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**The effect of social cognition and risk tolerance on marine pilots' safety behaviour**

# The effect of social cognition and risk tolerance on marine pilots' safety behaviour

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**Abstract:** The safety psychology of marine pilots affects their operational pilotage behavior. This paper aims to analyze how social cognition (i.e. attitude and perception) and personality traits (i.e. risk tolerance) of marine pilots affect their safety behavior through Structural Equation Modeling (SEM). Primary sample data is obtained by a survey from the pilots of Shanghai port, with totally 306 collected results. The results indicate the safety behavior of marine pilots concerning that 1) the hazardous attitude has a significant positive effect; 2) risk tolerance has an indirect influence; and 3) risk perception has both direct and indirect impacts. Based on this finding, the managerial implications for pilotage safety include that 1) the reduction of the level of hazardous attitude of marine pilots can improve the safety behavior of marine pilots, 2) the level of risk perception can increase through psychological training and safety education, which is beneficial to comprise the possible effect of increased ability by pilot skill training on risk tolerance.

**Keywords:** Maritime safety, Human factor, Risk tolerance, Hazardous attitude, Risk perception, Safety behavior, Structural Equation Model

## 1. Introduction

Maritime transportation rapidly develops due to its low cost and large capacity. While producing economic benefits, large ships render high risks when accidents happen, because the consequences of the associated accidents could be very serious (Xi et al., 2017). Ship pilotage is crucial to ensure the safety of a ship when sailing, anchoring and berthing in ports, where accidents take place more frequently than open water according to historical statistics. Safe pilotage contributes to the safety of ships as well as the prevention of water pollution. Although ship captains are still in charge of the vessel, marine pilots often take over its control when approaching to the port. It is evident that the correlation between ship accidents during pilotage and the pilot behavior is high (Hontvedt, 2015). According to the investigation of marine incidents (including near misses) in Shanghai port water areas in the past 20 years, 92% of pilotage accidents resulted from marine pilot and/or crew error (Xi et al, 2017). It is, therefore, necessary and urgent to analysis the safety-related behavior of marine pilots and the cognitive factors influencing pilotage safety.

For reducing the impact of human factor on shipboard safety, shipping companies are required to develop, implement and maintain a safety management system (SMS), according to the International Management Code for the Safe Operation of Ships and Pollution Prevention (the ISM Code). The ISM code intends to improve the safety behavior of seafarers by standardizing the safety management of the shipping company. However, the IMO has not yet regulated either the certification or operation of pilots or pilotage in its member states (IMO, 2004). It is mainly because each pilotage area needs highly specialized experience and local knowledge of the pilotage. As a result, different safety systems exist in pilotage practices of marine nations. For instance, all maritime pilotage associations in China are necessary to develop and implement a pilotage safety management system based on the ISM Code. Although the SMS in the ISM code is a systematic, scientific safety management scheme, one of its drawbacks is the difficulty to motivate marine pilots to behave safely (Bhattacharya, 2012) because pilots believe that it is the requirements of their commanders.

Therefore, it is very necessary to investigate marine pilot safety behavior particularly given the higher marine accident

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statistics in the waters near ports than at sea. In the current literature, there are mainly two different perspectives with regards to operators' safety behavior in the literature. One is the study on the relationship between organisational safety culture / safety climate and human safety behavior (e.g. Kvalheim and Dahl Ø,2016; Lu and Tsai, 2010; Lu and Yang,2011). As an effective supplement of SMS, a robust safety climate/safety culture is necessary to improve safety performance (Kim et al., 2019). Safety culture means an informal structure of values and norms which affect the approach of interaction of individuals and teams with each other or with people outside the organisation to improve the safety performance. Within the context of this study, the values and the long-established habits of marine pilots influence their safety behaviour. The study on social cognition or personality traits focuses on the unsafe practice of an operator and the personality differences in accident participation (Ji et al., 2011). The research on social cognition focuses on individual parameters (such as attitude, risk perception or social norms) and provides a basis for digesting the mechanism of these variables affecting people's safety behaviour. Personality psychology copes with individual personality traits (e.g. risk tolerance, personal bias) to predict their own safety behaviour. For the past years, more studies have been seen to integrate social cognition and personality traits together for better understanding the mechanisms of personnel safety performance from an overall perspective (e.g. Ji et al., 2011). As a safety-critical behavior-based occupation, marine pilots are usually defined as "local marine experts" (Orlandi and Brooks, 2018). Because of the noticeable skills of ship manoeuvring and rich knowledge of pilotage areas, they are well trained and experienced in safe pilotage. However, the unsafe behaviour resulting from the social cognition and personality traits of pilots has become a critical issue affecting their performance based on the investigation of ship pilotage accidents.

This paper is to explore the influence of social cognition and personality traits on the safety behaviour of a marine pilot. It is also to explore new feasible solutions to the adaptation of the integration of social cognition and personality traits in safe marine pilotage. To do so, it pioneers a study on the effect of the hazardous attitude of marine pilots on their behaviour safety to interpret the generated mechanism of marine pilots' safety behaviour and find some management implications for accident prevention. Additionally, a structural equation modelling (SEM) method is used to develop a structural path model because it is suitable for testing the constructed unobserved variables in this particular case.

The rest of this paper is structured as follows. In Section 2, the proposed hypothesis of the relationship between safety behaviour, risk perception, hazardous attitude, and risk tolerance are described based on the critical review of the relevant literature. The research method consisting of data collection and analysis is presented in Section3. The research results are described in Section 4, while the conclusion and discussion, including management implications and research limitations, are stated in Section 5.

## 2. Theoretical background

### 2.1 Safety behavior

Within the setting of marine pilotage, safety-related behaviour is regarded as a composition of maritime pilot compliance with behavioural safety routine pilotage and proactive participation in the improvement of safety work (Chen and Chen, 2014). The majority of safety behaviour related study is conducted from two angles — one on unsafe operational acts and the other on safety compliance and participation. The pioneering studies on unsafe operational acts include that Heinrich (1932) proposed dangerous human behaviour as a direct contributor to accidents. Reason (1990) classifies unsafe acts into mistakes and violations based on his human error model. The mainstream perspective of tackling safety behaviour is related to safety compliance and participation (Kvalheim and Dahl, 2016). Safety compliance indicates that a pilot is subject to safety procedures and the implementation of safety operation (Neal et al., 2000), while safety participation reflects the initiatives of marine pilots to safeguard safety issues. More specifically, safety participation does not directly influence individual safety. But still, it is helpful to create a safety-oriented environment, which includes the provision of safety assistance to colleagues and safety recommendations.

### 2.2 Hazardous attitude

Marine pilots provide a mandatory technical service of ship handling, and hence pilotage is a safety critical operation.

The attitude of individual pilots associates with the safety pilotage of a ship. Meanwhile, the attitude of the watch-keeper and pilots on a ship bridge affects each other and both of them work together towards the ship navigation safety. Wilkening (1973) defines approach as "a learned and relatively enduring perception, expressed or unexpressed, influencing a person to think or behave in a fairly predictable manner toward objects, persons, or situations". Recently, the hazardous attitude has especially drawn the attention of experts and scholars. Wiener and Nagel (1988) assert that a dangerous manner, as one of the critical human factors, influences pilots' decision-making processes. Hazardous attitude refers to individual motivational tendencies that respond to risk-related persons, circumstances, or events in a particular way that can affect people's thinking or behaviour, and hazardous attitude can be improved or modified through education or training (Ji et al., 2011). For mitigation of the dangerous manner, a pilot should have an awareness of the actual or potential danger and take proper and preventive actions, as hazardous attitude will interfere his regular judgment, and put the safety of navigation in peril. Similarly, Hunter (2005) indicates that the safety behaviour of civil aviation pilots has an indispensable relationship with their hazardous attitude. Taking into account the state-of-the-art findings from the literature mentioned above, the first hypothesis in this study is formulated as:

*$H_1$. Marine pilots' hazardous attitude have a negatively impact on their safety behaviour.*

## 2.3 Risk tolerance

The concept of risk tolerance comes from the economic field. On economic activities which are often surrounded by uncertainties, making a conservative or risky choice is related to the risk tolerance of a particular person. Financial risk tolerance is defined as "the willingness to engage in behaviour in which the outcomes remain uncertain with the possibility of an identifiable negative outcome" by Irwin (1993). Barsky et al. (1997) pointed out that risk tolerance means the inverse of risk aversion. Grable (2000) believed that risk tolerance is described as the acceptability of the amount of uncertainty or investment return volatility for an investor. Similarly, in safety-critical industries such as maritime transportation, people are encountering various types of risks at their workplaces. Risk tolerance is defined as the amount of risk an individual is willing to assume in pursuit of a goal (Hunter, 2002), and the tolerable risk always represents an acceptable risk that means acceptability is a subset of risk tolerance.

Based the concepts mentioned above, Wang, et al. (2019) proposed the two aspects of risk tolerance, "whether people are willing to take risks" is the subjective aspect, while "how many uncertainties or risks can be tolerated by an individual" is the objective part. Risk tolerance may be administered by the general trend of risk aversion and the individual value associated with a particular situation goal. Specific purposes may be regarded as an indicator of higher risk tolerance levels than an average level. From the subjective aspect, it is evident that high-risk tolerance will lead to high-risk behaviour. People who are willing to take risks are more tolerant of risks than those who do not (O'Hare, 1990). From the objective perspective, risk tolerance is limited by the capability of taking risks, and even an individual is willing to take risks. Therefore, in previous studies, it has demonstrated that risk tolerance and safety behaviour have no correlation (e.g. Knecht Wet al., 2004). In addition, studies have also revealed that risk tolerance is affected by multiple factors, including gender, family income, cultural (Griffin et al., 2008), educational background and marital status (Kannadhasan, 2015). All of them determine risk tolerance in a combined manner. In light of this fact, it is challenging to directly conduct an investigation of the relationship between risk tolerance and safety behaviour of marine pilots. Therefore, the following hypotheses are proposed.

*$H_2$. Marine pilots' risk tolerance has an indirect effect on safety behaviour.*

*$H_3$. Marine pilots' risk tolerance has a negative effect on hazardous attitude.*

## 2.4 Risk perception

Risk perception is the recognition of the risk inherent in a situation (Hunter, 2002). Whereas researchers assess risks for scientific analysis, most of people use their intuition to judge and evaluate them (Le et al., 2018), as a cognitive activity. Bauer (1960) proposed an original two-dimensional structure, including uncertainty and adverse consequences. Uncertainty refers to probabilistic beliefs, while adverse effects are in terms of the severity of losses such as social, physical, financial and time loss. From the above, risk perception is defined as a two-dimension (severity and probability of impact) and manifold (social, physical, financial, etc.) construct (Le et al., 2018).

As a subjective assessment of risk in a certain situation, the evaluation result, on one hand, is directly related to an individual decision-making and behavior (Taylor & Snyder, 2017). On the other hand, risk perception is closely associated with the personality such as risk tolerance (Ji et al., 2018) and individual capabilities (Hunter, 2002), that is, risk perception with other factors together affect the safety behavior. For instance, risk perception may be mediated both by the characteristics of the situation and that of the viewer (Ji et al., 2011). Misperception of risk may result from underestimation of the external operational situation or overrating of self-competency. Hunter (2005) concludes a negative correlation between measures from the risk perception itself and previous involvements in hazard events. Hunter (2002) found that high-risk perception of airplane pilots was associated with lower risk tolerance. Therefore, from the theoretical viewpoint, it is rational to investigate whether safety perception has an indirect or direct effect (Rundmo, 1995) on safety behaviour of marine pilots. Based on the above, we set the following hypotheses that

*$H_4$. Marine pilots' risk perception has a direct positive effect on safety behaviour.*

*$H_{4\text{-}1}$. Marine pilots' risk perception also has an indirect positive effect on safety behaviour.*

*$H_5$. Marine pilots' risk perception has a negative effect on risk tolerance.*

In summary, Fig. 1 is developed to investigate the analysed hypotheses in a systematic manner.

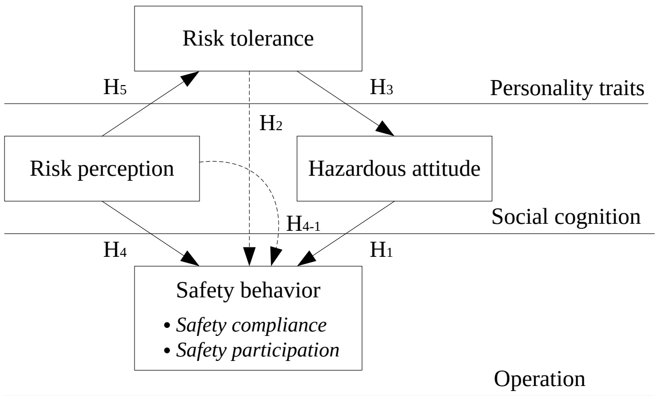


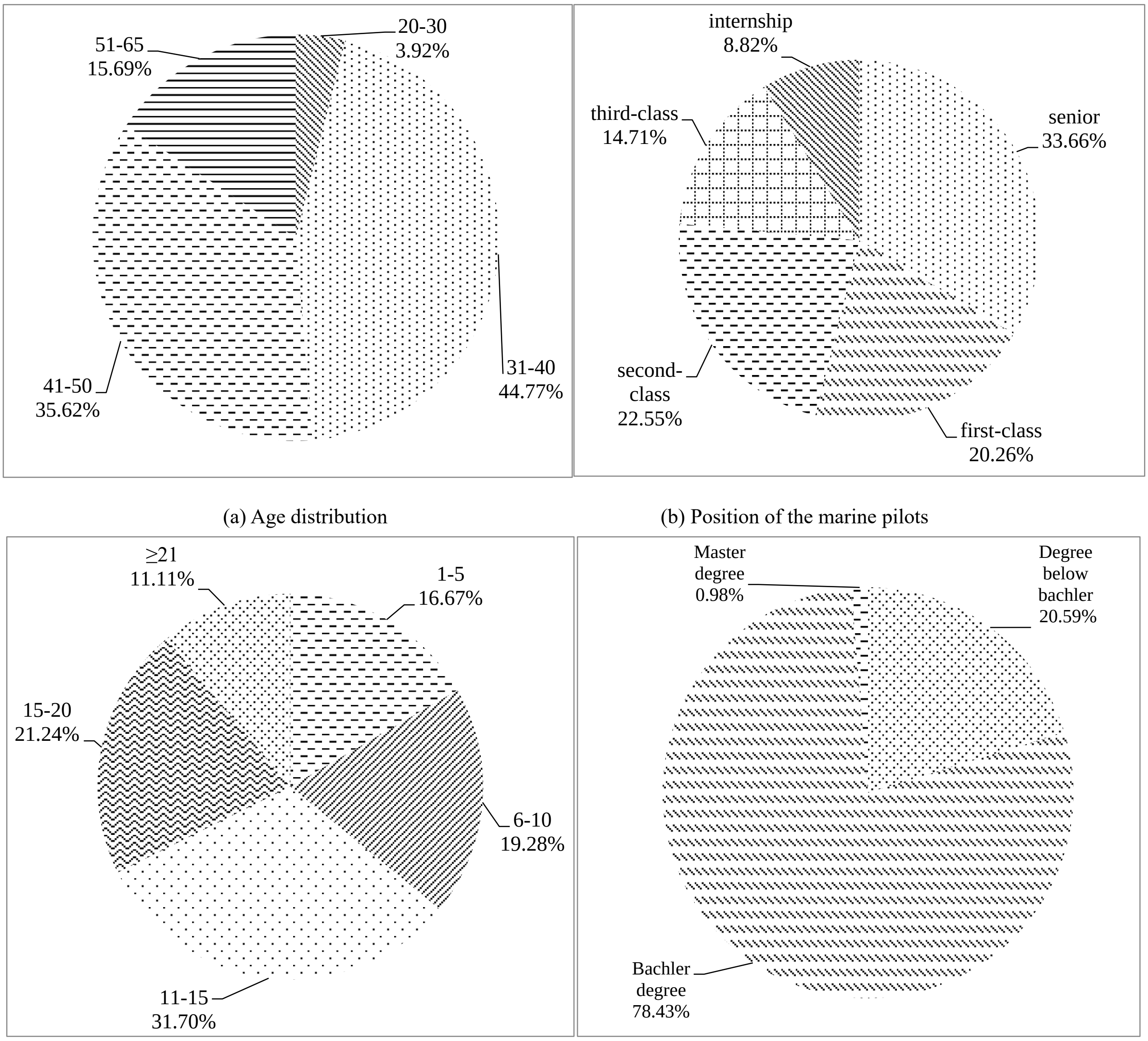

Fig.1. The conceptual model for the analysed hypotheses

# 3. Data and method

## 3.1 Data

The population of this study is the 313 marine pilots (including internship marine pilots) who are employed in Shanghai harbor. According to the pilotage schedules, an electronic website platform based survey was conducted using the opportunity of monthly safety meeting in three days. The marine pilots filled in the pre-defined scales to express their evaluations using the mobile phone through scanning the quick response code generated by the platform. The questionnaire provider explained each item to avoid misunderstanding of the meaning in advance. Data were collected in three days in June, 2018. In total, 306 usable samples (out of 313) were collected. Effective response rate is 97.8%. The high response rate is evident by the long lasting research collaboration between the authors and the Shanghai Pilotage Association through the previous research projects they jointly conducted with success. Due to the good understanding of the questionnaires and the high response rate, non-response bias can be ignored in this study.

The 306 marine pilots are all male and have an average age of 40.53 years old, including 3 of Master degrees, 240 of Bachler degrees, and 63 of degrees below Bachler. The respondents include pilots at all ranks, from interns to senior pilots. They can be specifically described as 103 senior, 62 first-class, 69 second-class, 45 third-class and 27 internship pilots. All data are collected from Shanghai port. The distribution of their age, classification, working experience and education background are shown in Fig. 2.




(a) Age distribution (b) Position of the marine pilots

(c) Working experience (d) Education background

Fig. 2. The age, position, working experience and education background distribution of participated marine pilots

## 3.2 Scales

The process of developing the questionnaire items is important in guaranteeing the validity of their content and the accuracy of survey instruments. In this study, the questionnaire items used in the scale are developed through a literature and interviews with experienced marine pilots to confirm the content validity. Firstly, a part of the questionnaire items are derived from previous studies in the same industry such as seafarers (Neal et al., 2000). Another part of items are derived from the related industries such as civil aviation pilots (Hunter, 2005), then modified based on the characteristics of maritime pilotage and marine pilots. Moreover, the rest of items are proposed by the authors to four marine pilots with 20 years' experience of Shanghai Pilotage Association through an interview. For further improving the reliability of the comprehension of words in the items, the four experienced marine pilots work together to get the consensus on the final modified contents. All items are used the Likert scales with agreement judgment.

### 3.2.1 Risk Tolerance Scales

The most well-known risk tolerance scales are designed by Kogan and Wallach (1964), which was originally developed with a consumer perspective. Nowadays, the research on the elements of safety cognition is largely from the aviation sector. The risk tolerance scales used in aviation are well established and commonly applied in safety psychology studies. Previous studies in aviation describe the risk tolerance scales into three parts: aircraft system failure, crew operational and aviation weather-related risk tolerance (Ji et al.,2011). However, marine pilots as the participants to perform the pilotage activities are required to meet different job descriptions. A new risk tolerance scale is created by taking into account the actual working environments and situations of marine pilots and in the meantime referring to the risk tolerance scales by Hunter (2002). It embeds 15 scenarios which often appear during marine pilotage. For example, "When the vessel is unberthing, a dense fog suddenly appeared; when a pilot is conning a vessel, severe convection weather suddenly appeared". The Likert scale is used to rate the degree of tolerance from definitely tolerable (1) to definitely intolerable (5). Respondents will decide to tolerate or accept such operational difficulty and demonstrate their choices on the defined scales. A high score indicates that the respondent is prepared to take high-risk tolerance. The comprehensive items are shown in Appendix 1.

3.2.2 Risk perception scales

At an early stage, the measurement of perceived risk was divided into inherent risk and handled risk in consumer background (Bettman, 1973). In the nuclear industry, the measurement of risk perception was categorized in the measures that have adopted nuclear-specialized measures for risk perception and the psychometric paradigm of risk perception (Roh & Lee, 2018). In aviation, Hunter (2005) developed 26 risky events to survey the perceived risk of airline pilots. These items were adopted by Ji et al (2011) to measure the risk perception of aviation pilots in China. Therefore, the measurement scales of risk perception vary from different locations and industries to a large extent. Careful fine tone of such measures was conducted before transferring them to this study. Consequently, 13 risk events and/or situations are developed by four senior marine pilots (each with over 20 years' experience) through a back-translation process to get a consensus. They are presented during marine pilotage procedure, including routine risks and high risks. Next, all the participants are asked to assess the risk as if they are involved in that situation. The five-point Likert scale is adopted to rate the risk from very low risk (1) to very high risk (5) (see Appendix 1).

3.2.3 Hazardous attitude scales

Hazardous attitude questionnaire is designed by incorporating the features of marine pilots and the scales of Hunter (2002) and Ji et al. (2011). The initially proposed hazardous attitude scales of marine pilots include six sub-constructs. There are 6 items of self-confidence, 5 of macho, 5 of anxiety, 5 of impulse, 5 of anti-authority and 5 of resignation. Although the evaluation of the attitude is well established, the designed scenarios must reflect marine pilots' work environments and the actual problems arising from their daily work. Four experienced senior marine pilots have verified the questionnaire in a workshop organized by the Shanghai Pilot Association.

3.2.4 Safety behavior scales

In the literature, many variables affect safety behavior, including work procedures, communication, team work, decision-making, workload and situational awareness, etc. You et al. 2009 use four essential variables to study the safety behaviour of the aviation pilots through the collaborative project with the Civil Aviation Administration of China (CCAA), including automation system understanding, leadership and management, situational awareness and decision-making, interpersonal communication and collaboration. The questionnaire of marine pilots' behaviour was set in terms of incorporating safety participation (6 items) and safety compliance (6 items) (Neal et al., 2000). The questionnaire also employs a five-point Likert scale to assess the safety-related pilot acts, and higher scores indicate that the participants have better safety behaviour.

## 3.3 Data analysis

Data analysis is carried out in three steps. First, a principal component extraction with a VARIMAX rotation technique is used to carry out the exploratory factor analysis (EFA) to examine the constructs of risk tolerance, hazardous attitude and risk perception scales. Eigenvalues, which represent the value of variance, are used to determine the numbers of elements (Chen and Chen, 2014). Secondly, confirmatory factor analysis (CFA) is adopted to validate the structure of a set of observed variables by using the Amos 21.0 computer program. Thirdly, Structural Equation Modeling (SEM) is carried out to construct and evaluate structural models by using Amos 21. Goodness-of-fit indices are applied to assess the model fit. In general, the ratio of the chi-square value to the degree of freedom ($\chi 2/df$) should be lower than 5. The comparative fit index (CFI), normed fit index (NFI), the goodness-of-fit index (GFI) and adjusted goodness-of-fit index (AGFI) should be 0.90 or more significant. The value of root mean residual (RMR) should be smaller than 0.05, and the heart means a square error of approximation (RMSEA) lower than 0.08 can be accepted.

# 4. Results

## 4.1 Exploratory factor analysis (EFA)

The conventional method bias should be tested before determining the dimensionality of the constructs,. The Harman's single factor testing is therefore adopted for the homology variance analysis (Harman, 1990). Five factors, whose eigenvalues are more than 1, are generated through principle component analysis. The first factor explains 23.9% of the total variance which is far less than the cumulative variance (68.90%) of the five factors. It shows that the common method bias is not obvious.

4.1.1 Dimensionality of risk tolerance

EFA with VARIMAX rotation is carried out to reduce the 16 risk tolerance items. The Kaiser-Meyer-Olkin (KMO) value of 0.93 shows that the data are suitable for undertaking factor analysis, and the Bartlett Test of Sphericity ($\chi^2$=2210.78, $p<0.01$) suggests that correlations exist among some of the response categories. A factor is kept only when its eigenvalue is higher than 1. Items are retained when their factor loading values are higher than 0.5 in a single factor only. Table 1 reveals the three factors that are found to underlie the risk tolerance of marine pilots.

The three factors (i.e. ship defects and failures tolerance, weather and hydrology situation tolerance and technical level tolerance) account for 69.49% of the total variance. Furthermore, an examination of factor loading in Table 1 indicates that all items are loaded on each factor at or more than 0.5. The first group of factors relates to "ship defects and failure", the second one connects to "weather and hydrology situation" and the third one concerns "technical level". The mean scores and standard deviation of each item are calculated and shown in Table 1.

Table 1 EFA of risk tolerance of marine pilots

| Risk tolerance item (α=0.92) | Factor loading | Mean | SD |
|---|---|---|---|
| RT1:Ship defects and failures (Eigenvalue= 7.18, Percentage of variance=44.89) | | | |
| RT101 (1) | 0.68 | 2.46 | 0.91 |
| RT102 (2) | 0.65 | 3.08 | 1.00 |
| RT103 (3) | 0.63 | 1.47 | 0.69 |
| RT104 (4) | 0.63 | 1.77 | 0.80 |
| RT105 (5) | 0.67 | 2.44 | 0.85 |
| RT2:Weather and hydrology situation (Eigenvalue= 2.40, Percentage of variance=17.01) | | | |
| RT206 (6) | 0.68 | 2.31 | 1.00 |
| RT207 (7) | 0.69 | 2.33 | 0.87 |
| RT208 (8) | 0.62 | 1.39 | 0.66 |
| RT209 (9) | 0.66 | 1.90 | 0.92 |
| RT210 (10) | 0.68 | 1.92 | 0.88 |
| RT3:Technical level (Eigenvalue= 1.22, Percentage of variance=7.59) | | | |
| RT311 (11) | 0.57 | 3.58 | 1.08 |
| RT312 (12) | 0.71 | 2.26 | 1.02 |
| RT313 (13) | 0.73 | 2.30 | 0.92 |
| RT314 (14) | 0.67 | 2.33 | 0.88 |
| RT315 (15) | 0.71 | 1.98 | 0.85 |
| RT316 (16) | 0.72 | 2.31 | 0.87 |

* *The number of the risk items in bracket refers to those with the same number in Appendix 1.*

4.1.2 Dimensionality of risk perception

In a similar way, EFA with VARIMAX rotation is conducted to reduce the 13 risk perception items. The results shown in Table 2 reveal that 9 items are kept and two factors are found to underlie the risk perception of marine pilots.

The two factors (i.e. risk environment and risk situation) account for 67.75% of the total variance. Furthermore, an examination of factor loading in Table 2 indicates all remained items are loaded on each of the factors at 0.5 or above. The first group of factor relates to “environment” when piloting and the second factor connects to “situation” of pilotage. The mean scores and standard deviation of each item is calculated and shown in Table 2.

Table 2 EFA of risk perception of marine pilots

| Risk perception item (α=0.85) | Factor loading | Mean | SD |
|---|---|---|---|
| RP1: risk environment (Eigenvalue=4.15 , Percentage of variance=46.15) | | | |
| RP101 (17) | 0.78 | 3.66 | 0.89 |
| RP102 (18) | 0.79 | 3.67 | 0.92 |
| RP103 (19) | 0.63 | 3.42 | 0.99 |
| RP104 (21) | 0.75 | 4.08 | 0.80 |
| RP105 (22) | 0.80 | 4.07 | 0.79 |
| RP106 (25) | 0.61 | 3.85 | 0.80 |
| RP2: risk situation (Eigenvalue=1.94 , Percentage of variance=21.60) | | | |
| RP207 (27) | 0.63 | 3.23 | 0.85 |
| RP208 (28) | 0.81 | 3.23 | 0.84 |
| RP209 (29) | 0.80 | 2.99 | 1.03 |

* *The number of the risk items in bracket refers to those with the same number in Appendix 1.*

4.1.3 Dimensionality of hazardous attitude

Similarly, EFA with VARIMAX rotation is conducted to reduce the 31 hazardous attitude items. The results in Table 3 reveal that 15 items are kept, and four factors are found to underlie the hazardous attitude of marine pilots. The four factors (i.e. self-confidence, anxiety, anti-authority and resignation) account for 61.22% of the total variance. The mean score and standard deviation of each item are calculated and shown in Table 3.

Table 3 EFA of hazardous attitude of marine pilots

| Hazard attitude item (α=0.71) | Factor loading | Mean | SD |
|---|---|---|---|
| HA1: self-confidence (Eigenvalue=2.44, Percentage of variance=12.63) | | | |
| HA101 (30) | 0.57 | 4.17 | 0.83 |
| HA102 (31) | 0.93 | 3.97 | 0.91 |
| HA103 (32) | 0.73 | 3.04 | 1.20 |
| HA104 (34) | 0.83 | 4.13 | 0.78 |
| HA2: anxiety (Eigenvalue=5.40 , Percentage of variance=27.94) | | | |
| HA205 (41) | 0.94 | 3.30 | 1.22 |
| HA206 (42) | 0.95 | 3.40 | 1.10 |
| HA207 (43) | 0.90 | 3.00 | 1.13 |
| HA208 (44) | 0.92 | 3.18 | 1.15 |
| HA3: anti-authority (Eigenvalue=1.32 , Percentage of variance=6.81) | | | |
| HA309 (51) | 0.86 | 2.92 | 1.08 |
| HA310 (52) | 0.57 | 2.48 | 1.03 |
| HA311 (54) | 0.70 | 2.75 | 0.89 |
| HA312 (55) | 0.64 | 3.19 | 0.87 |
| HA4: resignation (Eigenvalue=2.68 , Percentage of variance=13.84) | | | |
| HA413 (56) | 0.70 | 2.46 | 0.96 |
| HA414 (57) | 0.64 | 2.33 | 0.87 |
| HA415 (60) | 0.51 | 2.18 | 0.74 |

* *The number of the risk items in bracket refers to those with the same number in Appendix 1.*

4.1.4 Dimensionality of safety behavior

EFA with VARIMAX rotation is conducted to reduce the 12 safety behavior items. The results in Table 4 reveal that 6 items are kept and two factors are found to underlie the hazardous attitude of marine pilots. The two factors (i.e. safety compliance and safety participation) accounted for 77.03% of the total variance. The mean score and standard deviation of each item is calculated and shown in Table 4.

Table 4 EFA of safety behavior of marine pilots

| Safety behavior item ( α =0.76) | Factor loading | Mean | SD |
|---|---|---|---|
| SB1: safety compliance (Eigenvalue=2.14 , Percentage of variance=43.11) | | | |
| SB101: (61) | 0.66 | 3.71 | 0.89 |
| SB102: (63) | 0.59 | 4.06 | 0.80 |
| SB103: (64) | 0.50 | 4.51 | 0.58 |
| SB2: safety participation (Eigenvalue=1.68 , Percentage of variance=33.92) | | | |
| SB204: (68) | 0.58 | 3.95 | 0.70 |
| SB205: (70) | 0.65 | 3.79 | 0.76 |
| SB206: (71) | 0.58 | 3.94 | 0.74 |

* *The number of the risk items in bracket refers to those with the same number in Appendix 1.*

## 4.2 Confirmatory factor analysis

CFA is adapted to evaluate the validity and reliability of the constructs. It is used to evaluate the measurement model and the fit of risk tolerance, risk perception and hazardous attitude sub-scales of marine pilots to their respective latent constructs. Fit indices are used to examine the fitness of the model, such as GFI, AGFI, CFI and RMSEA. Values of GFI, AGFI and CFI being 0.9 or above, and an RMSEA being 0.08 or less indicate a good fit (Ji et al., 2011).

Cronbach's α coefficients and descriptive statistics are recalculated for all the constructs. Table 5 shows the number of items, means, standard deviations and internal consistency for all measures. The values of Cronbach's α are greater than the lowest acceptable value (i.e. 0.7).

Table 5 the constructs, number of items, mean values and Cronbach's α

| Constructs | Number of items | M | S.D. | Cronbach's α |
|---|---|---|---|---|
| *Risk tolerance* | | | | |
| RT1:Ship defects and failures | 5 | 2.24 | 0.64 | 0.80 |
| RT2:Weather and hydrology situations | 5 | 1.97 | 0.65 | 0.80 |
| RT3:Technical level | 6 | 2.46 | 0.71 | 0.85 |
| *Risk perception* | | | | |
| RP1: risk environment | 6 | 3.79 | 0.65 | 0.85 |
| RP2: risk situation | 3 | 3.33 | 0.64 | 0.87 |
| *Hazard attitude* | | | | |
| HA1: self-confidence | 4 | 3.37 | 0.78 | 0.70 |
| HA2: anxiety | 4 | 3.15 | 0.97 | 0.88 |
| HA3: anti-authority | 4 | 2.84 | 0.75 | 0.77 |
| HA4: resignation | 3 | 2.23 | 0.71 | 0.76 |
| *Safety behavior* | | | | |
| SB1: safety compliance | 3 | 4.09 | 0.57 | 0.70 |
| SB2: safety participation | 3 | 3.90 | 0.63 | 0.84 |

Dimensionality issues can be evaluated by means of EFA and Cronbach's α , while inner-constructs issues should be accessed by CFA. Two indicators, which are convergent validity and discriminant validity, are mainly used to access the un-dimensionality.

The indicators of convergent validity are τ-values, composite reliability (CR) and the variance extracted value (AVE). τ-value shows the statistical significance of the factor loading of sub-constructs. The statistical significance can be obtained if τ-value is more than 1.96 or smaller than -1.96. Composite reliability indicates the degree to which the sub-constructs or items shares the measurement of a construct. Highly inter-correlated sub-constructs or elements are measuring the reliable constructs. The value of composite reliability should be higher than 0.70. The AVE is another indicator for the composite reliability measurement and the value of AVE should be bigger than 0.50. Table 6 shows all the indicators of convergent reliability. The τ-values of all sub-constructs or items with statistical significance at $p<0.01$ are more significant than 1.96. The CR is in a range from 0.83 to 0.88 while the AVE is between 0.59 and 0.79. These results indicate the discriminant validity is satisfied.

Table 6 Convergent validity

| Constructs | Sub-constructs/items | Factor loading (standardized) | S.E. | τ | C R | AVE |
|---|---|---|---|---|---|---|
| Risk tolerance | RT1 | 0.80 | | | 0.87 | 0.69 |
| | RT2 | 0.84 | 0.07 | 15.64** | | |
| | RT3 | 0.85 | 0.08 | 15.98** | | |
| Hazardous attitude | HA1 | 0.75 | | | 0.85 | 0.59 |
| | HA2 | 0.79 | 0.05 | 14.44** | | |
| | HA3 | 0.71 | 0.08 | 14.94** | | |
| | HA4 | 0.82 | 0.08 | 15.62** | | |
| Risk perception | RP1 | 0.77 | | | 0.88 | 0.79 |
| | RP2 | 0.99 | 0.09 | 15.35** | | |
| Safety compliance | SB101 | 0.81 | | | 0.83 | 0.62 |
| | SB102 | 0.73 | 0.12 | 13.43** | | |
| | SB103 | 0.83 | 0.10 | 14.07** | | |
| Safety participation | SB204 | 0.80 | | | 0.84 | 0.64 |
| | SB205 | 0.86 | 0.08 | 14.03** | | |
| | SB206 | 0.73 | 0.08 | 12.61** | | |

**$p$<0.01.

The inter-construct correlations between two variables are shown in Table 7. Risk perception is significantly correlated with hazardous attitude and risk tolerance. Marine pilots with high scores of risk perception have low-risk tolerance and a negative and dangerous attitude. The dangerous position is significantly correlated with risk tolerance and safety compliance and participation. Marine pilots with high scores on hazardous attitude have high-risk tolerance and negative safety compliance and engagement.

Discriminant validity is analyzed by comparing the square root of the average variance extracted and the construct correlations. If the square root of the average variance extracted is higher than the value of relationships of the given construct between other constructs, the discriminant validity meets the requirements. The results in Table 7 verify the discriminant validity.

Table 7 Descriptive statistics, correlation among constructs and discriminant validity

| Constructs | Mean | SD | RT | HA | RP | SC | SP |
|---|---|---|---|---|---|---|---|
| RT | 2.22 | 0.59 | **0.83** | | | | |
| HA | 2.92 | 0.45 | 0.57** | **0.77** | | | |
| RP | 3.56 | 0.61 | -0.78** | -0.47** | **0.89** | | |
| SC | 4.09 | 0.57 | -0.02 | -0.68** | 0.02 | **0.79** | |
| SP | 3.90 | 0.64 | -0.04 | -0.46** | 0.01 | 0.56** | **0.80** |

*Note: RT, Risk Tolerance; HA, Hazardous Attitude; RP, Risk Perception; SP, Safety Compliance; SP, Safety Participation. Square root of average variance extracted (AVE) on diagonal in bold; **p<0.01.*

## 4.3 Structural model

To investigate the hypothesized interdependent effect among risk tolerance, risk perception, hazardous attitude and safety behavior, a SEM analysis is conducted. Fig.3 shows the structural path model with standardized path coefficients. The fit indices of the model are summarized as follows: $\chi^2$ = 404.72 ($p$=0.000), df = 146, $\chi^2$/df = 2.77, GFI = 0.92, AGFI = 0.90, RFI = 0.87 and NFI = 0.90. The alternative indices are CFI = 0.95, RMR = 0.04 and RMSEA = 0.08.

Hazardous attitude has a direct significant adverse effect on safety behaviour (including safety compliance and safety participation). It means that marine pilots of a dangerous high belief are less likely to carry out safety behaviour. H1 is thus verified. In terms of the effect of risk tolerance on safety compliance and safety participation, risk tolerance has no direct impact on safety compliance and safety participation. In contrast, it has a direct positive influence on hazardous attitude. It indicates that risk tolerance does not directly affect safety behaviour, while high-risk tolerance will result in robust and dangerous attitude, thus $H_2$ and $H_3$ are supported. Regarding risk perception, it has a significant direct effect on safety behaviour and also has an indirect impact on safety behaviour through safety tolerance and hazardous attitude, $H_4$ and $H_{4-1}$ are therefore confirmed. Furthermore, it has a significant effect on risk tolerance, which does not support $H_5$.

Table 8 shows the effect of hazardous attitudes, risk tolerance and risk perception on marine pilot safety compliance and safety participation. A one-way arrow between dependent and independent variables recognizes the relationship between two constructs (Chen and Chen, 2014). An indirect effect identifies sequence with at least one intervening construct involved. Hazardous attitude has only a direct impact; risk tolerance has only an indirect result, while risk perception has both direct and indirect effects.

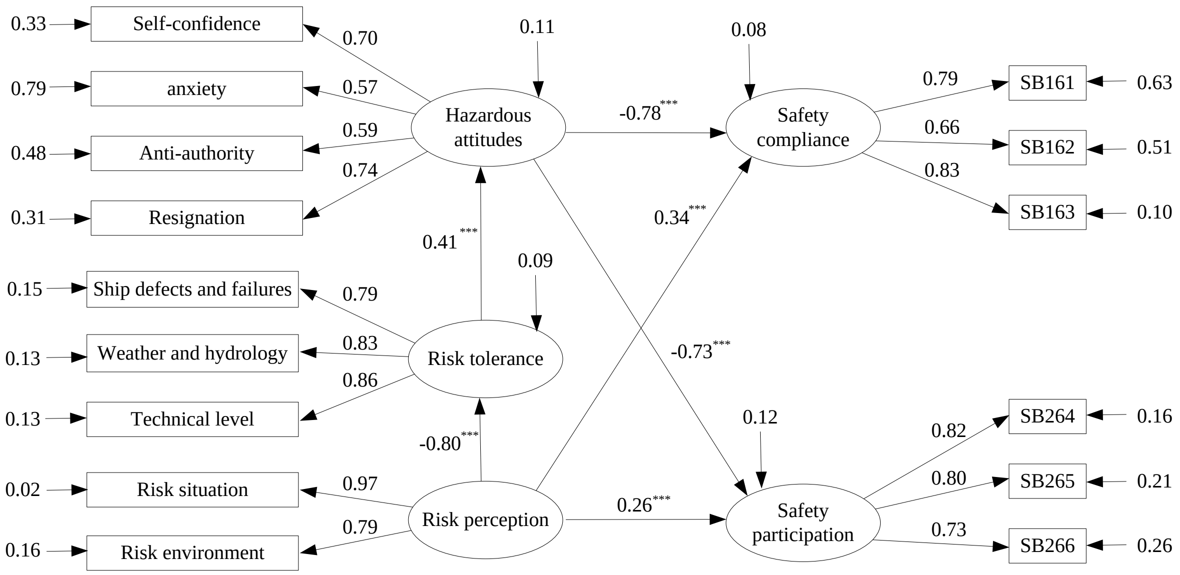



Fig.3 The structural path model. Note: Path estimates are standardized coefficients. ***$p<0.001$

Table 8 Effect on safety compliance and participation (Direct, indirect and total)

| Path | Direct effect | Indirect effect | Total effect |
|---|---|---|---|
| Hazardous attitude → safety compliance | -0.78 | — | -0.78 |
| Hazardous attitude → safety participation | -0.73 | — | -0.73 |
| Risk tolerance → safety compliance | — | -0.32 | -0.32 |
| Risk tolerance → safety participation | — | -0.30 | -0.30 |
| Risk perception → safety compliance | 0.34 | 0.26 | 0.60 |
| Risk perception → safety participation | 0.26 | 0.24 | 0.50 |

To further explore the effect of risk tolerance on risk perception and hazardous attitude and as the effect of hazardous attitude on risk tolerance and safety compliance/participation, the bias-corrected bootstrap method was conducted. The mediation effect is significant if the confidence interval does not contain 0. The results of the bootstrap analysis are shown in Table 9. In terms of the relationship between risk perception and hazardous attitude, the 95% confidence interval, lower and upper values of the bias-corrected percentile of the total indirect effect are -0.47 and -0.19 respectively. It does not contain 0 and hence, the mediation effect of risk tolerance on risk perception and hazardous attitude is significant. Similarly, the mediation effect of hazardous attitude between risk tolerance and safety behavior (including safety compliance and safety participation) is confirmed.

Table 9 The mediation effect test

| Variable | Mean effect estimate | Product of coefficients | | Bias-corrected 95%CI | |
|---|---|---|---|---|---|
| | | SE | Z | Lower | upper |
| Total effect | | | | | |
| RP→HA | -0.33 | 0.07 | -4.59 | -0.47 | -0.19 |
| RT→SC | -0.32 | 0.07 | -4.32 | -0.47 | -0.19 |

| | | | | | |
|---|---|---|---|---|---|
| RT→SP | -0.30 | 0.08 | -3.83 | -0.46 | -0.16 |
| Indirect effect | | | | | |
| RP→HA | -0.33 | 0.07 | -4.59 | -0.47 | -0.19 |
| RT→SC | -0.32 | 0.07 | -4.32 | -0.47 | -0.19 |
| RT→SP | -0.30 | 0.08 | -3.83 | -0.46 | -0.16 |
| Direct effect | | | | | |
| RP→HA | 0 | 0 | 0 | 0 | 0 |
| RT→SC | 0 | 0 | 0 | 0 | 0 |
| RT→SP | 0 | 0 | 0 | 0 | 0 |

# 5. Conclusion

## 5.1 Discussion and implications

Given no internationally recognized regulatory standards, marine pilot safety practices vary across countries and regions. Consequently, their safety perception and tolerance levels need be investigated from local/regional levels to guide marine pilot safety behaviour. This study takes into account both social cognitive (i.e. hazardous attitude and risk perception) and personality traits factors (i.e. risk tolerance) to identify their predictive powers on marine pilot safety behaviour (i.e. safety compliance and participation). The results reveal that a hazardous attitude has a direct negative effect, while risk tolerance has an indirect negative impact on safety behaviour. Risk perception has both direct and indirect positive effects on safety behaviour.

New findings are found and verified. First, similar to the aviation sector, hazardous attitude has a direct and predictive effect on pilot safety behaviour in the marine industry. It impedes marine pilots to make sensible decisions, particularly in emergency and thus levels up the probability of committing unsafe behaviour. The finding implies that the pilotage associations should not improve marine pilots' safety behaviour by only relying on the establishment of a high standard safety management system and strict supervision, but focusing more on changing pilots' attitude. In other words, the authorities of marine pilot associations that are now focusing on the improvement of safety rules and safety knowledge/techniques of pilots should pay more attention to the situation of pilots' psychology and make more efforts to improve their safety attitude. Previous studies often used six factors (Self-confidence, impulsive, worry/anxiety, macho, antiauthority and resignation) to measure dangerous attitude. The finding from this study suggests that macho and impulsive should not be taken into account in marine pilot attitude measurement.

Secondly, risk tolerance is considered as an essential variable in the personality research of industrial safety. However, the new finding from this study shows that the effect of risk tolerance on safety behaviour is indirect. Risk tolerance influences safety behaviour via hazardous attitude. Marine pilots with high-risk tolerance score tend to accept higher risk in pilotage, which manifests themselves in pilotage safety behaviour. Meanwhile, risk tolerance shows a mediation effect on the relationship between risk perception and hazardous attitude. It means that high-risk perception may lower the risk tolerance and then reduce the occurrence of dangerous attitude. Theoretically, the high-risk tolerance of a marine pilot result from the subjective willing or increased objective ability of risk control during ship pilotage. Therefore, the objective part of high-risk tolerance should be addressed through additional psychological safety education to improve pilots' risk perception, and it can compromise the possible effect of increased ability by pilot skill training.

Thirdly, many previous studies showed that the drivers and airplane pilots who lack accurate risk perception involve in driving and flight accidents more frequently. In the meantime some studies (Ulleberg and Rundmo, 2003) found that risk perception has almost no direct effect on safety behaviour. Unlike these results, the new finding from this study clarifies that for marine pilots, risk perception shows a direct effect on safety behaviour in the structural path model. It means marine pilots with high risk perception will result in good safety behaviour. Moreover, the considerable difference between the influence degrees on safety compliance ($\beta$=0.34) and participation ($\beta$=0.26) explains that the marine pilots with high-risk perception prefer to improve safety compliance rather than enhance the safety participation such as sharing safety information and safety discussion with other pilots. On the other hand, risk perception has a significant indirect effect on safety behaviour. Marine pilots with higher risk perception will reduce their risk tolerance, and then lower their dangerous attitude, finally improve their safety behaviour. However, high-risk perception aid to reduce the adverse effects of risk tolerance on safety behaviour.

As a result, it is found the risk perception of marine pilots can be increased by training and drilling to minimise the negative influence on safety behaviour.

### 5.2 Limitations and future research

This study provides empirical evidence on how hazardous attitude, risk tolerance and risk perception influence safety behaviour of marine pilots. However, there are several limitations to the study. Firstly, the self-reported scales are used for data collection to survey the hazardous attitude, risk tolerance, risk perception and safety behaviour of marine pilots. The data obtained may have inherent subjectivity. However, marine pilots are reluctant to report their actual safety behaviour for avoiding the associated negative influence on his career development. It is helpful to develop and implement the no-punishment policies to encourage the self-reporting on unsafe behavior. Secondly, the scenarios and situations are developed within the context of the Shanghai pilotage area. However, Shanghai port is the largest in China and the pilot practices in Shanghai port are very representative in China. The finding has general implication in the investigated region while the methods used can be tailored and applied to test the pilots in the other areas to generate more meaningful contributions such as best practice based on benchmarking in different regions. Furthermore, based on the analysed influencing mechanism among marine pilots' social cognation, personality traits and safety behaviour in this study, future work can investigate the issues as to how to build a good safety climate (Lu, et al., 2017), improve safety awareness (Lu, et al., 2018) and adjust adverse personality characteristics to promote marine pilots' safety behavior.

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Appendix 1. Items relating to risk tolerance, risk perception, hazardous attitude and safety behavior (*n=306*)

| NO. | Item | Mean | SD |
|---|---|---|---|
| *Risk tolerance* | | | |
| 1. | The navigation device (such as Radar or ECDIS) of the vessel is of poor performance. | 2.46 | 0.91 |
| 2. | The pilot AIS plug is not equipped or not available. | 3.08 | 1.00 |
| 3. | The steering engine is failed when piloting. | 1.47 | 0.69 |
| 4. | The main engine is abnormally stopped when piloting. | 1.77 | 0.80 |
| 5. | The vessel has a larger-scale of dead zone than usual. | 2.44 | 0.85 |
| 6. | The vessel has to un-berthing, when the visibility is reduced to a level below 800 m. | 2.31 | 1.00 |
| 7. | The vessel suddenly encounters severe convection weather, when sailing in open waters. | 2.33 | 0.87 |
| 8. | The vessel suddenly encounters severe convection weather, when sailing in narrow channel. | 1.39 | 0.66 |
| 9. | The vessel cannot contact with another vessel not in sight of one another and hence involve risk of collision, when piloting a vessel in restrict visibility in Shanghai port. | 1.90 | 0.92 |
| 10. | The vessel has no response to full rudder at slow speed, when sailing in a deep water channel and encountering extremely abnormal current. | 1.92 | 0.88 |
| 11. | The Under Keel Clearance of the piloting vessel is 0.7m when navigating in the Nancao Channel. | 3.58 | 1.08 |
| 12. | When piloting a vessel in restricted water area, the diameter of turning basin is less than 1.5 times of Length Over All. | 2.26 | 1.02 |
| 13. | The length of the berth is a little less than 120% Length Over All when berthing. | 2.30 | 0.92 |
| 14. | The vessel is conning a forward bridge vessel in Huangpu river (Shanghai). | 2.33 | 0.88 |
| 15. | The vessel is approaching a congested anchorage to anchor. | 1.98 | 0.85 |
| 16. | You are piloting a vessel constrained by her draught navigating in heavy traffic water area. | 2.31 | 0.87 |
| *Risk perception* | | | |
| 17 | When you are conning a vessel located outside buoy D12 of the Tangtze estuary deep-water channel, a small craft is crossing the channel so as to involve risk of collision. The distance of two vessels is 1 nautical mile, the vessel in the deep-water channel cannot get in touch with the crossing craft. | 3.66 | 0.89 |
| 18 | When you are conning a vessel in bound along the Yangtze estuary deep-water channel, a vessel of same course in front of you keeps a speed lower than your dead slow speed. | 3.67 | 0.92 |
| 19 | You are crossing with a head-on vessel and a dredging vessel, when you are piloting in the Yangtze estuary deep-water channel. | 3.42 | 0.99 |
| 20 | You are piloting a fully loaded container vessel, turning around and berthing Waigaoqiao Terminal. At this moment, a vessel are sailing outbound in 1 nautical mile. | 3.63 | 0.88 |
| 21 | During ship pilotage, a small vessel comes across the head and enters into the dead zone of your vessel. | 4.08 | 0.80 |
| 22 | After low tide of Wusong, you encounter many small vessels crossing the channel, when piloting a vessel in Wusong precautionary area. | 4.07 | 0.79 |
| 23 | While piloting a fully loaded bulk cargo vessel approaching Luojing terminal, the pilot decided to turn around and berth with a 5 knots speed. | 3.81 | 0.87 |
| 24 | While piloting a vessel approaching Zhanghuabang terminal, the pilot decided to enter Wusongkou with the berth occupied. | 4.04 | 0.72 |
| 25 | While piloting a vessel getting alongside by starboard side, the ship speed decelerates slowly and the ship yaws starboard obviously when reversing the engine. | 3.85 | 0.80 |
| 26 | While a pilot is embarking a vessel, the vessel does not make leeward or the pilot ladder is not in good condition. | 4.56 | 0.65 |
| 27 | The pilot has embarked a vessel at north side of D6 buoy and enters the channel by a clearance of 1 nautical mile between two vessels in the channel. | 3.23 | 0.85 |
| 28 | When you are overtaking another vessel in the channel, your speed 2-knot is faster than the overtaken vessel. | 3.23 | 0.84 |
| 29 | When anchoring in Wusong Anchorage, the anchor position is only 3 cables away from other vessels due to water area limitation. | 2.99 | 1.03 |
| *Hazardous attitude* | | | |
| 30 | I have a thorough knowledge of the pilotage water area and berths. | 4.17 | 0.83 |
| 31 | I am an excellent marine pilot. | 3.97 | 0.91 |
| 32 | It is unlikely that a pilot of my ability would be involved in an accident. | 3.04 | 1.20 |

| | | | |
|---|---|---|---|
| 33 | There are few situations I couldn't get out to during pilotage. | 3.56 | 0.99 |
| 34 | I know navigational regulations and procedures very well. | 4.13 | 0.78 |
| 35 | I never feel stressed when piloting a vessel in a heavy traffic area. | 2.91 | 1.20 |
| 36 | I like the feeling of speeding up and overtaking other vessels. | 4.17 | 0.83 |
| 37 | I like making turns on large angle. | 3.44 | 1.02 |
| 38 | I like using engine telegraph as seldom as possible when berthing. | 2.98 | 1.15 |
| 39 | If I hear other pilots discussing a new berthing approach that can be done on my vessel, I'll try it out. | 2.58 | 0.86 |
| 40 | If there is a maneuver that other pilot hard to do, I'll try and just to see if I can do it. | 3.38 | 0.95 |
| 41 | I always worry about an accident when I am conning a vessel. | 3.30 | 1.22 |
| 42 | I really worrying about the vessel not under control. | 3.40 | 1.10 |
| 43 | I always worry about a collision accident when sailing in heavy traffic water area. | 3.00 | 1.13 |
| 44 | I worry about not finding aids to navigational while piloting at night. | 3.18 | 1.15 |
| 45 | While navigating in narrow channels, I always worry about grounding or collision if the steering engine quits. | 3.03 | 1.14 |
| 46 | I really hate berthing or un-berthing delayed when piloting. | 3.77 | 1.08 |
| 47 | I am basically an impatient marine pilot. | 2.46 | 0.95 |
| 48 | If the vessel in front of me is very slow when navigating, I don't mind following her. | 2.68 | 0.99 |
| 49 | I get angry if I am on approach on base route and someone cuts in front of me doing a straight-in approach. | 2.32 | 0.82 |
| 50 | I'll yell at people who don't clear the berth fast enough when I am arriving at the berth. | 2.46 | 0.87 |
| 51 | The Maritime Safety Administration is more of a hindrance than a help. | 2.92 | 1.08 |
| 52 | Regulations and rules do not promote safety pilotage. | 2.48 | 1.03 |
| 53 | I find the rules of speed limit and overtaking Prohibition in precautionary water area is helpful. | 2.33 | 1.04 |
| 54 | In general, I find Vessel Traffic Service is very helpful. | 2.75 | 0.89 |
| 55 | I find VTS officer is very competent and professional. | 3.19 | 0.87 |
| 56 | In piloting, what will be, will be. | 2.46 | 0.96 |
| 57 | In a close-quarters situation, I trust to fate. | 2.33 | 0.87 |
| 58 | Sometimes I feel like the vessel has a mind of its own. | 3.04 | 0.99 |
| 59 | When I encountered a trouble, I figure if I make it, I make it, and if I don't, I don't. | 2.46 | 0.82 |
| 60 | If I am involved in an accident, it would be the result of bad luck. | 2.18 | 0.74 |
| *Safety behavior* | | | |
| 61 | I never disobey the safety regulations and procedures. | 3.71 | 0.89 |
| 62 | I always carry safety equipment and dress safety protection suit. | 4.58 | 0.55 |
| 63 | I always keep good communications with the master and other vessels. | 4.06 | 0.80 |
| 64 | I always keep safety awareness in piloting. | 4.51 | 0.58 |
| 65 | I don't neglect safety, even in a rush. | 4.55 | 0.55 |
| 66 | I always recognize the contingency may occur when piloting. | 3.65 | 0.83 |
| 67. | I actively participate to set safety goals of pilotage. | 4.10 | 0.73 |
| 68. | I actively make suggestions on how to improve safety. | 3.95 | 0.70 |
| 69 | I actively attend the safety meeting of my pilotage association. | 4.31 | 0.66 |
| 70 | I always give advice on safety to my colleagues or leaders. | 3.79 | 0.76 |
| 71 | I always encourage my colleagues to participate the discussion of safety issues. | 3.94 | 0.74 |
| 72 | I initiatively report the fatigue situation to my pilotage association. | 3.01 | 0.94 |

Range 1-5.