Xi, Y, Hu, S, Yang, Z, Fu, S and Weng, J

Analysis of safety climate effect on individual safety consciousness creation and safety behaviour improvement in shipping operations

Routledge
Taylor & Francis Group

Maritime Policy & Management

The flagship journal of international shipping and port research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tmpm20

Analysis of safety climate effect on individual safety consciousness creation and safety behaviour improvement in shipping operations

Yongtao Xi, Shenping Hu, Zaili Yang, Shanshan Fu & Jinxian Weng

MARITIME POLICY & MANAGEMENT
https://doi.org/10.1080/03088839.2022.2059718

Analysis of safety climate effect on individual safety consciousness creation and safety behaviour improvement in shipping operations

Yongtao Xi[a], Shenping Hu[a], Zaili Yang[b], Shanshan Fu[c] and Jinxian Weng[c]

[a]Merchant Marine College, Shanghai Maritime University, Shanghai, Pudonga, China; [b]Liverpool Logistics Offshore and Marine (LOOM) Research Institute, School of Engineering, Technology and Maritime Operations, Liverpool John Moores University, Liverpool, UK; [c]College of Transport & Communications, Shanghai Maritime University, Shanghai, Pudonga, China

ABSTRACT

Unsafe acts of ship officers have been a direct cause of many maritime accidents. In the maritime industry, much effort has been made to prevent unsafe acts and to improve safe behaviours of ship officers. The positive effect of organizational safety climate on human behaviour has been well documented in the literature. Within this context, this paper aims to pioneer the development of the measurement constructs of safety climate in shipping operations and analyze its impact on safety consciousness and behaviour of ship officers. Using primary data collected from 284 deck officers and captains, an exploratory and confirmatory factor analysis and a structural equation model are used to reveal the relationship among the constructs of safety climate, safety consciousness and safety behaviour. The research results show that (1) safety climate generates a direct positive effect on safety consciousness and behaviour; (2) safety consciousness has a positive effect on safety behaviour; and (3) safety consciousness acts as a mediator between safety climate and safety behaviour. Its managerial implications and practical contributions lie in the provision of useful insights on how ship managers can effectively gain the improved safety behaviours of ship officers by appropriate introduction of safety climate and consciousness.

KEYWORDS

Maritime safety; shipping management; safety climate; safety consciousness; safety behaviour

1. Introduction

Shipping is crucial for intercontinental goods transportation, as approximate 90% of cargoes are moved by sea (Lin and Chang 2021). It is often argued that shipping is the lifeline of global economy (Chen et al. 2019). Maritime transportation is among the most risky industries (Banda and Goerlandt 2018). Maritime accidents (e.g. the collision of CF Crystal and Sanchi in the East China Sea) often contribute to great loss to human lives, ocean environment, and properties abroad ships and ashore in various forms.

As a direct cause of many maritime accidents, unsafe acts and/or errors of crew caused 80%–90% of maritime accidents in a directly or indirectly way (Heij and Knapp 2018; Chang et al. 2021). Therefore, unsafe acts and behaviour errors of ship officers form a critical research problem to be tackled in the maritime industry. From the risk control point of view, behaviour-based studies for maritime accident prevention are broadly divided into two

CONTACT Zaili Yang z.yang@ljmu.ac.uk Liverpool Logistics Offshore and Marine (LOOM) Research Institute, Liverpool John Moores University, Liverpool L3 3AF, UK

categories such as unsafe acts prevention and safety behaviour (SB) promotion. In the former group, the Human Factor Analysis and Classification (HFACS) method, which was derived from the Swiss Cheese Model, was originally proposed in the aviation industry for the systematic analysis of the latent human factors in aviation accident investigations. In maritime safety research, HFACS is also widely applied for human and organizational factors investigation of maritime accidents (e.g. Soner, Asan, and Celik 2015). On the other hand, with the increased demand on probabilistic safety assessment (PSA), the study on the quantification of human error probability in the maritime field rapidly develops based on the Human Reliability Analysis (HRA) methods initiated from the nuclear and chemical industries. They include the applications of the first generation HRA methods in ship operations (e.g. Akyuz 2016), and the second generation HRA methods (e.g. Cognitive Reliability and Error analysis method (CREAM)) for operational error rate estimation in the maritime industry (e.g. Xi et al. 2017; Yang et al. 2019). Furthermore, the International Safety Management (ISM) code was issued by the International Maritime Organization (IMO) in 2002. As a compulsory standard, the ISM code requires shipping companies to establish a Safety Management System (SMS) to prevent the occurrence of crew operational errors via a systematic and scientific procedure. Due to the lack of a motivation function (Pantouvakis and Karakasnaki 2016), the effectiveness of SMS has been greatly reduced. Compared to the studies on effective approaches and practices for unsafe acts prevention in maritime operations, the measures to promote SB are comparatively more and attracting increasing research interest in the field.

In SB studies, safety climate (Zohar 1980) and safety culture (Hale 2000) have been intensively investigated in safety-critical industries. There are many studies investigating the relationship between safety climate and SB of operators (e.g. Lu and Tsai 2010; Lu and Yang 2011; Liu et al. 2015). Since the behaviours leading to accidents are often under the control of individuals (Hale and Glendon 1987), it is necessary to understand how the psychological factors such as safety consciousness underlying maritime accidents function between and intervene with shipping company safety climate and officers' behaviour. Therefore, the aim of this paper is to examine the complex interaction relationship among safety climate, safety consciousness, and SB of ship officers in the shipping industry. Its novelty is twofold, including (1) the addition of safety consciousness in the relationship analysis between safety climate and SB from a safety science perspective and (2) the relationship analysis of safety climate, safety consciousness, and SB within the maritime industry for the first time. The proposed methodology includes the methods of primary data collection and analysis and can be tailored to fit other safety-critical industries and provide effective solutions to accident prevention in general.

The rest of the paper is organized as follows. The relevant literature is reviewed to introduce the theoretical background and research hypotheses in Section 2. Section 3 describes the methodology including the data collection and analysis methods. Results of empirical analysis are shown in Section 4, and the implications are presented in Section 5. Section 6 concludes the paper.

2. Theoretical background and research hypotheses

2.1. Safety behaviour of ship officers

Behaviour refers to anything an individual does or says (Newaz et al. 2019). In psychology, behaviours are defined as reactions of persons to external or internal stimulus. Recently, SB is accepted as the safety indicator of workplace (Sherif 2002) and can be described as safety compliance and safety participation according to Neal and Griffin (2004). Safety compliance refers to the behaviours adhering to safety procedures and carrying out work in a safe manner (Griffin and Neal 2000), while safety participation is defined as the behaviours that do not directly contribute to an individual's personal safety but help develop an environment that supports safety (Neal and Griffin 2006). The

SBs of ship officers refer to the core performance that has to be carried out to maintain the safety on board ships including watch or executing such operations as adhering to standing orders, operational procedures, wearing personal protective equipment, and reporting fatigue status in a same manner.

2.2. Safety climate in a shipping company

The concept of safety climate was first proposed by Zohar in the early 80s (Zohar 1980) and is defined as a set of molar perceptions that employees share about their work environment and a frame of reference for guiding appropriate and adaptive task behaviours. Safety climate is also defined as a current-state reflection of the underlying safety culture by Mearns, Whitaker, and Flin (2003). Since then, safety climate has gained growing research attention (e.g. Flin et al. 2000; Neal and Griffin 2004; Lu and Yang 2011; Liu et al. 2015).

There is little consensus among the previous studies in terms of the number and content of safety climate constructs (Hon, Chan, and Yam 2014) across different industries. Five most frequently used constructs were summarized by Flin et al. (2000) including management/supervision, safety system, risk, work pressure, and competence. In the construction industry, the most common constructs of safety climate are management commitment to safety, safety rules and procedures, and workers' involvement in safety (Hon, Chan, and Yam 2014). Four safety climate constructs in the manufacturing industry are defined as co-worker's support, management commitment, safety supervision, and safety training (ST) (Liu et al. 2015). Therefore, the measurement of safety climate is described as 'universal' and 'industry-specific' approach by Probst et al. (2019). Given its contextual nature, it is essential to find the safety constructs in the maritime industry to prevent accident occurrence.

In maritime transportation, it is evident that safety climate is influenced by multiple variables such as safety policy (SP), safety motivation, emergency preparedness (EP), ST, and safety communication (SC) in ferry companies (Lu and Yang 2011) and SP and safety management in container shipping companies (Lu and Tsai 2010). SP has been unanimously recognized as one of the structures of safe climate in the maritime industry. Safety management, as a variable of safety climate, includes ST, SC, and EP that are related to actual practices and functions. The SMS-based ISM code as a structurized safety management system has not taken into account safety motivation due to lack of motivation measures (Xi et al. 2021). Safety motivation is, however, an essential element of safety climate. Furthermore, during the implementation of principles in practice, the way that managers' safety behave influence seafarers and their SBs. This is defined as an organizational safety attitude (SA). In terms of SA, the Theory of Reasoned Action (TRA) (Fishbein and Ajzen 1975) and the Theory of Planned Behaviour (Ajzen 1985) can explain the effects of SA on behaviour in an individual level. In an experimental study, it is accepted to treat attitude as a part of safety climate (Hvold 2005).

In this study, one new contribution is that SA is for the first time, investigated at a group level to measure shipping organizational performance on safety issues. Second, the current literature reveals that the state-of-the-art safety climate of a shipping company is measured from three aspects including organizational principles, organizational practice, and group performance on safety issues. Taking into account all the mentioned variables influencing safety climate, another new feature of this study is to measure safety climate using five dimensions, including SP, SA, EP, ST, and SC.

The direct positive effect of safety climate on SB has been demonstrated in many previous studies (e.g. Lu and Tsai 2010; Lu and Yang 2011; Liu et al. 2015). Therefore, it is reasonable to assume that safety climate has a direct positive effect on SB. Based the above proposed constructions, further investigation on the relationship between the variables and safety climate aids the development of five hypotheses that each of EP, SC, ST, SP, and SA has a direct positive effect on SB of seafarers on board ship (H_1 to H_5), respectively. The five hypotheses are shown in Table 1.

Table 1. Hypothetic relationships.

Hypothesis	Affecting factor	Effect/role	Affected factor
H_1	*Emergency preparedness*	*Direct positive*	*Safety behaviour*
H_2	*Safety communication*	*Direct positive*	*Safety behaviour*
H_3	*Safety training*	*Direct positive*	*Safety behaviour*
H_4	*Safety policy*	*Direct positive*	*Safety behaviour*
H_5	*Safety attitude*	*Direct positive*	*Safety behaviour*
H_6	*Emergency preparedness*	*Direct positive*	*Safety consciousness*
H_7	*Safety communication*	*Direct positive*	*Safety consciousness*
H_8	*Safety training*	*Direct positive*	*Safety consciousness*
H_9	*Safety policy*	*Direct positive*	*Safety consciousness*
H_{10}	*Safety attitude*	*Direct positive*	*Safety consciousness*
H_{11}	*safety consciousness*	*Direct positive*	*Safety behaviour*
H_{12}	*Safety consciousness*	*Mediation*	*Safety communication→ safety behaviour*
H_{13}	*Safety consciousness*	*Mediation*	*Safety training→ safety behaviour*
H_{14}	*Safety consciousness*	*Mediation*	*Safety policy→ safety behaviour*
H_{15}	*Safety consciousness*	*Mediation*	*Safety attitude→ safety behaviour*
H_{16}	*Safety consciousness*	*Mediation*	*Emergency preparedness→ safety behaviour*

2.3. Safety consciousness of ship officers

It is often assumed that individuals with high safety consciousness lead to a less error probability. In the psychology literature, little empirical research has examined safety consciousness (Westaby and Lee 2003). Safety consciousness is defined as an individual's awareness about and emphasis on safety issues (Prussia, Willis, and Rao 2019) or a positive attitude and awareness toward acting safely in general (Westaby and Lee 2003). It reflects both cognitive (mental awareness of safety at work) and behavioural (leading to safety practice) characteristics (Koster, Stam, and Balk 2011). Safety consciousness also belongs to learning acquisition (Seibert 2014) through the immersion in safety centered policy, management activities, and education. Therefore, safety consciousness conceptually differs from other safety-related concepts, such as safety climate, which examines the organizational aspects of safety. In this study, safety consciousness of officers is first measured at an individual level and then its effect on other constructs is analyzed at a group level across the onboard ship work context. In other words, safety consciousness concerns officers' comprehensive perception of safety which determines their operational safety manner (Koster, Stam, and Balk 2011). A significant correlation between awareness and safe practice was found by Walters, Lawrence, and Jalsa (2017). Therefore, the direct influence of safety consciousness on SB is obtained for actual proof.

Moreover, other studies also argue that safety climate plays an indirect role on SB which is mediated by certain personal conscious level factors such as mental stress (Cooper and Phillips 2004), safety norms and attitude on safety (Fugas, Silva, and Melia 2012), etc. As comprehensive expression of mental concern on safety, safety consciousness has obvious correlation on personal safety practice (Walters, Lawrence, and Jalsa 2017). The specific function of safety consciousness between safety climate and SB remains unclear, thereby leaving a research gap to be fulfilled. It is necessary to test the assumption that safety consciousness of ship officers is impacted by safety climate of the shipping company they belong to and simultaneously plays a decisive role on SB of ship officers and practice on board a ship. Meanwhile, safety consciousness shows a mediating effect on the relationship between safety climate and SB. The relation assumptions among safety climate, safety consciousness, and SB (H_6 to H_{16}) are shown in Table 1.

3. Research methodology

3.1. Data collection

The primary data in this paper were collected from different shipping companies in the mainland China in January 2020. In order to minimize the possible bias from common methods and non-response, the following control measures were used during the data collection process.

First, single sentences were used to design the items and each item went through cross-reading to reduce the ambiguity of the questions and make a clear expression of the items. The size of items was controlled to minimize the answer-question time and facilitate good response from participants. Secondly, 285 operational level, management level, and deck cadets were selected randomly from COSCO shipping (publicly owned) and Chinese-Polish Joint Stock Shipping Company (joint-venture company). They were asked by phone if they would be willing to take part in the survey. 284 crew members which agreed to be participants were provided with access code and took part in the survey. The high return rate is because of the support of the senior management teams of the two companies to this study. Third, a questionnaire website called Questionnaire Star (www.wjx.cn) was adopted for data collection to avoid social desirability. Incentives with a full research ethical approval were used to motivate the willingness of completing the survey and improve the response rate. All 284 participants responded in 1 week. Thus, it is confident that there was no obvious evidence of non-response bias. The statistical characteristics of data are shown in Table 2.

3.2. Scale items and measurement

Sampling data were collected through a self-built questionnaire survey. It contains two parts. The first part collected the demographic data, including age, education background, gender, position, and ship type of service. The second part was applied to measure the safety climate of a shipping company, safety consciousness, and SB of seafarers.

Previous studies on safety climate measurement included the pivotal constructs: SP, ST, EP, and SC (Zohar 1980; Flin et al. 2000; Griffin and Neal 2000; Mearns, Whitaker, and Flin 2003; Lu and Tsai 2010; Lu and Yang 2011). SA as a specific construct used to measure organizational performance has yet been investigated to find their contribution to safety climate. The items used to measure SA referred to Hvold (2005). As a result, 22 items derived from Hvold (2005) were used for measuring the five constructs of safety climate on board ship in this study.

Table 2. Profiles of respondents (*N*= 284).

Characteristics		Frequency	Percentage
Age	21–25	36	14.2%
	26–30	51	20.0%
	31–35	113	44.5%
	36–40	18	7.1%
	41–45	29	11.4%
	>45	7	2.8%
Education background	Master degree	3	1.2%
	Bachelor degree	98	38.6%
	Associate degree	130	51.1%
	Technical secondary school	16	6.3%
	High school/seaman training	7	2.8%
Position	Captain	31	12.2%
	C/O	102	40.2%
	2/O	59	23.2%
	3/O	27	10.6%
	Deck cadet	35	13.8%
Type of ship	Bulk carrier	98	38.6%
	Container ship	48	18.9%
	Oil-chemical tanker	60	23.6%
	Ro-Ro ship	8	3.1%
	Ocean engineering ship	33	13.0%
	Special cargo vessel	7	2.8%

The findings from previous studies had revealed the effect of safety consciousness on behaviour of seafarers in the maritime industry. Koster, Stam, and Balk (2011) and Wong, Man, and Chan (2021) indicated the influence of safety consciousness on SB of construction works. The items for measuring safety consciousness were developed on the basis of Wong, Man, and Chan (2021) and revised to make it applicable to the investigated context.

Although it is arguably to be more effective to measure SB by observation, it is often infeasible to conduct such observation when a ship and its crew members are in a full operation mode (Lu and Yang 2011). In this paper, the items used to measure SB were derived from Xi et al. (2021) first and then revised and verified by the interviews of safety managers from shipping companies. Seven items were adopted for measuring the SB of seafarers.

All items developed and the associated statistical information are shown in Table 3. The five-point Likert measurement from strongly disagree (1) to strongly agree (5) are employed to rate the relevance of the items.

Table 3. Descriptive statistics for items—mean value and standard deviation on a scale from 1 to 5 (N= 284).

No.	Items	Mean	SD
	Safety policy (Flin et al. 2000; Mearns, Whitaker, and Flin 2003; Lu and Tsai 2010; Lu and Yang 2011)		
SP1	My company has written safety policies.	4.01	1.11
SP2	My company has established a safety responsibility system.	4.11	1.16
SP3	My company makes sure the implementation of safety rules	4.01	1.11
SP4	My company has established safety rewards and punishment system.	3.88	1.12
SP5	My company provides ways for seafarers to participate the improvement of safety rules.	4.13	1.14
	Emergency preparedness (Flin et al. 2000; Mearns, Whitaker, and Flin 2003; Lu and Tsai 2010; Lu and Yang 2011)		
EP1	My company has set up an emergency plan.	3.07	1.22
EP2	My company informs all workers about the emergency plan.	3.04	1.16
EP3	In the emergency plan, all members have clearly defined duties.	3.14	1.19
EP4	My company carries out periodic drills to check the efficacy of the emergency plan.	3.09	1.17
	Safety communication (Flin et al. 2000; Mearns, Whitaker, and Flin 2003; Lu and Tsai 2010; Lu and Yang 2011)		
SC1	My ship holds regular job safety meetings.	3.67	1.16
SC2	My company provides seafarers about risks associated with their work.	3.70	1.14
SC3	My company provides seafarers about safety-related information.	3.63	1.10
SC4	Seafarers have chances to discuss safety issues with safety manager.	3.74	1.14
	Safety training (Flin et al. 2000; Mearns, Whitaker, and Flin 2003; Lu and Tsai 2010; Lu and Yang 2011)		
ST1	My company has established systematic training program.	3.71	1.06
ST2	Safety training programs have been adopted in my ship.	3.70	1.10
ST3	My company provides sufficient safety education.	3.69	1.09
ST4	My company provides enough safety training programs for new seafarers.	3.67	1.11
	Safety attitude (Hvold 2005)		
SA1	My company responds quickly to safety problem.	4.06	1.22
SA2	The company takes safety issues very seriously.	3.71	1.13
SA3	My company pays great importance to the safety and health of crew members.	3.69	1.12
SA4	Master of my ship never disregards safety problem.	3.83	1.18
SA5	Master of my ship responds quickly to safety problem.	3.69	1.14
	Safety consciousness (Koster, Stam, and Balk 2011; Wong, Man, and Chan 2021)		
SCs1	I always avoid dangerous situations on duty.	3.92	1.06
SCs2	I get upset when I see other officers acting dangerously.	3.90	1.05
SCs3	Doing the safest possible thing is always the best thing.	3.88	1.07
SCs4	I take extra time to work safely even if it slows down.	3.63	1.01
SCs5	I believe that safety rules are very important.	3.82	1.06
	Safety behaviour (Lu and Tsai 2010; Xi et al. 2021)		
SB1	I strictly obey standing orders when being on watch.	4.01	1.17
SB2	I always comply with safety operational procedures.	3.96	1.15
SB3	I comply with safety regulations when carrying out my job.	3.81	1.08
SB4	I normatively wear personal protective equipment.	3.95	1.16
SB5	I always check safety equipment to confirm being in good order.	3.78	1.12
SB6	I always report safety problems to my superior on time.	3.89	1.10
SB7	I always avoid fatigue when being on duty.	4.01	1.16

3.3. Data analysis method

The data were analytically processed in three parts. To examine the constructed factors and determine the stability and consistency of the scale, the first part of data analysis is to reduce the number of and verify the items relating to safety climate, safety consciousness, and SB measurement. Here, we used an Exploratory Factor Analysis (EFA) technique, which is adopted to find out the essential structure of multivariate observed variables and deal with dimensionality reduction, via Principal Component Analysis (PCA) with varimax rotation. After the dimensionality of constructs determined, un-dimensionality affairs should be reviewed and analyzed, such as construct model fitness test, convergent validity survey and discriminant validity inspection. In this part, a Confirmatory Factor Analysis (CFA) method was adopted to test whether the relationship between a factor and its corresponding measurement items consistent with the theoretical design. Third, model fitting and testing of hypothesized paths are carried out by using a Structural Equation Modeling (SEM) which is an important tool for multivariate data analysis and used for analyzing the relationships between factors such as safety climate of a shipping company, safety consciousness, and SB of ship officers. The software platforms used for supporting the above analysis are SPSS and AMOS.

4. Results of empirical analysis

4.1. EFA results

Before carrying out the EFA, the common method bias was examined. The Harman's single factor examination was used for the common method bias analysis. All items were put together for PCA, seven factors had an eigenvalue greater than 1 and were extracted. The eigenvalue of the first factor was 12.83. 29.80% total variance was found which was greatly smaller than the total variance (70.98%) when all seven factors were taken into account. Hence, the common method variance is acceptable.

The use of CFA with PCA here is to verify the constructs preset and test the factor loading of items. Before carrying out PCA, the Kaiser-Meyer-Olkin (KMO), and Bartlett Test of Sphericity were used for sample data testing to estimate the data suitability for PCA by comparing the simple correlation and partial correlation coefficients. As a result, KMO = 0.955 (>0.9), χ^2 = 6614.684, and p< 0.001. They indicate the sample is suitable for PCA.

PCA as one of the most widely used methods to identify principal factors in EFA is adapted to reduce the 34 items to a set of factors, such as ST of safety climate or SB. PCA with VARIMAX rotation helped to explore the existence of meaningful parts among the items and extract the main factors. The PCA results are shown in Table 4. Seven constructs have an eigenvalue bigger than 1 and are generated in this study. F1-F7 refer to behaviour, consciousness, attitude, EP, policy, training, and communication, respectively, which are consistent with the present structure. The factor loadings of all items are greater than 0.5, so all items are kept. As shown in Table 4, the seven constructs contribute to 70.98% of the total variance. The Cronbach's α value of each construct is greater than 0.86, which shows a satisfactory reliability.

4.2. CFA results

For purpose of testing the validity of the factors and the relationships between them, model fitness indices are required to measure the degree of fitness between the theoretical model and sample data and to prove that the fitting level of the model is acceptable. Model fitness test results are as follows: χ^2/df = 1.429 (<3), goodness-of-fit index (GFI) = 0.917 (>0.9), adjusted goodness-of-fit index (AGFI) = 0.897 (>0.8), normal fit index (NFI) = 0.931 (>0.9), comparative fit index (CFI) = 0.978 (>0.9), root mean square residual (RMR) = 0.032 (<0.05), and root mean square error of approximation (RMSEA) = 0.039 (<0.08). Such results reveal an acceptable fitness level of the model.

Table 4. EFA results of seven factors.

Items	F1 Safety behaviour	F2 Safety consciousness	F3 Safety attitude	F4 Emergency preparedness	F5 Safety policy	F6 Safety training	F7 Safety communication
SB1	0.64						
SB2	0.58						
SB3	0.59						
SB4	0.63						
SB5	0.66						
SB6	0.66						
SB7	0.67						
SCs1		0.71					
SCs2		0.67					
SCs3		0.69					
SCs4		0.67					
SCs5		0.79					
SA1			0.58				
SA2			0.68				
SA3			0.67				
SA4			0.73				
SA5			0.73				
EP1				0.88			
EP2				0.86			
EP3				0.86			
EP4				0.86			
SP1					0.68		
SP2					0.58		
SP3					0.63		
SP4					0.65		
SP5					0.64		
ST1						0.74	
ST2						0.71	
ST3						0.74	
ST4						0.70	
SC1							0.78
SC2							0.70
SC3							0.76
SC4							0.72
Eigenvalues	12.83	5.10	3.85	2.68	2.58	1.82	1.70
Percentage variance	29.80	11.85	8.94	6.22	6.00	4.23	3.94
Cumulative variance	29.80	41.64	50.59	56.81	62.81	67.04	70.98
Cronbach alpha	0.90	0.90	0.86	0.91	0.89	0.88	0.91
Mean	3.92	3.83	3.80	3.08	4.05	3.69	3.68
Standard deviation	0.89	0.88	0.92	1.05	1.01	0.94	1.00

4.2.1. Convergent validity analysis

A couple of parameters can be used for the convergent validity measurement. For instance, a critical ratio shows the representativeness of the measured constructs on the underlying items; and R^2 shows the measurement of an item's reliability. Normally, if a critical ratio is more than 1.96 or less than −1.96 and R^2 is greater than 0.3, the estimate and reliability can be accepted (Hair et al. 2010). Additionally, composite reliability (CR) is adopted to measure the degree of the items sharing the construct, CR value should be greater than 0.7 and another indicator of convergent reliability, named Average Variance Extraction (AVE) should be greater than 0.5. Standardized factor loading of each item is suggested to be more than 0.7 (Xi et al. 2021).

The results of convergent reliability analysis are shown in Table 5. The values of the critical ratio, R^2, CR, AVE, and factor loadings entirely meet the above mentioned thresholds. The model therefore has a satisfactory convergent validity.

4.2.2. Discriminant validity test

Discriminant validity can be examined via comparison of the square root of AVE and correlations among constructs. If the square root of AVE is greater than the correlations of one construct with others, it indicates that the correlation of a construct with itself is greater than that with the other constructs. The discriminant validity can then be verified. In Table 6, the values on the diagonal are the square roots of AVE, and they are all greater than the correlations with other constructs. All correlations among the constructs are significant at a 0.01 level.

4.3. Fitting of model and testing of the hypotheses

4.3.1. Construction and verification of the initial model

The five constructs used to model the safety climate of shipping companies, safety consciousness, and SB of ship officers were taken as independent variables, mediation variables, and dependent variables, respectively. The initial SEM was constructed and verified using the AMOS24 software.

Table 5. Confirmatory factor analysis and convergent validity.

Construct/item	Standardized factor loading	Standard error	Critical ratio	R^2	C R	AVE
Safety attitude (SA)					0.86	0.54
SA5	0.74			0.55		
SA4	0.76	0.09	12.27***	0.57		
SA3	0.71	0.08	11.43***	0.50		
SA2	0.76	0.08	12.35***	0.58		
SA1	0.72	0.09	11.70***	0.52		
Safety policy (SP)					0.89	0.62
SP5	0.80			0.64		
SP4	0.73	0.07	13.17***	0.53		
SP3	0.81	0.07	15.09***	0.65		
SP2	0.80	0.07	14.92***	0.64		
SP1	0.80	0.07	15.03***	0.64		
Safety training (ST)					0.88	0.65
ST4	0.82			0.66		
ST3	0.81	0.06	15.35***	0.66		
ST2	0.81	0.07	15.13***	0.65		
ST1	0.80	0.06	15.00***	0.64		
Emergency preparedness (EP)					0.91	0.72
EP4	0.85			0.72		
EP3	0.82	0.06	16.59***	0.67		
EP2	0.83	0.06	16.95***	0.69		
EP1	0.88	0.06	18.42***	0.78		
Safety communication (SC)					0.91	0.71
SC4	0.84			0.70		
SC3	0.83	0.06	16.78***	0.69		
SC2	0.82	0.06	16.38***	0.67		
SC1	0.88	0.06	18.20***	0.77		
Safety consciousness (SCs)					0.90	0.64
SCs1	0.82			0.67		
SCs2	0.81	0.06	15.55***	0.65		
SCs3	0.79	0.07	15.10***	0.63		
SCs4	0.74	0.06	13.71***	0.54		
SCs5	0.83	0.06	16.11***	0.69		
Safety behaviour (SB)					0.90	0.57
SB1	0.75			0.56		
SB2	0.77	0.08	13.12***	0.59		
SB3	0.72	0.07	12.78***	0.52		
SB4	0.79	0.08	13.52***	0.63		
SB5	0.72	0.08	12.34***	0.52		
SB6	0.73	0.07	12.41***	0.54		
SB7	0.79	0.08	13.55***	0.63		

*** $p < 0.001$

Table 6. Descriptive statistics, correlation of constructs, and discriminant validity.

Construct	Mean	SD	1	2	3	4	5	6	7
SA	3.80	0.92	0.737						
SP	4.05	1.01	0.675**	0.787					
ST	3.69	0.94	0.591**	0.684**	0.809				
EP	3.08	1.05	0.190**	0.284**	0.167**	0.846			
SC	3.68	1.00	0.592**	0.635**	0.637**	0.251**	0.840		
SCs	3.83	0.88	0.622**	0.674**	0.579**	0.277**	0.630**	0.798	
SB	3.92	0.89	0.651**	0.731**	0.642**	0.378**	0.625**	0.696**	0.754

** $p < 0.01$

The fitting indices of model #1 show the fitness of the bill. A critical ratio and P value are used to verify the significance of the preset paths. If a critical ratio is greater than 2 or P is less than 0.01/0.001, the path is significant. Figure 1 and Table 7 show that the coefficients of three paths EP→SCs, ST→SCs, and SC→SB, are not significant. It shows that both the effect of EP and CT on SCs and the one of SC on SB are not obvious. Under this circumstance, the model has to be modified, by deleting the three non-significant paths and re-examining the model.

4.3.2. Modification of the initial model

First, the path (ST→SCs) with the minimum critical ratio value was deleted. After the deletion, the Chi-square value of the new model slightly changed, meaning that the deletion of this path was feasible. Then, the paths of SC→SB and EP→SCs were deleted in the SEM model and the change of Chi-square was observed. The Chi-square values gradually increased from 640.727 to 643.449, indicating that it is sensible to delete these three paths.

After deleting the three paths, model #2 was obtained. The factor loadings of all items were calculated to be between 0.50 and 0.95. The critical ratio and p value of each path reached a significant level, and the measurement errors were all positive, indicating that the model fitting was in line with the standard. The modified model (i.e. #2) is shown in Figure 2. The verification of the path model and fitness test is shown in Tables 8 and 9, respectively, which indicates the good fitness of model #2.

From the hypothesis testing, the results (Table 8) show that 8 out of 11 hypotheses (H_1 to H_{11}) were supported. Specifically, SA, SP, and SC had a significant positive effect on SCs. SA, SP, ST, and EP had a significant effect on SB. SCs had a significant positive effect on SB.

4.3.3. Mediation effect test

A biased corrected Bootstrap program in AMOS24 was used to test the significance of the mediation effect, and the test results were shown in Table 10. It can be found from Table 10 that among the three indirect effects of SP→SB, SA→SB, and SC→SB, the upper and lower bounds of the biased corrected confidence intervals are (0.032, 0.020), (0.012, 0.015), and (0.020, 0.014) respectively, excluding zero. Therefore, the mediation effects of safety consciousness between SP, SA, SC, and SB are significant. SP and SA have direct positive effect on SB. Furthermore, safety consciousness plays a partial mediating role in terms of the influence of SP and SA on SB, while it plays a complete mediating role in terms of the influence of SC on SB. However, safety consciousness has no mediating effect on the relationship between ST, EP, and SB. Correspondingly, H_{12}, H_{14}, and H_{15} are verified while H_{13} and H_{16} are not valid.

5. Discussion

This study through a new research model, analyses the relationship among safety climate, SCs, and SB of ship officers. It focuses on the safety climate (including SP, ST, SC, SA, and EP) and SCs and explains the SB of ship officers and the mediation effect of SCs on the relationship between the

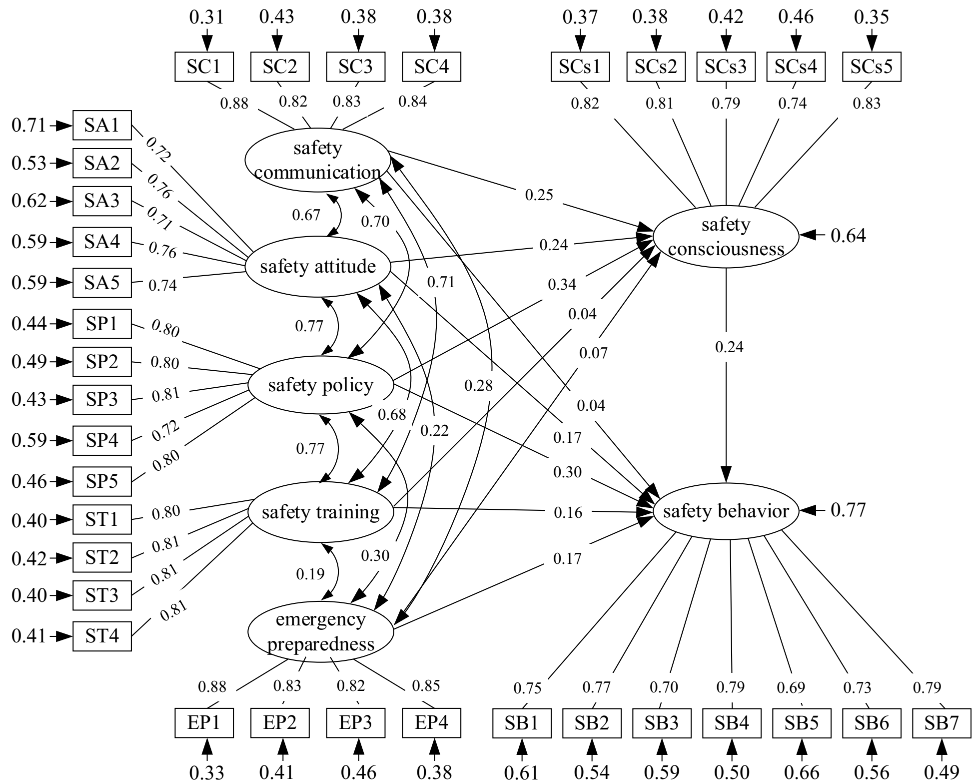

Figure 1. Model #1.

Table 7. Coefficient result and test of model #1.

Path	Standardized coefficient	Standard deviation	Critical ratio	p	Significance
SA→SCs	0.238	0.091	2.692	<0.01	Yes
SP→SCs	0.337	0.100	3.191	<0.01	Yes
SC→SCs	0.251	0.070	3.261	<0.01	Yes
EP→SCs	0.072	0.042	1.514	0.130	No
ST→SCs	0.038	0.084	0.437	0.662	No
SA→SB	0.169	0.081	2.172	<0.01	Yes
SP→SB	0.300	0.091	3.153	<0.01	Yes
ST→SB	0.155	0.074	2.044	<0.01	Yes
EP→SB	0.174	0.038	4.085	<0.001	Yes
SC→SB	0.044	0.062	0.654	0.513	No
SCs→SB	0.240	0.074	3.292	<0.001	Yes

safety climate and the SB. The insights on the improvement function of safety climate on SCs and SB are obtained. The results can be adopted for making rational safety policies in the maritime industry.

5.1. Implications in theory

Theoretically, the results show that SA and SP have a direct positive effect on SCs and SB of ship officers. ST and EP have a direct effect on SB but do not have such an effect on SCs. SC has a direct positive effect on SCs, but ST and EP do not have such an effect. The interesting outcome suggests that SA and SP could influence both SCs and SB, ST, and EP are more inclined to influence SB directly, while SC affects SCs more. This does not mean that SC has no effect on SB. Instead, SC acts

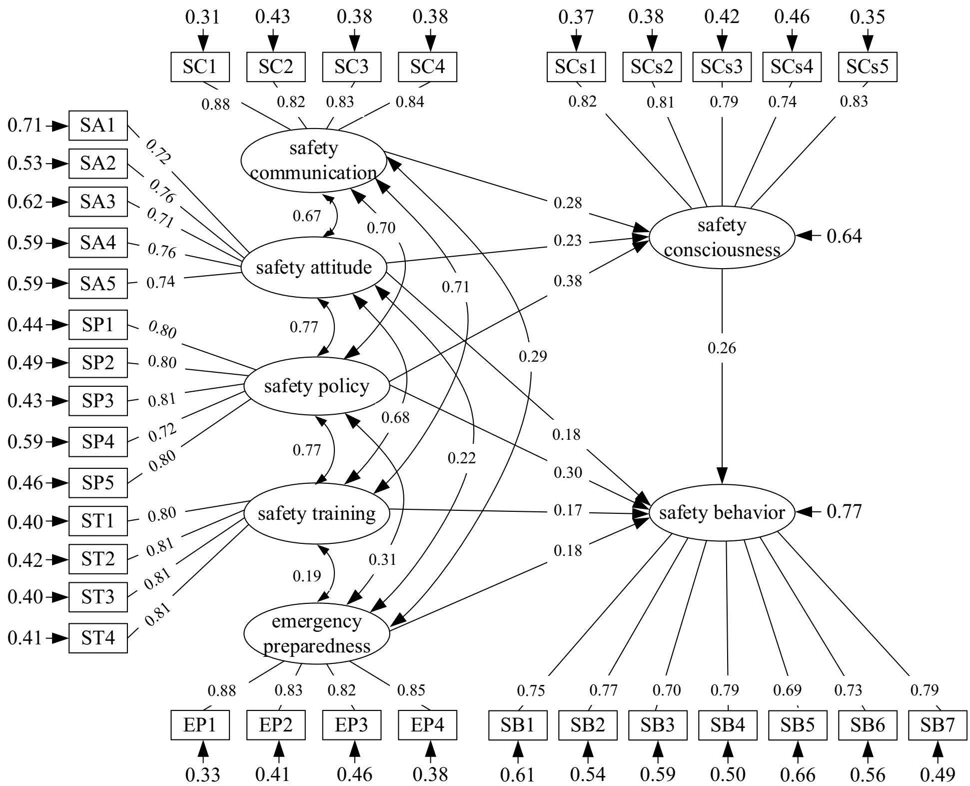

Figure 2. Model #2.

Table 8. Coefficient results and test of model #2.

Path	Standardized coefficient	Standard deviation	Critical ratio	p	Significance
SA→SCs	0.227	0.091	2.571	<0.01	Yes
SP→SCs	0.383	0.087	4.160	<0.001	Yes
SC→SCs	0.276	0.066	3.819	<0.001	Yes
SA→SB	0.177	0.080	2.300	<0.01	Yes
SP→SB	0.300	0.093	3.087	<0.01	Yes
ST→SB	0.174	0.069	2.425	<0.01	Yes
EP→SB	0.179	0.037	4.235	<0.001	Yes
SCs→SB	0.255	0.071	3.635	<0.001	Yes

Table 9. Results of model #2 fitting.

Index	χ^2/df	CFI	TLI	IFI	NFI	RMSEA	PNFI
Criteria	<3	>0.9	>0.9	>0.9	>0.9	<0.08	>0.5
Value	1.264	0.979	0.977	0.979	0.907	0.031	0.823

indirectly on SB through the mediating effect of SCs. It explains why SC is added to the model to explore the specific function of SCs between safety climate and SB. It helps verify both cognitive and behavioural characteristics (Prussia, Willis, and Rao 2019). On one hand, this study is the first to integrate SA to increase the influential power of safety climate on SB. Simultaneously, it shows that organizational SA has a significant effect on both SCs and SB. On the other hand, the integration of

Table 10. Bootstrap analysis for mediating effect test.

Variable	Average effect estimates	Standardized effect estimation	95% confidence interval	
		SE×Z	Lower bound	upper bound
Total effect				
SP→SB	0.381	0.122 × 3.12	0.148	0.626
SA→SB	0.244	0.095 × 2.57	0.058	0.428
SC→SB	0.064	0.031 × 2.06	0.020	0.142
Indirect effect				
SP→SB	0.093	0.043 × 2.16	0.032	0.020
SA→SB	0.060	0.030 × 2.00	0.012	0.015
SC→SB	0.064	0.031 × 2.06	0.020	0.014
Direct effect				
SP→SB	0.287	0.128 × 2.24	0.021	0.529
SA→SB	0.184	0.096 × 1.92	−0.009	0.374
SC→SB	0.00	0.00 × 0.00	0.00	00.00

SCs in the study refines the specific role of different elements of safety climate on behaviour and/or consciousness. It provides useful insights on the understanding of whether SCs contributes to the effect of different factors of safety climate on SB.

5.2. *Implications in practice*

In safety management practice, the findings derived from this study can provide safety managers of any shipping company with practical recommendations on how to improve SC and SB of ship officers, to reduce the occurrence likelihood of maritime accidents.

Based on the established SMS by a shipping company, including safety management manual, operational procedures, and guidelines, officers on board already acquire knowledge and experience for practice in a safe manner. Therefore, the important role of the SMS on prevention of unsafe acts cannot be ignored. However, the effect of good safety climate in a shipping company on SCs creation and SB improvement needs to be rigorously examined and scientifically explained. Facing the ever-increasing pressure on maritime safety, safety climate has attracted increasing attention far beyond the scope of the SMS in maritime safety management research.

Furthermore, as basic safety management measures, ST and EP can regulate the crew's routine operation and emergency SB but not necessarily improve the SCs. Therefore, safety managers should better understand the logic and do not enhance ST and EP for achieving improved crew SCs. However, safety managers can, on the basis of safety operation training and EP, increase the training of safety theory and strengthen the theoretical background of EP to improve the understanding of safety issues and prevent ship board accidents. As far as SC is concerned, in view of its significant effect on SCs, safety managers should supply ship officers and captains with sufficient safety information, maritime risk trend, and hold a safety committee meeting and discuss safety issues. All these activities aid in improving the SCs to promote the SB level by the mediating effect of SCs. Taking into account the direct effect of SP on both SCs and SB and its indirect effect on SB, such measures as 'promoting crew's understanding and implementation of safety policy' and 'actively participating in the modification of safety procedures' play an important role in ensuring maritime safety. Especially, given the strong influence of SA on SCs and SB, safety managers should demonstrate the ability to quickly deal with safety issues and emphasis on occupational health in safety management activities.

Moreover, from a psychological point of view, whether the behaviour of an officer continues to be safe over time, it depends, to large extent, on the stability of SCs which is inseparable with SB. Via immersion in safety climate, an officer could experience organizational attitude and practice of safety management. All the officer's gains from the company's safety climate can help strengthen his/her consciousness on safety practice and hence improve his/her SB.

6. Conclusion

This study proposed and empirically validated a new model that aids to explore the effect of SP, SC, ST, EP, and SA on ship officer' SCs and SB. The relationship paths among these factors were comprehensively tested by SEM. The underlying implications on how SP, SC, ST, EP, and SA of a shipping company affect ship officers' SB with SCs were investigated by mediating tests. The importance of SA, SP, and SC in determining the SCs of ship officers, as well as of the SA, SP, ST, and EP in encouraging the emergence of SB were experimentally analyzed. The findings of this study will significantly contribute to the literature of ship safety management. More importantly, it provided ship safety managers with a powerful tool to develop effective measures to improve the SCs and SB of ship officers.

Despite showing attractiveness, this paper still reveals some limitations. First, the sampling data were collected from Mainland China. The validity of the results in other regions with different culture need to be further investigated. Second, other variables such as safety motivation can be incorporated into future studies to analyze its impact on SCs and SB of ship officers.

Acknowledgments

The authors also acknowledge the funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 823904 (ENHANCE). The authors would like to thank all captains and officers for their support in data provision. The authors would also like to thank the anonymous reviewers for their constructive suggestions. The usual disclaimers apply.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was financially supported by China National Key Research and Development Project [Grant No. 2019YFB1600602] and 'the science and technology innovation program' key project in soft science of Shanghai, China [Grant No. 20692107700]

ORCID

Shanshan Fu http://orcid.org/0000-0003-2495-0572

References

Ajzen, I. 1985. "From Intentions to Actions: A Theory of Planned Behaviour." In *Action-control: From Cognition to Behavior*, edited by J. Kuhl and J. Beckman,11–39. Heidelberg: Springer.

Akyuz, E. 2016. "Quantitative Human Error Assessment during Abandon Ship Procedures in Maritime Transportation." *Ocean Engineering* 120: 21–29. doi:10.1016/j.oceaneng.2016.05.017.

Banda, O. A., and F. Goerlandt. 2018. "A STAMP-based Approach for Designing Maritime Safety Management Systems." *Safety Science* 109: 109–129. doi:10.1016/j.ssci.2018.05.003.

Chang, C. H., C. Kontovas, Q. Yu, and Z. Yang. 2021. "Risk Assessment of the Operations of Maritime Autonomous Surface Ships." *Reliability Engineering & System Safety* 207: 107324. doi:10.1016/j.ress.2020.107324.

Chen, J., W. Bian, Z. Wan, Z. Yang, H. Zheng, and P. Wang. 2019. "Identifying Factors Influencing Total-loss Marine Accidents in the World: Analysis and Evaluation Based on Ship Types and Sea Regions." *Ocean Engineering* 191: 106495. doi:10.1016/j.oceaneng.2019.106495.

Cooper, M. D., and R. A. Phillips. 2004. "Exploratory Analysis of the Safety Climate and Safety Behavior Relationship." *Journal of Safety Research* 35 (5): 497–512. doi:10.1016/j.jsr.2013.07.033.

Fishbein, M., and I. Ajzen. 1975. *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research.* MA: Addison-Wesley.

Flin, R., K. Mearns, P. O'Connor, and R. Bryden. 2000. "Measuring Safety Climate: Identifying the Common Features." *Safety Science* 34 (1–3): 177–192. doi:10.1016/s0925-7535(00)00012-6.

Fugas, C. S., S. A. Silva, and J. L. Melia. 2012. "Another Look at Safety Climate and Safety Behavior: Deepening the Cognitive and Social Mediator Mechanisms." *Accident Analysis & Prevention* 45: 468–477. doi:10.1016/j.aap.2011.08.013.

Griffin, M. A., and A. Neal. 2000. "Perceptions of Safety at Work: A Framework for Linking Safety Climate to Safety Performance, Knowledge, and Motivation." *Journal of Occupational Health Psychology* 5 (3): 347–358. doi:10.1037//1076-8998.5.3.347.

Hair, J. F., W. C. Black, B. J. Babin, and R. E. Anderson. 2010. *Multivariate Data Analysis*. 7th ed. Upper Saddle River, NJ: Prentice-Hall.

Hale, A. R. 2000. "Culture's Confusions." *Safety Science* 34: 1–14. doi:10.1016/S0925-7535(00)00003-5.

Hale, A. R., and A. I. Glendon. 1987. *Individual Behaviour in the Control of Danger*. Amsterdam: Elsevier.

Heij, C., and S. Knapp. 2018. "Predictive Power of Inspection Outcomes for Future Shipping Accidents–an Empirical Appraisal with Special Attention for Human Factor Aspects." *Maritime Policy & Management* 45 (5): 604–621. doi:10.1080/03088839.2018.1440441.

Hon, C. K. H., A. P. C. Chan, and M. C. H. Yam. 2014. "Relationships between Safety Climate and Safety Performance of Building Repair, Maintenance, Minor Alteration, and Addition (RMAA) Works." *Safety Science* 65: 10–19. doi:10.1016/j.ssci.2013.12.012.

Hvold, J. I. 2005. "Safety-culture in a Norwegian Shipping Company." *Journal of Safety Research* 36 (5): 441–458. doi:10.1016/j.jsr.2005.08.005.

Koster, R. B., D. Stam, and B. M. Balk. 2011. "Accidents Happen: The Influence of Safety Specific Transformational Leadership, Safety Consciousness, and Hazard Reducing Systems on Warehouse Accidents." *Journal of Operations Management* 29 (7–8): 753–765. doi:10.1016/j.jom.2011.06.005.

Lin, C. C., and C. H. Chang. 2021. "Evaluating Employee's Perception toward the Promotion of Safety Marketing at Ports." *International Journal of Shipping and Transport Logistics* 13 (3–4): 275–299. doi:10.1504/IJSTL.2021.113985.

Liu, X., G. Huang, H. Huang, S. Wang, Y. Xiao, and W. Chen. 2015. "Safety Climate, Safety Behaviour, and Worker Injuries in the Chinese Manufacturing Industry." *Safety Science* 78: 173–178. doi:10.1016/j.ssci.2015.04.023.

Lu, C., and C. Tsai. 2010. "The Effect of Safety Climate on Seafarers' Safety Behaviours in Container Shipping." *Accident Analysis and Prevention* 42: 1999–2006. doi:10.1016/j.aap.2010.06.008.

Lu, C., and C. Yang. 2011. "Safety Climate and Safety Behaviour in the Passenger Ferry Context." *Accident Analysis and Prevention* 43 (1): 329–341. doi:10.1016/j.aap.2010.09.001.

Mearns, K., S. M. Whitaker, and R. Flin. 2003. "Safety Climate, Safety Management Practice and Safety Performance in Offshore Environments." *Safety Science* 41 (8): 641–680. doi:10.1016/s0925-7535(02)00011-5.

Neal, A., and M. A. Griffin. 2004. "Safety Climate and Safety at Work ." In *The Psychology of Workplace Safety*, edited by J. Barling and M. R. Frone, 15–34. Washington, DC: American Psychological Association.

Neal, A., and M. A. Griffin. 2006. "A Study of the Lagged Relationships among Safety Climate, Safety Motivation, Safety Behaviour and Accidents at the Individual and Group Levels." *Journal of Applied Psychology* 91 (4): 946–953. doi:10.1037/0021-9010.91.4.946.

Newaz, M. T., P. Davis, M. Jefferies, and M. Pillay. 2019. "The Psychological Contract: A Missing Link between Safety Climate and Safety Behaviour on Construction Sites." *Safety Science* 112: 9–17. doi:10.1016/j.ssci.2018.10.002.

Pantouvakis, A., and M. Karakasnaki. 2016. "An Empirical Assessment of ISM Code Effectiveness on Performance: The Role of ISO Certification." *Maritime Policy & Management* 43 (7): 874–886. doi:10.1080/03088839.2016.1169451.

Probst, T. M., L. M. Goldenhar, J. L. Byrd, and E. Betit. 2019. "The Safety Climate Assessment Tool (S-cat): A Rubric-based Approach to Measuring Construction Safety Climate." *Journal of Safety Research* 69: 43–51. doi:10.1016/j.jsr.2019.02.004.

Prussia, G., G. Willis, and M. Rao. 2019. "Influences on Safety Consciousness in A Utility Company: A Sequential Mediation Model." *Journal of Safety Research* 68 (2): 119–129. doi:10.1016/j.jsr.2018.12.002.

Seibert, S. A. 2014. "Safety Consciousness: Assignments that Expand Focus beyond the Bedside." *Nurse Education Today* 34 (2): 233–236. doi:10.1016/j.nedt.2013.08.002.

Sherif, M. 2002. "Safety Climate in Construction Site Environments." *Journal of Construction Engineering & Management* 128 (5): 375–384. doi:10.1061/(ASCE)0733-9364(2002)128:5(375).

Soner, O., U. Asan, and M. Celik. 2015. "Use of HFACS–FCM in Fire Prevention Modelling on Board Ships." *Safety Science* 77: 25–41. doi:10.1016/j.ssci.2015.03.007.

Walters, A. U. C., W. Lawrence, and N. K. Jalsa. 2017. "Chemical Laboratory Safety Awareness, Attitudes and Practices of Tertiary Students." *Safety Science* 96: 161–171. doi:10.1016/j.ssci.2017.03.017.

Westaby, J. D., and B. C. Lee. 2003. "Antecedents of Injury among Youth in Agricultural Settings: A Longitudinal Examination of Safety Consciousness, Dangerous Risk Taking, and Safety Knowledge." *Journal of Safety Research* 34 (3): 227–240. doi:10.1016/S0022-4375(03)00030-6.

Wong, T., S. S. Man, and A. Chan. 2021. "Exploring the Acceptance of PPE by Construction Workers: An Extension of the Technology Acceptance Model with Safety Management Practices and Safety Consciousness." *Safety Science* 139: 105239. doi:10.1016/j.ssci.2021.10523.

Xi, Y. T., Z. L. Yang, Q. G. Fang, W. J. Chen, and J. Wang. 2017. "A New Hybrid Approach to Human Error Probability Quantification–applications in Maritime Operations." *Ocean Engineering* 138: 45–54. doi:10.1016/j.oceaneng.2017.04.018.

Xi, Y. T., Q. X. Zhang, S. P. Hu, Z. L. Yang, and S. S. Fu. 2021. "The Effect of Social Cognition and Risk Tolerance on Marine Pilots' Safety Behaviour." *Maritime Policy & Management* 48 (1): 1–18. doi:10.1080/03088839.2020.1847338.

Yang, Z. L., K. M. Abujaafar, Z. Qu, J. Wang, S. Nazir, and C. Wan. 2019. "Use of Evidential Reasoning for Eliciting Bayesian Subjective Probabilities in Human Reliability Analysis: A Maritime Case." *Ocean Engineering* 186: 106095. doi:10.1016/j.oceaneng.2019.05.077.

Zohar, D. 1980. "Safety Climate in Industrial Organizations: Theoretical and Applied Implications." *Journal of Applied Psychology* 65 (1): 96–102. doi:10.1037//0021-9010.65.1.96.