Passengers' safety awareness and perception of wayfinding tools in a Ro-Ro passenger ship during an emergency evacuation

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Abstract

Wayfinding tools are important parts of the emergency evacuation identification system, which can improve passengers' understanding of the evacuation process, and guide people to evacuate quickly. However, there are few systematic studies on passengers' safety awareness and perception of wayfinding tools and evacuation procedures in case of passenger ship emergencies. This paper aims to demonstrate the current levels and status of ship passenger's safety awareness, the perception of emergency wayfinding tools and the demographic differences regarding safety awareness and perception. These objectives are achieved by examining the characteristics of passengers of a vessel transport route between Yantai and Dalian through the application of questionnaires and statistical analysis techniques. Questionnaire responses of 1,373 passengers indicated that a number of passengers had seen the ship emergency evacuation plan (56.8%), exit signs (56%), and emergency public address (PA) (53.5%). However, 32.2% did not fully understand or comprehend the content and availability of the vessel's emergency evacuation plan, 31.5% did not understand the exit signs and 32.9% did not understand the emergency PA. The obtained ordered logistic regression results show that there are demographic differences in safety awareness, perception of wayfinding tools among passengers.

Keywords: Safety awareness, Safety perception, Passenger ship safety, Emergency evacuation, Wayfinding

1. Introduction

In the past 20 years, although modern ships have made continuous progress in their structural design, operating practices, marine technologies and regulations, passenger vessel accidents still occur from time to time, several of which have caused evacuation of passengers and resulted in casualties (Brown, 2016; Huang *et al.*, 2020; Österman *et al.*, 2020; Sarvari *et al.*, 2019; Uğurlu *et al.*, 2018). This is demonstrated in tragedies such as, the capsize of the "Dashun" Ro-Ro passenger vessel on its way from Yantai to Dalian in 1999, where 290 SOBs (Souls on Board) lost their lives (Wang *et al.*, 2020), the grounding of the ''Costa Concordia'' cruise vessel near Isola del Giglio in 2012, which caused 32 SOBs casualties, and the sinking of the ''Sewol'' Ro-Ro passenger vessel near Screen Island in 2014, which caused the loss of 304 SOBs, including 8 dead or missing (Wang *et al.*, 2021). The safety and effective movement of passengers becomes the main challenge of passenger ship management during the evacuation of passengers in the above passenger ship accidents (Kim *et al.*, 2019; Sun *et al.*, 2018b; Wang *et al.*, 2020). Due to the confined ship environment, in an emergency, active planning of crowd management in congested areas, developing and implementing effective wayfinding tools and evacuation procedures are key factors in ensuring the safety of passengers and crew (Haghani, 2020b; Shiwakoti *et al.*, 2019b; Wang *et al.*, 2020).

Existing studies have shown that, due to the complex structure of transportation systems and passengers' unfamiliarity with the environment, providing passengers with wayfinding assistance or guidance information in an emergency is extremely important to the evacuation process (Fridolf *et al.*, 2013; Shiwakoti *et al.*, 2016). Wayfinding information and tools such as evacuation map, exit sign, emergency alarm, succinct directions to assembly areas can positively influence the routing choice behaviour and evacuation process of passengers (Shiwakoti *et al.*, 2016; 2019b).

Currently, some researchers have studied how people in buildings (Bode and Codling, 2013; Galea *et al.*, 2014a; Galea *et al.*, 2017; Xie *et al.*, 2012), road tunnel (Lovreglio *et al.*, 2015a, b; Ronchi *et al.*, 2018; 2015; 2016), train stations (Haghani and Sarvi, 2016; Shiwakoti *et al.*, 2016) and airports (Shiwakoti *et al.*, 2019b, 2020)

perceive emergency wayfinding tools and evacuation procedures. However, there is little research on passengers' perception of emergency wayfinding information and tools in passenger vessels. In the study of passenger vessel evacuation, most existing studies focus on developing evacuation models and simulation software based on mathematical theory, identifying congestion points, calculating evacuation time and providing suggestions for passenger vessel construction (Ha *et al.*, 2012; IMO, 2016; Kim *et al.*, 2019; Wang *et al.*, 2020). Several ship evacuation trials have been conducted by research teams, but these trials mainly intended to obtain evacuation time, response time, and passenger movement time (Galea *et al.*, 2011; Galea *et al.*, 2013, 2014b). Similarly, existing laboratory walking experiments under controlled conditions tend to only understand the impact of personnel flow and walking speed (Sun *et al.*, 2018a; Sun *et al.*, 2018b; Wang *et al.*, 2021), rather than examining passengers' safety awareness and perceptions of emergency wayfinding tools and evacuation procedures during an emergency.

In general, although there have been studies on passengers' perception of emergency wayfinding tools and evacuation procedures in land-based infrastructure, there are few systematic investigations into passengers' safety awareness and perception of wayfinding tools and evacuation procedures in case of passenger vessel emergencies. There is very little research on passengers' perception of the safety of passenger vessels in China. Thus, this research is conducted to address the lack of empirical data on the subject. The purpose of this research is to study passengers' safety awareness, and perception of emergency evacuation wayfinding tools. Twenty years have passed since the sinking of the "Dashun", and it is still vitally important to study the safety awareness of Ro-Ro passenger vessels on the route from Yantai to Dalian. The research is useful to understand the availability of emergency wayfinding tools, develop and verify evacuation sign systems in passenger vessels. It will also provide suggestions for crowd management and training for passenger vessels so as to improve their safety.

2. Literature review

In recent years, many researchers have investigated individuals' perception of the evacuation process (Haghani, 2020a; Shiwakoti *et al.*, 2019b), the interaction between people and their surrounding environments (Lovreglio *et al.*, 2018; Lu *et al.*, 2018), individuals' perception of wayfinding tools (Ronchi *et al.*, 2018; 2016;

Shiwakoti *et al.*, 2016; 2020), the effectiveness of signage in wayfinding systems (Galea *et al.*, 2014a; 2017; Xie *et al.*, 2012), safety perception of transportation infrastructure (Priye and Manoj, 2020; Shiwakoti *et al.*, 2019a), and influence of age, ethnic background and gender on safety perception (Chang and Yang, 2011; Delbosc and Currie, 2012; Shiwakoti *et al.*, 2019b).

The concept of safety awareness draws from situational awareness, which refers to the perception of safety elements and potential hazards in a certain environment within a certain time and space, as well as a prediction of its future status (Korkmaz and Park, 2019; Lau *et al.*, 2020; Uzuntarla *et al.*, 2020). Lu *et al.* (2018) used the data obtained from a survey of 316 ferry passengers in Hong Kong to conduct structural equation modelling, and studied the impact of safety marketing incentives on passengers' safety awareness and behaviour, and found that passengers' familiarity with the ship's environment affects their safety awareness, which in turn can positively affect passengers' behaviour. It was suggested that ferry operators should increase their attention to safety videos, guides and notices to increase their safety awareness of passengers (Lau *et al.*, 2020; Lu *et al.*, 2018). A survey study at the Melbourne Train Station by Shiwakoti *et al*. (2016) found that many passengers did not have a clear understanding of wayfinding tools and evacuation processes. However, 80.6% of passengers were found to be familiar with the Melbourne Train Station, 43.2% of passengers did not know the location of emergency exits, and 66.5% did not know the location of the assemble station (Shiwakoti *et al.*, 2016). Another survey by Baker (2013) of cruise passengers in the western Caribbean reveals that cruise passengers generally have a good understanding of the location of life jackets, the nearest fire exits and other safety-critical information. Hystad *et al.* (2016) conducted research on a cruise ship in Norway and showed that passenger safety-related knowledge may be described as being intermediate to good. Passengers on long voyages are willing to spend more time in getting familiar with the evacuation procedures, including knowledge of safety-critical equipment and procedures.

A wayfinding tool is an important part of the emergency evacuation identification system, which can improve passengers' personal perception of the evacuation process, and guide people to evacuate quickly (Shiwakoti *et al.*, 2016; 2019b; Xie *et al.*, 2012). Bode *et al.* (Bode and Codling, 2019; Bode *et al.*, 2015) and Lovreglio *et al.* (Lovreglio *et al.*, 2018; 2016) have studied evacuation from

buildings, attempting to demonstrate how humans may choose an escape route. Ronchi *et al.* (2016) investigated the design of Variable Message Sign (VMS) as a wayfinding auxiliary tool design for tunnel evacuation, and evaluated the use of VMS for road tunnel emergency evacuations. The results showed that the "emergency exit" graphic symbol was preferred over the warning symbol due to cognitive revelation enhancement, panel size increase and the use of flashing lights (Ronchi *et al.*, 2016). Shiwakoti *et al.* (2019b) conducted a questionnaire survey on airport passengers in Australia and China, and used 17 questions to obtain passengers' awareness of wayfinding information tools and evacuation procedures. It was suggested to understand the perception and knowledge of different cultural groups on emergency wayfinding tools and evacuation procedures, which is of great significance for the development and improvement of airport emergency plans and procedures. An analysis of the 1991 Zurich subway fire accident by Fridolf *et al.* (2013) found that passengers rarely noticed evacuation tools such as handrails in subway tunnels and emergency directions on the wall. These results suggested that exit signs should be placed at locations where it is easily identifiable to reduce the risk of passengers either missing or misunderstanding these safety indicators (Fridolf *et al.*, 2013). Similarly, Galea *et al.* (Galea *et al.*, 2014a; 2017; Xie *et al.*, 2012) found that participants who can observe the wayfinding signs save half of the average time required to make a wayfinding decision when compared with those who cannot correctly interpret the signs. However, only 38% of people will see the conventional static emergency signs in an unfamiliar building environment (Galea *et al.*, 2014a). To solve this problem, Galea *et al.* (2014a) have designed novel dynamic signage, and test results identified that 77% of people did observe and follow the dynamic signal instructions. Shiwakoti *et al.* (2020) applied the "role-rule" model to study passengers' perception of safe evacuation ability from the airport during emergency evacuation. It was found that passengers were less likely to trust emergency wayfinding tools and procedures to evacuate safely. It was suggested that planners and managers should conduct evacuation strategies and training activities to guide passengers in using wayfinding tools such as emergency evacuation maps/plans, assembly areas and public address systems during evacuation (Shiwakoti *et al.*, 2020).

The views and feelings of passengers on public transport are important factors in the choice of travel modes. In order to ensure that the services of transport

vehicles can meet the expectations of passengers, researchers actively have carried out research to understand passengers' feelings on the safety of transport vehicles (Delbosc and Currie, 2012; Shiwakoti *et al.*, 2019a). Studies of public transit stations have shown that passengers' feeling of safety greatly affects the way they use the station, and that strategies to improve the personal safety experience of public transportation may increase the use of it (Shiwakoti *et al.*, 2019a). Studies of passengers' feelings of safety while travelling on railways/trains have shown that one in five passengers travelling by train feels unsafe (Cox *et al.*, 2006). Another study on the feeling of the safety of three-wheeled electric rickshaws shows that passengers are not satisfied with the overall safety of electric rickshaws (Priye and Manoj, 2020). Contrary to the above results, in the study of passengers' feelings of airport security, passengers at the airport all said they felt safe (Shiwakoti *et al.*, 2019b).

In conclusion, although there are many studies on passengers' safety awareness, perception of emergency wayfinding tools and evacuation procedures in crowded places such as buildings, trains, road tunnel and airports, there are still limited studies on passenger's safety awareness, perception of wayfinding tools and evacuation procedures in passenger vessels. A few studies of passenger safety knowledge in the literatures focus on Norway (Hystad *et al.*, 2016) and the Caribbean (Baker, 2013, 2015). In these countries or regions, the families of passengers are relatively wealthy and generally have a good education. This is somewhat contradictory to the fact that 80% of passenger vessel accidents occur in developing countries (Baird, 2018). In view of the high risk stake of passenger vessels, the International Maritime Organization (IMO) believes that it is necessary to focus on ferries and Ro-Ro passenger vessels that are not subject to the SOLAS Convention, and strive to improve the safety level of "non-convention" ships such as inland ferries or Ro-Ro passenger vessels on domestic routes (IMO, 2020). For this reason, it is still necessary to carry out research in different countries, regions and shipping routes to understand the current status of passengers' safety knowledge, so as to optimise evacuation wayfinding tools, carry out safety education and training, and improve safety management levels and capabilities.

3. Data and method

3.1 Description of the study object

A questionnaire was designed to investigate the demographic characteristics of passengers on the shipping route between Yantai and Dalian, such as gender, age, education level, personal experience, *etc*., to study passengers' safety awareness and perception of wayfinding tools and processes, and their feeling of passenger vessel safety.

The passenger vessel route across Bohai Bay is one of the major routes in China. It is the longest cross-strait passenger route and a high-risk sea area for maritime transport (Yantai, 2017). By the end of 2017, 23 Ro-Ro passenger vessels were serving Bohai Bay, which had a daily passenger capacity of 32,340 people and 3,442 vehicle spaces. In 2017, the Bohai Bay Ro-Ro passenger vessels completed transportation of 5.5 million passengers, and 1.24 million vehicles, with an increase of 6% and 9% from the previous year, respectively (Wang *et al.*, 2020).

COSCO Shipping Passenger Transport Co., Ltd. is a state-owned sea passenger transport enterprise directly under the management of COSCO Shipping Group. This company mainly undertakes maritime transportation tasks of passengers and vehicles in China's coastal areas, particularly in Bohai Bay. It has eight large luxury Ro-Ro passenger ships such as "Bang Chui Dao" and "Yong Xing Dao". For example, "Yong Xing Dao" has a length of 167.5 m, a width of 25.2 m and a deadweight of 24,572 tons. The vessel has the capacity for 23 crewmembers, 27 service staff, 1,400 passengers and a deck space of 2,000 m for cars. The vessels travel to and from Yantai and Dalian once a day with each voyage taking approximately 6 hours.

It is important to conduct research in a real environment, as visual perception appears to be indicative to human understanding of the safety of a particular product or process (Ahola *et al.*, 2014). The relevant ethics clearance was obtained from Dalian Maritime University’s Human Research Ethics Committee, and dissemination of the questionnaire was approved by the ship’s Master and COSCO. The survey was carried out randomly, voluntarily, independently and anonymously, after the passengers were on board. The survey was disseminated on the 5th April 2019 by service staff on board the ship and returned to researchers on the 20th May 2019. Before the survey, the research group trained the service staff so that passengers could be given clear and coherent answers when asking questions about the survey (e.g. an evacuation experience). Finally, each questionnaire took an average of 3 minutes to complete.

3.2 Measurement method

Following discussions with passenger ship staff, reviewing the past research results, and drawing on the research results of Shiwakoti *et al.* (2016; 2019b, 2020) and Hystad *et al.* (2016) on passenger surveys at train stations, airports and cruise ships, a preliminary survey questionnaire was formulated. Three volunteers were allocated to distribute an initial survey on the Ro-Ro passenger vessel, from Yantai to Dalian, in March 2019, where 139 passengers completed survey. Based on the results of the initial survey and the feedback from the respondents, the questionnaire was amended. Following the amendments, the questionnaire was re-distributed on the vessel on the same shipping route to analyse the reliability and validity of the questionnaire. Subsequently, the amended questionnaire was determined to be reasonable in terms of its reliability and validity, thus the final questionnaire was redistributed in April 2019.

The questionnaire is divided into two parts: basic information and, safety awareness and perception. The basic information section investigates the passengers' demographic characteristics, such as gender, age group, education level, mobility, their experience levels onboard ships, the number of people accompanying them, and experiences in ship evacuation education/training. Among them, ship evacuation education/training refers to the provision of information that passengers need to have about ship evacuation knowledge during the period from boarding the ship to off-boarding.

The safety awareness and perception section is divided into three main groups with 10 items: situational awareness, emergency wayfinding, and feelings about ships' safety, as shown in Table 1. *Situational awareness* aims to understand how familiar the passengers are with the ship's evacuation procedures, including familiarity with the ship, knowledge of the mustering station, and familiar with the ship's evacuation alarm. The purpose of *emergency wayfinding* is to understand passengers' perception of wayfinding tools and processes in emergencies, such as emergency exit signs, evacuation plans/maps, and evacuation Public Address systems/announcements (PA). The final criterion relates to the passenger's *general feeling of the ship's safety*, which aims to understand passengers' general perceptions of whether they feel safe on the ship.

The participants' responses were measured using a 5-point Likert scale, ranging from 1 to 5, where "1" represents Strongly Disagree, "2" for Disagree, "3" for Neutral, "4" for Agree, and "5" stands for Strongly Agree. For example, the respondents' response to 'familiar with the ship' is 19.4% ("Strongly disagree"), 37.1% ("Disagree"), 19.1% ("Neutral"), 19.5% ("Agree"), 4.9% ("Strongly agree"), with a mean of 2.53 and a standard error (SE) of 0.031.

Table 1 Summary of passengers' awareness and perception

Question NO.	Variables	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean	SE
QA	***Situational Awareness***							
1	Familiar with the ship	19.4	37.1	19.1	19.5	4.9	2.53	0.031
2	Knowledge of the mustering station	15.5	37.4	15.1	26.3	5.7	2.69	0.032
3	Familiar with the evacuation alarm	6.2	27.5	20.4	21.0	24.9	3.31	0.034
QB	***Emergency Wayfinding***							
4	Have seen the emergency plan/map	5.4	21.3	16.5	16.6	40.2	3.65	0.036
5	Understanding how the emergency plan/map is used	10.9	35.6	21.3	24.1	8.1	2.83	0.031
6	Have seen the emergency exit signs	4.5	23.1	16.4	16.2	39.8	3.64	0.036
7	Understanding how the emergency exit signs are used	8.6	35.3	23.6	23.0	9.5	2.90	0.031
8	Have seen or heard the emergency PA	6.4	24.0	16.1	15.3	38.2	3.55	0.037
9	Understanding how the emergency PA is used	11.8	35.9	19.4	24.3	8.6	2.82	0.032
QC	***General feeling of ship safety***							
10	Feel unsafe about the environment around the ship	7.3	20.3	16.7	28.8	26.9	3.31	0.034

3.3 Participants in the survey

In this research, a total of 1,800 questionnaires were disseminated, 1,578 of them were returned, and 1,373 valid questionnaires were obtained after the incomplete and/or damaged questionnaires were filtered out. Thus, the proportion of valid questionnaires retrieved and useful was 76.27%. The demographic characteristics of the 1,373 respondents are shown in Table 2.

Table 2

Demographic characteristics of survey participants

Demographic characteristics	Classification	Frequency	Percentage
Age	16 and below	83	6.0%
	17-25	376	27.4%
	26-30	232	16.9%
	31-40	136	9.9%
	41-50	262	19.1%
	51-60	246	17.9%
	61 and above	38	2.8%
Gender	Male	565	41.2%
	Female	808	58.8%
Education level	Primary and below	246	18%
	Secondary school	650	47.3%
	College	309	22.5%
	Graduate students and above	168	12.2%
Mobility level	Very poor	60	4.4%
	Poor	131	9.5%

	Neutral	451	32.8%
	Good	384	28%
	Very good	347	25.3%
Experience on board	0	118	8.6%
	1	272	19.8%
	2-4	773	56.3%
	5 or more	210	15.3%
Number of people travelling	Alone	121	8.8%
	1	208	15.1%
	2-5	549	40.0%
	6-10	401	29.2%
	11 or more	94	6.9%
Experience in evacuation education/ training	Never	382	27.8%
	Have, but do not remember	533	38.8%
	Once a year	213	15.5%
	More than once a year	245	17.9%

Although the questionnaire study is valuable in the field of passenger ship safety, it does have some limitations. Firstly, limited data was collected relating to passenger demographics and safety awareness on a Ro-Ro passenger ship on the shipping route for 45 days. Thus, the sample size could potentially be increased. Secondly, this research focuses on the methods based on passenger self-reporting, and respondents do not necessarily experience all of the situations relating to the criteria in the survey.

3.4 Data analysis

Statistical analyses are conducted with SPSS (Version 22.0). Chi-square statistics and their significances are used in parallel line tests (also called a proportional odds assumption) to verify the validity of the proportional odds model (ordered logistic regression model) and the Wald chi-square statistics are used to check the variable significance.

Since the sample data does not obey a normal distribution, a series of Wilcoxon single-sample tests were performed for each item to verify that the average of each item is different from the neutral score of 3. At the 99% significance level, if the null hypothesis that the mean is equal to the neutral value of 3 is rejected, on average, then a score greater than 3 is likely to occur, and a score less than 3 is unlikely to occur (Shiwakoti *et al.*, 2016; Wang *et al.*, 2020).

To better understand the differences between passengers' safety awareness, the perception of emergency wayfinding tools and evacuation procedures, the feeling of ship safety and demographic characteristics, a series of ordered logistic regression models were established using Eq. (1) on the 5-point Likert scale based on the dependent and independent variable types. The dependent variable in each model is a

selected safety awareness or perception of wayfinding tools or the feeling of ship safety, and the independent variables are the demographic characteristics. Categorical variables, such as gender, experience on board, are treated as dummy variables before analysis (Wang *et al.*, 2020). For gender, male (man) was taken as the reference, for other categorical variables, the first classification listed under each variable was used as the reference. Since the dependent variable is an ordered multiple classification variable, an ordered logistic regression model containing several cumulative logit functions can be established and estimated during data analysis. In the ordinal logistic regression, it is assumed that the coefficients of the independent variables in several binary logistic regressions are equal, and it is necessary to test the hypothesis that the coefficients of the independent variables are equal (parallel line test), when the test significant result p is larger than 0.05 ($p > 0.05$), indicating that the assumption can be accepted, and the proportional odds assumption is true for all logits.

The magnitude of the influence can be expressed by the Odds Ratios (OR), which is a measurement of change of a variable due to the increase of another variable by one unit while all other variables are kept unchanged (Wang *et al.*, 2020; Weng *et al.*, 2019). In this study OR is used to indicate the degree of influence of the given variables using Eq. (2). To facilitate the analysis, all cumulative response variables are sorted in a reverse order, *i.e.*, highest versus all lower categories (such as strongly agree vs. strongly disagree, disagree, neutral and agree) of the response variable.

The probability of a response having a Likert level j would be given by (Long, 1997; Shiwakoti *et al.*, 2017; 2019b):

$$\Pr\{Y_i > j\} = \frac{\exp(X_i\beta' - \theta_j)}{1+\exp(X_i\beta' - \theta_j)} \qquad j=1\ldots, 5 \qquad (1)$$

$$OR_j = \exp(\beta') \qquad (2)$$

where i is an index for independent variables, j is an index of different categories of a dependent variable, Y_i represents the dependent variable vector, X_i represents the independent variable vector, θ_j represents the cut-points, and β' represents the regression coefficient vector. The dependent variable is a selected level of item and independent variables are the demographic characteristics. The parameters of the

301 model (β') and the cut-points (θ_j) were estimated by the method of maximum
302 likelihood. OR is the magnitude of the influence by a selected demographic
303 characteristic.

304 **4. Results**

305 Table 1 lists the statistics of passengers' familiarity with the evacuation
306 procedures, their perception of emergency wayfinding tools, and their feelings about
307 the safety of the ship. All the Wilcoxon single-sample tests reject the null hypothesis
308 that the mean is equal to the neutral value of 3. Therefore, it can be known that, on
309 average, passengers tend to agree with the 5 items, 'familiar with the evacuation
310 alarm', 'have seen the emergency plans/maps', 'have seen the emergency exit signs',
311 'have seen or heard the emergency PA', 'feel unsafe about the environment around the
312 ship', and disagree with the other 5 items. In terms of familiarity with the evacuation
313 procedures, 56.5% of the passengers surveyed indicated that they were unfamiliar
314 with the ship's environment, and only 24.4% indicated that they were familiar with the
315 ship's environment. Similarly, the 52.9% indicated that they did not know the location
316 of the mustering station, 32% indicated that they knew the location of the mustering
317 station, whereas 45.9% of passengers expressed familiarity with evacuation alarm.
318 With respect to the perception of emergency evacuation wayfinding tools and
319 procedures, 56.8% of passengers stated that they had seen the ship's emergency
320 evacuation plan, 56% had seen the emergency exit signs, and 53.5% had heard of or
321 understood the emergency evacuation PA, 32.2% stated that they rarely knew the
322 contents and availability of the ship's emergency evacuation plan. Furthermore, 31.5%
323 had not known emergency exit signs and 32.9% had not heard of the emergency
324 evacuation PA. With regard to the general feeling of ship safety, 55.7% of passengers
325 said that the ship's environment made them feel unsafe.

326 The box plot in Fig. 1 shows the distribution of respondents' answers to different
327 items. It can be easily seen how close the selected data is to neutral or extreme values.
328 The three items that passengers most agree with are: 'have seen the emergency plan/
329 map', 'have seen the emergency exit signs', and 'have seen or heard the emergency
330 PA'. The three items that passengers disagree most with are: 'familiar with the ship',

‘knowledge of the mustering station’ and ‘understanding how the emergency PA is used’.

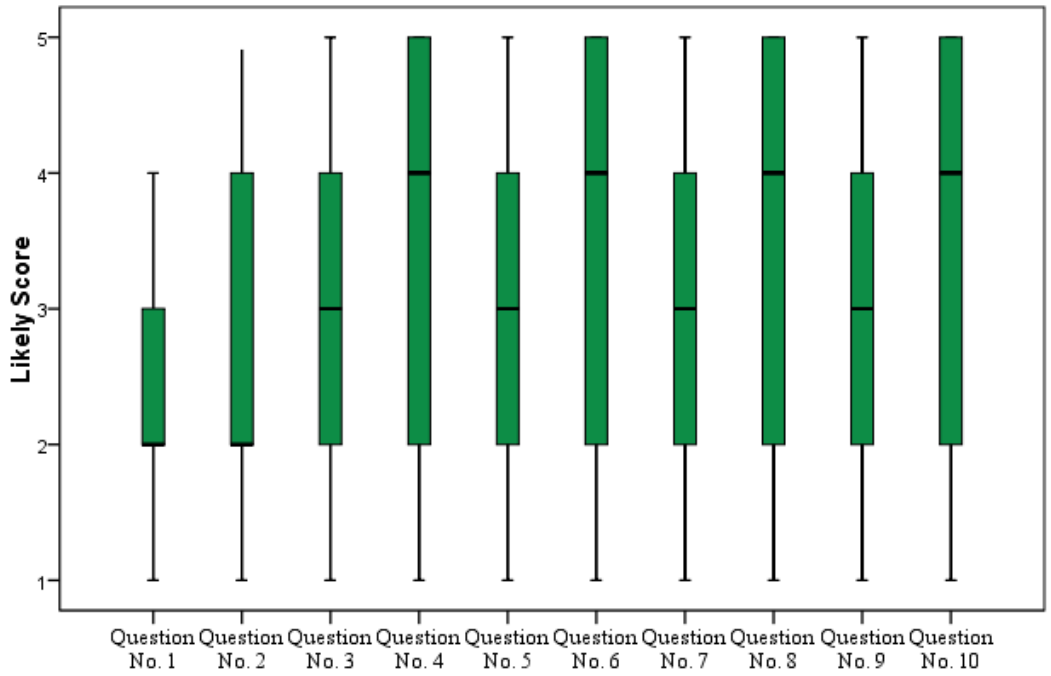

Fig.1. Box plots of passenger’s safety awareness and perception

In the ordered logistic regression models, each model passed the parallel line test, and accepted the null hypothesis that the coefficients of the independent variables in several binary logistic regressions are equal, indicating that the ordered logistic regression models are effective. The results of ordered logistic regression models are shown in Table 3, it can be seen, at the alpha significance level of 99% or 95%, only 1 item is statistically significant for the number of people travelling; for gender, only 3 items are statistically significant; for age group and experience in ship evacuation education/training, all issues are statistically significant. For example, the regression coefficients between age group and the number of people travelling for "feel unsafe about the environment around the ship" are 0.198 and 0.135, respectively, which are statistically significant at the significance levels of 99% and 95%, respectively.

Table 3 Ordinal Logit Models of the effects of demographic

Items	Gender	Age group	Education Level	Mobility	Experience on board	Number of people travelling	Evacuation education experience
Familiar with the ship	-0.233 (-2.259*)	0.114 (3.684**)	0.162 (2.638**)	0.154 (3.048**)	0.538 (6.377**)	-0.034 (-0.538)	1.166 (18.473**)
Knowledge of the mustering station	-0.019 (-0.184)	0.103 (3.333**)	0.130 (2.119*)	0.156 (3.104**)	0.585 (6.940**)	0.005 (0.076)	0.954 (15.683**)

Familiar with the evacuation alarm	-0.175 (-1.763)	0.167 (5.583**)	0.209 (3.495**)	0.125 (2.584**)	0.249 (3.096**)	-0.050 (-0.817)	0.440 (8.005**)
Have seen the emergency plan/ map	-0.199 (-1.939)	0.287 (9.204**)	-0.044 (-0.712)	0.309 (6.199**)	0.219 (2.662**)	-0.009 (-0.139)	0.468 (8.164**)
Understanding how the emergency plan/map is used	-0.281 (-2.799**)	0.093 (3.096**)	0.287 (4.769**)	0.070 (1.440)	0.342 (4.194**)	0.052 (0.835)	0.579 (10.279**)
Have seen the emergency exit signs	-0.148 (-1.441)	0.318 (10.134**)	-0.029 (-0.471)	0.365 (7.277**)	0.214 (2.599**)	-0.053 (-0.839)	0.394 (6.919**)
Understanding how the emergency exit signs are used	-0.296 (-2.951**)	0.089 (2.986**)	0.412 (6.793**)	0.079 (1.619)	0.505 (6.162**)	-0.040 (-0.644)	0.413 (7.461**)
Have seen or heard the emergency PA	-0.108 (-1.060)	0.281 (9.063**)	-0.091 (-1.480)	0.398 (7.939**)	0.227 (2.760**)	-0.068 (-1.065)	0.494 (8.625**)
Understanding how the emergency PA is used	-0.166 (-1.657)	0.128 (4.258**)	0.238 (3.962**)	0.052 (1.069)	0.500 (6.094**)	-0.075 (-1.204)	0.610 (10.781**)
Feel unsafe about the environment around the ship	-0.159 (-1.610)	0.198 (6.637**)	0.184 (3.097**)	0.195 (4.049**)	-0.004 (-0.051)	0.135 (2.211*)	0.232 (4.282**)

Note: Regression coefficients reported in the first row, the Z value reported in second row in the bracket.
* $p < 0.05$ (two-tailed), statistically significant at the significance level of 95%.
** $p < 0.01$ (two-tailed), statistically significant at the significance level of 99%.

There are three statistically significant criteria related to gender, these are: 'familiar with the ship', 'understanding how the emergency plan/map is used' and 'understanding how the emergency exit signs are used'. The regression coefficients regarding these three criteria are all negative, meaning that male passengers tended to report that they were more familiar with ships, and have more understanding of the content or availability of emergency evacuation plans/maps and exit signs. In terms of age groups, older passengers tended to answer with "agree" to the questions, reporting greater familiarity with the ship and more concerned about safety-related items. Regarding education levels, passengers with a higher education level tended to report that they were more familiar with the ship, had a stronger awareness of safety, and better understand the content of emergency wayfinding tools. Furthermore, under the criterion of mobility, passengers with better mobility reported that they were more familiar with the ship, more aware of safety, and tend to agree to the items, 'have seen the emergency plans/maps', 'have seen the emergency exit signs', and 'have seen or heard the emergency PA'.

In terms of the criterion "experience on board", and with the exception of 'feel unsafe about the environment around the ship', passengers with more experience on board tended to agree to all other criteria in the questionnaire. They reported high levels of familiarity with the evacuation procedures and the perception of wayfinding tools. Under the criterion of "experience in ship evacuation education/training", passengers with more ship evacuation/training experienced generally answered "agree" to the other criteria. They also reported higher levels of familiarity with the ship and

perception of emergency wayfinding tools. Finally, more passengers tended to agree with the criterion of “feel unsafe about the environment around the ship”, if they were in the following groups: the elderly, those of a higher education level, better mobility, large travelling parties, and people with more ship evacuation education/training experience.

Although the sign of the estimated coefficients of an ordered logistic regression model can provide information on whether changes in given variables increase or decrease the likelihood of passenger safety awareness and perception, they do not provide information on the degree of impact (Weng *et al.*, 2019). Ordered logistic regression assumes that the coefficients that describe the relationship between the highest and all lower categories (strongly agree vs. strongly disagree, disagree, neutral and agree) of the response variable are the same, as those that describe the relationship between the next highest category and all lower categories (strongly agree and agree vs. strongly disagree, disagree and neutral). The degree of influence of demographic data on the possibility of passenger safety awareness and perception is shown in Fig. 2. For example, the criterion “ship evacuation education/training experience” has the greatest impact on passengers' safety awareness and perception, especially the familiarity with the ship's environment. The OR for this criterion is 3.21, which means that, in terms of all the cumulative logit (strongly agree vs. strongly disagree, disagree, neutral and agree; strongly agree and agree vs. strongly disagree, disagree and neutral; strongly agree, agree and neutral vs. strongly disagree and disagree; strongly agree, agree, neutral and disagree vs. strongly disagree), "ship evacuation education/training experience" is increased by one unit, the rate of change in the "log-odds" of “passenger's familiarity with the ship” is increased by 3.21 ($e^{1.166}$=3.21) units while all other variables in the model are held constant. This impact analysis is also applied to the rest of the study. The criterion “experience on board” has the greatest impact on passengers' knowledge of the mustering station, with the OR calculated as 1.794. Furthermore, the criterion associated with education level has a significant effect on passengers' perception of wayfinding tools, especially whether they have seen or heard PA, with the OR calculated as 1.509.

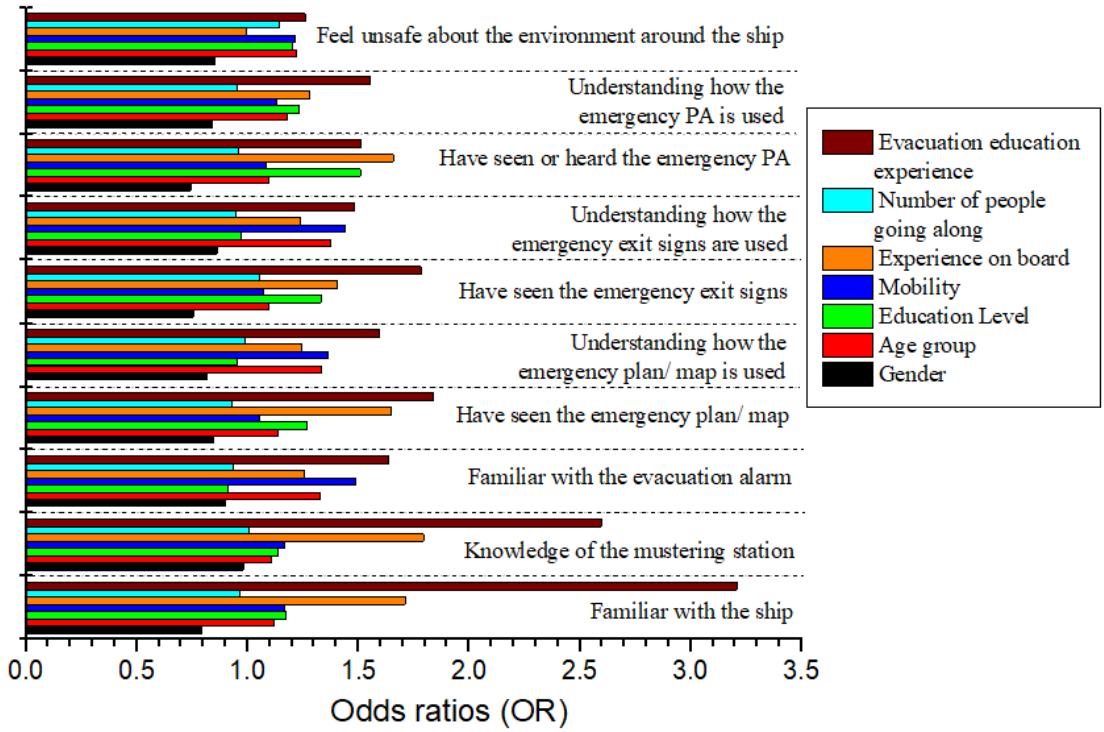

Fig. 2. Odds ratios of demographic on the passengers' safety awareness and perception

5. Discussion

This study found that passengers on the shipping route from Yantai to Dalian still had a relatively low awareness level with the ship's evacuation alarm, and the ship's environment, especially the location of the mustering station. This is different from the research results regarding train stations (Shiwakoti *et al.*, 2016) and cruise ships (Baker, 2013, 2015; Hystad *et al.*, 2016), where passengers are familiar with the layout of the train station and ship. This may be related to the national/regional safety knowledge education and national education level. For example, 87% of the passengers in the survey conducted by Baker (2015) received a university education. In this study, only 34.7% of the passengers in the survey have received a university education.

Passengers' safety awareness and perception of wayfinding tools or guidance information are considered to be a key driver of their behaviours, which are extremely important in emergency evacuation in complex environments (Fridolf *et al.*, 2013; Shiwakoti *et al.*, 2020). In this study, the results of passengers' perception of

wayfinding tools are similar to the survey results at the Melbourne Train Station (Shiwakoti *et al.*, 2016) and the Melbourne Airport (Shiwakoti *et al.*, 2019b), but unlike the findings of Qingdao Airport (Shiwakoti *et al.*, 2019b). Passengers at Qingdao Airport had more perception of evacuation wayfinding tools and evacuation procedures. Shiwakoti *et al.* (2019b) argued that this may be related to the inclusion of fire prevention, emergency plans and procedural knowledge in Chinese education institutions. However, when compared with passengers at Qingdao Airport, vessel passengers have less knowledge of evacuation tools and procedures, which may be related to insufficient publicity and education on marine safety in China.

Passengers' general feeling of safety of transportation is one of the important service factors, which directly affects their attitude and behaviour towards using public transportation (Shiwakoti *et al.*, 2019a). In this study, passengers had a poor feeling of ship safety, which is contradictory to the results from passenger surveys of airport safety (Shiwakoti *et al.*, 2019b). In a study by Ahola *et al.* (2014), passengers stated that the factor that caused the most fear was the weather conditions and the impact of the weather conditions on the vessel. If the wind is strong and the sea is rough, passengers wished to be notified of the weather conditions to increase their preparedness. Therefore, feeling unsafe on the ship may be related to the fact that most passengers are unfamiliar with the ship's evacuation procedures, the content and availability of emergency wayfinding tools, and may also be related to external factors such as weather and sea conditions.

In terms of demographic differences, this study shows that male passengers have a higher perception of emergency wayfinding tools, which is consistent with the results of studies at the Melbourne Train Station (Shiwakoti *et al.*, 2016) and the Melbourne Airport (Shiwakoti *et al.*, 2019b). Older passengers had more awareness of evacuation procedures, which is again consistent with the survey results of the safety knowledge of air passengers (Lee *et al.*, 2018). This research found that passengers with a higher education level, better mobility, more experience on board, and passengers with more ship evacuation experience on education/training are more familiar with the evacuation procedures. It is indicative that passengers' familiarity

453 with evacuation procedures should and can be improved through experience on board
454 and ship evacuation education/training activities. The results also show that male
455 passengers tended to demonstrate their knowledge of the contents and availability of
456 the evacuation plan and emergency exit signs, which is consistent with the survey
457 analysis of the Melbourne Train Station (Shiwakoti *et al.*, 2016). Furthermore, in
458 terms of the age groups regarding the six criteria under "*emergency wayfinding*", the
459 logistic regression coefficients are all positive, indicating that the age group has a
460 positive impact on the perception of emergency wayfinding tools. Older passengers
461 are more concerned about safety issues related to emergency wayfinding, which is
462 consistent with the survey results of the cruise vessel research conducted by Hystad *et*
463 *al.*(2016) and airline passenger research by Chang & Liao (2009) and Lee *et al.*
464 (2018). Finally, it is important to note that significant differences were found between
465 the experience of passengers on board and ship evacuation education/training
466 experience in all of the emergency wayfinding criteria, consistent with the research
467 results of air passengers (Lee *et al.*, 2018) and cruise passengers (Baker, 2013). This
468 indicates that the more frequently a person sails, the more likely they are to focus on
469 safety issues, understand their cabins' location with respect to the ship layout and the
470 nearest fire escape. However, this study did not find any relationship between the
471 experience on board and the passengers' general feeling of safety.

472 Misunderstanding or insufficient understanding of emergency evacuation
473 guidance tools and procedures may lead to difficulties in the wayfinding of personnel,
474 resulting in additional evacuation delays (Fridolf *et al.*, 2013; Haghani, 2020a, b).
475 Given these results it is recommended that passenger vessel management companies
476 learn from the best practices of the aviation safety education programs (Chang and
477 Liao, 2008, 2009) and optimize the contents of safety briefings and safety videos for
478 passenger safety. For example, passenger shipping companies can invite celebrities to
479 produce compelling pre-voyage safety communication materials and safety
480 demonstration videos. In the passenger cabin, safety-related information can be
481 delivered to passengers through safety demonstration videos and safety information
482 cards; in the seating area, evacuation-related knowledge can be provided to

passengers through safety demonstrations and safety information cards. Simultaneously, it is suggested that ship designers should emphasize reference points or draw reference from dynamic evacuation signs in buildings when designing ships, to facilitate passengers' self-navigation or positioning. For example, it is recommended that ships colour to indicate different areas, and place dynamic evacuation indication signs to provide effective instructions for passengers.

The passenger vessel accidents are a continuous reminder that there is an unprecedented need to maintain and improve passenger safety awareness and safety skills during the operation of passenger ships. Emergency evacuation is a relatively rare event. When passengers feel safe it may have a detrimental effect on their safety awareness due to complacency. Also, if an evacuation event does occur, passengers may overly rely on staff members' evacuation guidance, rather than emergency wayfinding tools (Shiwakoti *et al.*, 2019b). However, passengers' overreliance on staff is not always correct. As stated in the research results in the field of aviation safety, the crew may be incapacitated in an emergency, and at this time, the passengers must rely on their capabilities to carry out evacuation or rescue task (Chang and Liao, 2009). For example, in the 1999 "Dashun" vessel accident, the captain arranged the staff to persuade passengers who were already wearing life jackets and waiting on the assembly deck to return to the cabin given the ship's increasing left lean. However, the captain underestimated the possibility that the ship may capsize at any time and its potential consequences. The captain did not announce the abandonment of the ship in time and did not organize the passengers and crew to return to the assembly deck. As a result, most passengers and crew were still in their cabin when the ship capsized. Of the few rescued, most were passengers waiting on the high deck for the order to abandon the ship (Wang, 2001; Xu *et al.*, 2000). A similar situation also occurred in the "Sewol" vessel accident. After the accident, the captain and the crew requested that the passengers stay in place and wait for rescue. The evacuation instructions were not issued until half an hour after the accident. Captain and crew abandoned ship without giving timely information to the passengers, leaving a large number of passengers dead in their cabins before they could be

evacuated (Kim *et al.*, 2016). This demonstrates once again that passengers must have the ability and knowledge to rescue themselves to reduce casualties, when crew members or staff members are not capable of guiding passengers to evacuate correctly.

6. Conclusion

In 1912, the “Titanic” disaster gave birth to the first International Safety of Life at Sea (SOLAS), establishing technical standards for ship construction and operation management (Baker, 2013). In 2012, after the "Costa Concordia" accident, the Maritime Safety Committee reached a consensus on temporary recommendations for passenger ship operating measures. In June 2013, the "SOLAS" Convention was amended and stated that muster drills of all embarking passengers are required take place prior to or immediately upon departure for all ships engaged on a voyage where passengers are scheduled to be on board for more than 24 hours (Kvamme, 2017). Science and technology have been developed rapidly in the maritime industry, but passenger vessel safety is still a topic worthy of attention, and active planning for the evacuation of personnel is still the main challenge for the safe operation of passenger vessels.

The safety awareness of passengers and their perception of emergency wayfinding tools positively affect their path selection behaviour, and then affect the entire evacuation process. Based on the existing literature, a questionnaire survey was conducted on the demographic characteristics and safety awareness and perception of passengers on vessels travelling between Yantai and Dalian. Based on the results of this research, it is recommended that the maritime industry investigates the adoption of a similar style of building evacuation signs design and aviation safety education. During the construction and management of passenger ships, the use of dynamic emergency evacuation signs to enhance passengers’ perception of wayfinding tools, the use of safety demonstrations or safety videos to strengthen the education of passenger safety knowledge, and enhancing emergency response capabilities are key factors that should be of a priority. The results of this research are of great significance for understanding passenger safety awareness and availability of emergency wayfinding tools during passenger ship evacuations for developing and verifying evacuation sign systems in passenger ship environments. The results of this survey are useful for passenger ship managers to formulate appropriate management

rules, carry out targeted evacuation education and training activities, make emergency response plans, improve crew knowledge in terms of crowd management during an emergency evacuation, and improve passenger ship safety. This research focuses on passengers' safety awareness and perception of safety information on this particular shipping route, it is valuable in the research field of passenger vessel evacuation. In the future, it would be prudent to study passenger ship safety awareness in different regions, on different lengths of routes, and of varying vessel sizes for more comprehensive analysis.

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