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Research on the Risk Assessment of Man Overboard in the Performance of Flag Vessel Fleet (FVF)

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ABSTRACT: The performance of Flag Vessels impressed the viewers deeply at the opening ceremony of 2010 Shanghai Expo. Safety of the trainees is the key factor being considered by the organizer in the course of trainings, rehearsals and final performance. Complex chevron shape of fleet increased the risk, such as collision, grounding, waves damaging etc., which made it necessary to assess the risk of performers, especially the risk of man overboard. In this paper, Formal Safety Assessment (FSA) method recommended by International Maritime Organization (IMO) was adopted to guarantee/assess the safety of the performers, especially decrease the risk of man overboard. FSA includes five steps in general, which are Hazard Identification (HAZID), Risk Assessment (RA), Risk Control Options (RCOs), Cost Benefit Assessment (CBA) and Recommendations for Decision-Making (RDM) respectively. In this paper, Brainstorming and Fault Tree Analysis (FTA) methods were both used in HAZID step. Then the combination of the two indexes was employed to calculate the risk distribution of the fleet in RA step. One is the possibility of man overboard and the other is the consequence once the incident happens. Moreover, several RCOs were provided based on the risk distribution mentioned above. Finally, based on the results of FSA assessment, some suggestions were carried out to decrease the risk of performers according to CBA, like personnel arrangement according to risk degree of different areas in fleet. It has been proved that applying FSA method to the fleet of flag vessels can reduce the overall degree of risk and ensure the success of performance.

The performance of Flag Vessels Fleet (FVF), composed by almost 350 teachers and students from Shanghai Maritime University (SMU), impressed the viewers deeply at the opening ceremony of 2010 Shanghai Expo. Safety of the trainees is the most important factor being considered by the organizer and also by our university. In order to guarantee the success of the program, the average risk of the Flag Vessels fleet need to be controlled. Therefore, Formal Safety Assessment (FSA) method was applied to identify, control and reduce the risk during the trainings, rehearsals and performance. FSA is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost benefit assessment [1]. In the middle of 1990s, the International Maritime Organization (IMO) adopted FSA, initially put forward by Maritime and Coast Guard Agency (MCA) at the 62nd meeting of Maritime Safety Committee (MSC), introduced FSA to the marine industry and put it into use, and asked its members to be actively involved in the research on ship safety [2]. After that, FSA methodology was applied in different aspects of shipping industry, such as safety assessment of containerships [3], cruise ships [4] and fishing vessels [5]. Besides, the theory and methodology of FSA was further studied, covering its theoretical basis and origin [6], details in every step [7-8].

This paper mainly focuses on the application of FSA in quantitative risk assessment of man overboard. Based on the analysis and conclusion of FSA approach, some useful suggestions are provided to promote and improve safety of the FVF performance.

1 INTRODUCTION

The FVF, composed by 220 ships, formed a complex chevron shape, and the complex chevron

shaped fleet includes two v-shaped groups showed as figure 1. Each group includes eleven teams and each team includes one motor rubber boat (MRB) and ten non-power driven vessels (NPDV) which were towed by the MRB.

The distance of each team should be kept as ten meters and two vessels were towed by a ten-meter line. The distance of two groups is fifty meters according to original plan. Each team has one captain who drives the motor rub and gives orders to this team. Two VHF calls is given to the first MRB and the last NPDV. As shown in figure 1, from the top to the bottom, the MRBs are numbered as A1, A2,⋯, A11 in group A and the same in group B. From the left side to the right side, the NPDVs are numbered as Ai-1, Ai-1, ⋯, Ai-10 $i \in [1,11]$.

The performance was hold at the Expo Culture Center (ECC), which is located in Pudong New Area between Nanpu Bridge and Lupu Bridge beside the Huangpu River as shown in figure 2. FVF should keep the chevron shape when the fleet marches across Huangpu River from the Nanpu Bridge toward the ECC. The segment of the Huangpu River adjacent to the ECC is a curved channel, so the captains of all eleven MRBs in each group should make a turn at the same time and the MRBs located in outer circle needs to be accelerated respectively in order to keep the shape. Besides, the distance between two teams should be kept as ten meters which need be judged by the eyes of the captains. The current speed in the channel is irregular and the current direction near the bank is onshore. Therefore, it is difficult to keep the shape of the fleet.

The control of performance time is another problem. The distance between two bridges is approximately 1.5 nautical miles (NM) and the distance passing by ECC which should be gone through within 5 minutes is about 0.6 NM. According to the Tide Table, the FVF will run against the tide and the current speed is about 3 knots, so the marching speed of the FVF will be 9 knots to meet the time according to the program. The performance trace across the Huangpu River was showed in figure 2.

Figure 2: The map of performance trace across the Huangpu River

2 HAZARD IDENTIFICATION

The hazard factors of FVF performance can be generally classified as three aspects: damage or loss of the flag vessels, damage of navigational aids in the channel, death or injury of the performers. Where the importance of Shanghai Expo is concerned, to the utmost guaranteeing no casualty is the organizer's primary task. The boats and Flag Vessels is small tonnage and not made of steels, so the possible casualties are not directly caused by collision, grounding and wave damage etc., but mainly by the man overboard. Therefore, all possible factors leading to the man overboard are identified and assessed, and the emergency plan of the research and rescue should be provided to ensure the safety of every performers.

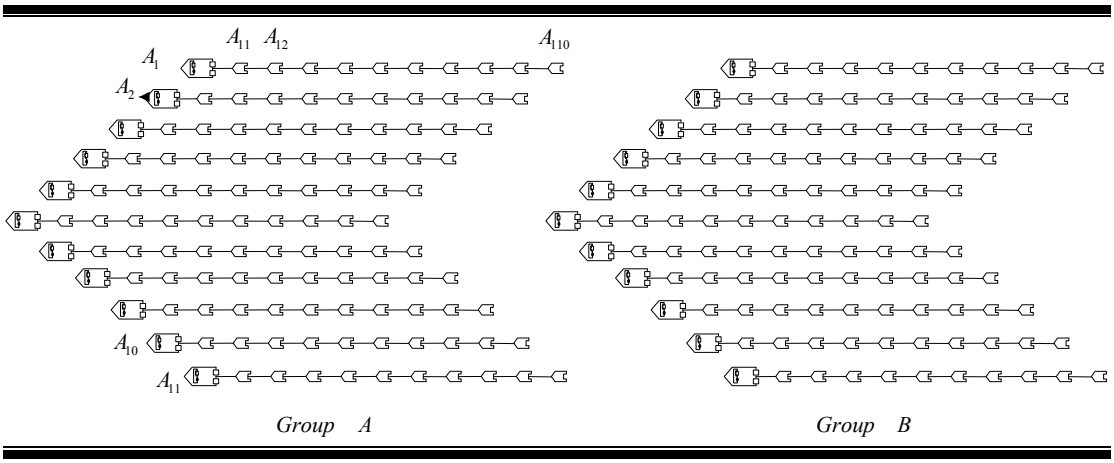

Figure 1: The top view of Flag Vessels Fleet (FVF) with complex chevron shape

In order to get the factors resulting in the man overboard, Delphi method was adopted. Inquiry sheets were sent to 15 experts including captains, instructors, and trainers as well. In addition, Accident Records including all kinds of accidents happened during the training were analyzed. According to the investigation results, the prime hazard factors were summed up as follows:

- The MRBs need to be accelerated or decelerated frequently to keep the chevron shape, which may lead to the man overboard due to doddering.
- The movement of MRBs will make huge wave, which may lead to the man overboard due to swaying.
- The Flag Vessel (UPDVs) may be trimmed by the head because of rolling and pitching, which may lead to the man overboard due to flooding.
- The Flag Vessel (UPDVs) will be damaged or capsized by the collision with the aids to navigation or by grounding, which may lead to the man overboard.
- The Flag Vessel (UPDVs) between two teams may collide or fouled with each other because of the irregular of the current speed and direction, which may lead to the man overboard.

Hazard identification helps to quantify the frequency and severity of every performer overboard.

3 RISK ASSESSMENT

Frequency, the common statistics for computing possibility elements, is introduced to describe the possible occurrences of hazardous accidents or abnormal events. Generally, the frequency is described using such phases as ‘‘frequent’’, “reasonably probable’’, ‘‘remote’’ and ‘‘extremely remote’’. As for man overboard, this paper suggests five grades to describe the possibility of performers falling into water, so that the frequency of the man overboard can be quantified accurately. Details of the criteria are showed in table 1:

Table 1 Frequency/probability criteria table for the man overboard

Nature	Index	Value	Description
Always happened	F5	5	Always happened during an activity
Frequent	F4	4	Frequently happened during an activity
Reasonably Probable	F3	3	Possibly happened during an activity
Remote	F2	2	Occasionally happened, but not often
Extremely	F1	1	Almost would not have happened During an activity, but should not exclude the existence

The MRBs are equipped with two engines and 60HP each, some of them 90HP. The maximum speed can reach more than 40 knots. While they tow 10 UPDVs, the maximum speed is less than 10 knots, and the inflammable rubber bands around MRBs are railed for protecting men from falling into water.

The UPDVs next to the MRBs (that is Ai-1 or Bi-1, $i \in [1,11]$) is relatively easy to be impacted by green water, which was caused by two high speed engines. Man overboard frequently happened. Besides, the more close to the center of the UPDVs fleet the crew is, more rough the wave is, and he is easier to fall into the water. According to the analysis mentioned above and consulting to the coach team, the matrix of possibility of man overboard at different position of the FVF was obtained as follows (figure 3):

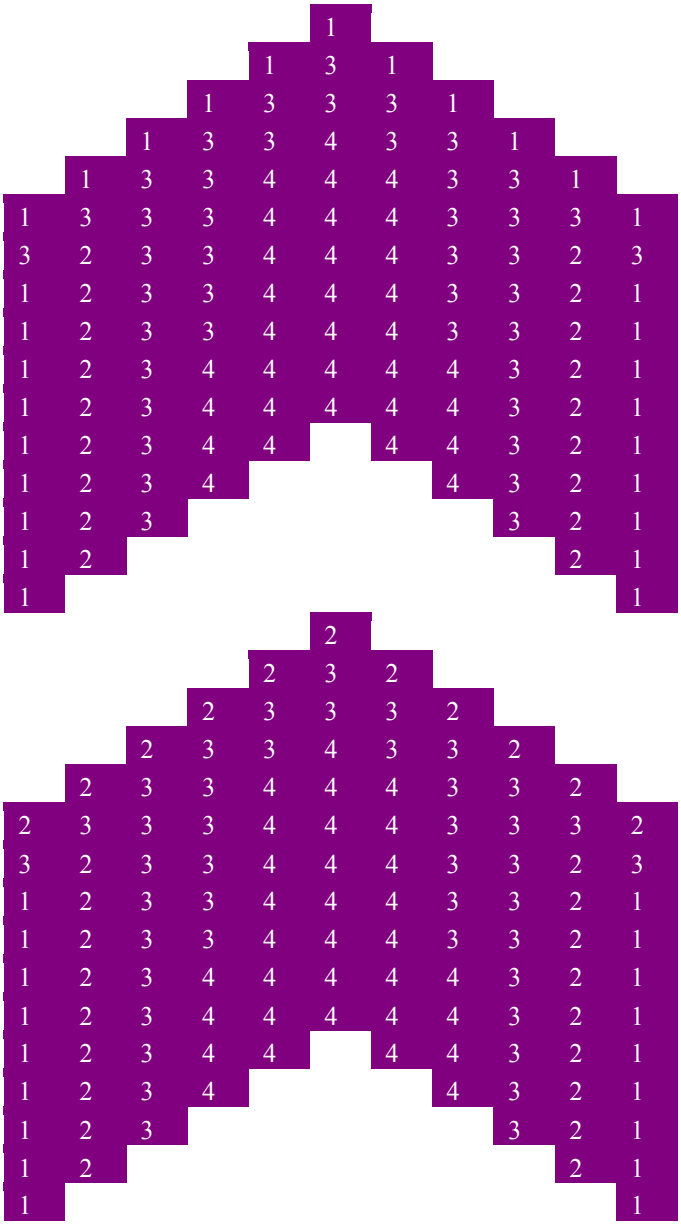

Figure 3 matrix of possibility of man overboard at different position

Severity is utilized to describe the consequences of casualties. Quantifying the severity is complicated issue in safety assessment. Generally, the severity is described using such words as ‘‘Catastrophic’’, “Major’’, ‘‘Minor’’, and ‘‘Insignificant’’. As for man overboard, this paper provides their definitions in table 2 as follows:

Table 2 Severity criteria table for the man overboard

Nature	Index	Value	Description
Fatal injury	C5	5	The injury probably was fatal if the incident happened
Major injury	C4	4	The injury probably was not fatal but serious if the incident happened
Moderate injury	C3	3	The injury probably was less serious if the incident happened
Miner injury	C2	2	The injury is slight during an incident
Insignifi-cant injury	C1	1	Almost no injury or the injury can be neglected

During the FVF, the fatality comes from high-speed MRBs. The man overboard can be hurt by propellers or drawn into the whirlpool, and hit by the UPDVs. Besides, that the UPDVs probably press upon the man overboard is another consequence of injury. So the man overboard in group A is more in danger than those in group B. And in each group, closer to the front the UPDVs locate in, more serious the severity of them is.

Based on the results, the matrix of severity of man overboard at different position of the FVF was obtained as follows (figure 4):

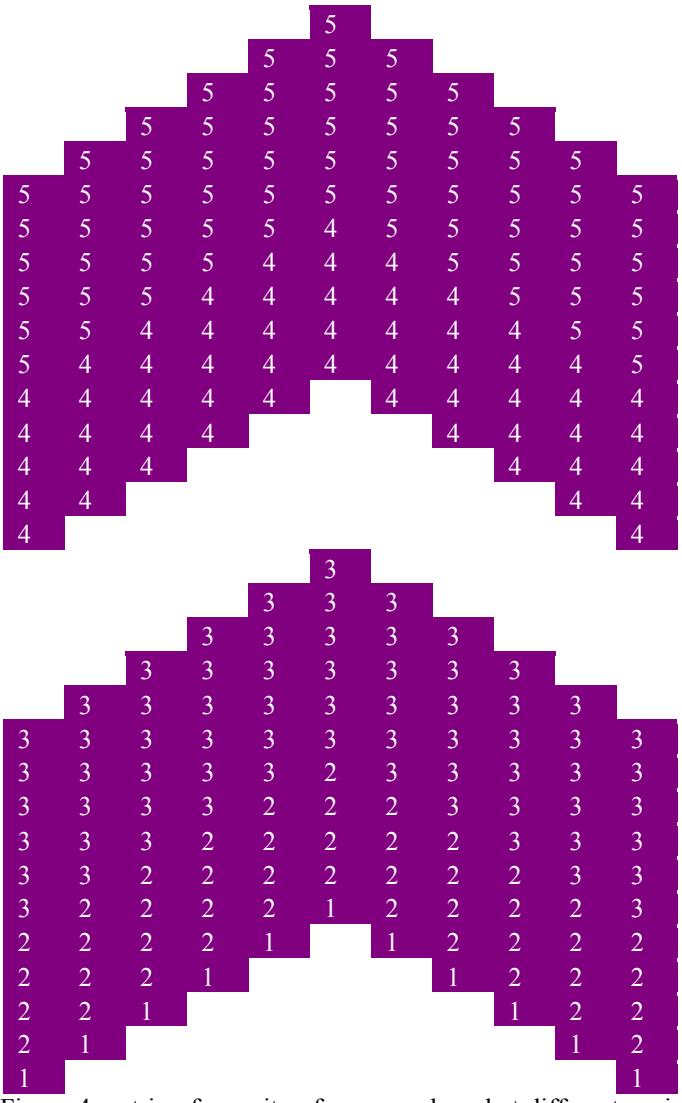

Figure 4 matrix of severity of man overboard at different position

Risk is defined as a combination of possibility (F) and severity (C), characterized by Risk = (F, C). The following formula is provided to describe the degree of the risk:

$$r = f \times c$$

r is the value of risk

f is the frequency of man overboard

c is the severity or consequence of the man overboard

$\times$ is the multiplication operation

According to the formula, the risk value of each person can be calculated and the risk matrix can be obtained, which will not be given here due to the limited space. After consulting to the coach team and the experts composed by the experienced captains from SMU, the risk matrix is divided into three risk regions which are given as follows:

$I_1 = \{\text{negligible risks}\}$ and if $r \in I_1$, then $0 < r \leq 5$.

$I_2 = \{\text{risks as low as reasonably practical (ALARM)}\}$ and if $r \in I_2$, then $5 < r \leq 15$.

$I_3 = \{\text{high level risks}\}$ and if $r \in I_3$, then $15 < r \leq 25$.

Based on the divisions, the persons on the black shades and vessels need to be carefully paid attention to as shown in figure 5, because they are in the high-level risks.

Risk Control Options (RCOs) will be reflected in the step of Recommendations for Decision-Making (RDM). Compared with the vast budgets of Shanghai Expo and with the safety of performers, Cost Benefit Assessment (CBA) cannot be a primary issue, so the steps RCOs and CBA will not be discussed in detail here.

4 RECOMMENDATIONS FOR DECISION-MAKING

According to the results of assessment, some recommendations and suggestions are drawn as follows:

Firstly, all performers should be able to swim and female performers should be evacuated from the high risk region. According to the assessment results, risk of persons on the MRBs and the last UPDVs is very low, so all female persons were arranged on those positions and accompanied by a male person to decrease the whole risk.

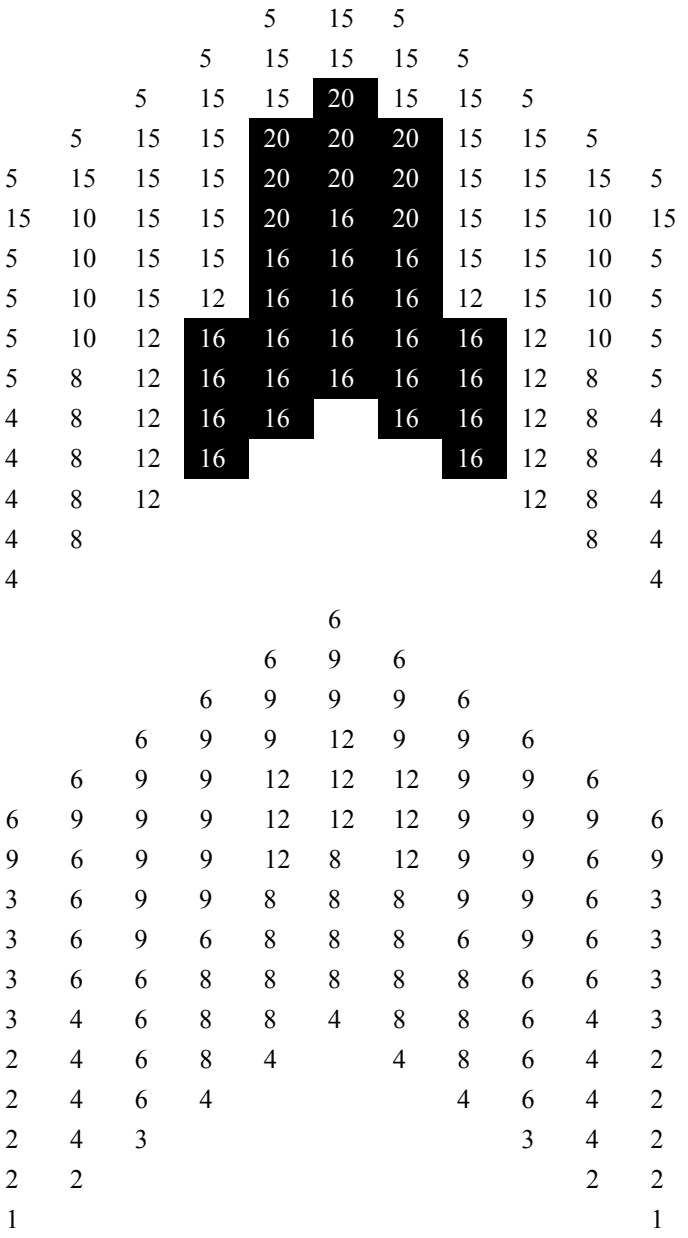

Figure 5 risk matrix

Secondly, each sailor on the MRBs was responsible for an extra duty for reminding and supervising. According to the original plan, each MRB was manned one captain, one second captain, one coordinator and one sailor. The captain drove the MRB and gave orders. The second captain was substitute for the captain. The coordinator issued the order from the captain by VHF and the sailor did something of berthing and unberthing. While the person on the fist UPDV of each team was in the region of the high-level risk. Therefore, the sailor should remind and oversee his/her misoperation, unsafe action and carelessness.

Thirdly, everyone's position in the ship should be fixed. In order to decrease the possibility of green wave due to rolling and pitching, the person on the UPDV was required to be seated at the stern as far as possible, to prevent the vessel from being trimmed by the head. The coordinator in the MRB should stand at the bow, the captain and second captain in the middle, and the sailor at the stern respectively.

Fourthly, the distance of group A and group B need adjusting at any time. The distance of two groups was kept as 50 meters for the wholeness, artistry and compactness, so the distance was unchangeable generally. From the assessing result, high-level risk region lies around the column A_6, so the column B_6 was more dangerous. If the distance of two groups kept unchangeable, it is better to recede B_6 about 10 meters to keep the column B_5, B_6 and B_7 in parallel. So B_6 was away from the high-level risk region about 60 meters and the captain of team B_6 had more time to find the potential risk and take immediate actions to avoid it. Besides, the wholeness, artistry and compactness of the performance were kept as plan.

Fifthly, four big horse-power MRBs were selected as convey for search and rescue. Four 90 horse-power MRBs was used to protect the FVF, among which, one MRB was operated by Eastsea Rescue, two by the coach team and one by the trainers from Yangchenghu Club respectively.

Sixthly, the handling method of vessels and the self rescue method of the man overboard were worked out. If someone happened to fall into water, teams near the man overboard should alter course immediately regardless of the distance of two teams and other teams should alter their courses correspondingly. At the same time, the coordinator would report the position of the man overboard vie the public channel of VHF. Persons should keep eyes on him and wave their hands to be noticed promptly. The man fell into water should take out his light stick from his lifejacket so that the salvagers could find him.

The FVF performance of Shanghai Expo took a high success and was recognized greatly by the leaders of the country and Shanghai City and was elected as one of the most ten advantageous performances. Performers of FVF were awarded for their special contributions. Here, I will thanks all the students and teachers attending for their painstaking work.

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