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Identification and challenge of human factors under the trend of MASS development

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IDENTIFICATION AND CHALLENGE OF HUMAN FACTORS UNDER THE TREND OF MASS DEVELOPMENT

By

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The People's Republic of China

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2020

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: …………………………..

Date: …………………………..

Supervised by: ……Lv Hongguang……………………..

Supervisor’s affiliation: ……Dalian Maritime University…………………..

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ABSTRACT

Title of Dissertation: **Identification and challenge of human factors under the trend of MASS development**

Degree: **Master of Science**

With the development of technology, MASS has gradually been widely used, and the crew has changed from the previous operator to the monitor. However, many accidents caused by human factors occurred during this process. At present, most scholars explore the human factors of MASS from one or several aspects, and they are independent of each other. The degree of influence of the main factors cannot be distinguished effectively, so it is necessary to explore the human factors in MASS.

This paper first introduces the types and main technologies of MASS, and then takes ship company A as the research object. Questionnaire survey is used to collect the relevant information of the crew and determine the main set of human factors considered by the crew in company A. Through the investigation, the main human factors in MASS are responsibility awareness, information overload, dependence on automation, loss of situational awareness, fatigue and boredom from normal work, mistakes in Programming, communication between shore-based operators and other relevant organizations and security on the Network. Then identify the analyzed factors and discuss the rationality of why choose these human factors. Then, through literature review method to investigate the human factors in different fields of automation equipment, compare the human factors in MASS. It is proved that these human factors may also occur on MASS. Finally, the author puts forward reasonable control and solutions to help MASS prevent risks in advance or reduce risks caused by human factors.

KEYWORDS: MASS; SCC; Human factor; SHELL model; Scenario identification

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LIST OF ABBREVIATIONS

SCC	Ship Control Center
MASS	Maritime Autonomous Surface Ship
IMO	International Maritime Organization
MUNIN	Maritime Unmanned Navigation through Intelligence in Networks
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea
UAV	Unmanned aerial vehicle
FOV	Field of View
GCS	Ground Control Station
SOP	Standard operation procedures

CHAPTER 1 INTRODUCTION

1.1 Research background

In recent years, drones and autonomous vehicles have become increasingly popular and have been used in daily life, military activities and scientific exploration. However, applications related to unmanned vessels have only been proposed in recent years, as they have not yet matured to the extent that they can be applied in daily life on a large scale. The benefits of Maritime Autonomous Surface ships (MASS) to the shipping industry are undeniable. On one hand, MASS reduce human input. The navigation and maneuvering of MASS are mainly accomplished through autonomous decision making, or remotely controlled by a few shore-based personnel. Unmanned vessels reduce the need for full-time crew members on maritime patrol vessels, reducing manpower costs. On the other hand, the use efficiency is improved. MASS do not need crew space and equipment, thus reducing the power demand of crew, greatly improving the space and energy efficiency of ships, and providing feasibility for modular application of MASS. Moreover, the MASS has strong adaptability to the environment and can perform tasks such as cruise and search and rescue in severe sea conditions, especially at night. The time investment and risk investment of the crew are reduced, and the use efficiency of the watercraft is improved. Human factors usually refer to any factors related to people. An international definition of it is put forward by Professor Edwards, that is, "human factor is to optimize the relationship between human and its activities in the framework of system engineering through the application of human science in systems" (Qiu, 2003) . But human factors bring us opportunities as well as challenges, and the most heatedly debated topic is the safety features of MASS. In proposing the Smart Ship project, Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) has ensured that MASS will be at least as safe as conventional transport vessels. Perhaps some experts in the maritime sector would argue that the advent of MASS would dramatically improve safety, as they are unmanned. Could not it take the human element out of the navigation process? It should be understood that 80% of maritime accidents are related to human factors. But the fact is that MASS do not mean that they can solve all the problems caused by human errors. On the contrary, unmanned vessels bring more human factors problems. Even though the MASS will not be disturbed by the operator, the operator is still part of the autonomous system. When some intelligent systems cannot solve the problem, they still need operators to take over MASS. Although the safety of MASS is the focus of many documents nowadays, human factors which should be considered are still insufficient. (M.A. Ramos&J.E. Vinnem, 2018) This article introduces the human factors challenges faced by MASS, and then compares them with those of intelligent facilities in other fields, so as to give reasonable suggestions to MASS to improve safety.

1.2 Research status

1.2.1 Development of MASS Abroad

After nine IMO member countries, such as the United States, Norway and Denmark, submitted proposals to the Maritime Safety Committee to define the scope of legislation in the MASS field, the International Maritime Organization put the issue of self-driving ships on the agenda of the 98th session of the Maritime Safety Committee held in June 2017. The meeting called on the shipping industry and relevant scientific research institutions to put into the research of MASS as soon as possible and develop intelligent or automatic ships of different levels. Firstly, semi-automated or even fully-automated operation of short-distance dry cargo transport and small special operation vessels operating in port areas, and then automation of long-distance cargo transport will be considered. After that, in order to strive for a better working environment, reduce transportation costs, reduce global demand for emissions, and improve shipping safety. EU implements feasibility of MASS and definition of shore-based center in the Seventh Framework MUNIN. MUNIN believes that a crew member on an unmanned vessel is sufficient to help the ship call port, but a monitor is needed at the shore-based center to switch from automatic to manual navigation if necessary. At the same time, AAWA has different views on the automation level of MASS. AAWA believes that MASS should be fully automatic, should not have crew on board, and can dynamically adjust their own state. This means that the MASS will change its automatic level according to the different tasks it performs.

1.2.2 Research Progress on Human Factors of MASS Abroad

Research on human factors of MASS system can be divided into two aspects. One is the overall research on the influence of automation on human behavior, and the other is targeted unilateral research on influencing factors.

1.2.2.1 An Overall Study of Human Factors in Automation

MASS have been the topic of discussion in recent years, and human factors in automation systems have been concerned and studied for many years, so many scholars in this field have chosen to directly study the unilateral human factors that affect MASS. In 1999, Funk made a preliminary discussion on the human factors in the automation environment and summarized 102 related issues. By means of questionnaire and statistical analysis, 10 questions with the largest proportion are concluded (Shappell S et al., 2007) . After Funk's research, the overall identification research on the identification of influencing factors of automation system on human has gradually decreased. however, with the introduction of new types of automation systems, the discussion on human and automation issues has attracted the attention of scholars. In 2009, NaidooP conducted a research on the perception of pilots in modern advanced automated cockpit. Through the questionnaire method, it was concluded that the driver's understanding, training and trust degree of automation were the main factors affecting the perception of pilots in cockpit. In 2013, K.B. Sullivan and others used BP neural network method to identify hazard sources for the interaction between human and automation system, and found that cross-checking errors, task allocation and situational awareness are unstable factors affecting human in automation.

1.2.2.2 Unilateral Study on Human Factors in MASS

Table 1-Unilateral research of human factors by different foreign scholars

	Research direction and achievements	Deficiencies in Research
Yemao Man	He made use of the differences in tetrahedral harmony model to reveal the changes in situational awareness requirements during the transfer from ship to shore. It was found that the separation of the operator and the ship greatly affected the generation of situational awareness (Yemao Man et al ., 2015) .	The prediction of the operator's ability has become a research challenge, especially the level of the captain and senior crew. The tetrahedronal model can not control the change of personal ability demand.
Yemao Man, Monica Lundh	Monica Lundh and others put forward the idea of designing a comprehensive system by screening key investigation objects and investigating the key aspects of human factors that maintain the sense of ship. Through the analysis of the characteristics of the shipboard and shore-based environment, the inherent variability of human factors in these applications is revealed (Yemao Man et al., 2014) .	Maintenance of MASS has become a new problem
M.A. Ramos	M.A. Ramos identified and modeled the interaction between the operator and the MASS, and determined the possible human factor accidents caused by these interactions (M.A. Ramos et	There is no discussion on how to reduce accidents caused by human factors

	al., 2018) .	
Reto Weber	Retowber uses remote monitoring system to simulate automated merchant ships, studies the influence of human factors and interface design, and finds that even a nearly perfect unrealistic system will have human factors. And it provided an ecological approach to the design of the system, since he considered the coupling between the pilot and the environment to be an ecological issue, in order to be able to create a technical tool that could truly support the pilot in dealing with the complexities of the unmanned ship domain (Yemao Man et al., 2018) .	In the future, they will consider the ecological problems and language environment problems
Krzysztof Wrobel	Krzysztof Wrobel listed the risk influencing factors that affect the safety of MASS. The 4P4F framework is introduced, which consists of four operation stages (voyage planning, berthing or disengaging, port approaching or departing, open sea passage) and four different factors (human factor, ship factor, environment factor, technology factor). Based on this framework, it is analyzed that the high seas are the places where risk influencing factors occur most, and	Some factors outside the 4P4F framework may be ignored, such as inappropriate organizational structure level, shift handover, and inappropriate SCC design

	most risk influencing factors are related to human factors. The research results help designers and operators to overcome or reduce these shortcomings of risk influencing factors, thus promoting the safe operation of MASS (Fan et al., 2020) .	

Source: Author

1.3 Purpose and Significance of Research

Safety is an issue that cannot be ignored at every stage of the development of intelligent ships, and the safety requirements for MASS should at least be the same as the safety of the current manned ships. Utne (2017) proposed risk influencing factors to analyze autonomous ship collision hazards from three perspectives: mission, environment, and system. Krzysztof Wróbel analyzed the safety control structure of the autonomous ship itself, and the list of hazards and mitigation measures from the structure (Yemao, 2014) . M Lutzhoft (2019) analyzed how human beings cooperate or hand over with automatic ships by holding expert seminars, and mapped and investigated the potential gap between current seamen's skill training and future autonomous navigation. Hogg and Ghosh (2016) studied the effective factors influencing the commissioning of automated merchant ships from the legal, safety, seafarer and automated machine coordination and social perspectives. Montewka, Jakub developed a precautionary approach to the failure of human factors at MASS. However, only a few papers have discussed the potential impact of human factors on MASS (Montewka&Jakub, 2019) .

Nowadays, due to the rapid development of MASS, most countries have focused on the development of science and technology. Almost no attention has been paid to how shore-based operators are educated and trained, and the traditional crew cannot be arranged directly to the shore base. On the one hand, on-shore working is a different environment; on the other hand, crews may transfer the human factors on board the ship directly to the SCC. It must be understood that when completely MASS are used, the human factor still exists. The shore-based control of ships includes new safety problems. The interaction between manned and unmanned ships in the same traffic area will become a mixed traffic situation. If these problems are not found and solved in time, it will bring more troubles. This paper focuses on the influence of human factors on MASS by comparing the influence of human factors in other automation fields. Will the human factors of MASS different from traditional ships? What challenges will it bring to MASS at this stage? How to correct the details ignored by the personnel of the ship control center or the crew of the semi-automatic ship, so as to better reduce the navigation risks of MASS and protect the safety of the sea and life and property?

CHAPTER 2 RELATED CONCEPTS OF MASS

2.1 Classification of ships

Generally speaking, there are three types of ships as shown in Figure 1.

The first is automated ships. Most traditional ships have different degrees of intelligence and have achieved partial automation, mainly reflected in the following three aspects. First, the crew can control the ship remotely. Second, in the event of a malfunction while the ship is underway, the system can automatically alarm and input relevant information into the computer, so that the crew can effectively correct it, and even realize automatic repair and adjustment of some faults. Third, the navigation system can automatically control the ship's navigation according to the ship's pre-determined operating route, but this kind of navigation has some risks. Crews must supervise when encountering complex routes. In the event of a collision hazard, the crew is required to give detection and command from a remote location.

The second is the intelligent ships. Intelligentization refers to a mode in which modern communication technology, intelligent control technology and computer network technology are jointly applied to the ship. It has the functions of evaluation, diagnosis, prediction and decision-making. This vessel can use technologies such as radar, AIS and electronic nautical charts to accurately identify obstacles in transit and provide timely warning so that the vessel can be controlled to avoid the detected obstacles successfully. In recent years, intelligent ships have been a mainstream research direction in many countries, and such developments will reduce the number of crew and shipping costs. The intelligence of the ship needs to evolve gradually, starting with remote monitoring and troubleshooting of faults, followed by optimization and decision support. The link with shore-based center gives effective decision-making on ship operations. Then remote or semi-autonomous operation is achieved.

The third type is unmanned ships. It is an almost completely unmanned ship, where the ship requires only a small number of people to direct assistance while berthing and loading and unloading cargo. Sometimes no human involvement is even required. And when the ship encounters problems that it cannot handle on its own, the shore-based operator steps in and exercises remote control until problem solving (Marilia Abilio Ramos et al., 2019) . This is the highest level of intelligent ship development. It is equivalent to an intelligent robot, which can realize external perception and make corresponding decisions.

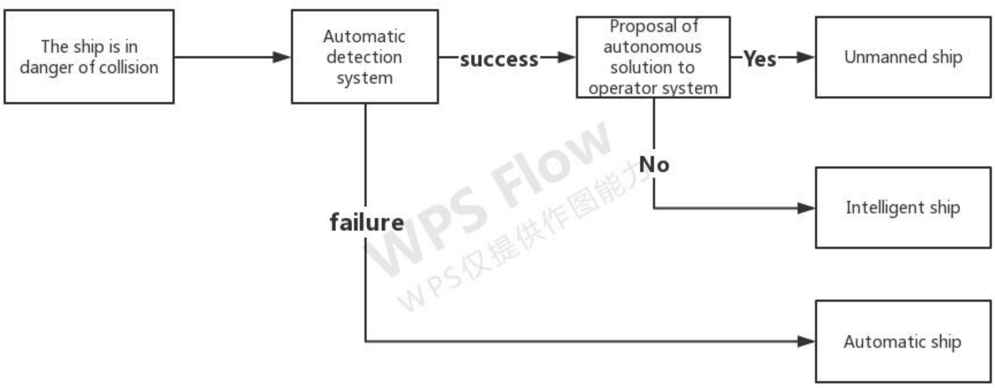


Figure 1-Treatment of three kinds of ships in collision

Source: Author

The three types of autonomous vessels described above must be progressively more intelligent and cannot be promoted directly from manned to unmanned vessels, and no country is likely to make such a risky attempt (Laurinen, 2016; Utne et al., 2017) . At the same time, most people remain skeptical about the safety of intelligent ships, suggesting that unmanned ships should be restricted in some way and should be supervised or controlled by a ship command center at all times.

2.2 Key Technologies of MASS

MASS refers to a ship that uses sensors, communication, Internet of Things, Internet and other technical means to automatically sense and obtain information and data of the ship itself, shipping environment, logistics, ports and other aspects. Moreover, it can be based on artificial intelligence technology, computer technology, automatic control technology and big data processing and analysis technology to realize intelligent operation in ship navigation, management, maintenance, cargo transportation and other aspects. MASS will be safer, more environmentally friendly, more economical and more reliable. MASS mainly include four key technologies as listed below:

2.2.1 Ship Intelligent Sensing Technology

Ship Intelligent Sensing Technology includes the intelligent perception of ship external information and ship internal information. Among them, the external information mainly includes the basic parameters of wind, waves and currents in the navigation areas, the situation of obstacles, other ships, etc. Internal information mainly refers to the hull status, engine room status, cargo status, energy efficiency status, as well as the parameters, vibration, noise, corrosion, fatigue, etc. of the ship's equipment in the process of design, construction and navigation. The stable acquisition of information reduces the human error caused by insufficient observation.

2.2.2 Intelligent decision-making technology for ships

Intelligent decision-making technology for ships can use computer technology and control technology to analyze and process the acquired external information and internal information, and make intelligent decisions to realize ship route optimization, risk early warning, intelligent collision avoidance, energy efficiency management, autonomous weather routing, intelligent processing of navigation information, etc. This technology can help reduce human error. In normal navigation or in danger, the system can provide some advice to the operator. Whether on board or SCC, operators can avoid accidents caused by personal reckless operation and enhance the safety of MASS.

2.2.3 Ship Intelligent Execution Technology

Various facilities, equipments and instruments on board the ship should fully understand and execute the instructions issued in the intelligent decision-making process, and can feed back the intelligent execution results to the intelligent decision-making center.

2.2.4 Ship-shore Cooperation Support Technology

The MASS transmits all information and data in the process of intelligent perception, intelligent decision-making and intelligent execution to the shore in real time through the ship-shore cooperative support system, so that shore-based personnel can carry out real-time online monitoring to understand the ship's navigation state and make reasonable necessary responses. Although this technology can represent that mass has reached a high level of intelligence. But at the same time, human factors are also transferred from the ship to the control center.

CHAPTER 3 HUMAN FACTOR IDENTIFICATION OF UNMANNED VESSEL

3.1 Selection of influencing factors identification method for unmanned craft

This paper takes the human factors of unmanned vessel as the research object, and fully considers the feeling of the operators in the actual navigation in the research process. The questionnaires given can comprehensively and objectively reflect the influencing factors of unmanned vessel on the pilot's behavior.

3.2 Selection and introduction of research objects

3.2.1 Research object selection conditions

In this paper, we should consider the two aspects of human and automation when selecting the research objects. First of all, on the human side: the research object should have enough crew members. The average distribution of crew navigation experience, and the proportion of new and old crew members should also be appropriate. Secondly, ships: there should be a certain number of ships. Ship manufacturers should be complete, and there should be a variety of ships equipped with complete automation system equipment.

3.2.2 Research object

In this study, the branches of shipping company A are taken as the main research objects. The shipping company currently has 110 crew members, mainly engaged in passenger and cargo transportation.

3.3 Determination of main factors

3.3.1 Identification of factors

This chapter explores the identification of human factors in MASS. It is necessary to identify all factors affecting operators in SCC. This identification must be comprehensive and not be analyzed by a single accident. On the other hand, this paper focuses on human beings. In order to make the analysis more comprehensive and make the classification clear, the author intends to analyze the factors from four aspects: human, hardware, environment and software. This is a reference to the SHELL model proposed by Edward and modified by Hawkins. The four elements constitute the interface system around the human factors in the middle. In this way, the relationship between different factors can be identified more intuitively.

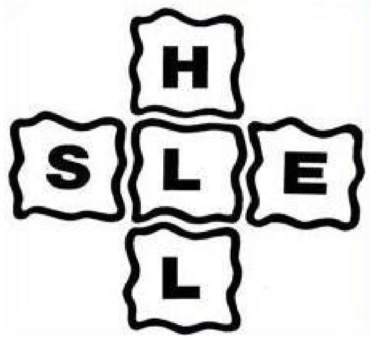


Figure 2-SHELL model
Source: Internet

The L in the center of the picture is the most important part. Human factors and other factors influence each other. This paper will make a table according to the first level factors and the second level factors. The first level factors are L-L, L-E, L-H and L-S. the second level factors are the influencing factors extended from the first level factors.

Table 2-All human factors considered by the author

The first factors	The second factors
Only L	Workload, Lack of basic skills, Level of trust in the system, Recognition of automation system, Fatigue and boredom from normal work, Sense of responsibility, Situational awareness, Experience level, Tension level, Preparation before sailing
L-L	Coordination with successors, Crew cooperation, Communication with trainers
L-H	Complexity of automation system, Reliability of automation system, Mistakes in Programming, Number of monitors, Instrument light, Security on the Network
L-E	Noise, Weather condition, Bridge space

L-S	Inadequate navigation supervision, Training of shipping company, Navigation information

Source: Author

3.3.2 Questionnaire

In the shipping company A, 80 crew members were randomly selected for questionnaire test. 78 questionnaires were collected, of which 75 were available, and the effective rate of the questionnaire was 93.75%. The data collected are as follows:

Table 3-Results of the questionnaire

	Very unimportant（1 point）	unimportant（2 points）	intermediate（3 points）	Important(4 points)	Very important(5 points)
Workload	0	0	37	31	6
Communication with trainers	0	0	41	18	5
Fatigue and boredom from normal work	0	0	20	40	20
Lack of basic skills	0	0	44	19	1
Experience level	0	27	42	5	0
Recognition of automation system	0	17	42	15	0
Situational	0	0	7	45	23

awareness					
Level of trust in the system	0	40	15	20	0
Tension level	0	14	35	21	0
Preparation before sailing	0	10	46	12	7
Crew cooperation	0	0	10	57	7
Coordination with successors	0	50	20	10	0
Security on the Network	0	0	33	39	2
Inadequate navigation supervision	0	0	50	25	0
Training of shipping company	3	55	17	0	0
Navigation information	11	53	11	0	0
Complexity of automation system	0	20	37	18	0
Reliability of	0	0	10	45	19

automation system					
Mistakes in Programming	0	0	24	48	3
Instrument light	0	50	10	15	0
Number of monitors	0	0	60	7	7
Bridge space	0	60	25	2	0
Sense of responsibility	0	0	26	41	7
noise	0	15	46	14	0
weather condition	0	45	26	4	0

Source: Author

The scores of different important grades have been marked in the table. According to the number of votes shown in the questionnaire, the total scores are calculated.

Table 4-Observe the importance of different factors through total scores

The first factors	The second factors	Total scores
Operator's own ability (only L)	Workload	265
	Lack of basic skills	213
	Level of trust in the system	205
	Recognition of automation system	220

	Fatigue and boredom from normal work	320
	Sense of responsibility	277
	Situational awareness	316
	Experience level	200
	Tension level	217
	Preparation before sailing	206
Relationship between operator and other workers (L-L)	Coordination with successors	200
	Crew cooperation	293
	Communication with trainers	220
Relationship between operator and hardware (L-H)	Complexity of automation system	223
	Reliability of automation system	305
	Mistakes in Programming	279
	Number of monitors	243
	Instrument light	190
	Security on the Network	265
Relationship between operator and environment (L-E)	Noise	224
	Weather condition	184
	Bridge space	203

Relationship between operator and software (L-S)	Inadequate navigation supervision	250
	Training of shipping company	164
	Navigation information	150

Source: Author

Through the above data, the main human factors in MASS are responsibility awareness, information overload, dependence on automation, loss of situational awareness, fatigue and boredom from normal work, mistakes in programming, communication between shore-based operators and other relevant organizations and security on the network.

3.4 Main human factors identification of MASS

3.4.1 Responsibility awareness

Crew members should understand the responsibilities of all parties involved in an operation. They should know the situation of this ship and other ships in time when avoiding collision, because most sea areas in the future will be mixed traffic areas with MASS and normal ships. SCC operators or a few crew members on MASS need to know the responsibilities and consequences brought about by each operation. (Wang&Sun, 2019) The most important provision in Convention on the International Regulations for Preventing Collisions at Sea (COLREGS) , for example, is the second liability clause, which has two meanings: first, COLREGS does not exempt the ship, master, owner or crew from liability for the consequences of "any negligence in complying with the provisions of these Rules", "in accordance with the usual practice of seafarers" or "any negligence in the exercise of caution required by the particular circumstances of the case". Secondly, in complying with the collision avoidance rules, "due regard shall be given to all hazards of navigation and collision" and "any special circumstances, including the limitations of the ship's conditions", even if these hazards and special circumstances would lead to a departure from certain provisions of the collision avoidance rules (Wang, 2018) . This raises another fundamental problem. For departure from the rules, from the point of view of a semi-automatic ship, the shore-based operator must have extensive seagoing experience in order to know what decisions to take in response to sea conditions. But few crew members will encounter departure from the rule, so there is no guarantee that the shore-based personnel will be able to make the correct decisions in the event of an emergency deviation. For fully automated ships, instilling the meaning of COLREGS into the system is very difficult. Currently, MASS engineers can develop collision avoidance methods at sea using shipboard cameras and sonar to identify objects. (Wang, 2018) But when to take an action contrary to COLREGS is difficult to achieve by procedure.

3.4.2 Information overload

As shown in Figure 3, shore-based operators often receive a very high volume of information, as their normal workload is to monitor six vessels simultaneously, as well as to obtain information about the vessels by constantly monitoring six gauges. There are nine top marks on the top of the instrument and these are divided into three colors, green to indicate that the vessel is operating normally and is not in danger of collision, yellow to alert shore-based personnel that there may be a vessel in the distance that needs to be avoided, or that there is some deviation from the values set for the vessel at the beginning, and red to indicate a critical situation that should be dealt with immediately. The circle next to the dashboard indicates a mode viewer, in order to solve the problem of management control in the system. Even though every effort has been made to solve the complexities of automation, it can still result in information overload. It is easy for operators to forget or fail to recognize the relevant information, so they cannot understand the sea conditions. At the same time, different sensors are installed on different ships, and the information given by these sensors may conflict with each other, which will lead to errors when shore-based personnel switch operations from one ship to another. The impact of such errors is often very serious (Yemao et al., 2015) . Secondly, the three-dimensional vision of the operation center is used to replace the feeling of shaking on the ship, which is very stressful for the crew (Porathe et al., 2014) .

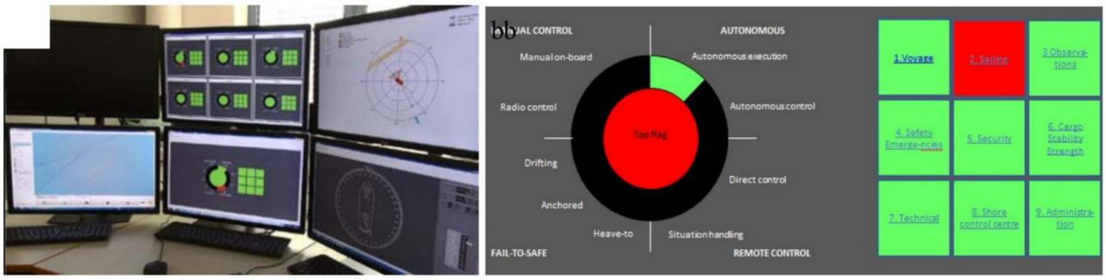


Figure 3-The operator’s work station and one dashboard to display 9 group information from one unmanned ship

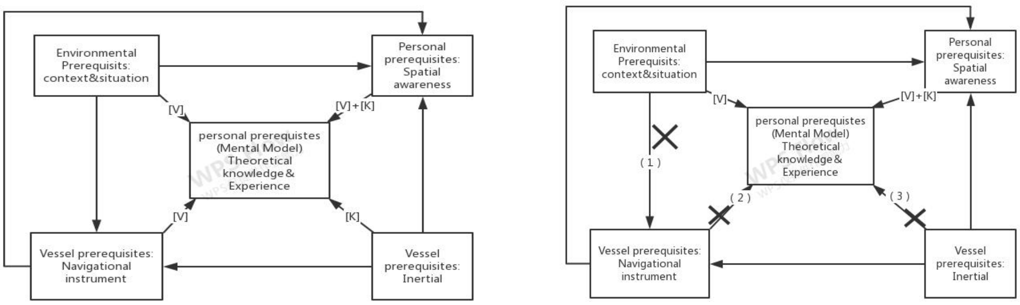
Source: Yemao Man, Monica Lundh, Thomas Porathe, Scott MacKinnon (2015), From desk to field - Human factor issues in remote monitoring and controlling of autonomous unmanned vessels, ScienceDirect

3.4.3 Dependence on automation

Since the alert level of MASS should be at least the same as or even higher than that of manned ships, in many cases shore-based personnel may excessively trust operators in SCC, resulting in reduced monitoring efforts and accidents occurrence. This is a well known situation, and most people who are exposed to automation on a regular basis will develop new bad habits. In daily life, for example, a driver has a new car and it is equipped with parking radar. For a while after the device is installed, the driver still stops the car and looks in the rear-view mirror to see if there are any rocks around. But as the number of stops increases, the driver realizes that his parking radar will alert him even if there is an obstacle, so he gradually stop worrying about wiping out his car. Moreover, it will make drivers stop more and more casually so as to speed up the speed of parking. This kind of habit may lead to deterioration of safety awareness and new dangerous situations in the end (Ahvenjärvi, 2016).

3.4.4 Loss of situational awareness

Shore-based personnel have no direct physical connection with the ship and cannot directly know the environment around the ship. Electronic interfaces have replaced the traditional human perception in the crew field. Even experienced captains may lose situational awareness without visual perception of the surrounding environment. Only counting on the data of the wave direction shown in the instruments is quite dangerous. Remote steering without a sense of rocking in the boat is difficult even under smooth sailing situation. From some of the research reports, it has emerged that the two main elements in maintaining the "harmony" of a ship are the tacit understanding of the seafarers and the "sense of ship" which cannot be lost (Prison,2013) . "Harmony" means to maintain the ship to a dynamic balance through the efforts of all aspects of the crew. If the sense of ship is lost, harmony will be lost. The following two pictures describe the relationship between situational awareness and elements in "harmony". The analysis proves three differences in the requirements of situational awareness between ships and shore bases. The picture on the left is Fig. 4(a). The picture on the right is Fig. 4(b).



V：visual information K：kinetic information

Figure 4-(a) tetrahedral model adapted from harmony; (b) four discrepancies are identified for further analysis

Source: J. Prison, J. Dahlman, and M. Lundh, (2013) "Ship sense - striving for harmony in ship manoeuvring," WMU Journal of Maritime Affairs

(1)All environmental data and equipment real-time parameters need to be collected by sensors and then sent to SCC. Environmental factors are a prerequisite for the formation of situational awareness. Previous technologies cannot solve the problem, but the new technology has the function of data communication as much as possible.

(2)From the dynamic on-board environment to the static SCC control room, the operator cannot feel the shaking of the ship, nor can he judge bow-trimmed or stern-trimmed. Static environment has greatly affected the generation of situational awareness.

(3)The operator can only obtain the situation on board the ship according to the information of sensors. In SCC, monitoring becomes the main task. This part shows that the main task is to analyze the task and make clear the appropriate operation suggestions.

3.4.5 Fatigue and boredom from normal work

Under normal circumstances, the degree of fatigue will be directly affected according to factors such as crew working time and workload. If extra working hours are too long (maybe 3 to 4 hours), fatigue will grow very rapidly, and this growth is more obvious when the workload and pressure increase. Since operators of SCC need to pay attention to six ships at the same time, shore-based operators will have a series of adverse effects once fatigue occurs. For example, negligence of lookout, unclear thinking, misjudgment, inflexible and maladjusted movements, difficulty in bringing good navigation skills into full play, and decline in the level of ship handling until accidents such as ship collision occur due to insufficient response speed. In addition, boredom can also be defined as a state of fatigue, produced by the constant repetition of dull and tedious activities (Fan, 2020) .

3.4.6 Mistakes in Programming

Even if the ship is unmanned, every act of MASS and the computer program to maintain the operation of the ship are attended by people. In software development, some simple human accidents often occur, such as spelling mistakes in some similar coding processes, which can be easily corrected. However, what is difficult to detect is the algorithm of the computer when an abnormal situation occurs. The designed algorithm leads to dangerous operations under special circumstances. S. Ahvenjärvi analyzed such situations in 2009. After all, the software designer cannot tell the operator whether he can safely drive the ship (Ahvenjärvi, 2016) .The expert group writing the software cannot predict some accidents in advance.

3.4.7 Communication between shore-based operators and relevant organizations

Shore-based personnel need to have full and close communication with other ships, VTS and other departments. In VTS supervision work, VTS attendants use VTS, AIS and other equipment every day to closely monitor the ship dynamics in the waters under their jurisdiction. At the same time, they listen to VHF channels and complete the key work of directing and monitoring ships entering and leaving ports, entering and leaving anchorages, passing through narrow waterways and bypassing dangerous water areas. To ensure a good navigation environment and a stable security situation in the jurisdiction area. If a ship operated by shore-based personnel finds that the ship may sink in a short period of time or a large amount of oil spill pollutes the marine environment, VTS personnel need to be contacted to deal with such emergencies. VTS personnel need to fully understand the on-site information and think about it. This is to adapt to the variability, complexity and uncertainty of the environment. In reality, due to lack of emergency rescue experience and inaccurate role positioning in emergency rescue, some VTS workers are panicked and slow in response to dangerous situations, with disorganized emergency handling procedures, delaying the best rescue time and affecting the rescue effect.

3.4.8 Security on the Network

Due to the anonymity and connectivity of the Internet, Internet security risks have become a new maritime security problem. Anonymity gives users appropriate protection so that they can freely express their ideas through the Internet, but it also gives criminals cover (Wang&Sun, 2018) . Traditional pirates threaten shipping companies by taking ships hostage. MASS ensure the safety of personnel, but the insecure SCC network system provides convenience for hackers to attack MASS computer systems. Hackers will threaten shipping companies by controlling MASS to use the value of goods or MASS themselves as chips. The anonymity of the Internet makes human factors in new piracy simpler and pirate attacks more covert. In addition, the risk of the perpetrators being arrested at the time of the act is lower, and connectivity enables Internet users to achieve global connectivity (Duan, 2019) . Although there are computers on ships now, they are "closed systems" independent of the Internet. The computers on ships have no connection with other computers on the Internet. However, with the development of MASS, ship owners will rely more and more on the Internet to issue orders to manipulate ships. The Internet has become an invisible path for hackers to attack.

CHAPTER 4 HUMAN FACTORS OF AUTOMATION IN RELATED FIELDS

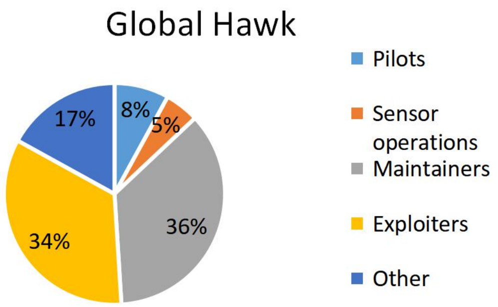
This chapter looks up various documents about different infrastructures evolving into unmanned intelligent devices. These devices are more dependent on direct decision-making on land than ships before becoming intelligent, so when they develop into unmanned equipment, they need to face more severe challenges of monitoring and remote command. This paper will consider various aspects, such as safety, practicality, emergency handling, situational awareness and the impact on society. Then an analyze on the impact of human factors on unmanned devices in these areas and search for previous solutions to eliminate human factors will be given. The comparison between these solutions to an unmanned vessel, and whether the study would contribute to the human factors suggested chapter 3. Mutual research between fields is the exchange of technologies and consideration of potential risks, these include: unmanned cars, drones, space operations, military, metro, docks, and cranes. Identify the challenges and possibilities of unmanned vessels through these areas and analyze the human factor from both onboard and SCC perspectives.

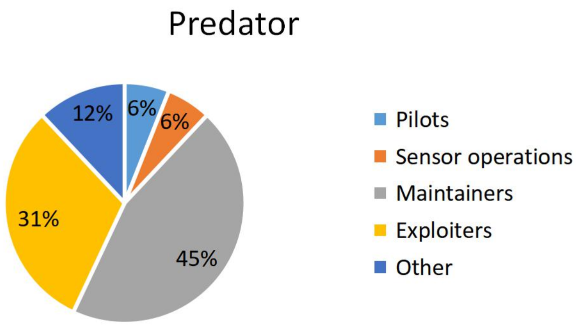
4.1 Unmanned aerial vehicle (UAV)

With the continuous progress of unmanned aerial vehicle system technology, the accident rate of unmanned aerial vehicle system is also increasing year by year. Investigation shows that more than 40% of accidents are caused by improper operation or mistakes of operators (Waraich et al., 2013) . RQ-4 Global Hawk and

Predator UAV System is the primary provider of continuous intelligence, surveillance and reconnaissance information. They can fly at high altitude for more than 30 hours. Global Hawk is designed to collect large area near real-time and high-resolution images under various weather conditions. In addition to intelligence gathering, part of Predator is responsible for providing communications relay support for air and ground users. In 2012, the crash rates of these two types of UAV are shown in the table below:

Table 5-Global Hawk and predictor crash rate in 2012





Source: Internet

It can be seen from the table that human factors have a high accident rate even in unmanned aerial vehicles. Therefore, it is very important to research the influence of human factors on the operation of UAV system to improve the safety level of UAV system and the operation level of operators. Generally speaking, eight positive aspects can be learned from UAV system.

4.1.1 Teamwork in UAV

No task performed by a drone can be accomplished by a single operator, and its success depends on a team effort. Some scholars based on a series of unmanned aerial vehicle simulation tasks between one operator and two operators of the comparative study have shown that an operator alone control unmanned aerial vehicle can not effectively complete the task (Qi, 2015) . There needs to be an unmanned aerial vehicle organization, which includes aircraft operators, commanders, intelligence analysts, air traffic controllers and maintenance personnel. Each role in the group has different responsibilities. In addition, in order to ensure the efficiency of task operation, each member of the team must cooperate with the lowest conflict and misunderstanding state under the same goal, which can reduce misunderstanding caused in the process of information sharing and improve the efficiency of information transmission and use.

In MASS, this mechanism of teamwork is also worth learning. MASS are divided into semi-automatic and full-automatic. In semi-automatic MASS, ships need close cooperation between ship personnel and shore-based personnel. Both need to establish a more effective communication and authorization mechanism so that instruction given by shore-based personnel can be executed immediately, and emergency event can be better handled. For semi-automatic ships, the risk of coordination is much smaller than that of fully automatic ships. In fully automated ships, most of the shore-based personnel in SCC need to pay attention at all times. They not only need to monitor multiple ships at the same time, but also need to give appropriate instructions. This workload exceeds their load. Therefore, the control center needs to train other types of personnel to reduce the burden of shore-based personnel. For example, MASS can add cabin monitoring personnel and emergency treatment experts to their original posts. The original operator is still responsible for understanding the surrounding environment and preventing cabin monitoring personnel are responsible for observing the status of different equipments in the cabin at all times. When an emergency occurs, the emergency operator can take control from the normal operator to check and control the failure, so as to help the damaged ship or deal with unexpected emergencies, preventing damage to the hull or loss of cargo due to incomplete command by the operator alone. At the same time, emergency handling procedures and crisis handling plans shall be established, and group drills shall be conducted to improve the ability of the operator group to deal with emergencies. Of course, the group must also have perfect pre-simulation plans and analysis solutions, so as to better improve navigation safety.

4.1.2 Reasonable Distribution of Human and Machine Functions

For UAV operators, the most effective interface and control system should allow for an optimal balance between human resources and UAV mission requirements. The best optimization in UAV is that the system enters a state between the two extreme states of full manual and full automatic control. For example, power aided steering, anti-skid braking and speed control help the operator to maintain auxiliary control, while other functions such as engine cooling, fuel pressure, lighting and locking are automatically completed (Alan Hobbs&Beth Lyall, 2015) .

The application of this aspect can also be tried on MASS. In the remote control state, the MASS operator is mainly responsible for the realization of all system functions in the navigation process, including navigation speed, collision avoidance and target marking, etc, which need to be completed manually. In contrast, full automation of system functions prohibits operators from performing any task operation. However, if reasonable allocation can be achieved, the system can perform some low-order operations, such as controlling navigation and obstacle avoidance. Advanced operations are implemented by operators, such as target ship selection, termination of tasks, emergency handling, etc. This arrangement frees the operator from the tedious task of navigation and allows him to focus on mission execution and completion. If during periods of specific risk, it is associated with system mode errors and coordination failures. At this time, the MASS can automatically transfer the control to the system. Of course, after the system is processed, the operator will smoothly resume control of the ship.

4.1.3 The health of the crew will be improved

Many pilots will get sick due to various aviation medical problems, such as air pressure injury, anoxia, spatial disorientation caused by vibration and acceleration, but unmanned aerial vehicles have perfectly solved this problem and ensured the health of pilots. MASS are similar. Seasickness has always been a problem for many crew members. It increases the fatigue of the crew and increases the probability of accidents. But this kind of difficult problem will appear on MASS.

In general, the adaptability of MASS to severe weather is very high, and it can provide safety guarantee through professional team cooperation or reasonable work distribution. However, some problems of UAV may also appear on the MASS.

4.1.4 Lack of design standards

Different designers will create different kinds of ground control stations, many of which have little aviation experience or do not involve airlines in the design process. This may lead to the design of ground control stations underdeveloped mission requirements、rough edges of very new tech and divergence from aviation standards (Qaisar R. Waraich et al., 2013) . All of these will bring unnecessary fatigue, tension and even danger to pilots. For example, in response to an emergency, the pilot mistakenly thinks that the unmanned flight system is in an emergency state, or the emergency situation may not be displayed on the screen, causing the pilot not to understand.

MASS also face this problem. Most MASS designers have no experience in ship operation and do not understand the situation on board. They can only design step by step according to the written knowledge. This will cause major problems in emergency situations. For example, in the process of collision avoidance of multiple ships, it is difficult for MASS to analyze the order of collision avoidance. Improper actions will lead to failure of collision avoidance and damage to ships. Fortunately, even if the design criteria are not perfect, the errors will not become more because of the longer time in the system life cycle. And as the mistakes are corrected, the MASS network system will become more perfect. Unlike hull or equipment, the system will become old due to long time, and errors will increase with their aging.

4.1.5 Limitations to See & Avoid Capability

Due to video technology limitations (cost, bandwidth, size) remote pilots' eye receives less visual information than the airborne pilot's human eye. In this regard, the difficulties faced by operators of UAV and MASS are almost the same.

– Limited in higher contrast settings (sunrise, sunset, sun/lights in camera FOV); Low light environments.

– Bandwidth / framerate / latency / (cost)

– Video quality dependent on data link quality

– Resolution / Acuity - as displayed in GCS/SCC

– Wide FOV vs human peripheral vision, & Zoomed FOV vs human focal vision; Auto-focus

4.1.6 Loss of situational awareness

Generally, situational awareness is described as the operator's cognition of the state and change in machine operation. This recognition enables operators to respond quickly and appropriately to unexpected events. An experimental study by Hussmann shows that compared with the traditional driving mode, the automatic driving operator takes longer reaction time. The problem that can be seen from this is that many drivers perform improper operations on the mode of automation, which is called mode error. Traditional pilots can use hearing, smell, vision and touch to get a lot of clues which are beneficial to flight safety. It is difficult for the pilot to understand the flight status of the UAV if these signals are not available. Therefore, compared with the pilots of manned aircraft, the UAV ground station operators can be said to operate the UAV in an " isolation" environment. A variety of accidents can prove that the causes are rarely caused by one human error or a single event. They are actually all formed by a series of minor errors.

Situational awareness is the ability to identify a fault chain and break it before the accident. It can know what is going to happen related to the safety of ships and equipment at any time and identify the fault in time. Likewise, T. Porathe realized that there was no "ship sense" in SCC (Porathe, 2014) . On ordinary ships, the shaking degree, smell, smoke, navigation instrument information, current and wave size of the ship can all be the clues for the crew to find the "ship sense". The ship sense can help them reduce the pressure. Only with enough situational awareness can take corresponding actions in case of an accident, because the body's response is faster than the instrument. The operators in SCC for autonomous ships may pay most attention to the monitoring equipment, ignore the perception of the external environment and at last lose the situational awareness. SCC needs to acquire more data information and video images, and achieve a dynamic and continuous balance state through reliable communication between the unmanned ship and the ground and other MASS, which can make up for the lack of situational awareness as much as possible (Yemao Man et al., 2015) .

4.1.7 Over dependence

Excessive dependence on automation in the unmanned area shows that people do not doubt the safety of automation and do not fully check automation. When the operator relies too much on automatic driving, on the one hand, he loses the instant information of the system, and he will be distracted and judged, on the other hand, in the long time, his handling skill will be reduced (Zhang, 2000) . Once an abnormal situation occurs, it is difficult for the operator to identify it. Even if it is found, jumping from automatic driving to manual driving to correct errors may take more effort. Some studies have shown that under the condition of high load and after using automatic control, the change of dynamic characteristics of the system is slower be found by operators than under the condition of manual operation. If the manual operation of the driver is still needed when the automatic control fails, it is necessary to pay attention to the retraining of the manual operation of the operator. This will maintain the necessary experience of manual operation. At this point, the airline companies and shipping companies have been quite perfect in simulation training, but some details should be improved.

4.1.8 Communication with various parties

In the field of UAV, GCS personnel need to communicate with all aspects of staff. First of all, crew members should have clear responsibilities, and remember to cross check (Harris D, 2009) . Fully understand each other with air traffic control personnel to prevent single communication mode and misunderstanding of English terms. Coordinating with the crew in advance is necessary to prevent someone to take over when their physical condition is not suitable for duty. During the flight training, communicating with the flight instructor and ask questions, so as to better understand the automation system are required. Communicating the status of UAV with the maintenance personnel directly or through flight notes, and informing the maintenance personnel in time in case of any problem are highly recommended.

In the field of unmanned vessel, SCC not only needs to fully communicate with the staff, but also faces the uncertainty of some human factors. As for the communication with the staff of the port, different countries may have differences in language and culture. And in the process of collision avoidance, the two ships communicate through VHF, and they always have different opinions on the understanding of rules.

4.2 Unmanned crane

With the development of science and technology, many wharfs are faced with the increase of labor cost, and personnel are often injured in the process of operation. So many wharfs use intelligent crane technology to realize unmanned and automation. There are many kinds of technologies involved in the specific process of intelligent unmanned crane, among which the more important technology types are sensor technology, communication technology, automation technology, etc. From the current situation, the application of automation technology is the most common. ERP information technology has also been popularized, and with the expansion of its application scope, people have also strengthened the research on the technical content. However, in this environment, unmanned cranes bring many uncertain factors to the operator's work.

4.2.1 Too much load on operators due to diverse work

In the terminal, the main task of the remote operator is to load and unload the container, and his activities are only aimed at controlling the crane to load and unload the cargo, which takes a very short time. But in the traditional cabin, the staff need a long process to put the goods safely. For example, each operation needs to carefully position the goods, and then move the goods from the stack to the truck and then to the container. The advantage of this operation is that the operator can not only keep a high concentration all the time, but also have time to predict the next step in the whole process (Karvonen et al., 2012) . Many similar jobs will receive temporary tasks. This requires a very high level of remote operators, who need to respond quickly in a short time. This task is not only different every time, but also giving the operator not enough time to response in the remote cabin, which greatly increases the operator's fatigue.

The same is true in the field of MASS. In traditional navigation, taking over, being on duty and sailing are carried out in a long period of time. Even if there are additional tasks, the captain will not be assigned to the current pilot. But the operators in SCC are different. They need to monitor multiple ships all the time. Too many temporary tasks will inevitably put a lot of pressure on the operator.

4.2.2 Lack of perspective

When working in the traditional crane cabin, the operator can use vision to observe the situation of the terminal and the location of the surrounding containers, so as to determine the best location reasonably. In the whole process of loading and unloading, the most important thing is to know the location of each container. But if the three-dimensional sense and perspective dimension are damaged in the remote control cabin, they need to rely on limited video and pictures to restore the main view of the container terminal, and they cannot use direct vision to observe the loading area (Sun et al., 2016) . This is the limitation of video transmission. Operators need to learn new methods to adapt to this mode.

In the field of MASS, visual deterioration will also cause trouble to the operators in SCC. During the navigation, they may not have a more direct and detailed outlook through video observation. Even if GPS and radar can give them part of the surrounding information, it is very difficult to judge the timing of collision avoidance, steering amplitude and other factors without using visual observation. With visual observation, when berthing the ship, the pilot can not only get the prompt of the tug crew on the ground, but also judge the berthing distance more accurately. Therefore, operators in SCC need to adapt to and perceive the new operating environment.

4.3 Self-driving cars

Nowadays, the degree of automation of car driving is more and more high. Technology helps cars to have the technologies of distress alarm, adaptive cruise, collision avoidance, active lane keeping and so on. Although automated vehicles have been studied for nearly half a century, they still face some challenges. Moreover, these problems do not belong to "hard" problems in hardware and equipment, but belong to "soft" problems aiming at the coordination, acceptability and practical operation of human factors (Neale,. & Dingus, 1998) .

4.3.1 Adaptive automation

Automated cars can change the driving state according to driving conditions (such as surrounding environment, traffic density, weather conditions) and driver conditions (such as age, driving time, gender) . The system can filter out unnecessary information according to urban planning, road conditions and other factors, and provide more direct and effective information for drivers (Pavone, 2016) . In the process of driving, choosing the right route can not only reduce the driver's pressure, but also alleviate the traffic congestion. The automatic car can "anti monitor" the driver, judge the safety level of driving according to the physical and mental state of the driver, and remind the driver when he is sleepy and tired (Victor, 2000) .

These are also applicable to the field of navigation, the complexity of navigation water areas is more complex than the road conditions of car driving. Therefore, it is more necessary to add adaptive automation to the system. In the system, different navigation modes can be selected by referring to the offshore distance, sea conditions and weather conditions. At the same time, SCC should change the original warning system, which is not suitable for all crew members. Over emphasized and non emergency alarms are annoying; too early or wrong alarms can lead to distraction, ignoring alarms or even shutting down the alarm system, resulting in the "wolf coming" effect. Too late alarms may not prevent accidents. Abe and Richardson (2005) points out that drivers believe in early collision warnings rather than late warnings. From these conditions, it can be analyzed that the alarm system needs to judge the alarm time according to the operator's experience. The inexperienced crew members need to be reminded in advance, otherwise the accident will occur.

4.3.2 Anxiety

When unmanned technology is formed and applied to normal life, we ignore an important factor, the negative impact of anxiety and the interaction of positive evaluation and anxiety. In society, many people's attitude towards unmanned technology is still to understand and fear to use (Christoph Hohenberger et al, 2017) . The most important reason is that automation is not safe enough. Some people also think that automated driving gives hackers the opportunity to control their cars remotely, or even stop them at any time. In short, the higher the anxiety level, the lower the willingness to use autopilot.

In the traditional maritime navigation, there are not a few crew members who refuse the unmanned ship or intelligent ship. They think that the automation is not the highest degree, but the automatic driving system of medium degree. It may be particularly dangerous because people can not keep vigilance for a long time.

Venkatesh also proposed that people will have a huge psychological load whether automation is reliable or not (Venkatesh&Bala, 2008) . When the automation is reliable, the crew may show complacency and relax their vigilance; when the automation is not reliable, the operator needs to solve the problems caused by automation, which is difficult for the crew without enough professional knowledge. This kind of anxiety brought into daily work will have an impact on the operation, and the crew will be afraid to make mistakes that they cannot correct. The popularization of MASS is only a matter of time, so how to solve the negative effects brought by this anxiety? I think it's necessary to have enough professional knowledge reserve and deal with emergency situations before working. Self height technical improvement is more effective than any external help, because they are eager to show their ability to protect others' safety, so as to overcome the influence of anxiety.

4.3.3 Behavioral adaptation

In the field of unmanned cars, people who often use intelligent driving will have lower risk rate, higher work efficiency and more rest time than those who do not often use intelligent driving. This is very relevant to proficiency. This phenomenon can be explained by risk balance theory (Ward, 2000) . It can be understood that when the perceived risk of drivers changes, drivers will adjust their behavior and restore their preferred target risk level, in other words, they are more willing to be close to the cyclist who wear helmet.

The same is true in the field of navigation, and the difference between unmanned ship and unmanned driving is that the operator in SCC is not on the ship, while the driver of unmanned car is on the car. This ensures the safety factor of operators, and their anxiety and fear of danger will be greatly reduced. But at the same time, as this sense of crisis decreases, they may be more prone to make mistakes when operating. For example, when two ships are close to each other, most operators in SCC will follow the route map given by the system, which is correct from the data of sensors and other equipment, but causes risks in actual operation.

4.3.4 Learn more relevant knowledge

The operator should know enough automation knowledge before driving the unmanned vehicle or the MASS, which is very important to deal with the special situation of the equipment. In the field of rally, Wahlström invented a rally control center for remote monitoring of the rally schedule. They found that in general rallies, when accidents occur, it is the spectators who call to communicate with the center, but the spectators can not accurately report the specific location of the accident, so most of the competition schedule will be suspended or even forced to end. But if the control center has an expert on rally cars and the local environment, he can predict where the accident happened and help the ambulance get to the right place (Wahlström et al., 2011) . For the field of unmanned cars, if people cannot enhance their understanding of automation in the training, they can only add an expert in the field of automation in SCC.

4.4 Unmanned subway

The application of unmanned metro in the field of global rail transit is gradually favored by all countries. The unmanned metro in Paris, Singapore and other cities has been officially put into operation. In addition, Marseille, Berlin and other cities are transforming the original traditional metro into unmanned one. Like MASS, unmanned subways are monitored by operators in the control room. Because there are a large number of passengers in the subway, this situation needs to be compared with intelligent merchant ships. The conclusions reached have the following effects on intelligent merchant ships:

4.4.1 Recognition of Obstacles

Unmanned subways have their own functions of detecting roadblocks and route planning. If dangerous barricades are detected, even the operator in the control room is not required to control them, the subway will automatically give an alarm or even stop (M. Wahlström et al., 2013) . But now the defect of the system is that it can only detect the obstacle, but is impossible to distinguish whether to directly pass or stop the obstacle, only to detect the obstacle or not. In this way, the small obstacles on the track will make the unmanned subway generate false alarm.

This is also a challenge for MASS. The MASS system needs to have an accurate comprehensive evaluation of the target. For animals in the sea, people in the water and small fishing boats, the system should give the order to stay away. For floating branches and some marine garbage, the obstacles can be ignored. If the MASS is sailing in the ice area, the situation will be more complicated. This kind of decision is very difficult for automation. SCC needs to evaluate whether the MASS needs an icebreaker, which belongs to the task of SCC. This needs to be considered in the design process.

4.4.2 Parking clearance

The first thing to note is that when the traditional subway stops at each station, the driver can get a lot of information by observing the surrounding environment. They can observe the abnormal part of the crowd, such as the drunk, the disabled, children and other passengers who need special attention, or passengers who use trolleys, brackets and other items. Since drivers encounter many similar situations at work before, they quickly judge the situation by experience. The driver has enough time to predict the needs or potential problems of these passengers. But how can an unmanned subway do this? The second point is about the accident caused by passengers. In the traditional subway, the opening and closing time is fixed. If the passengers' body or goods are sandwiched in the door, the driver can open the subway door again, so as to avoid the occurrence of danger. Some passengers may block the door with their bodies in order to let their late friends get on the subway. Under normal circumstances, they will be given a warning. But for unmanned subway, this behavior is very dangerous (Karvonen et al., 2011) .

In the field of MASS, for the first point, when two ships meet, the MASS cannot judge the intention of other ships, and cannot grasp many opportunities in the collision avoidance rules. For example how to understand the time when the collision cannot be avoided only by the action of giving way vessel, when to adopt the departure rules, etc. The probability of accidents will be greatly increased. The semi-automatic ship sometimes needs the crew to manage the loading and unloading, but the time of the ship staying in the port is controlled by SCC. If there is a single way of communication between the staff on board and the operators of SCC, inadequate mutual understanding or misunderstanding in English terms, these may cause property damage or accidents. For intelligent cruise ships that may appear in the future, we should not only pay attention to the danger of improper boarding time, but also consider how to pacify, evacuate and save ourselves in case of fire or terrorist attack when there is no pilot on board. With the automation system, SCC can only dispatch ships from the nearest wharf, which will waste a lot of time.

4.5 Militarization automation

In the military field, it is often a combination of a variety of automation facilities. For example, MASS, drones, unmanned submarines, etc. These devices make militarization easier and more accurate. At present, they have been put into anti-terrorism operations. Compared with special forces and bombers, they can reduce the number of casualties on our side. Drones and submarines can stay in enemy territory for hours, which is hard to detect. However, in long-range operations, human factors will still have an impact on the unmanned system.

4.5.1 Fatigue and boredom of remote operation

Traditional pilots are usually tired because of the disorder of biological clock, lack of sleep and uncertainty of working time. The UAV operators are tired from operating the UAV in Ground Control Station (GCS) . In 2008, the U.S. Air Force raised the standard of UAV operation and extended the working hours every day. GCS became a 24-hour shift system control center. After Tvaryanas and Thompson's investigation of GCS working environment, rest interval and working time limit, they also inquired about the frequency of overtime work due to special circumstances and temporary work. Investigators found that UAV crew members tend to be more fatigued than traditional pilots. In addition, other workers in GCS, such as maintenance personnel and emergency experts always feel tired. This is because most UAV missions will last a long time, and the crew must adjust their biological clock for a long time.

In the field of MASS, the working and rest time of SCC staff are also very irregular, they are facing day and night imbalance. Because there are always people who have to choose night shift in the working mode of the whole day. For people on night shifts, the quality of sleep during the day will be affected by temperature, noise and light. Daytime sleep is usually 1-4 hours less than that at night. For a long time, this will lead to their physical disorder, insomnia during daytime rest and sleepiness during the working hours at night. This will inevitably lead to memory loss, slow decision-making and inattention due to fatigue at work.

4.5.2 Distinguish friends and foes

The increasing number of UAVs in the war has led to legal and ethical disputes on the use of UAVs. According to a survey conducted by Columbia University, the number of people injured by drones accounted for 35% of the total victims in 2011.

Conor Friedersdorf once published in the monthly magazine that "unmanned operation is an unprecedented assassination and will never end (Etzioni, 2013) . Keith Shurtleff also said: "as war becomes safer and easier, soldiers gradually get rid of the terror of war. They no longer regard enemies as human, but as light spots on the screen. The deterrence brought by such terrorist acts is unimaginable. Although UAVs can distinguish whether buildings are targets, they cannot identify enemies and innocent civilians. Similarly, there is no way for MASS to distinguish between pirates, victims and normal people. SCC should consider such issues in the design process.

CHAPTER 5 RISK COUNTERMEASURES OF HUMAN FACTORS IN MASS

5.1 Improve the operator's ability

5.1.1 Enhance operator's understanding of automation system

(1) In the initial training stage, the ship company should introduce the knowledge of automation system, and this kind of knowledge learning should be throughout the whole training process. During the training, the concept of automation system should be defined and explained, which is helpful for the operator to transform the automation theory into the actual operation of SCC. It takes time for the operator to get to know and master the automation system. Therefore, the company should arrange enough time in the training stage. In addition, in order to ensure that the navigation skills, cognitive level and attitude of each operator can be basically kept at the same level during the training process, the company should consider their learning ability when recruiting operators, rather than focusing on the physical factors.

(2) Operators should spend more time learning navigation management system and navigation control system before entering the actual simulation navigation. These two systems are the core systems of many cockpit automation systems, so it is helpful for the operator to grasp these two systems thoroughly, which will help the operator to transition to the actual operation in the simulator more smoothly and quickly. In addition, in the process of crew recruitment, the ability of the crew to master technology should also be considered. They should not conflict with the disciplines involved in automation in mentality. It is recommended that the shipping company should select some students who are interested in relevant technical disciplines.

(3) During the training, the ship company should focus on the explanation of the principle of automation system so that the operator thoroughly understand the working principle of the automation system and fully understand the interdependence between the systems. Especially in China, where English is not an official language, it is necessary to ensure that operators fully understand the meaning of various symbols and warnings, grasp the technology different from the traditional way of navigation, and maximize the functions of the automation system. In addition, a large number of case verification should be added to the training. So that operators can understand all

kinds of situations in the course of navigation. Moreover, the communication between operators should be facilitated, so that they can better understand the automation system.

(4) During the training, the ship company should pay attention to the characteristics of each operator. Even the most some experienced crew members will have their own special needs. Therefore, the trainers should pay attention to teaching students according to their aptitude, increase the interaction with students, encourage students to put forward their own problems, and focus on the training according to each student's characteristics.

(5) The simulation report system should be established. When the crew is at the primary level, they will be very nervous when using the automation system. The establishment of the simulation report system can encourage the crew to say their own problems, so that the trainer can better understand the level of the students and carry out targeted training.

5.1.2 Maintain situational awareness

(1) Keep external perception of mass at all times. The operator keeps a sense of the state of the unmanned vessel and keeps himself in the state. In order to understand the dynamic information of the system at all times during the navigation, it is necessary to monitor the MASS status and working status closely. In case of any complex situation, the automatic operation should be shut down in time and changed to manual operation.

(2) Strengthen the understanding of system information. In the process of navigation, operators should not only be able to master the navigation status at all times, but also be able to find problems in time. It is more important to understand the meaning of the automated system, otherwise it will cause the same result that the problem is found and the problem is not found during the operation(Zhao, 2006) .

(3) Strengthen operators' ability to predict risks. When there is a problem with MASS,

the operator can find and understand it in time, and predict the cause and severity of the problem, and take effective measures. This requires the operator to simulate the data changes of the ship under special circumstances in the simulation training.

(4) Under the condition of less workload and good weather, operators should be encouraged to turn off the automation system and use manual operation instead, so as to keep them alert all the time.

(5) Create a fault manual to describe various possible faults and effective countermeasures. Ensure that information is available when the operator loses situational awareness.

5.1.3 Appropriate attitude towards automation system

(1) Complacency is a common negative emotion in advanced automation operation. The focus of the training is to ensure the operator's situational awareness and the habit of using automatic equipment and original navigation equipment alternately. In the process of training, the operation of traditional equipment should be properly added, so as to ensure the basic navigation skills of operators. Through training, operators can understand the basic principle of MASS. This will also increase the confidence of operators in the automation system and generate complacency. Therefore, when training, trainers should pay attention to establish their awareness of vigilance and inform them of the serious consequences of automation system, which can relieve their overconfidence in the system.

(2) The research shows that when the automation system breaks down, the operator will hesitate. In this case, operators often choose to rely on the automation system rather than listen to the advice of other SCC personnel. Therefore, operators must understand the ability limit of automation system. SCC should make it clear that the automation system only acts as an auxiliary tool and cannot completely replace the operator. Operators should be clear about their own central position, not blindly rely on automation.

(3) To establish a trust boundary, operators should know when to use automation and when to perform manual operation. It is more important to know when to use automation than how to use it.

5.2 Strengthen the cooperation between operators and other personnel

5.2.1 Strengthen cooperation among SCC personnel

(1) Define the responsibilities of SCC. In the process of navigation, operators are easily influenced by conformity psychology, which causes psychological state error and deviates from their own tasks. As members of SCC, they should always be clear about their tasks and know what to do and what not to do (Wang, 2008). Under special circumstances, if the operators in the same group lose their own ability, another operator should be able to assume the responsibility of the incapacitated driver. This mechanism should be more explicit when the operator conducts initial training. It is necessary to fully mobilize their subjective initiative, respect the tasks that both parties are responsible for during the voyage, and do not intervene excessively.

(2) Implement and strengthen cross inspection. The cooperation and cross inspection of SCC personnel are the most important elements to ensure the safety of navigation. Operators must constantly monitor the automatic mode on each others' display. If there is any change of navigation mode, the operator must use the corresponding navigation mode according to the instructions of the display. Any information change on the MASS must be announced by the operator who actually operates the MASS and confirmed by the operator who is responsible for monitoring. If the operator who operates the MASS does not give a warning under special circumstances, the operator responsible for monitoring must announce it and require the operator who operates the MASS to confirm it.

5.2.2 Improve communication between operators and SCC managers

(1) Try to improve the operation procedures, and operators and administrators should

use standard terms carefully. Formulating practical rules of language to guide operators and controllers in what way and language to correctly query and convey instructions. Simulation training should be used to improve the level of both sides to use normative language.

(2) Formulate corresponding standards, and stipulate that the operator and controller shall have oral communication in different situations. Develop communication equipment and classify the information level released by administrators so that operators can better distinguish the severity level of tasks and make reasonable judgments.

(3) In the operator training and administrator route training stage, they should enhance their understanding of the basic operation principle of mutual automation system. Ensure that the operator and the administrator can better understand each others' intention in the process of communication.

5.3 Improve procedures

5.3.1 Improve training content

(1) Arrange training time reasonably. In the training, the factor that the operator needs time to master the automation system should be fully considered. Therefore, the company should arrange the training time reasonably, and arrange the learning automation and understanding system in each stage of the training, so as to control the automation system more conveniently. For example: simple and natural dialogue; clear and easy information prompt; more intuitive monitoring system.

(2) Adjust the training content. The focus of training is on the understanding of automation, rather than simple button operation. Training should be given to operators on problems they encounter in an automated environment, increase the application of computer simulation software, let the computer simulate all kinds of special situations, and let everyone discuss and analyze, and get effective countermeasures

(3) Ensure enough training time and quality. In order to improve the company's

performance, some companies reduce the investment cost of operator training. The training time and content shall be strictly followed after being formulated. Fully consider the time needed for operators to learn and master the automation system to ensure the effective implementation of the training plan.

(4) Due to the continuous development of automation system, the training program should be adjusted, updated and improved at any time, and new instrument display equipment, such as navigation system, should be used in the training. Ensure that the training content is consistent with the actual operation.

5.3.2 Establish reasonable standard operation procedures(SOP)

While exploring and establishing the operation mode, enterprises should also pay attention to the formulation of procedures. According to different ship types and the actual situation of each ship company, the standard operation procedures should be formulated. In addition, when formulating SOP, routine standard operation procedures and operation procedures in various emergencies should be included. In this way, operators can be guided by SOP in special and dangerous situations, helping them make correct judgment and operation, reduce operation risk and improve safety level.

5.4 Improve the design of automation system

5.4.1 Follow the design principle of "human centered"

Following the design principle of "human centered", its goal is to have an impact on the design of human-machine system in technology, so as to consider human capabilities and limitations from the early design stage to the final design stage of the system. In the design process of automation system, the purpose of design should always be clear. Automation system is to enable operators to better understand the system and operate more safely.

5.4.2 Improve navigation interface design

(1) Simplify the system interface. The purpose of automation design is to enable

operators to better understand the system and control automation system more conveniently. For example: simple and natural dialogue; clear and easy information prompt; more intuitive monitoring system.

(2) Add information prompts for important systems. While simplifying the interface of the bridge, the intermediate computing process of the system should be added information so that the operator can fully understand the operation of the automation system. With reference to the results of calculation, the importance level and suggested measures shall be given.

5.4.3 Introduce more advanced position and navigation system

At present, the ship anti-collision system of MASS only works when two search ships are close. Ground radar system can monitor the position of MASS, but this kind of monitoring makes MASS in a passive state. So it is necessary to introduce a new positioning system. At present, global positioning system (GPS) is playing an important role in many fields. But it is used as an auxiliary navigation in commercial unmanned vessel. The disadvantage of GPS is that users can only know their own position, but do not know the position of the other.

5.4.4 Increase system information feedback

The information feedback of the system to the crew operation not only provides the SCC with the opportunity to correct, but also helps the SCC deepen the understanding of the problem. In the process of information input, feedback, collection and correction, SCC can effectively improve the ability of decision-making and judgment, generate a virtuous cycle, and ensure the safety of navigation.

5.4.5 Consider individual operator habits

In the future, the control center will pay more attention to the "user experience". The users here refer to the operators instead of the ordinary passengers. In the future, they should pay attention to improving the ergonomics of SCC and the driving habits of operators. The next control center may not look "cool" to the operator, but it must be easier to use. Therefore, the future display technology of control center is not only dedicated to adding new technologies and functions, but also should pay more attention to the use habits, operation convenience and training time of operators, so as to provide operators with more vivid situational cognition.

5.4.6 Enhance the design of non-automatic system

Due to the high complexity of automation system, perfect system can not be developed. The designers of control center should consider the design of some non-automatic systems in order to make up for the defect of automatic system. In particular, improve the design of non-automation system that are related to automation system. For example, the design of the seat in the control center. The comfortable seat can make the operator find the feeling of "passenger", as if he is a part of the MASS when controlling the system.

5.4.7 Enhance network protection system

Due to the connectivity of the network, MASS needs to accept the signal of SCC at any time, which is no longer the closed network of traditional ships. Therefore, when designing the system, the designer should consider the hacker's invasion in many aspects, design the firewall system and add the function of regular and comprehensive inspection to the system. Even considering the worst results, emergency procedures are added to the system. When the MASS is invaded by hackers, the system will automatically shut-down after sending messages to the authorities and SCC.

5.5 Strengthen company management

5.5.1 Strengthen company organization

(1) Strengthen resource management. The company must always guarantee the investment in safety and training, and cannot reduce the necessary expenses in this aspect even in the period of shortage of funds so as to ensure the advanced and complete degree of training equipment and a good training environment.

(2) Enterprises should pay attention to the training quality of operators. In terms of navigation and training time, they cannot be content with only reaching the minimum standard. The training shall be carried out according to the actual situation of each operator, and the corresponding regulations should be written into the training plan of the enterprise (Zhao, 2008) .

(3) Establish reasonable reward and punishment policies, encourage operators to improve their navigation level, and punish operators who violate regulations. Strengthen the management of the relevant navigation manual to avoid the operator losing the situational awareness due to the wrong information.

5.5.2 Establish a good safety culture

(1) Establish operator safety culture awareness. Strengthen the training of operators' safety awareness, so that they always keep the idea of safety first in subconscious. Remove the safety propaganda of slogan way, formulate and implement the corresponding safety policy practically, add the thought of safety into SOP, and start from ensuring safety when formulating the corresponding laws and regulations. When making safety policy, it is necessary to focus on navigation related departments, and provide organizational support and safety commitment for operators. Let them have a sense of belonging to the company and put the company first.

(2) Voluntary reporting system. The company should attach importance to the accident part of the voluntary reporting system. Do not just focus on punishing the operator. It is necessary to investigate and analyze the problems reported by the operators, propose effective countermeasures, and feed back the corresponding results to the operators or write them into the relevant manuals. Those who admit mistakes initiatively should be punished as little as possible and kept secret. This can improve their enthusiasm and provide more information for the development of accident prevention measures.

(3) The company needs to strengthen the supervision of the unsafe behaviors of operators, be intolerant of the violations, and criticize and educate them. In addition,

the company should pay attention to whether there is a bad competitive relationship between operators, which leads to a bad atmosphere in the company. The company's own safety department should also be supervised to avoid the reduction of safety management level caused by benefits.

CONCLUSION

The application of MASS in society will be more and more common. If we want to give full play to the role of MASS, there are still many problems to be solved. This paper focuses on reducing accidents caused by operator errors by focusing on human factors related to MASS operators. Summing up the whole article, it can be found that the operator working environment in SCC is diverse, and the operators need to play different roles. Their responsibilities are not just basic navigation tasks. If they cannot understand since their position correctly, it is difficult to take over and control the automation system. In addition, for the intelligent control system, it is necessary to emphasize that the traditional ship's pilot is an interface when communicating with other ships, but the logic of the automatic system operation is not suitable for the crew. When the system communicates with the crew, it is difficult for the crew to predict the next action of the system. In order to be widely used in the future, it is hoped that appropriate coordination can be carried out to satisfy both the shipowner and the crew.

In this paper, we predict some human errors that may occur in MASS through the analogy with intelligent devices in different industries. The possible challenges of MASS are identified. Some of these challenges are related to the environment (such as the loss of situational awareness); some are related to the system hardware (such as the allocation of human-computer tasks); some are related to people (such as communication with SCC personnel). It is believed that that only when there is an accident in the intelligent system in real life can there be greater progress in the research of unmanned ships, but there are few real cases. The causes of such accidents are difficult to predict, which is also the limitation of this article. We can only prepare preventive measures and solutions from the environment, hardware, company and training as much as possible.

The human factors of MASS can also be extended to other areas. The environment that MASS faces is uncontrollable. When designing the system, the designer should add any bad weather to the system at any time. If we regard the automation system as a closed system and ignore the dynamic factors that suddenly appear, the security problems will appear. For example, the UAV may encounter a storm or bird during flight, so it is better to set emergency procedures for such emergencies.

In the future, the automation level of MASS will only be higher and higher, and the actual skills of operators need to keep up with the development progress, so as not to lose the control of the system.

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QUESTIONNAIRE

Shipping Company A Sampling Questionnaire Of Main Human Factors

In order to further study the influence of unmanned vessel on crew behavior, promote the practical application of theoretical research results, and reduce accidents caused by human factors, we conducted a sampling survey on the operators of a ship company. The main purpose of this questionnaire is to determine the risk factors that are likely to affect peoples unsafe behaviors. Please refer to the survey as a representative of navigation practitioners. This investigation is anonymous and strictly confidential.

1、Gender (Single choice questions)

○ Male

○ Female

2、Age (Single choice questions)

○ Under 30

○ 30-39 years old

○ 40-49 years old

○ Over 50yearsold

3、Degree of education (Single choice questions)

○ vacation

○ undergraduate

○ postgraduate

4、duties (Single choice questions)

○ captain

○ chief officer

○ the second officer

○ the third officer

5、The type of ship you are driving

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6、sailing age (Single choice questions)

○ 1-2 years
○ 3-5years
○ 6-10years
○ more than 10 years

An investigation on the influencing factors of unmanned vessel on human behavior

7、The following table lists the human factors of the unmanned ship. Please choose according to your own experience and understanding in the corresponding degree of influence.

	Very unimportant（1 point）	unimportant（2points）	intermediate（3points）	important（4points）	Very important（5points）
Workload	○	○	○	○	○
Education level	○	○	○	○	○
Fatigue and boredom from normal work	○	○	○	○	○
Lack of basic skills	○	○	○	○	○
Experience level	○	○	○	○	○
Recognition of automation system	○	○	○	○	○
Situational awareness	○	○	○	○	○
Level of trust in the system	○	○	○	○	○
Tension level	○	○	○	○	○
Preparation before sailing	○	○	○	○	○
Crew cooperation	○	○	○	○	○
Coordination with successors	○	○	○	○	○

Security on the Network	○	○	○	○	○
Inadequate navigation supervision	○	○	○	○	○
Training of shipping company	○	○	○	○	○
Navigation information	○	○	○	○	○
Complexity of automation system	○	○	○	○	○
Reliability of automation system	○	○	○	○	○
Mistakes in Programming	○	○	○	○	○
Instrument light	○	○	○	○	○
Number of monitors	○	○	○	○	○
Bridge space	○	○	○	○	○
Bridge light	○	○	○	○	○
noise	○	○	○	○	○
weather condition	○	○	○	○	○

Suggestions for supplement and modification

8、What other influencing factors do you think should be added？

____

9、What are your comments on the above influencing factors？

____