's alpha should be significantly larger than the correlations between aspects corrected for attenuation.

3.5. *Applying a variable hierarchical cluster analysis*

The relationships between the aspects, based on the aspects' correlations, were investigated by applying variable hierarchical cluster analysis. The SPSS computer program was used to establish the cluster solutions. The clustering method, average linkage (between groups), was used in the analyses. In comparative studies, this method has performed as well or better than alternative methods and should be strongly considered when one chooses a clustering method [36]. The measure chosen to represent the distance between aspects (i.e., how closely related two aspects are) was based on the Pearson correlation subtracted from unity (to form a distance rather than similarity measure).

The resulting classification trees (or dendrograms) from the cluster analyses are presented in the results section. The dendrograms do not provide any other information than can be found in a correlation matrix. However, correlation matrices tend to be quite large, obscuring the relations between variables. The dataset used in this paper with the nine different aspects studied yielded 36 cells in a correlation matrix that needed to be accounted for, not only one-by-one but also the relation to the value of each of the other 35 cells. The use of dendrograms to illustrate these relations is a compelling tool to gain a better understanding of how the different aspects are related to each other. The overview provided facilitates the combination of a qualitative understanding of the phenomenon of safety culture and quantitative evidence from the data. A more narrow-sighted statistical table would result in the analyst not being able to "see the forest for all the trees".

3.6. *Interpreting and discussing results*

The qualitative understanding of the safety culture phenomenon is facilitated by the visualized results presented in the dendrograms. However, for the results to serve as an important input to the continuous improvement processes for safety and safety culture in a shipping company, the organization needs to finalize the work process by arranging work sessions that enable the analysis, interpretation, and discussion of results. The sessions should focus on the current state of safety in the organization and the identified relationships between the safety culture aspects, their implications and how to react to them. It would be preferable if the discussions were facilitated by representatives of the organization who have competence in human and organizational factors and safety. The discussion sessions should be seen as the first step in a subsequent work process, that of the Plan-Do-Check-Act cycle [37], which constitutes organizational learning and action for continuous improvement. It is important that the discussions enable participation among employees as this will enhance commitment and motivation to learn and make changes when needed. The discussion group would benefit from having members from different areas of the organization to improve the ability to speculate constructively about safety culture results and future actions. It is imperative that the issues identified are taken seriously by the management and employees and that effort are made to come up with solutions. Otherwise, overall motivation and commitment among questionnaire respondents will most likely decrease.

4. Results

The Methods and material section presented the work process which includes five steps that enables the analysis and interpretation of the relationships between safety culture aspects. The results from applying the different steps on safety culture questionnaire data will be presented here. However, for *Step* 1. *Compilation of safety culture aspects* see Section 3.2.

4.1. *Step 2a. Applying a missing data analysis and estimation to the questionnaire dataset*

In the questionnaire dataset, on average 2.7% of the entries per questionnaire item were missing. On 98% of the items, the frequency of non-response was below 10% and on 83% of the items, the non-response was below 5%. Even if the overall frequency of missing data was quite low, it is important to accurately estimate the missing values since this might influence the results in a way that is difficult to acknowledge when the results are later interpreted.

The pattern of missing data was first analyzed for signs of independence of other variables in the dataset by use of Little's MCAR test [34]. The result was statistically significant on the 0.001-level ($\chi^2=20838$, DF$=20152$) and therefore the test failed to prove that the missing data were randomly distributed across the dataset. To check the significance of background variables a MANOVA was performed which showed statistical significance on a number of background variables inferring that the missing data was not missing at random. It was concluded that multiple imputation should be used to approximate the missing data. However, in this case, it was possible to perform the cluster analyses on only a single imputation if there were no statistical significant differences between the covariance matrixes of the different imputations. Therefore, Box's M test was performed to investigate this using three imputations and also using a dataset where the missing data was estimated using the expectation maximization (EM) technique. The result was highly non-significant ($p=1.000$) (Box's M$=1356.2$, $F=0.067$, df1$=18315$, df2$=9232421$) concluding that either dataset could be used in the cluster analyses. It was decided to apply the EM estimated dataset in the cluster analyses.

4.2. *Step 2b. Determining the internal consistency of the safety culture aspects*

For a high degree of internal consistency, the Cronbach's alpha values should be significantly larger than the correlations between aspects corrected for attenuation. The results presented in Table 2 indicate a fairly high level of (corrected) correlation between aspects compared to the Cronbach's alpha values. This was expected since all nine aspects are sub-aspects of the super construct "Safety Culture", and therefore should experience a high degree of correlation. The conclusion was drawn that the grouping of items into nine aspects is not justified by the data itself. However, the groupings have a solid theoretical basis in the research literature. It should also be noted that the absolute values of the Cronbach's alpha are quite high compared to the cut-off value commonly used (.70 [38]) indicating that they do indeed

Table 2
Internal consistency (Cronbach's coefficient alpha), observed correlations, and attenuated correlations for the nine safety culture aspects for six vessels[a].

	Work situation	Flexibility	Communication	Reporting	Justness	Learning	Behaviors	Attitudes	Risk perception
Work situation	**.87**	.73	.89	.77	.66	.62	.75	.67	.73
Flexibility	.57	**.69**	.78	.77	.79	.64	.67	.76	.69
Communication	.76	.60	**.85**	.92	.77	.77	.87	.81	.83
Reporting	.67	.59	.79	**.87**	.77	.84	.78	.81	.77
Justness	.56	.60	.65	.66	**.84**	.76	.76	.73	.76
Learning	.55	.51	.67	.74	.67	**.90**	.85	.85	.79
Behaviors	.65	.52	.75	.68	.66	.75	**.87**	.83	.94
Attitudes	.58	.59	.70	.71	.63	.76	.72	**.88**	.57
Risk perception	.59	.49	.66	.62	.60	.65	.75	.71	**.75**

[a] Cronbach's coefficient alpha values are presented in the diagonal, observed correlations between aspects below the diagonal, and correlations corrected for attenuation above the diagonal.

measure the same property, but what they measure is not well discriminated between the different aspects.

4.3. Step 3. Applying a variable hierarchical cluster analysis

The results from the variable hierarchical cluster analyses of the relationships among the nine safety culture aspects are presented in Figs. 1–3. Fig. 1 presents the results for all six passenger vessels. Figs. 2 and 3 present the results for the four Ropax and the two high speed vessels, respectively. In the three figures, the resulting classification trees or dendrograms show the nine safety culture aspects on the *x*-axis. The *y*-axis shows the distance between the clusters (or aspects when the cluster in the current iteration only contains a single aspect) when they are combined. The more related the aspects, the smaller the distance between them. The horizontal lines show the distances at which clusters are formed and with which aspects.

4.3.1. Rank and department of seafarers

Additional cluster analyses were performed to see if cluster analysis results differed according to factors such as rank or department of seafarers. When comparing with the results for all

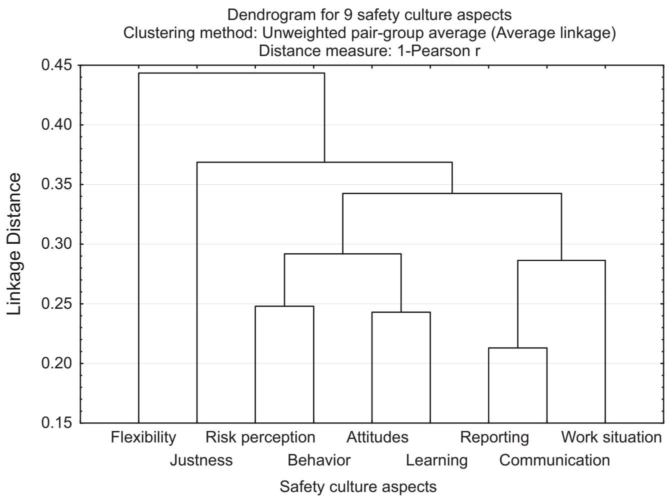

Fig. 1. Dendrogram from variable cluster analysis presenting the relationships between nine safety culture aspects for all six passenger vessels (N=528).

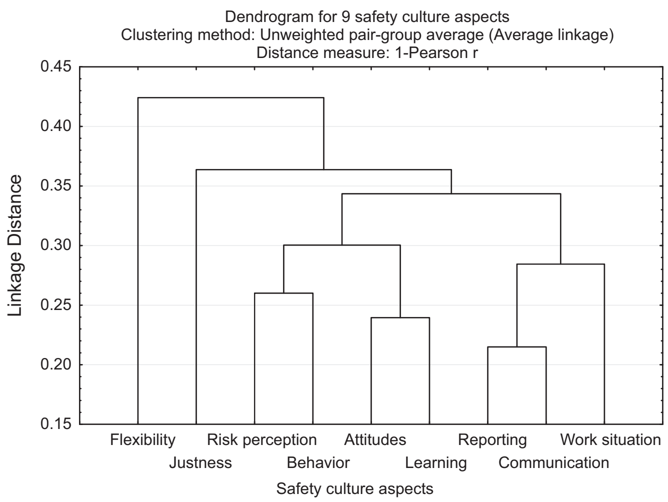

Fig. 2. Dendrogram from variable cluster analysis presenting the relationships between nine safety culture aspects for the four Ropax vessels (N=406).

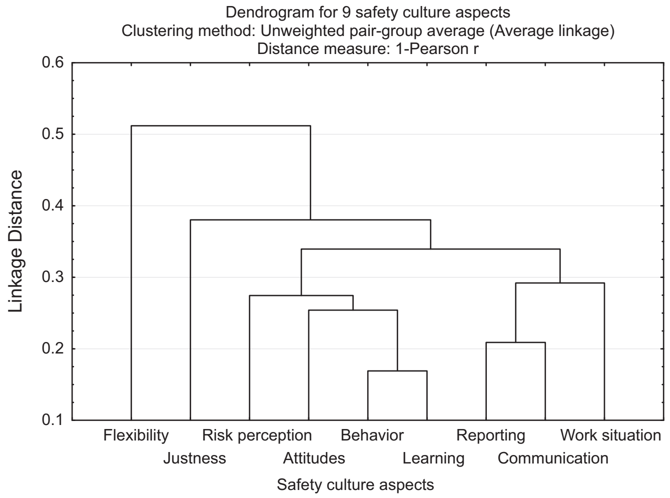

Fig. 3. Dendrogram from variable cluster analysis presenting the relationships between nine safety culture aspects for the two high speed craft vessels (N=122).

ships (Fig. 1), if was found that the catering department (for all ships) had almost the same cluster solution and that the deck and engine departments had somewhat similar solutions. This was also the case for the two types of vessels, especially the Ropax. Officers compared to the crew showed minor differences in cluster solutions, were the crew was almost identical as in Fig. 1. Comparisons between officers and crew on the two vessel types where not performed due to small group sizes.

4.4. Step 4. Interpreting and discussing results

The visualized safety culture results presented in dendrograms facilitate a qualitative understanding of the safety culture concept in an organization. To serve as input to the continuous improvement processes for safety it is imperative that the organization arrange work sessions that enable the interpretation and discussion of results. Important considerations about the design of such work sessions were presented in Section 3.6. In the current case, the authors have interpreted and discussed the results based on theoretical assumptions and this is presented in the following Discussion section.

5. Discussion

This paper proposes a work process that facilitates the analysis and interpretation of the relationships between safety culture aspects studied using questionnaires. When presenting results from such a questionnaire, a common method is to calculate the frequencies for different responses for each item. However, operations on aggregated levels of data, using more sophisticated methods, are also of interest in order to investigate, interpret, and explore organizational characteristics assumed to be related to safety and safety culture. The proposed work process, using dendrograms to present variable hierarchical cluster analyses results, is one way to enable this. A dendrogram is an excellent tool that is able to visualize complex relationships in quantitative data and to facilitate the understanding of the safety culture concept. Such an understanding is never a question of .87 or .85 but rather of overarching patterns. This is more clearly expressed in a dendrogram than by using a table.

The safety culture aspects applied in the current research are based on theoretical assumptions. The interpretation of the proposed method's cluster solutions is therefore also based on these assumptions. However, other interpretations are possible.

For the four Ropax ships included, the results revealed a close relationship between the *Communication* and *Reporting* aspects. *Work situation* also influenced this relationship. A functioning, normal, everyday communication between crew members on board a ship where the instructions and information are clearly given enables the ship to be run safely. Good communication can also promote openness among the crew encouraging discussions of issues relating to safety. This relates to *Reporting* and thus the identification and forwarding of work, technical, and situational factors that can provide insights about system weaknesses and drift in safety performance. Controlling safety in complicated, and complex safety-critical systems, by detecting latent conditions, provide a high potential for improving safety performance.

The *Work situation* and the working conditions on board can influence communication, reporting and the openness of discussing safety issues. The working situation is colored by, for example, the training received to perform the job, physical and mental exhaustion, the experiences of cooperation among crew members, and support from superiors.

Learning and *Attitudes towards safety* proved to be closely related. The willingness to learn for safety, both as an individual and as an organization, is enabled by the importance that is placed on safety by the individual and the organization. The leaderships' commitment and attitudes to safety are vital in a safety culture, and form the foundation of the willingness to learn. Learning can be seen as the basis of a proactively informed culture for safety. Often emphasized in safety research and practice is leaderships' encouragement of safe work practices and enabling of crew member's participation in the planning and implementation of safety management work. An important characteristic of a learning organization is its adaptiveness to the surrounding, changing environment. For successful organizational change, crew member participation is vital as well as the will to make changes and improvements.

Interestingly, the *Reporting* and *Learning* aspects were not closely related as they belonged to different clusters. In practical work settings, this is not uncommon. In Sweden, for example, shipping companies have made some progress along the path of setting up reporting systems and reporting incidents, although not to the extent expected or desired to achieve good learning for safety. The succeeding steps in the learning cycle – those of analyzing and extracting safety knowledge from reports and of establishing feedback systems on the improvements implemented – are not well developed in shipping companies or in the shipping industry. Results from other sectors, such as the process industry, show similar weaknesses. Jacobsson et al. [26], who studied learning from incidents in chemical process industries, found weaknesses in the organizational learning, both in horizontal learning (geographical spread of lessons learned) and vertical learning (double-loop learning). The results also showed that the effectiveness in the different steps of the learning cycle was low due to insufficient information in incident reports, superficial analyses of the reports, decisions that focus on solving the problem locally where the incident took place, and late implementations of weak solutions [39]. Similar weaknesses are also believed to exist in the maritime sector and in many countries.

The two aspects of *Safety-related behavior* and *Risk perception* were closely related, and to some extent there was a relationship to the *Attitudes towards safety* aspect. Studies have shown that risk perception may influence risk-taking behavior at an individual level e.g., [40–42]. There is comprehensive empirical support for the attitude-behavior relationship [42]. Concerning traffic safety, Iversen [43] summarizes findings on the relationships between attitudes towards safety and risk behavior.

The *Justness* aspect was found to be a separate concept that did not belong to any cluster of aspects. Justness has to do with not blaming people for mistakes but learning from them. This, along with reporting, contributes to organizational learning. Lack of justness can permeate an organization and hinder employees from calling attention to deficiencies in work and safety. This can result in their hesitation to take initiative on the job because of anxiety of what could happen if something went wrong. However, on another level, a just culture is also about an organization having insight and knowledge about human, organizational, and situational factors and their combining contribution to accidents and incidents. Justness has to do with knowledge about how to view an accident or incident and how to view the role of humans in the light of existing latent conditions in the organization that affect safety. As such, justness becomes a fundamental aspect in a safety culture, which may explain why it is separated from the other aspects in the cluster solution. Justness can fundamentally influence the working situation on board regarding, for example, just treatment in working life, crew members' opportunities to participate in safety activities and, in the case of multicultural crews, the treatment of different cultural and ethnical groups.

Flexibility was also found to be a separate aspect. It is one of the features of high reliability organizations (i.e., deference to expertise) [44]. It is an organization's ability to adapt to changing or upcoming demands by flattening the hierarchies and pushing decision-making and problem solving down to the front line people with the most expertise, regardless of rank [44]. A flexible on board hierarchical organization of a ship could immediately respond to signals of trouble, especially weak signals. An example is the case of the capsizing *Herald of Free Enterprise*, where the signal was the active failure to close the bow door at departure, and the response was to take action immediately.

Two vessel types were included in the current study of safety culture. The cluster solution for the two high speed crafts was in general similar to that of the Ropax ships. This could be an indication that the somewhat differing safety organization on board the high speed crafts did not, in this case, have a great impact on the safety culture results. However, the *Learning*, *Safety-related behavior*, *Attitudes towards safety* and *Risk perception* aspects did have somewhat different relationships compared to those of the Ropax ships, although they were on the whole in the same cluster. The similarities in results for the two vessel types emphasize generic strategies for safety culture and safety. Comparisons between departments and between officers and crew revealed similarities but also somewhat differing cluster solutions. In practice, such similarities and differences could serve as valuable input to the safety culture discussions in a company and can increase the understanding of the concept.

The safety culture data used in the current study was limited to six passenger/cargo vessels from three Swedish shipping companies (two from each company). As the data was limited it is difficult to draw conclusions about the generality of the safety culture results. It is most likely that results will vary when focusing on different geographical areas of the world. A safety culture is part of an organizational culture, which in turn is part of an industrial culture and, at a higher level, the national culture. Also, results will probably vary if similar studies were performed in other sectors of the maritime industry, for example in the cargo sector. Factors such as type of cargo, crew sizes, and mixed crews or not do most probably add to the complexity of the safety culture concept.

The work process proposed in this paper was found to be usable and valuable in analyzing and interpreting safety culture results. When applied to a shipping company and on board ships, the visualized results in the dendrograms can constitute important input to the ongoing improvement processes for safety. These results enable group discussions about safety culture aspects and can initiate individual thought processes as well as organizational improvement processes for safety. Group discussions can take place on different organizational levels. The group composition can be varied with advantage to include different crew members' perspectives and understanding of safety culture issues.

6. Conclusions

The work process proposed in this paper where safety culture results are visualized in dendrograms facilitates a qualitative understanding of the phenomena safety culture. The output results identify related safety culture aspects and these relationships can guide the design of improvement measures for safety culture and safety in an organization.

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