

An Extension of m-SHEL Model for Analysis of Human Factors at Ship Operation

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ABSTRACT:

In order to understand how people respond to different circumstances, a classification system is required that specifies the knowledge and attitude of people and the effect of circumstances. In this paper, we propose a human factors classification framework to classify the seafarer's safety-related factors. The m-SHEL (Software-Hardware-Environment-Liveware with their management) model was adopted as a conceptual base of generic human factors, and extended to accommodate ship navigation domain. According to navigation practices, especially pertaining to collision and grounding avoidance, our model defines a detailed category for each of the m-SHEL interfaces. By counting the original m-SHEL interfaces as level 1, and by considering human factors that relate to the two types of circumstances, we have defined 13 specific categories descending from them as level 2 classification and 38 more specific subcategories as level 3.

It is common to the navigational operations that ships are often involved in a circumstance of meeting other ships in traffic. However there are rather scanty direct communications among them, existence of approaching ships causes considerable influence on the operator. The framework therefore is intended to be applicable to the circumstances of being in traffic.

To gain experimental data on critical situations related to collision and grounding, questionnaire surveys were carried out, and from the answers, operators' opinions about safe navigations and human factors are profiled according to the proposed classification framework. This paper provides an overview for human factors in two types of critical circumstances, i.e. collision and grounding avoidance, and an in-depth exploration of collision factors. Some statistical analysis and discussion on the profiles show that the relations between seafarer's attributes and safety attitudes are reasonable, and thus the proposed classification framework contributes to the understanding of human factors in ship operation.

1. INTRODUCTION

The increasing use of modern technology improves the capabilities to maneuver, but also increases the technical complexity, which is regarded as a major risk factor behind marine accidents. Many reported collision and grounding accidents are due to human erroneous actions in the complex navigational systems. To reduce accidents associated with human erroneous actions, and enhance safety in navigational operations, it is necessary to increase understanding of human factors aspects of operators in charge of it. In our past research, we have investigated operator's awareness of critical situations by comparing and contrasting the difference between reports of casualty and incident during navigational operations (Itoh, 2002). However, there is a gap between the operators' cognition and actual hazard, each experimental data on critical situations expresses the operator's human factor very well. In order to understand the human factors from the opinions, a method to elicit and express the factors that relate to knowledge and attitude of an individual and interactions between an individual and surrounding environment is required.

In this paper, we propose a human factors classification framework to specify the seafarer's safety-related characteristics. The m-SHEL (Software-Hardware-Environment-Liveware with their management) model was adopted as a conceptual base of generic human factors, and extended to accommodate ship navigation domain. It is common to the navigational operations that, not to mention while collision evasive maneuvers, ships are often involved in a circumstance of meeting other ships in traffic. However there are rather scanty direct

communications among them, existence of approaching ships causes considerable influence on the operator. The framework therefore is intended to be applicable to the circumstances of being in traffic. Considering navigation practices, especially pertaining to the situations of collision and grounding avoidance, our model defines a detailed category for each of the m-SHEL interfaces. By counting the original m-SHEL interfaces as level 1, and considering the human factors that relate to the two kinds of circumstances, i.e. collision and grounding, we have defined 13 specific categories descending from them as level 2 classification and 38 more specific subcategories as level 3.

To gain an overview on the public opinion about the human factors, a questionnaire survey was carried out. From the answers, operators' opinions about safe navigations and human factors are profiled according to the proposed classification framework. Then some statistical analysis on the profile that discusses the relations between seafarer's attributes and safety attitudes will be provided.

2. THE M-SHEL MODEL

2.1 *The m-SHEL Model*

The m-SHEL model is a variation of the SHEL model (Kawano, 2002). The SHEL model was originally proposed by Edwards in 1972, and modified by Hawkins (Hawkins, 1987). It is now formally introduced as a human factor framework by IMO (International Maritime Organization). The SHEL model is a conceptual model that attempts to indicate the interactions between the various components of system and the operator. It comprises four components: Software

(rules, manuals, and regulations) – S, Hardware (equipment) – H, Environment (physical factors) – E, and Liveware – L. The m-SHEL model added "m- (management)" to the SHEL model.

Software represents any components such as policies, rules, computational codes and practices that define the way in which the different components of the system interact with each other and with the external environment.

Hardware represents any physical and non-human component of the system, such as equipment, vehicles, tools, manuals and signs.

Environment represents the socio-political and economic environment in which the different component interaction.

Liveware represents the operational personnel themselves in the center. Role and communicational aspects are mainly focused.

Management represents the control of whole system.

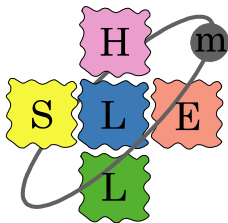


Figure 1. The m-SHEL model (adopted from Kawano)

2.2 The m-SHEL Model for ship operation

We have extended the m-SHEL model for ship operation to analyze human factors that contributes marine accidents and incidents. By counting the original m-SHEL interfaces as level 1, we have defined specific categories descending from them as level 2. It requires more concrete circumstances to be assumed as the definition goes into detail. Thus we decided to target the two types of circumstances (collision and grounding), and had discussions among experts in order to define level 2 categories. In the domain of ship operation, many interactions reside in interfaces between an operator and physical or nonphysical elements that adjacent to the operator; such as navigation instruments, regulations, ambient environment conditions, and those who are involved in the operation. Determining to which category these communications and interactions should be belonged was controversial because they have complex structures and relations with multiple interfaces. For example, the human factor aspects in a problem of meeting with other ships in a narrow waterway may be related to L-L, L-E, and L-S interfaces. A tentative set of categories were created after the discussions. Then it has been revised through a grouping work of the comments to the questionnaire (described in the following section). Finally, 13 specific categories are defined as level 2. For example, Liveware is partitioned into two categories: L-1 and L-2.

L-1 Operators' basic qualifications as a seaman

L-2 Operators' technical qualifications as a seaman

In the same way, L-L, L-H L-E, L-S, and L-m interfaces have level 2 categories. Descending from level 2 categories, we have defined 38 more specific categories as level 3 categories. Categories defined are listed in Table 1.

3. QUESTIONNAIRE SURVEY

3.1 The Survey

In order to gain experimental data on critical situations related to collision and grounding, questionnaire surveys were carried out on 2001 and 2002, respectively. The questionnaires are composed of three parts: introduction part that explains the objective of the

questionnaire and some instructions, respondent information part that asks questions such as occupational category and age, and questionnaire items part. The questionnaire items part includes fixed-alternative (with space for "other" or "comments") questions on the respondents' experiments, i.e., frequency and types of critical incidents. The numbers of the fixed-alternative questions are 7 in collision avoidance survey and 16 in grounding avoidance survey. At the end of the questionnaire items part there are two open-ended questions to ask operators principal concerns. The questions are:

- ◆ What do you regard as the most important thing to avoid ships collide[go aground]? The frequency you get into a situation that makes you regard so should be added if possible.
- ◆ What do you regard as the most effective action to secure the safety of navigation? Any new instruments to be developed may be included.

3.2 The Sample: Respondents for Collision Avoidance

The questionnaire was mailed to ship operators through coastal shipping companies, passenger boat companies, and National Institute for Sea Training. The response numbers were 345 for collision avoidance survey and 455 for aground avoidance survey.

Figure 2 and 3 show breakdown of respondents' attributes. Age of fifties has the largest number of respondents and sixties has the smallest. Ratio of captain is highest in sixties group and lowest in twenties group. Ship types are classified into six categories: passenger ships, cargo carriers, training ships, tug boats, fishing boats, and others/unknown.

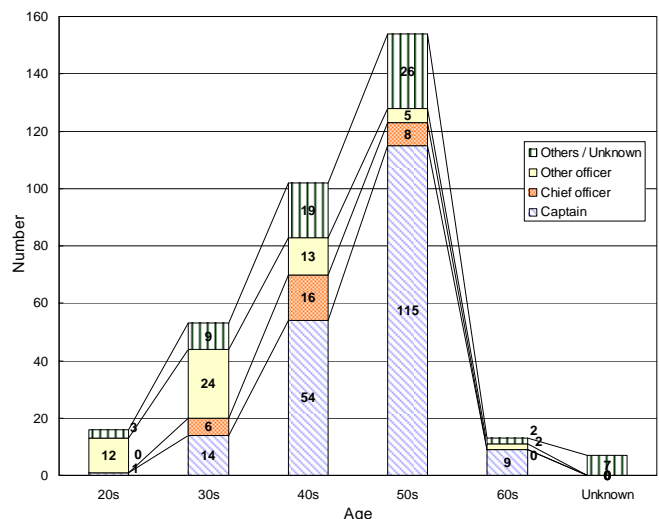


Figure 2. Attributes of the respondents.

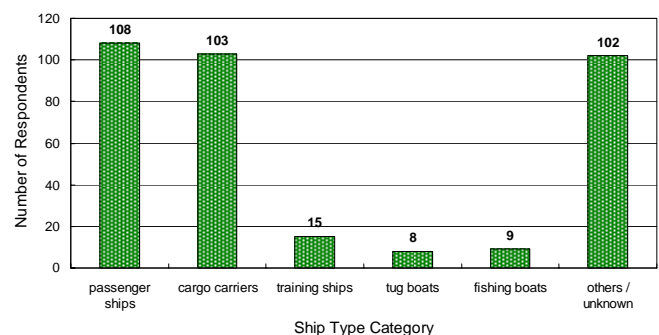


Figure 3. Ship types of the respondents.

4. ANALYSIS

In this section, we first provide a view of collision and grounding surveys, and then look into further details in collision survey.

4.1 Collision vs. Grounding

Figure 4 shows the results of the respondents to two questionnaire surveys classified according to the classification of Table 1. The results were categorized from the perspective of m-SHEL level 2. The numbers in the graph indicate the number of answer per respondent.

Despite the differences in survey item, participant population, and conducted timing between the two surveys, characteristics of distribution have common features. A large part of the result concentrates in LS-2, L-2, and L-1 interfaces. On the other hand LS-1, LH-1, LE-1, LE-2, and Lm-2 obtained only few opinions. The largest difference between the results is that whilst grounding avoidance obtained lower values in most items, the opinion belongs to L-m interface reached twice the number of collision avoidance and comes in third. The possible cause of this is that groundings are assumed to be caused by doze at the wheel, and for this reason they regard preventing such situation by keeping operators' condition as an important issue in management.

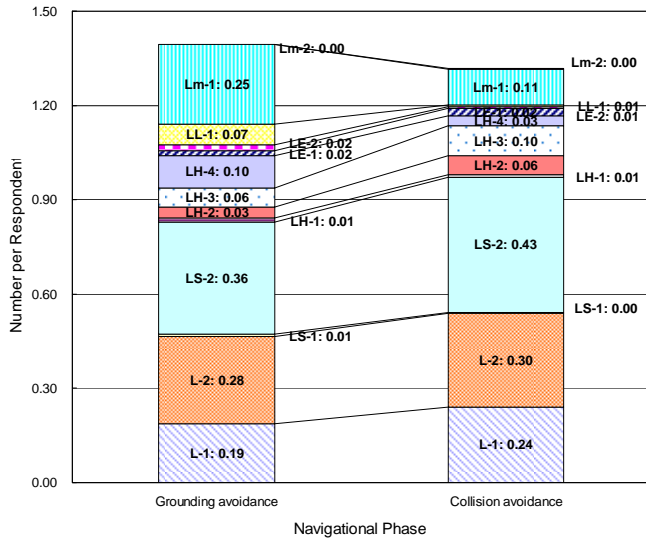


Figure 4. Number of respondent by navigational phase.

4.2 Collision Avoidance Profiles

In this section we closely examine answers to collision avoidance survey. A comparison among operators grouped by ship types is shown in Figure 5. Whilst L and LS makes relatively high values across the board, the number of answers for LE and LL are only between 0 and 0.05 per person, except for 0.13 per person of tugboats' LE category. High values for L and LS reflect that the operators pointing out the importance of internal aspects and contact with software elements for collision avoidance situations. Passenger ships and cargo carriers categories, which include more than 100 respondents, are coincide with each other in LS and LH. The values in Lm, LL, and LE for fishing boats indicate that most of the operators work solitary on their own ships.

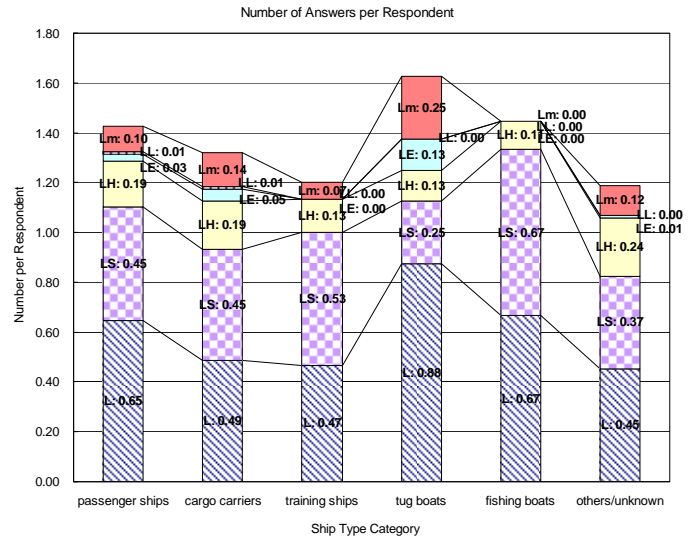


Figure 5. The m-SHEL profile of "collision avoidance" by ship type.

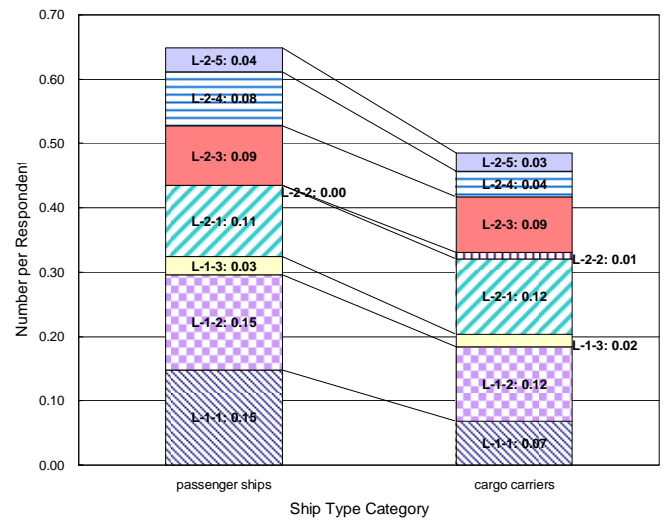


Figure 6. A breakdown of "L" aspects by ship type.

A breakdown of L answers of passenger ships and cargo carriers categories is shown in Figure 6. Training ships, tugboats, and fishing boat categories were not broken down due to very small number of the answer. As seen in the figure, passenger ships category has higher values especially in the elements that relate to mental attitude with rules and manners, and skill acquisition aspects. The possible cause of this is that in many instances passenger ships are faster and more maneuverable than cargo carriers and thus they consciously lay themselves under the obligation of encountering collision avoidance in more cases.

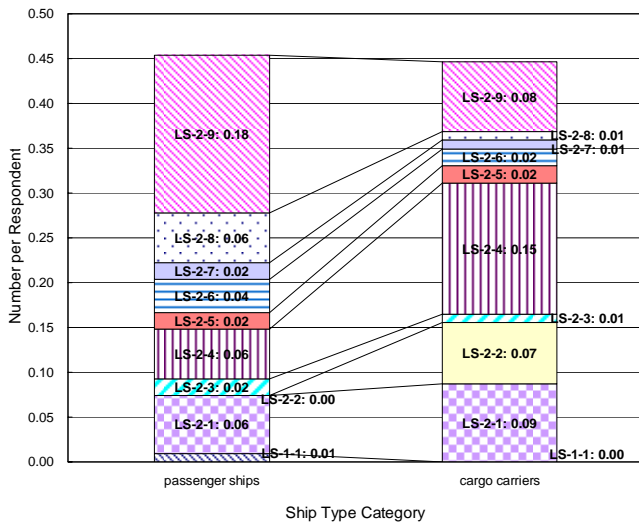


Figure 7. A breakdown of "LS" interface by ship type.

Figure 7 represents a breakdown of LS answer into level 3. It is obvious that passenger ships category thinks instruments on the water is more important than other elements in the navigational environment. However cargo carrier category thinks the same element as important, they place more importance on legal regulations related to fishing boats, to navigational rules, and to foreign vessels. The importance of procedures and manuals was not pointed out by either of them in this survey.

Figure 8 shows a breakdown of collision avoidance survey into m-SHEL level 1 by age of respondent. The graph shows that respondents in their twenties pointed smaller numbers of important matter than any other group, especially in L-m and L-E interfaces. By looking into each answer, we could see that they place knowledge about navigation, improvement in quality and performance of nautical instruments, and consolidation of legal system on navigational instruments on the sea (L-1-2, LH-2-1, and LS-2-9). Respondents in their thirties pointed larger numbers of important matter in L and L-S interface by double than that of twenties, while they pointed smaller number in L-H interface. Among elements in LS interface, consolidation of legal system on fishing boats and navigational instruments on the sea (LS-2-4 and LS-2-9) are highlighted. Respondents in their forties have a characteristic that they have the largest number in L. Especially rules, knowledge about navigation, and technical aspects for collision avoidance and lookout (L-1-1, L-1-2, L-2-1, and L-2-3) are focused. Respondents in their fifties have similar characteristics to that of forties, however, they have larger values in L-L, L-E, and L-m interfaces. Respondents in their sixties compared with any other ages have larger value in L-H interface. Especially maintenance of instruments, and design and installation of systems (LH-1-1 and LH-4-1) are focused.

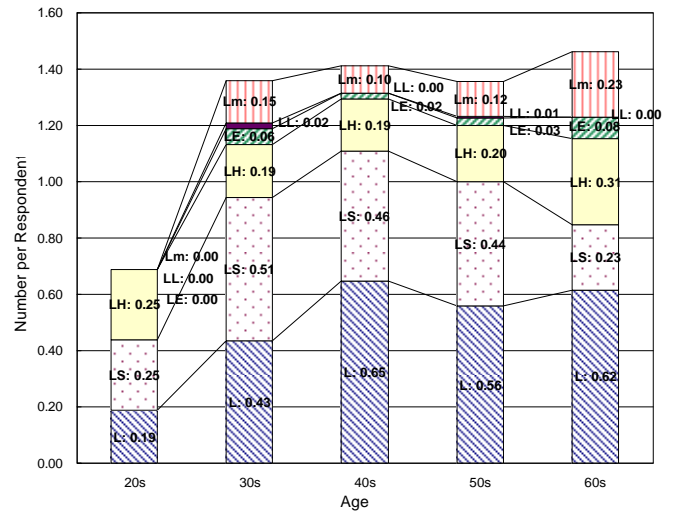


Figure 8. The m-SHEL profile of "collision avoidance" by age.

5. CONCLUSIONS

In this paper, we proposed a human factors classification framework to specify the seafarer's safety-related characteristics. The m-SHEL model was adopted as a conceptual base of generic human factors, and extended to accommodate ship navigation domain. Operators' opinions about safe navigations, gained from questionnaire surveys, are profiled according to the proposed classification framework. An overview for human factors in two types of critical circumstances, i.e. collision and grounding avoidance, and an in-depth exploration of collision factors are provided. Relations between seafarer's attributes and safety attitudes are examined and explained reasonably. To improve the proposed categories, other types of critical circumstances should be considered as a future work.

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Table 1 A Classified Table for Ship Operation m-SHEL Model.

Lv.1	Level.2		Level.3	
L	L-1	basic qualifications as a seaman	L-1-1	rules and manners
			L-1-2	knowledge about navigation
			L-1-3	basic qualification
	L-2	technical qualifications as a seaman	L-2-1	techniques for collision avoidance
			L-2-2	techniques for position measuring
			L-2-3	techniques for lookout
			L-2-4	skills acquisition and training
			L-2-5	knowledge about sea area
	L-L	LL-1	human relationship within bridge	LL-1-1
LL-1-2				communication within bridge
L-H	LH-1	instrument reliability	LH-1-1	maintenance of instruments
	LH-2	improvement in quality and performance of instruments	LH-2-1	nautical instrument
			LH-2-2	facilities and equipment
	LH-3	development of instruments	LH-3-1	watch support for collision avoidance
			LH-3-2	watch support for aground avoidance
			LH-3-3	watch support for position measuring
			LH-3-4	other support systems
	LH-4	role sharing between operators and instruments	LH-4-1	design and installation of systems
			LH-4-2	instrument functions
			LH-4-3	others (e.g. facilities on land)
	L-E	LE-1	labour environment	LE-1-1
LE-2		maintenance of sea lanes and water	LE-2-1	waiting space
			LE-2-2	making sure of water depth
			LE-2-3	sufficient information of the area
L-S	LS-1	improvement of procedure manuals	LS-1-1	instruction manuals and harbour guides
	LS-2	legal regulations on navigational environment	LS-2-1	in common
			LS-2-2	foreign vessels
			LS-2-3	domestic vessels
			LS-2-4	fishing boats and leisure fishing boats
			LS-2-5	small crafts
			LS-2-6	boats without a light
			LS-2-7	waterway
			LS-2-8	identification of other ships and fairways
			LS-2-9	install required instruments
L-m	Lm-1	lighten workload of deck officer	Lm-1-1	duties of employers and captains
			Lm-1-2	duties of politics
	Lm-2	enhancement of technical capabilities	Lm-2-1	hand skills on to the next generation
			Lm-2-2	accumulation, analysis, and sharing of experiences